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Conceptual and Experiential Dance Languages: Digital Representation and Interaction

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ΕΘΝΙΚΟ ΚΑΙ ΚΑΠΟΔΙΣΤΡΙΑΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ

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ΔΙΔΑΚΤΟΡΙΚΗ ΔΙΑΤΡΙΒΗ

Εννοιολογικές και Βιωματικές Γλώσσες Χορού: Ψηφιακή Αναπαράσταση και Αλληλεπίδραση

Αικατερίνη Ε. Ελ Ράχεμπ

ΑΘΗΝΑ

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ABSTRACT

Dance and movement are integral part of human, social and artistic expression, in every historical period and geographical area. Contemporary technologies, such as motion capture, video recording and analysis, offer significant means for documenting movement, opening new pathways in the domains of Dance Research, Intangible Cultural Heritage Preservation, Dance Education, as well as for the Creative and Choreographic process. While dance data that are related to movement are growing every day, the need for methodological frameworks and technological tools to represent movement and to manage such data is also growing rapidly. The objective is to make these data searchable, accessible and reusable. In parallel, the need for designing frameworks and workflows for the development of proper interfaces that are meaningful for the dance community is growing as well. The main ‘question of this thesis is how we can represent movement in a way that suggests effective communication through both the Conceptual and Experiential Languages for Dance, using digital representations and interactions. Apart from the complexity of defining what dance is, what makes this question challenging is the fact that dance movement is by nature multidimensional and diverse. Dance knowledge is mainly based on embodied transmission. The lack of a universal, dance representation language or notational system that could be used both by dance researchers and practitioners makes the problem even more complicated. In this thesis, based on existing notation systems such as Labanotation and methodologies of Choreological analysis, as well as a continuous dialogue with dance theory and practice, including first person experience, we develop a semantic and methodological framework for dance that covers both the Conceptual and Experiential Languages for Dance. The framework has been evaluated through the design, development and use of relevant applications. The contribution of the thesis can be summarized as follows:

1. Development of conceptual models and ontologies for the semantic representation of dance movement. For this development we use as theoretical background the Choreological, morphological analysis for dance as well as the Labanotation system for documenting movement, and we combine them with the capabilities of Semantic Web Technologies, such as OWL-2. This contribution comprises the study of the Conceptual Languages for Dance.

2. The extension and implementation of the semantic representations for the design and development of user interfaces for movement, and the design and implementation of annotation tools and strategies, as well as the development of web-based systems for the management of information related to movement.

3. Development of a workflow, as well as experiences for the whole-body interaction for dance. Guided by the semantic model, as well as a survey on the existing systems for dance, we propose a workflow for the design of virtual and interactive experiences for dance. The workflow is evaluated through the design and development

of relevant interfaces. The last two points comprise the study on the Experiential Languages for Dance.

The thesis proposes formalisation for the modeling and enrichment of dance metadata, and suggests hierarchical vocabularies for annotating movement and its characteristics, aiming at searching archives using knowledge that is related to dance movement. The aforementioned framework is implemented and integrated in digital web-based interfaces, as well as embodied interactions that are evaluated by dance experts. In addition, the proposed model of representation can be implemented for the extraction of movement knowledge from motion capture datasets. Last but not least, the extensible nature of the framework, including all of the methodological, and technological tools can be investigated and applied in other use-cases for dance research, education and creative process, in the future.

SUBJECT AREA: Computing Systems and Applications

KEYWORDS: Semantic Web, Ontologies, Knowledge Representation, Human Computer Interaction, Dance, Documentation, Intangible Cultural Heritage, Human Movement, Movement Analysis, Semantic Movement Representation, Embodied Interaction, Language, Σημειογραφία

ΠΕΡΙΛΗΨΗ

Η κίνηση και ο χορός αποτελούν ένα αναπόσπαστο κομμάτι της ανθρώπινης κοινωνικής και καλλιτεχνικής έκφρασης, σε κάθε ιστορική περίοδο και γεωγραφικό πλάτος. Τα σύγχρονα ψηφιακά μέσα προσφέρουν σημαντικές δυνατότητες καταγραφής της κίνησης του σώματος ανοίγοντας νέους δρόμους στη μελέτη και έρευνα του χορού, τη διατήρηση της άυλης πολιτιστικης κληρονομιάς αλλά και την εκπαιδευτική και τη δημιουργική διαδικασία. Ωστόσο, όσο τα ψηφιακά δεδομένα που αφορούν στην κίνηση όπως βίντεο, αρχεία σύλληψης κίνησης κ.α. αυξάνονται, δημιουργείται η έντονη ανάγκη για μεθοδολογικά πλαίσια και τεχνολογικά εργαλεία τα οποία θα επιτρέπουν την αναπαράσταση της κίνησης και τη διαχείριση σχετικών αρχείων. Στόχος είναι τα δεδομένα αυτά να είναι αναζητήσιμα, προσβάσιμα και επαναχρησιμοποιήσιμα. Παράλληλα, δημιουργείται η ανάγκη για σχεδιαστικά πλαίσια και διαγράμματα ροής για την ανάπτυξη διεπαφών με απώτερο σκοπό να έχουν νόημα τόσο στης έρευνα και όσο και στην πρακτική του χορού. Το ερώτημα που πραγματεύεται η παρούσα διατριβή επικεντρώνεται στο πώς μπορούμε να αναπαραστήσουμε την κίνηση, έτσι ώστε να επιτυγχάνεται αποτελεσματική επικοινωνία τόσο των Εννοιολογικών όσο και των Βιωματικών γλωσσών του χορού, μέσα από την ψηφιακή διάδραση. Η δυσκολία στο να απαντήσουμε στην παραπάνω ερώτημα έγκειται αφενός στην πολυπλοκότητα και πολυμορφία της ανθρώπινης κίνησης αλλά και του ορισμού του ίδιου του χορού. Αφετέρου οφείλεται στο γεγονός ότι ο χορός, βασίζεται κυρίως στην ενσώματη γνώση, και στην έλλειψη μιας ενιαίας γλώσσας αναπαράστασης, η οποία να χρησιμοποιείται στην πράξη τόσο από τους ερευνητές όσο και από τους δημιουργούς, εκπαιδευτικούς, και πρακτικούς του χορού. Στην παρούσα διατριβή, βασιζόμενοι σε υπάρχοντα συστήματα σημειογραφίας και χορολογικές μεθοδολογίες χορού, αλλά και μέσα από ένα συνεχή διάλογο με την χορευτική πράξη αναπτύξαμε ένα σημασιολογικό και μεθοδολογικό πλαίσιο το οποίο αφορά τόσο στις Εννοιολογικές όσο και στα Βιωματικές Γλώσσες του Χορού. Το πλαίσιο αυτό, αξιολογήθηκε μέσα από τη σχεδίαση, ανάπτυξη και χρήση εφαρμογών. Η συνεισφορά της διδακτορικής διατριβής συνοψίζεται στα εξής αποτελέσματα:

1. την ανάπτυξη εννοιολογικών μοντέλων και οντολογιών για τη σημασιολογική αναπαράσταση της χορευτικής κίνησης. Για την ανάπτυξη του εννοιολογικού μοντέλου βασιζόμαστε στη χορολογική και μορφολογική ανάλυση του χορού, καθώς και στο σύστημα σημειογραφίας της κίνησης του Λάμπαν (Labanotation). Το σκέλος αυτό αφορά στη μελέτη των Εννοιολογικών γλωσσών του χορού.

2. την επέκταση και εφαρμογή των σημασιολογικών αναπαραστάσεων για τη σχεδίαση και ανάπτυξη των διεπαφών χρήστη για την επισημείωση της κίνησης καθώς και την ανάπτυξη διαδικτυακών συστημάτων για τη διαχείριση πληροφορίας σχετικής με το χορό και την κίνηση.

3. την ανάπτυξη διαγράμματος ροής καθώς και εφαρμογών που αφορούν στην ενσώματη διάδραση μέσω κίνησης. Με γνώμονα το αρχικό σημασιολογικό μοντέλο, την

χαρτογράφηση της υπάρχουσας κατάστασης, προτείνεται διάγραμμα ροής για τη σχεδίαση αντίστοιχων εικονικών και διαδραστικών διεπαφών. Το διάγραμμα αυτό, αξιολογείται μέσα από τη σχεδίαση και ανάπτυξη διαδραστικών εφαρμογών για την πρακτική του χορού. Τα δύο τελευταία σκέλη εστιάζουν στη μελέτη των Βιωματικών γλωσσών του χορού.

Η διατριβή προτείνει τη μοντελοποίηση της κίνησης για την διατύπωση και επαύξηση μεταδεδομένων για το χορό, και καθώς και ιεραρχικά λεξιλόγια για την επισημείωση των κινήσεων και χαρακτηριστικών τους, με σκοπό την αναζήτηση αρχείων με γνώση που αφορά απευθείας στην κίνηση. Το προτεινόμενο μοντέλο αναπαράστασης χρησιμοποιείται ως μεθοδολογία για την εξαγωγή πληροφορίας μέσα από σύνολα δεδομένων καταγραφής κίνησης. Τέλος τα μοντέλα αυτά εφαρμόζονται μέσα σε τέτοιες ψηφιακές διαδικτυακές εφαρμογές και εξετάζονται ως προς τη χρηστοκεντρική τους αξία για την κοινότητα των χορευτών, αλλά και διερευνάται η χρήση ψηφιακών μέσων για την υποστήριξη της έρευνας, εκπαίδευσης και της δημιουργικής διαδικασίας του χορού.

ΘΕΜΑΤΙΚΗ ΠΕΡΙΟΧΗ: Υπολογιστικά Συστήματα και Εφαρμογές

ΛΕΞΕΙΣ ΚΛΕΙΔΙΑ: Σημασιολογικός Ιστός, Οντολογίες, Αναπαράσταση Γνώσης, Επικοινωνία Ανθρώπου Μηχανής, Χορός, Καταγραφή, Άυλη Πολιτιστική Κληρονομιά, Ανθρώπινη Κίνηση, Ανάλυση Κίνησης, Σημασιολογική Αναπαράσταση Κίνησης, Ενσώματη Διάδραση, Γλώσσα, Σημειογραφία

ΣΥΝΟΠΤΙΚΗ ΠΑΡΟΥΣΙΑΣΗ ΤΗΣ ΔΙΔΑΚΤΟΡΙΚΗΣ ΔΙΑΤΡΙΒΗΣ

Η παρούσα διατριβή επικεντρώνεται στον τρόπο με τον οποίο αναπαριστούμε Εννοιολογικά και Βιωματικά το χορό με χρήση σύγχρονων μέσων της πληροφορικής. Μας απασχολεί το πώς τα μέσα αναπαράστασης, διαχείρισης και εμπλουτισμού της πληροφορίας μπορούν να συνδράμουν τόσο στην αποτελεσματική αποθήκευση, διατήρηση και διάδοση του χορού, όσο και η μελέτη και ο μετασχηματισμός της κίνησης στο πλαίσιο των ψηφιακών, εικονικών ή και ενσώματων εμπειριών. Τα αποτελέσματα της διατριβής συνιστούν ένα ενιαίο πλαίσιο σημασιολογικής περιγραφής το οποίο αξιολογείται μέσα από μια σειρά από μεθοδολογικά και τεχνολογικά εργαλεία προς αυτή την κατεύθυνση.

Figure 1: Δομή της διατριβής: Θεωρητικό υπόβαθρο, μεθοδολογία και αποτελέσματα

Έτσι η παρούσα διατριβή όπως φαίνεται και στο παραπάνω σχήμα 1, δομείται ως εξής και αποτελείται από το ακόλουθα μέρη:

- το Θεωρητικό Υπόβαθρο το οποίο βασίζεται 1) στις Τεχνολογίες Σημασιολογικού Ιστού, 2) στο σύστημα σημειογραφίας και ανάλυσης κίνησης του Laban, 3) σε Χορολογικές μεθόδους για τη δομική και μορφολογική ανάλυση του χορού, και 4) σε υπάρχουσα ορολογία και κινησιολογία του χορού.

- τη μελέτη και διατύπωση των *Εννοιολογικών Γλωσσών του Χορού*, μέσα από τη δημιουργία οντολογιών και τη σημασιολογική αναπαράσταση της κίνησης.

- τη μελέτη των *Βιωματικών Γλωσσών του Χορού*, εξετάζοντας το ερώτημα του πώς σχεδιάζουμε, αναπτύσσουμε και αξιολογούμε διεπαφές χρήστη για το χορό. Αποτελείται από δύο μέρη: 1) Τις διεπαφές επισημείωσης κίνησης και τα διαδικτυακά συστήματα διαχείρισης της πληροφορίας σχετικής με το χορό. 2) Τις διεπαφές ενσώματης διάδρασης και της μελέτης της απεικόνισης του σώματος και της κίνησης.

- τα Μεθοδολογικά Εργαλεία για τη μελλοντική σχεδίαση αντίστοιχων εφαρμογών και τα οποία αποτελούνται από δύο μέρη: 1) τη βιβλιογραφική ανασκόπηση αντίστοιχων συστημάτων διάδρασης για το χορό τα οποία χρησιμοποιούν τεχνολογίες σύλληψης κίνησης και εικονικά περιβάλλοντα και 2) την ανάπτυξη διαγράμματος ροής που καθορίζει τα μέρη μια ανάλογης εφαρμογής και θέτει τα αντίστοιχα σχεδιαστικά ερωτήματα.

1. Εισαγωγή: Καταγραφή κίνησης με χρήση νέων τεχνολογιών

Η καταγραφή και η ανάλυση του χορού, αποτελεί ένα πολύπλοκο και πολυδιάστατο πρόβλημα που προϋπάρχει της ανάπτυξης και διάδοσης των σύγχρονων ψηφιακών μέσων και νέων τεχνολογιών. Μέρος αυτού του προβλήματος έγκειται στην πολυπλοκότητα και πολυμορφία του χορού αλλά και την πολυσημία της ίδιας της έννοιας του χορού. Ο χορός εκτός από σημαντικό μέρος της άυλης πολιτιστικής κληρονομιάς, σύμφωνα με την UNESCO, [135], αποτελεί αναπόσπαστο κομμάτι της Κοινωνικής και Πολιτισμικής επικοινωνίας, και αντικείμενο μελέτης της Ανθρωπολογίας και άλλων Ανθρωπιστικών Επιστημών. Ταυτόχρονα αποτελεί μια σημαντική παραστατική τέχνη, μέρος της ομαδικής και προσωπικής καλλιτεχνικής έκφρασης και δημιουργίας, αλλά και μέσο ψυχαγωγίας. Ο χορός συχνά χαρακτηρίζεται ως εφήμερη τέχνη, μια και δεν μπορεί κανείς να κρατήσει ένα αντίγραφο, και να το αναπαράγει όπως θα έκανε με ένα κείμενο, αλλά ούτε και να το τοποθετήσει σε ένα μουσείο, όπως συμβαίνει με κάποιο απτό έργο τέχνης.

Αρκετές βιβλιοθήκες χορού εμπλουτίζονται με περιεχόμενο, όπως λεκτικές περιγραφές, εικόνες, βίντεο, παρτιτούρες μουσικής κ.τ.λ. Κανένα όμως από αυτά τα επιμέρους στοιχεία δεν προσφέρει τη δυνατότητα απευθείας αναζήτησης περιεχομένου, με βάση τα χαρακτηριστικά της κίνησης, τα μοτίβα ή τις ονομασίες και τα λεξιλόγια που αφορούν την κίνηση. Οι σύγχρονες τεχνολογίες, όπως το βίντεο, οι κάμερες βάθους, και οι τεχνολογίες σύλληψης κίνησης, προσφέρουν τη δυνατότητα καταγραφής συγκεκριμένης επιτέλεσης καθώς και της κίνησης του σώματος με ακρίβεια ανάλογη με την πολυπλοκότητα του εξοπλισμού, προσβασιμότητας και του κόστους. Όμως οι παραπάνω τεχνολογίες δεν προσφέρουν τη δυνατότητα οργάνωσης της πληροφορίας σε σχέση με τα δομικά και οργανωτικά χαρακτηριστικά της κίνησης καθαυτής, σε ένα αφαιρετικό επίπεδο. Επιπρόσθετα, όπως διαπιστώσαμε κατά την εκπόνηση της διατριβής υπάρχουν πλήθος ερωτήματα τα οποία σχετίζονται με το τρόπο με τον οποίο αυτή η πληροφορία θα επικοινωνείται στον τελικό χρήστη.

2. Σύντομη αναφορά υπάρχουσας κατάστασης

Τις τελευταίες δεκαετίες, διάφορες ερευνητικές προσπάθειες [45, 63, 14, 179, 133, 194] επικεντρώνονται στη διάσωση και ανάδειξη της πολιτισμικής κληρονομιάς, αλλά και την υποστήριξη της δημιουργικότητας, της εκπαίδευσης και της διεπιστημονικής έρευνας μέσα από τις σύγχρονες ψηφιακές τεχνολογίες. Κάποια από αυτά τα έργα έχουν δημιουργήσει βιβλιοθήκες δεδομένων με αλληλουχίες ανθρώπινων κινήσεων και χορού, σε ερευνητικό επίπεδο.

Παράλληλα, σε μαζικό επίπεδο, οι σύγχρονες πλατφόρμες περιεχομένου όπως το Youtube και των υπόλοιπων κοινωνικών δικτύων κατακλύζονται από βίντεο, τα οποία ”φορτώνονται” καθημερινά τόσο από επαγγελματίες όσο και από ερασιτέχνες χρήστες.

Οι δύο αυτές κατηγορίες προέλευσης αρχείων έρχονται να προστεθούν στα οργανωμένα αρχεία καταγραφής συγκεκριμένων οργανισμών, οι οποίοι συνήθως προτείνουν κάποιο σχήμα μεταδεδομένων για τα αρχεία αυτά. Έτσι τα αρχεία αυτά συνήθως συμπεριλαμβάνουν πληροφορία όπως π.χ. όνομα χορού, χορεύτριας/τη, ομάδας, χορογράφου, χρονολογίας κ.α. τα οποία είναι μεν σημαντικά, ωστόσο δεν παρέχουν πληροφορίες για το είδος των κινήσεων που περιλαμβάνονται σε αυτό το περιεχόμενο, ούτε προτείνουν τρόπους αναζήτησης αυτών.

Οι τεχνολογίες που προαναφέραμε επιτρέπουν την αποθήκευση της καταγεγραμμένης κίνησης και των φυσικών χαρακτηριστικών της (μεταβολή γωνίας και στρέψης στις αρθρώσεις, επιτάχυνση κ.α.) με μεγάλη λεπτομέρεια σε συνάρτηση με το χρόνο, όμως τα δεδομένα αυτά δεν αντιστοιχούν σε κάποιο εννοιολογικό μοντέλο ανάλυσης της κίνησης. Άρα, ακόμα και αν υπάρχουν δεδομένα τα οποία έχουν προκύψει από αντίστοιχες τεχνολογίες, μένει να απαντηθεί το πρόβλημα της διαχείρισης αυτής της πληροφορίας σε ένα υψηλότερο επίπεδο [52].

Οι τεχνολογίες σύλληψης της κίνησης μας δίνουν τη δυνατότητα αποθήκευσης ενός βήματος, ως μια σειράς από στιγμιότυπα (frames) με όλες τις λεπτομέρειες θέσης της κάθε άρθρωσης του ποδιού ή και του υπόλοιπου σώματος. Όμως για να είναι ικανή μια τέτοια διαδικασία να παρέχει ουσιαστική πληροφορία σε έναν αναλυτή κίνησης, θα πρέπει να ακολουθηθεί μια μέθοδος ”μετάφρασης” των δεδομένων σε κάτι που ο τελικός χρήστης (ή και το σύστημα) μπορεί να καταλάβει ως μια έννοια σε ένα υψηλότερο επίπεδο π.χ. «βήμα μπρος με το δεξί πόδι και λυγισμένα πόδια».

Διακρίνουμε συνεπώς ένα μεγάλο κενό μεταξύ της καταγραφής και ανάλυσης συγκεκριμένων επιτελέσεων χορού σε φυσικό επίπεδο, και της περιγραφής της κίνησης σε εννοιολογικό επίπεδο το οποίο θα επέτρεπε σε κάποιον τελικό χρήστη (ερευνητή του χορού, σπουδαστή, επαγγελματία ή ερασιτέχνη χορευτή) να αναζητήσει και να εντοπίσει κινήσεις με βάση ονομασίες ή άλλα χαρακτηριστικά.

Το κίνητρο αυτής της διατριβής είναι να δοθεί η δυνατότητα στον χρήστη μιας βάσης δεδομένων ή γνώσης που περιλαμβάνει πολλά αρχεία, να αναζητήσει και να εντοπίσει με ευκολία π.χ. ”το περιεχόμενο το οποίο περιλαμβάνει ένα συγκεκριμένο μοτίβο παραδοσιακού χορού ή ακόμα και μια πιρουέτα κλασικού μπαλέτου”, ανεξαρτήτως του τρόπου με τον οποίο μια τέτοια πληροφορία είναι καταχωρημένη.

Επιπρόσθετα, να ορίσει τον τρόπο με τον οποίο ένας χρήστης πραγματοποιεί αναζήτηση σε μια αντίστοιχη βάση δεδομένων. Π.χ. η βάση να ”επιστρέφει” ως αποτέλεσμα ”στροφές” όπου αυτές συμπεριλαμβάνονται, είτε πρόκειται για πιρουέτες μπαλέτου, είτε ως μέρος ενός αυτοσχεδιασμού ενός χορευτή σύγχρονου χορού, είτε ως μέρος ενός παραδοσιακού. Με άλλα λόγια το ενδιαφέρον αυτής της διατριβής εστιάζεται στη σημασιολογική αναπαράσταση της κίνησης, ορίζοντας και αναπαριστώντας ”Κινητικές οντότητες” (Movement Entities), καθώς και στη μελέτη των μεταξύ τους σχέσεων και ιεραρχιών.

3. Θεωρητικό Υπόβαθρο

Σε πρώτη φάση μελετήσαμε εκτενώς τη βιβλιογραφία ώστε να προσδιορίσουμε τι σημαίνει «αποθηκεύω ψηφιακά έναν χορό». Τελευταία συναντάμε όλο και πιο συχνά ψηφιακά αρχεία χορού [191, 5] ή ψηφιακές βιβλιοθήκες χορού. Συνήθως τα προαναφερθέντα αρχεία περιέχουν φωτογραφικό υλικό, βίντεο, ή ακόμα και περιγραφές-«οδηγίες» βημάτων υπό μορφή κειμένου [66] . Όμως το να ορίσει κανείς τι σημαίνει ο όρος «δεδομένα», όταν πρόκειται για κάτι τόσο εφήμερο και ευαίσθητο στο χρόνο αλλά και δύσκολο στην περιγραφή όπως ο χορός, είναι μια μεγάλη πρόκληση. Ανατρέχοντας σε μελέτες [171] και άρθρα [84] που αφορούν στην Καταγραφή του Χορού (Dance Documentation), διαπιστώνουμε πως δεν επαρκεί να θεωρεί κανείς τα δεδομένα του χορού ταυτόσημα με την βιντεοσκόπηση μιας παράστασης-εκτέλεσης, πόσο μάλλον με την λεκτική ή φωτογραφική καταγραφή τους.

Τα συστήματα σημειογραφίας [118] (Labanotation [120, 119], Eshkol – Wachman [82], Benesh [161]) δίνουν ένα πολύτιμο εργαλείο για την συστηματική τεκμηρίωση της κίνησης του χορού. Ο λόγος που ανατρέξαμε σε εργασίες Χορολόγων όσο και Εθνοχορολόγων, είναι το γεγονός ότι η επιστήμη της μελέτης του χορού παρέχει σημαντικά μεθοδολογικά εργαλεία και λεξιλόγια για να αναλύσουμε την κίνηση του χορού και να ορίσουμε κάποιες παραμέτρους.

Αρκετές εργασίες στο χώρο της πληροφορικής [35] έχουν βασιστεί στα συστήματα σημειογραφίας και συγκεκριμένα το Labanotation, είτε για να αναπτύξουν εργαλεία και επεξεργαστές όπως το LabanWriter [163] και άλλα [116, 130, 154], αλλά και για τη μεταφορά μέρους της σημασιολογίας του συστήματος σε δομημένες γλώσσες όπως XML [107, 157], είτε για να εφαρμόσουν το σύστημα ανάλυσης του Laban με σκοπό τη μοντελοποίηση μηχανικής κίνησης σε ρομπότ [115] και τη βελτίωση μοντέλων Επικοινωνίας Ανθρώπου Μηχανής [85, 139], μέσω κίνησης και επαφής. Αντίστοιχα μπορεί κανείς να βρει στο διαδίκτυο, ιστοσελίδες με τις βασικές αρχές αυτών των συστημάτων [101, 96]. Βέβαια, εδώ πρέπει να τονίσουμε ότι οι παράμετροι που ορίζουν το χορό και την κίνησή δεν είναι ανεξάρτητοι του συστήματος ανάλυσης και θέτουν σαφή ερωτήματα, άρρηκτα συνδεδεμένα με το πλαίσιο στο οποίο δημιουργείται ένας χορός, είτε πρόκειται για παραστατικό χορό, είτε για παραδοσιακό και κοινωνικό χορό. Για αυτόν ακριβώς το λόγο, η καταγραφή και η Χορολογική ανάλυση συνοδεύεται πάντα από συνεντεύξεις/συζητήσεις με το χορογράφο [186] ή και τους χορευτές αν πρόκειται για παραστατικό χορό, είτε με επιτόπια έρευνα και συζήτηση με τους ντόπιους χορευτές εάν πρόκειται για παραδοσιακό χορό [162].

Το όραμα μιας παγκόσμιας ψηφιακής βιβλιοθήκης στην οποία θα υπάρχουν καταγεγραμμένοι όλοι οι χοροί και οι χορευτές του κόσμου είναι όντως δελεαστικό και υπάρχουν κάποιες πολύ ενδιαφέρουσες πρωτοβουλίες σ' αυτήν την κατεύθυνση [32].

Το ερώτημα είναι εάν ένα σύστημα καταγραφής και ανάλυσης κίνησης, όπως το Labanotation, ανεξάρτητα από το είδος του χορού, θα μπορούσε να λύσει το πρόβλημα της καταγραφής από μόνο του; Στην πράξη, δεν υπάρχει κάποια καθιερωμένη και καθολικά αποδεκτή προσέγγιση που να απαντάει στο ερώτημα ποια είναι σημαντική πληροφορία για την κίνηση στο χορό, με τέτοιο τρόπο που να καλύπτει όλα τα είδη χορού παγκοσμίως. Αυτό το οποίο μπορεί να είναι άχρηστη λεπτομέρεια για τον ελληνικό παραδοσιακό χορό, όσον αφορά στην κίνηση του σώματος, π.χ., τι κάνουν τα δάχτυλα του χεριού, μπορεί να είναι υψίστης σημασίας για άλλα είδη, όπως τον παραδοσιακό ινδικό χορό. Έτσι, ενώ κάτι τέτοιο δεν είναι μείζον στοιχείο της παρούσας εργασίας, είναι ωστόσο αδύνατον να μοντελοποιήσουμε «τα δεδομένα του χορού», χωρίς να λάβουμε υπόψη μας τις πρακτικές, μεθοδολογικές, επιστημονικές, εκπαιδευτικές ή και φιλοσοφικές θέσεις που υπάρχουν πίσω από τις υπόλοιπες προσεγγίσεις, ακόμα και αν πρόκειται αποκλειστικά για την κίνηση του σώματος και αφήσουμε εκτός, προς το παρόν, παράγοντες όπως μουσική, κουστούμια, τόπος και χρόνος εκτέλεσης, είδος, δραματουργία, ιστορία, κ.τ.λ.

4. Εννοιολογικές και Βιωματικές Γλώσσες για το Χορό

Στο σημείο αυτό της διατριβής ερευνούμε νέους και αποτελεσματικούς τρόπους αποθήκευσης των δεδομένων της κίνησης, με τρόπο τέτοιο ώστε να είναι επιτρεπτή η αναζήτηση συγκεκριμένων κινητικών δομών (κινήσεων, μοτίβων, φράσεων κ.τ.λ.).

Το πρώτο βήμα για τη δημιουργία μιας βάσης γνώσης είναι η μοντελοποίηση του πεδίου της κίνησης και του χορού. Για το σκοπό αυτό χρησιμοποιήσαμε τα εργαλεία και την τεχνολογία του Σημασιολογικού Ιστού, αναπτύσσοντας μια οντολογία σε OWL-2[1] για την αναπαράσταση της κινησιολογίας του χορού. Ως θεωρητικό υπόβαθρο για τη μοντελοποίηση χρησιμοποιήθηκε η σημειογραφία του Laban (Labanotation ή Kinetography Laban) [119], το πλέον διαδεδομένο και τεκμηριωμένο σύστημα ανάλυσης και καταγραφής χορού (ανεξάρτητα από το είδος), το οποίο και υποστηρίζεται από διεθνείς οργανισμούς, όπως το 1) International Council for Kinetography Laban/Labanotation [35] και το 2) Dance Notation Bureau [39]. Παρουσιάζουμε συνοπτικά τη μεθοδολογία και τα αποτελέσματα που αφορούν στο πρώτο σκέλος, δηλαδή τις Εννοιολογικές Γλώσσες για το Χορό.

Αφορά στο πώς αναπαριστούμε, δομούμε και επεξεργαζόμαστε την κίνηση σε ένα λογικό, εννοιολογικό επιπεδο και πώς ορίζουμε και μελετάμε τις Κινητικές Οντότητες που απαρτίζουν το χορό.

Έχοντας λοιπόν χτίσει τον πυρήνα της εννοιολογικής και σημασιολογικής αναπαράστασης μέσα από μια χρηστοκεντρική και επαναληπτική διαδικασία όπου αναπτύχθηκαν μια σειρά από εργαλεία, αξιολογούμε τη χρήση του εννοιολογικού μοντέλου μας.

[1] https://www.w3.org/TR/owl2-overview/

Συγκεκριμένα, τα εργαλεία αυτά αφορούν σε δύο κατηγορίες:

- διαδικτυακά εργαλεία διαχείρισης και επισημείωσης περιεχομένου χορού όπως βίντεο ή τρισδιάστατες αναπαραστάσεις, προερχόμενες από σύλληψη κίνησης (Motion Capture).

  Το εννοιολογικό μοντέλο, χρησιμοποιήθηκε αλλά και αναπτύχθηκε ώστε να προσφέρει την οργάνωση των μεταδεδομένων, καθώς και λεξικά επισημείωση, και εμπλουτισμού της υπάρχουσας γνώσης με νέα γνώση, εφαρμόζοντας κανόνες συμπερασμού.

- εμπειρίες ενσώματης αλληλεπίδρασης που χρησιμοποιούν την κίνηση σε πραγματικό χρόνο. Πραγματοποιήθηκε βιβλιογραφική ανασκόπηση (survey) που αφορά στη σχεδίαση και έρευνα αντίστοιχων εμπειριών με σκοπό την εκπαίδευση ή την καλλιτεχνική δημιουργία του χορού, όπου εντοπίστηκαν οι βασικές προκλήσεις από πλευράς Επικοινωνίας Ανθρώπου Μηχανής, και προτάθηκε διάγραμμα ροής για τη σχεδίαση αντίστοιχων εμπειριών. Παράλληλα μέσα από τη ανάπτυξη και αξιολόγηση εφαρμογής που αφορά την οπτικοποίηση της κίνησης σε πραγματικό χρόνο, μελετήθηκε η αντίδραση των χρηστών σε σχέση με την αναπαράσταση του σώματος με τρισδιάστατες αναπαραστάσεις.

4.1. Οντολογική και γλωσσολογική προσέγγιση για την ψηφιακή αναπαράσταση και επεξεργασία

Προτείνουμε μια οντολογική και γλωσσολογική προσέγγιση στη σημασιολογική αναπαράσταση της κίνησης, η οποία λαμβάνει υπόψη υπάρχοντα θεωρητικά πλαίσια για την ανάλυση της κίνησης, με απώτερο σκοπό την υπολογιστική επεξεργασία και ψηφιακή αναπαράσταση της κίνησης. Το σύστημα ανάλυσης του Laban (Laban Movement Analysis) και συγκεκριμένα της κινησιογραφίας ή συστήματος σημειογραφίας Labanotation, μας προσφέρει το θεωρητικό υπόβαθρο για τον ορισμό των βασικών εννοιών που απαρτίζουν την ανθρώπινη κίνηση σε ένα αφαιρετικό επίπεδο, ανεξάρτητα από το είδος του χορού.

Παράλληλα, η επιστήμη της Χορολογίας και της Ανθρωπολογίας του χορού προσθέτει το μεθοδολογικό υπόβαθρο για την ανάλυση της δομικής ανάπτυξης της κίνησης για τη δημιουργία του χορού, ορίζοντας την ανάπτυξη της μορφολογίας της κίνησης μέσα από ένα γλωσσολογικό πρίσμα παραλληλίας του χορού και της γλώσσας. Τέλος η μελέτη των κινητικών λεξικών και της αντίστοιχης ορολογίας και η σχέση κάποιων ειδών του χορού με αυτά όπως π.χ. το κλασικό μπαλέτο, μας προσφέρουν άλλον ένα μεγάλο όγκο πληροφορίας για τις γλώσσες με τις οποίες οι κοινότητες του χορού, επικοινωνούν μεταξύ τους και δημιουργούν έννοιες που αντιστοιχούν σε συγκεκριμένες θέσεις ή αλληλουχίες κινήσεων.

4.2 Τεχνολογίες Σημασιολογικού Ιστού για την Αναπαράσταση του Χορού

Χρησιμοποιώντας τα εργαλεία του Σημασιολογικού Ιστού όπως τη γλώσσα των οντολογιών OWL, RDF και τη γλώσσα επερωτήσεων SPARQL, δημιουργήσαμε μια σειρά από επεκτάσιμες οντολογίες, τις οποίες και επεκτείναμε και ανανεώσαμε μέσα από μια επαναληπτική μέθοδο.

Ξεκινώντας από μια πρώτη έκδοση της οντολογίας, η οποία είχε σκοπό να μεταφέρει τις έννοιες του Labanotation σε OWL και τη δημιουργία μιας πιλοτικής βάσης γνώσης με επτά παραδοσιακούς χορούς, εντοπίστηκαν οι προκλήσεις που αφορούν τόσο στην ίδια την αναπαράσταση της κίνησης (πολυμορφία χορού, πολυπλοκότητα ανθρώπινου σώματος, αμφισημία περιγραφών, αναπαράσταση χρόνου), όσο και στις διαφορές που υπάρχουν μεταξύ της συμβολικής γλώσσας της σημειογραφίας του Labanotation και της γλώσσας των οντολογιών (ή και μιας οποιαδήποτε υπολογιστικής- μαθηματικής γλώσσας).

Ο λόγος που στραφήκαμε στην τεχνολογία του Σημασιολογικού Ιστού είναι αφενός η δυνατότητα που μας προσφέρει η γλώσσα των οντολογιών OWL να αναπαραστήσουμε πολύπλοκες σχέσεις και ιεραρχίες, αλλά και το γεγονός ότι παρέχει τη δυνατότητα να συνδυαστεί με αντίστοιχα «λεξιλόγια» παρεμφερών πεδίων, όπως π.χ., της μουσικής [122, 189]. Μας επιτρέπει δηλαδή να ορίσουμε κάποιες έννοιες αποδίδοντας με αυτόν τον τρόπο κάποιο είδος σημασίας στα δεδομένα, κάτι που είναι κατανοητό και από τον υπολογιστή μέσα από τη διαδικασία εξαγωγής συλλογισμών. Με τον τρόπο αυτό αφήνουμε ανοιχτό το ενδεχόμενο να συσχετιστεί ή και να επεκταθεί η οντολογία με άλλες οντολογίες σχετικών πεδίων, καθότι όπως αναφέραμε παραπάνω η κίνηση στο χορό είναι μεν το πρωταρχικό στοιχείο, ωστόσο όπως συμβαίνει σε κάθε μορφή τέχνης, βρίσκεται σ' ένα ευρύτερο πλαίσιο και συνδέεται με στοιχεία που είτε το αφορούν άμεσα, όπως η μουσική, οι συντελεστές, ο χώρος, είτε έμμεσα, όπως ο τόπος της δημιουργίας ή της προέλευσης, το ιστορικό-κοινωνικό πλαίσιο, κ.α., αλλά ακόμη και αντικείμενα και άλλες μορφές καταγραφής (κείμενο, φωτογραφικό υλικό, αρχεία ήχου, κ.τ.λ.).

4.3 Ανάπτυξη Λεξιλογίων για την Κίνηση (Vocabularies/Dance Knowledge)

Όπως αναφέραμε και πιο πάνω, παρά κάποιες θέσεις που παραλληλίζουν τη δομή και τη μορφολογία το χορού με αυτή της γλώσσας, όπως της Kaeppler [125], ο χορός, ως ένα μέσο μη λεκτικής επικοινωνίας δεν διέπεται από ένα συγκεκριμένο λεξιλόγιο. Αν θέλουμε να συγκρίνουμε τον χορό με τη γλώσσα ως έννοιες, τότε με τον ίδιο τρόπο που η γλώσσα ως ένα σύστημα επικοινωνίας και μια δραστηριότητα κοινή για το ανθρώπινο είδος, δεν ταυτίζεται μερικώς με καμία από τις γλώσσες που μιλάει κάθε λαός ή περιοχή ξεχωριστά αλλά ούτε και με το άθροισμα αυτών, αντίστοιχα ο χορός ως έννοια, δεν ορίζεται από το πεπερασμένο άθροισμα των χορών και των κινήσεων που εξασκεί ο κάθε χορευτής, χορογράφος, λαός, κ.τ.λ. Δεν «μιλάμε» όλοι την ίδια χορευτική γλώσσα, ή ακόμα και αν χρησιμοποιούμε το ίδιο κινητικό λεξιλόγιο (τις ίδιες κινήσεις) δεν χρησιμοποιούμε τις ίδιες λέξεις για να περιγράψουμε την ίδια κίνηση [113], αφού η κίνηση προέρχεται κάθε φορά από μία διαφορετική «οντολογία», έναν τελείως διαφορετικό κόσμο. Άλλους όρους χρησιμοποιεί ένας δάσκαλός παραδοσιακών χορών, άλλους ένας δάσκαλος κλασικού χορού, άλλους ο κάθε σύγχρονος χορογράφος ή δάσκαλος/χορευτής αυτοσχεδιασμού, κ.ο.κ. Το γεγονός αυτό έχει οδηγήσει κάποια έργα στην έρευνα της δημιουργίας και της συσχέτισης τέτοιου είδους λεξιλογίων [95] με στόχο να δημιουργήσουν κάποια αποθετήρια γνώσης όπου οι κρυμμένες συσχετίσεις και πρότυπα (patterns) μέσα από την κατάλληλη ανάδειξη και παρουσίαση μπορούν να οδηγήσουν σε νέα γνώση αλλά και έμπνευση άλλων δημιουργών του χορού και όχι μόνο. Στο σημείο αυτό ο στόχος μας είναι με ποιο τρόπο θα μπορούμε να επεκτείνουμε τις εξαγωγές συμπερασμάτων σε ευρύτερο πλαίσιο, είτε προσθέτοντας διαφορετικά είδη χορού, είτε λαμβάνοντας υπ' όψιν και ευρύτερες παραμέτρους που αφορούν στο πλαίσιο του χορού.

Στο σημείο αυτό, θα θέλαμε να τονίσουμε τη χρήση των οντολογιών σε αντίστοιχες δουλειές με στόχο την περιγραφή και τη σύγκριση αντικειμένων πολιτισμικής κληρονομιάς όπως το μοντέλο CIDOC [97] και διάφορες επεκτάσεις τους στα πλαίσια εφαρμογών όπως το FRBRoo [64]. Ιδιαίτερο ενδιαφέρον για μας παρουσιάζει το πρόσφατο άρθρο των W. Ceusters και B. Smith[47], το οποίο τονίζει τη συμβολή που μπορούν να έχουν οι τεχνολογίες του Σημασιολογικού Ιστού στο χώρο της καταγραφής του χορού.

Κατά τη διαδικασία αυτή εστιάσαμε σε συγκεκριμένα πραγματικά παραδείγματα καταγραφής παραδοσιακού χορού από το αρχείο του προγράμματός Θράκη και τη μεταφορά τους σε οντολογική αναπαράσταση. Η διαδικασία αυτή είχε ως αποτέλεσμα την επέκταση της αρχικής οντολογίας, διακρίνοντας τα στοιχεία που αφορούν την αρχειακή αναπαράσταση χορού από αυτά της κίνησης, αλλά και της ανάπτυξης της σε σύγκριση με υπάρχοντα εννοιολογικά συστήματα για αρχεία και πολιτιστική κληρονομιά όπως αυτά του CIDOC και του FRBRoo. Παράλληλα διακρίνονται τα διαφορετικά εννοιολογικά επίπεδα περιγραφής τα οποία μπορεί να απαρτίζουν μια πλήρη αναπαράσταση, ανεξάρτητα από τη φυσική τους υπόσταση και συγκρίνονται με αντίστοιχα μοντέλα στη μουσική. Τέλος εντοπίζονται οι προκλήσεις που υπάρχουν όσον αφορά η αναπαράσταση του χρόνου και προτείνονται εναλλακτικοί τρόποι ψηφιακής αναπαράστασης όπως η Datalog. Συγκεκριμένα, τα θέματα τα οποία θα εξετάσουμε είναι οι χωρικές, χρονικές και οι μερικές σχέσεις που προκύπτουν από την κίνηση, ενώ παράλληλα μελετάμε προσεγγίσεις τυπικών οντολογιών. Ένα από τα ερευνητικά θέματα τα οποία σχετίζονται με το θέμα μας είναι ο χρονικός συλλογισμός (Temporal Reasoning) [165, 34, 42]. Εξάλλου, μιλώντας για κίνηση, άρα για κάτι που περιλαμβάνει την έννοια της αλλαγής, ακόμα και οι χωρικές σχέσεις είναι κάτι μεταβλητό ως προς το χρόνο.

5. Μεθοδολογία: Η Χορευτική Κίνηση ως Άυλη Πολιτιστική Κληρονομιά και μέρος ενός Αρχείου

Για την διατύπωση των Εννοιολογικών Γλωσσών για το Χορό αποτέλεσε η μελέτη της καταγραφής από υπάρχοντα κινησιογράμματα στο σύστημα Labanotation, και τη μετατροπή τους σε στιγμιότυπα και ιδιότητες της οντολογίας. Με τον τρόπο αυτό, αξιολογείται και επαναπροσδιορίζεται το μοντέλο, ενώ ερευνήσαμε τρόπους που θα οδηγήσουν σε μια πιο αποτελεσματική απεικόνιση αλλά και διαχείριση των δεδομένων, με απώτερο στόχο τη δημιουργίας μιας βάσης γνώσης με λειτουργίες προηγμένης-έξυπνης αναζήτησης.

Συγκεκριμένα, μελετήσαμε κινησιογράμματα τα οποία προέκυψαν από την καταγραφή της επιτόπιας έρευνας του προγράμματος Θράκη [162]. Παράλληλα δουλεύουμε στη δημιουργία ενός πειραματικού αρχείου με ελληνικούς παραδοσιακούς χορούς. Το αρχείο αυτό προέρχεται από τη μεταφορά/μετάφραση των κινησιογραμμάτων του Προγράμματος

Θράκη ή κινησιογραμμάτων άλλων χορών εφόσον είναι διαθέσιμα. Στόχος είναι η ανάπτυξη ενός αρχείου ομοειδών χορών που προέρχονται από παρόμοιες καταγραφές, έτσι ώστε να μπορούμε να εξάγουμε κάποια πρώτα συμπεράσματα και στατιστικά. Με αυτόν τον τρόπο, αξιολογούμε την μεθοδολογία που αναπτύχθηκε στην προηγούμενη φάση μέσα από πραγματικά δεδομένα. Αντίστοιχα, εξετάζουμε τη σχέση του μοντέλου που αναπτύξει με άλλες μεθόδους ανάλυσης και διακριτοποίησης της ανθρώπινης κίνησης όπως η «γλωσσολογική» προσέγγιση της Kaeppler [125, 123] και της Loutzaki [142] στην περίπτωση του ελληνικού παραδοσιακού χορού.

Η βελτίωση της οντολογίας, ακολούθησε μια επαναληπτική μέθοδο η οποία οδήγησε στον εμπλουτισμό της με λεπτομέρειες που αφορούν στην ορθότερη αναπαράσταση του χρόνου, βασιζόμενοι στις σχέσεις Allen [7] με τρόπο παρόμοιο που παρουσιάζονται στην time-OWL [111]. Στην παρούσα διατριβή παρουσιάζουμε τόσο τις βασικές δομές της οντολογίας έτσι όπως δημοσιεύτηκαν στα άρθρα [72, 73, 75, 74]. Ταυτόχρονα παρουσιάζεται η μεθοδολογία μεταφοράς της σημασιολογίας του συστήματος σημειογραφίας του Laban σε OWL -2, επιτυγχάνοντας τη δημιουργία μιας βάσης γνώσης βασισμένης σε Περιγραφικές Λογικές με δυνατότητα εξαγωγής συμπερασμάτων μέσω συλλογισμών, και συζητάμε τις προκλήσεις που προέκυψαν από αυτή τη διαδικασία.

Τέλος μελετώνται και παρουσιάζονται οι σχέσεις μεταξύ των εννοιών της Παρτιτούρας ή Κινησιογράμματος (Score), της καταγραφής (Recording), των οντοτήτων του Χορού και των Κινητικών Οντοτήτων (Movement Entities) και εξετάζονται αναλογίες μεταξύ της γλώσσας αλλά της σημειογραφίας της μουσικής μέσα από μια μελέτη περίπτωσης στο μπαλέτο.

6. Σχεδίαση, ανάπτυξη και αξιολογση διεπαφών διαχείρισης δεδομένων χορού και επισημείωσης με επίκεντρο την κίνηση

Η επόμενη ενότητα της διατριβής αφορά στη χρήση και περαιτέρω ανάπτυξη των παραπάνω οντολογιών και σημασιολογικών μοντέλων, με στόχο τη διαχείριση πληροφορίας μέσα σε περιεχόμενο χορού, που απαρτίζεται από βίντεο και τρισδιάστατα αρχεία προερχόμενα από τη διαδικασία σύλληψης κίνησης. Στην περίπτωση αυτή, τα προαναφερθέντα σημασιολογικά μοντέλα περιγραφής κίνησης λειτουργούν ως βάση τόσο για την ανάπτυξη του σχήματος μεταδεδομένων, όσο και ως ιεραρχικά λεξιλόγια για την επισημείωση της κίνησης. Η ανάπτυξη των παραπάνω λεξιλογίων σε τεχνολογίες Σημασιολογικού Ιστού, μας επιτρέπει τον συμπερασμό νέας πληροφορίας που προκύπτει μέσα από τις ιεραρχίες και τους κανόνες που έχουν ήδη οριστεί. Συγκεκριμένα, στο σημείο αυτό παρουσιάζονται τρεις εκδοχές των διαδικτυακών εφαρμογών επισημείωσης.

1) έχοντας ως μελέτη περίπτωσης το μπαλέτο, ενσωματώνεται επέκταση της οντολογίας για την αναπαράσταση της κινησιολογίας και ορολογίας του μπαλέτου, επιτρέποντας την αναζήτηση περιεχομένου με βάση αυτή την πληροφορία.

2) στην ίδια πλατφόρμα, αντιμετωπίζουμε το πρόβλημα του χρονικού συμπερασμού, μεταφέροντας μέρος της οντολογίας σε γλώσσα DatalogMTL, με σκοπό το συμπερασμό που προκύπτει από συνδυασμό των επισημειώσεων και των κανόνων ορισμού στην οντολογία.

Στα δύο προηγούμενα παραδείγματα η επισημείωση αφορά σε αρχεία βίντεο. Τέλος,

3) σχεδιάστηκε και αναπτύχθηκε πλατφόρμα (WML) η οποία αφορά στη διαχείριση 780 αρχείων που προέκυψαν από τη σύλληψη κίνησης τεσσάρων διαφορετικών ειδών χορού και παρουσιάζονται στο χρήστη μέσα από βίντεο και τρισδιάστατη απεικόνιση.

Η σχεδίαση και η αξιολόγηση των διεπαφών επισημείωσης έγινε με τη συμμετοχή ειδικών του χορού, ακολουθώντας μια χρηστοκεντρική μεθοδολογία. Η διαδικασία αυτή ανέδειξε ένα πλήθος από σχεδιαστικές, τεχνολογικές και σημασιολογικές προκλήσεις που σχετίζονται με το θέμα της επισημείωσης της κίνησης. Έτσι, ενώ τα μοντέλα που αναπτύχθηκαν απαντούν στο θέμα του καθορισμού των Εννοιολογικών στοιχείων που αφορούν στο χορό, η σχεδίαση και οι τρόποι της διάδρασης διαμορφώνουν με τη σειρά τους νέες γλώσσες για τη Βιωματική αντίληψη και αναπαράσταση του χορού. Σε αυτή την περίπτωση ωστόσο, ασχολούμαστε κυρίως με την οπτικοποίηση και όχι ακόμα με την ενσώματη διάδραση που αποτελεί το θέμα που κατεξοχήν μας απασχολεί στο τελευταίο μέρος της διατριβής.

7. Ενσώματη Διάδραση για το χορό: Βιβλιογραφική μελέτη, διάγραμμα ροής και εφαρμογές

Στο τελευταίο κεφάλαιο της διατριβής μας απασχολούν κυρίως οι Βιωματικές Γλώσσες του Χορού. Θα πρέπει να τονίσουμε ότι σε αυτή την περίπτωση μας απασχολεί ο τρόπος με τον οποίο οι σύγχρονες τεχνολογίες μπορούν να μετασχηματίσουν την εμπειρία του χορού, μέσα από ενσώματες και διαδραστικές εφαρμογές, δίνοντας έμφαση στο στοιχείο της μάθησης. Στο σημείο αυτό πραγματοποιήσαμε εκτενή βιβλιογραφική μελέτη της υπάρχουσας κατάστασης σε σχέση με τα Ψηφιακά Συστήματα Μάθησης Χορού. Τα αποτελέσματα της έρευνας αυτής, τα οποία έχουν δημοσιευτεί σε αντίστοιχο περιοδικό πληροφορικής [172], ορίζουν ένα διάγραμμα ροής το οποίο θέτει τα βασικά σχεδιαστικά ερωτήματα που καλείται να απαντήσει κανείς αν θέλει να σχεδιάσει μια εμπειρία ενσώματης μάθησης για το χορό. Στη συνέχεια, μέσω του συστήματος ενσώματης διάδρασης και οπτικοποίησης κίνησης σε πραγματικό χρόνο, μελετήθηκε η αντίδραση των χρηστών σε σχέση με την απεικόνιση τους στο εικονικό περιβάλλον. Τα αποτελέσματα επιβεβαιώνουν την αρχική μας υπόθεση, ότι η ψηφιακή αναπαράσταση της κίνησης, όταν πλέον μετασχηματίζεται σε εμπειρία, έχει άμεση επιρροή στα βιωματικά χαρακτηριστικά του χορού.

Με τα αποτελέσματα αυτά και τη συνοπτική παρουσίαση όλων των επιμέρους θεμάτων, της δικής μας συνεισφοράς σε αυτά αλλά και την αναφορά των ανοικτών προβλημάτων και των μελλοντικών κατευθύνσεων, κλείνει η παρούσα διατριβή.

To my family and friends for their endless support and love. To whoever reminds me that: "In a manner of speaking. Semantics won't do. In this life that we live, we live, we only make do." [200]

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During this journey of working on my thesis, there have been many moments that I imagined myself writting this part. The completion of something, a milestone is always important. Nevertheless, it is much more than another accomplishment, it is a chance to reflect on these years and feel grateful for the chance to come across and collaborate with some wonderful people and appreciate their role in this accomplishment. Without these humans this would not be feasible.

First of all, I would like to thank my supervisor, Professor Yannis Ioannidis, for trusting to me this challenging thesis. A topic that I know that it was a vision of his since some years ago, and that required a combination of disciplines that I will be always excited about. I thank him, for always pushing me to become better researcher, scientist, and human being. I am grateful for his faith in me and his generosity in supporting not just my thesis, but my personal development on so many levels. I would like to thank my professor Manolis Koubarakis, as he was the first to inspire me about Semantic Web Technologies, Logics and Ontologies and he was always available for advice, with positive and supportive energy. I feel really happy that I had the chance to be also supervised by an important dance researcher and personality, Professor Irene Loutzaki. She had opened for me new perspectives on observing dance, as a form of social and human activity and research subject.

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1. INTRODUCTION

"You have to love dancing to stick to it. It gives you nothing back, no manuscripts to store away, no paintings to show on walls and maybe hang in museums, no poems to be printed and sold, nothing but that single fleeting moment when you feel alive." -Merce Cunningham

1.1 General idea

Nowadays technologies can offer extremely useful tools for recording, analysing, transforming and transmitting dance knowledge within a variety of contexts and purposes such as dance research, learning and education, supporting creativity and choreography. Such technologies can also support and enhance the preservation of intangible cultural heritage, and offer useful tools for the research of social, aesthetical, and anthropological aspects related to movement.

Contemporary technologies such as video, motion capture, computer vision, and experiences such as augmented and virtual reality, open new opportunities for experiencing dance content in a variety of contexts. In parallel, data related to movement and dance are increasing, demanding efficient and meaningful ways of online data management that facilitates findability, accessibility, reuse of existing digital movement segments for the community of dance practitioners. We argue that an interdisciplinary approach taking into account existing methodologies for dance analysis, is necessary for describing, analysing and enriching these data, as well as for organising the capture of data in future, and propose workflows for meaningful experiences.

Dance, integrating the universal human capacity for non-verbal communication and artistic expression, can be seen as a core activity that reflects the aspects of human societies, historical periods, cultures of specific regions, complex political and social dynamics, as well as human embodied identities [132].

While computer science can offer a powerful tool for the transformation of the dance research, learning and creation, this can only be achieved successfully through a dialogue between the existing methodologies of the domain while, or even better before, applying technologies. Moreover, dance in comparison to other learning subjects or cultural domains present a variety of challenges due not only to the complexity of the human body and its movement, but also to the lack of standardized ways to describe movement in general, in a consistent, computational language, without presenting important limitations in terms of expressivity and capacity to describe the richness human movement. Of course, a variety of theoretical and computational attempts have been proposed the last decades and we discuss within this thesis. In fact, one of our main statements is that the computational analysis of human movement, especially if we are referring to dance, needs to take into account the theoretical background in movement analysis, Choreology and Anthropology of dance.

Another challenge rise from the fact that when we talk about dance it is important to take into account that although the capacity of humans to express through their bodies and dancing and is universal, there is a huge amount of dance languages, practices, techniques and approaches. In this thesis deals with the representation and analysis of movement, focusing on the transmitting and processing of dance genres that rely on particular forms with the intention to describe, search and re-use in digital environments mainly from the perspectives of intangible cultural heritage and education.

We address this problem by using tools from the Semantic Web technologies, such as Web Ontology Language (OWL), and propose an ontological perspective for the semantic representation of movement and dance. We ground our framework on existing theoretical systems for analysing and describing movement such as Laban Movement Analysis and Labanotation, as well as Choreological approaches that suggest an analogy between Dance and Language. While this analogy provides the tools for the structural and morphological analysis of movement, we extend this framework, to include both the Conceptual as well as the Experiential aspects of dance. We apply an iterative approach, investigating a number of use-cases of different dance genres and interactions.

Our objective is to research the limitations of finding a general framework for dance and its digital transmission, while respecting its complexity and cultural diversity. To do so our use-cases range from transfering the semantics of formal notation to whole-body interaction experiences. We acknowledging the fact that one solution to fit all might be impossible and a universal upper-ontology to describe all kinds of dance would create a model that is far away from the reality of dance education, creation and practice. Thus our model suggests rather a modular, multilayer and extensible approach, proposing a number of representational methodologies and workflows for design.

This iterative approach includes not only a continuous study of the theory and semantics underlying formal descriptions of movement but also a continuous dialogue with notators and dance experts to build tools through a user-centered perspective. The tools that we have designed, developed and studied, integrate and evaluate our framework and conceptual model, consist of two main categories: 1) web-based dance data management and enrichment existing dance content, and 2) visualisation and whole-body interaction experiences.

The web-based annotation tools integrate a complete data and user management system and implement functionalities of searching the library of content with ”movement descriptors and characteristics.

1.2 Outline

The rest of this thesis is organized as follows:

In **Chapter** 2 we introduce the relationship of dance and technologies and our motivation for this work. After a short historical introduction on the relationship of dance and technology, we present the different purposes of applying computational methods for dance,

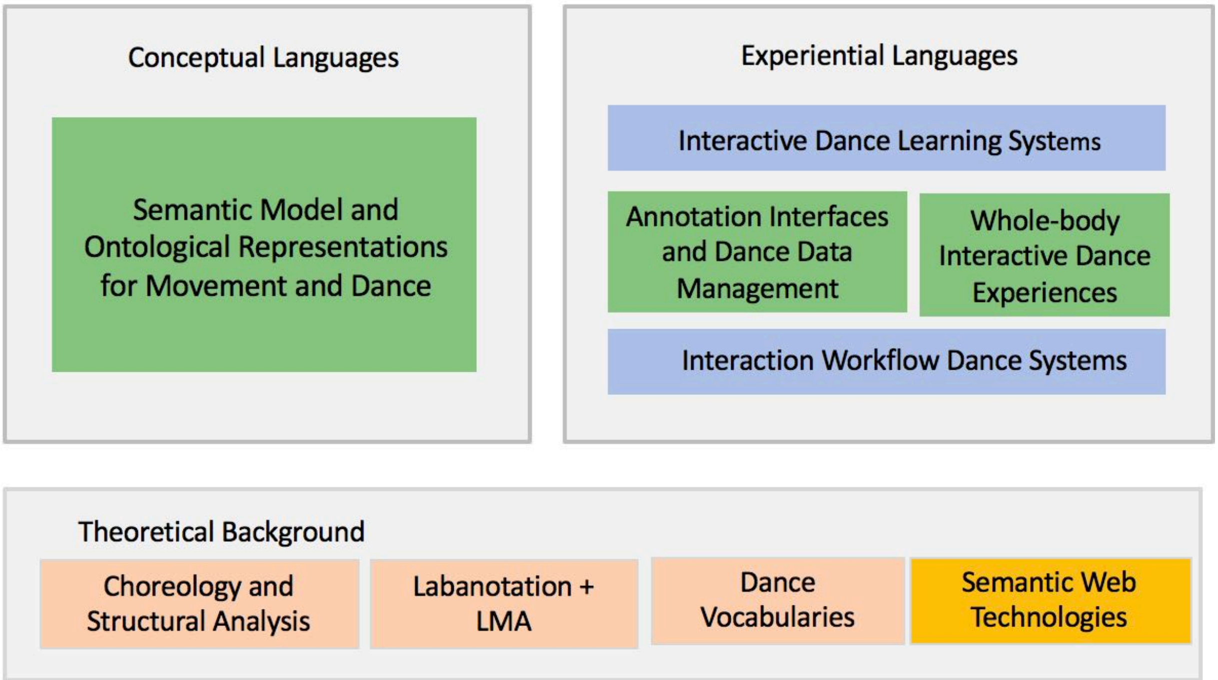


Figure 2: Overview of the thesis theoretical background, methodology and contribution

focusing on cultural heritage and educational perspectives. Finally, we dicuss the technical and interdisciplinary challenges that are related to the introduction of conceptual frameworks and semantic representation of movement.

In **Chapter** 3 we describe our theoretical background and we explain how the analogy between dance and language, in combination with dance notational system can provide a methodological tool for movement representation and analysis and therefore guide the development of digital applications and computational systems.

In **Chapter** 4 we present the semantic representation of movemen and we describe the ontological implementations that we have been developed based on the movement representation models and we present the different use cases of extending both the semantic model and dance vocabularies.

In **Chapter** 5 we explain how the aforementioned models and ontologies are integrated on applications for the end-users and we present the implementation of annotation interfaces for different dance genres (ballet, contemporary, Greek folk and flamenco). In the same chapter we discuss the challenges of annotation and we present the results of the evaluations involving dance experts through a user-centered iterative approach.

In **Chapter** 6 we present the outcome of our investigation in extending our conceptual model into an interactive workflow that can be integrated for whole-body interaction applications for dance learning and we present particular use-cases for addressing the challenges that emerge in these paradigms. While in the previous use-cases we focus on applications that deal with the structural part of dance, in this chapter we showcase examples of systems and methodological tools that deal with the qualitative and expressive aspects of dance.

Finally, **Chapter** 7 concludes this thesis and discusses possible future directions.

1.3 Contribution and List of Publications

The following publications in journals and conferences consists the main contribution of the thesis in the field of movement and computing, semantic web and human computer interaction. Parts of these publication formalisations, results and discussion are included and/or citated in this document.

1.3.1 Thesis Publications

Thesis Journal Publications

1. **El Raheb, K.**, Stergiou, M., Katifori, A., and Ioannidis, Y. (2019). Dance Interactive Learning Systems: A Study on Interaction Workflow and Teaching Approaches. ACM Computing Surveys (CSUR), 52(3), 50.

2. **El Raheb, K.**, Katifori, A.,and Ioannidis, Y. (2016). HCI Challenges in Dance Education. EAI Endorsed Transactions.

Thesis Conference Publications

1. **El Raheb K.**, Stergiou M., Katifori M., Ioannidis Y., Mirror-mirror on the screen am I the most aligned than I have ever been? (2019) In the proceedings of the 1st Workshop on HCI Challenges in Human Movement Analysis at the 17th IFIP TC.13 International Conference on Human-Computer Interaction, (to appear)

2. Stergiou M, **El Raheb K.**, Ioannidis Y. (2019)-Imagery and metaphors: from movement practices to digital and immersive environments, In Proceedings of the 6th International Conference on Movement and Computing. ACM. (to appear)

3. **El Raheb, K.**, Tsampounaris, G., Katifori, A.,and Ioannidis, Y. (2018, May). Choreomorphy: a whole-body interaction experience for dance improvisation and visual experimentation. In Proceedings of the 2018 International Conference on Advanced Visual Interfaces (p. 27). ACM.

4. **El Raheb, K.**, Kasomoulis, A., Katifori, A., Rezkalla, M.,and Ioannidis, Y. (2018, June). A Web-based system for annotation of dance multimodal recordings by dance practitioners and experts. In Proceedings of the 5th International Conference on Movement and Computing (p. 8). ACM.

5. **El Raheb, K.**, Mailis, T., Ryzhikov, V., Papapetrou, N.,and Ioannidis, Y. (2017, May). Balonse: Temporal aspects of dance movement and its ontological representation. In European Semantic Web Conference (pp. 49-64). Springer, Cham.

6. Tsampounaris, G., **El Raheb**, K., Katifori, V., and Ioannidis, Y. (2016, November). Exploring Visualizations in Real-time Motion Capture for Dance Education. In Proceedings of the 20th Pan-Hellenic Conference on Informatics (p. 76). ACM.

7. **El Raheb, K.**, Papapetrou, N., Katifori, V.,and Ioannidis, Y. (2016, July). Balonse: ballet ontology for annotating and searching video performances. In Proceedings of the 3rd International Symposium on Movement and Computing (p. 5). ACM.

8. **El Raheb, K.**, and Ioannidis, Y. (2014, June). From dance notation to conceptual models: a multilayer approach. In Proceedings of the 2014 International Workshop on Movement and Computing (p. 25). ACM.

9. **El Raheb, K.**, and Ioannidis, Y. (2013). Dance in the World of Data and Objects. In Information Technologies for Performing Arts, Media Access, and Entertainment (pp. 192-204). Springer, Berlin, Heidelberg.

10. **El Raheb, K.**, and Ioannidis, Y. (2014, September). Modeling abstractions for dance digital libraries. In Proceedings of the 14th ACM/IEEE-CS Joint Conference on Digital Libraries (pp. 431-432). IEEE Press.

11. Ludovico, L. A., **El Raheb, K.** , and Ioannidis, Y. (2013). An XML-based web interface to present and analyze the music aspect of dance. In International Symposium on Computer Music Multidisciplinary Research (CMMR) (pp. 631-639).

12. **El Raheb, K.**, and Ioannidis, Y. (2011, May). A Labanotation based ontology for representing dance movement. In International Gesture Workshop (pp. 106-117). Springer, Berlin, Heidelberg.

1.3.2 Related Publications and Presentations

The following publications and presentations are not directly included to the outcomes of this thesis. Nevertheless, they have been published during the same period, and therefore informed my work and shaped my academic interests and research landscape.

1. **El Raheb, K.**, Whatley, S.,and Camurri, A. (2018, June). A Conceptual Framework for Creating and Analyzing Dance Learning Digital Cont nt. In Proceedings of the 5th International Conference on Movement and Computing (p. 2). ACM.

2. Rizzo, A.,**El Raheb, K.**, Whatley, S., Cisneros, R. M., Zanoni, M., Camurri, A., ...and Markatzi, A. WhoLoDancE: Whole-body Interaction Learning for Dance Education.CIRA@EuroMed 2018: 41-50

3. **Κατερίνα Ελ Ράχεμπ**, Γιάννης Ιωαννίδης «Ανάλυση κίνησης με χρήση σύγχρονων τεχνολογιών: νέα εργαλεία για την δημιουργική διαδικασία, την εκπαίδευση, την πρακτική και ερεύνα του χορού» 2nd Congress Performing Arts in Education, 2018

4. Camurri, A. ,**El Raheb, K.**, Even-Zohar, O., Ioannidis, Y., Markatzi, A., Matos, J. M., ...and Di Pietro, S. (2016, July). WhoLoDancE: towards a methodology for selecting motion capture data across different dance learning practice. In Proceedings of the 3rd International Symposium on Movement and Computing (p. 43). ACM.

5. **El Raheb K.**, Katifori V., Ioannidis Y., Camurri A., E. Kostic Cisneros, R, Even O., Gibson R., Markatzi A., Matos, JM, Palacio P, Di Pietro S, Romero M, Sarti A, Viro V, Whatley S. WhoLoDancE project: Towards virtual and holographic dance learning experiences. EuroVR 2016.

6. **Katerina El Raheb**, “Wholodance: How state-of-the art technologies can support dance education and enhance the experience of dance” 44th World Congress on Dance Research (CID-UNESCO), 2016.

7. **El Raheb K.**, Dance Ontology: Towards a searchable knowledge base Workshop on Movement Qualities and Physical Models Visualization, IRCAM Centre Pompidou, Paris 2012.

1.3.3 Other Publications

1. Ioannidis, Y., Toli, E., **El Raheb, K.**, ,and Boile, M. (2014, November). Using ICT in Cultural Heritage, bless or mess? Stakeholders’ and practitioners’ view through the eCultValue project. In Euro-Mediterranean Conference (pp. 811-818). Springer, Cham.

2. Ioannidis, Y., **El Raheb, K.**, Toli, E., Katifori, A., Boile, M.,and Mazura, M. (2013, October). One object many stories: Introducing ict in museums and collections through digital storytelling. In Digital Heritage International Congress (DigitalHeritage), 2013 (Vol. 1, pp. 421-424). IEEE.

3. **El Raheb, K.**, Athanasopoulos, G., Candela, L., Castelli, D., Innocenti, P., Ioannidis, Y., ...andThanos, C. (2012). Paving the way for interoperability in digital libraries: The DL. org project. In New Trends In Qualitative And Quantitative Methods In Libraries: Selected Papers Presented at the 2nd Qualitative and Quantitative Methods in Libraries (pp. 345-352).

4. Athanasopoulos, G., **El Raheb, K.**, Fox, E., Kakaletris, G., Manola, N., Meghini, C., ...andSoergel, D. A Framework for Digital Library Function Description, Publication, and Discovery: A prerequisite for interoperable digital libraries. In Workshop on Making Digital Libraries Interoperable: ChallengesandApproaches (Vol. 20).

Relevant invited lectures and presentations

1. Challenges for Cultural and Creative Industries- Movement and European industrial leadership, AIMove Post-Master's Degree in Artificial Intelligence and Movement, ParisTech-Ecole de Mines, Paris 2019

2. Εικονική Πραγματικότητα και Χορός, Εικονική Πραγματικότητα Έρευνα και Εφαρμογές στην Ελλάδα Σήμερα, Στέγη Τεχνών και Γραμμάτων, 24-25 Νοεμβρίου 2019

3. Managing and enriching dance data and movement knowledge Summer School GAIIA, Thessaloniki 5-9 June 2017.

1.4 Credits

Some of the contents of this thesis are based on published work that was conducted in collaboration with others. Specifically: Akrivi Katifori [172, 76, 77, 79], Marina Stergiou [172], Theofilos Mailis and Vladislav Ryznikov [78], Nikolas Papapetrou [79, 78], George Tsampounaris [80, 199], Aristotelis Kasomoulis and Marianna Rezkalla [76], and Luca Ludovico [143] .

Some of the published work [79, 77, 78, 76, 172] has been supported by the funding framework of WhoLoDancE: WhoLe Body Interaction Learning for Dance Education (688865).

2. DANCE DOCUMENTATION AND APPLICATIONS

"In a few years, if you can read notation, the dances of the world will be as close to you as your local library"- [184].

2.1 Motivation

The aforementioned is one of the quotes that was expressed by Schurman in 1972, in his book about notation for modern dance, stressing the importance of dance notation in preserving and transmitting dance knowledge.

In the beginning of this research, we rephrased this statement as "In a few years, whether you can read notation or not, the dances of the world will be as close to you as your digital library".

- Yet, which parts of this quote are still relevant, when millions of dance videos are available in social media channels and massive online platforms?
- What can be the role of or need for conceptually documenting movement in an era where recording and sharing a dance sequence is being as easy as holding a mobile phone for a few seconds and uploading in some minutes on existing platforms?
- Last but not least, what could be the needs and role of dance notation and Choreological research for complementing the role of available high-end and low-end technologies and computational models for capturing, analysing, visualising and interacting with movement?

Our motivation can be summarized in two phrases:

- how can digital technologies contribute to dance documentation, in a manner that makes this knowledge findable, acccessible, interoperable and reusable? In other words, how can the contemporary ves of dance data compliant with FAIR principle [206]?
- what are the optimal ways to represent and transmit movement knowledge, for a variety of purposes such as dance analysis and research, education and creativity?

In this Chapter we provide an overview of applying technologies in dance, we present relevant tools and we describe the main challenges, and our focus. In particular we start with a short introduction to the historical relationship of dance and technologies, we present the various objectives for designing and developing computational tools for dance, and we explain our motivation, as well as the need for developing semantic representation models for dance movement and list the respective challenges.

2.2 Dance Documentation: a Challenging Problem

Dance documentation is an open challenge that has been investigated by dance researchers, notators, historians, anthropologists, and archivists, long before the emergence of digital technologies for recording movement, such as motion capture, or even video.

Many dance analysts, anthropologists, or dance therapists [198] still prefer formal archiving methodologies expressed in standard languages like Laban Movement Analysis [204, 137] and or Labanotation [119], a system that we will analyse in Chapter 3, which provide a common vocabulary that enables communication among researchers for comparative analysis or future use.

Such notational or formal systems for describing movement, as we describe in detail in Chapter 3 is not a common practice for dance practitioners such as performers, choreographers and educators. On the other hand, the technologies of video recording have definitely revolusionised the way both dance researchers and dancers record movement for teaching, learning, archiving, observing, analysing, recreating in their everyday life.

Motion capture technologies, although not yet accessible for the wide audience due to high cost and complexity, can generate 3D animation with extreme accuracy and can capture the 3D dimensionality of the motion and thus is an approach followed by many research projects and teams recently such as the WhoLoDancE [179] and iTresure [63] EU funded projects, and other efforts [191].

It is obvious that motion capture technologies and expertise provide an extremely powerful know-how for capturing a particular movement of a performer. It is worth mentioning that these technologies are mainly and widely applied in gaming and entertainment industry. Nevertheless, the methodological and analytical tools that are needed for dance documentation, analysis and transmission is a highly complex interdisciplinary challenge.

Although Motion Capture equipment allows the recording of dance in high precision, there are still some limitations, at least at its current state of development. For example, full optical motion capture equipment such as Vicon [1] or Qualisis [2], require a dedicated space to capture the movement onstage performer or a dancer in real-life environment, and usually it is done in a studio to propose animation. One good example, of combining lab high fidelity equipment with an ecological theatrical environment is the lab in Casa Paganini [1], shown in Figure 3.

In addition, motion capture raw data need long hours of cleaning, curating and organising the sequences into meaningful data, and the need for conceptual models to manage, search and analyse these data is high.

Contemporary technologies for motion capture allow the recording of human movement with precision. On the other hand, the level of description of these data falls far of describing the movement in a comprehensive way for humans and machines. In parallel,

[1] https://www.vicon.com/
[2] https://www.qualisys.com/
[1] http://www.casapaganini.org/

Figure 3: Casa Paganini- InfoMuse, an example of an ecological setting that uses motion capture within a theater stage. photo by WhoLoDancE project

since decades, many dance digital libraries exist online providing photos, audio and video content as well, as textual descriptions and scores written in specialised notation systems.

2.3 The Triadic Relationship of Performer, Observer and the Medium

Capturing a dance can either mean anything of the following:

- capturing the movement and steps of dance, to revisit later, in order to enhance the sequence, memorize, or leave for the next generations.
- capturing a specific performance at a particular time and place.
- disseminating and sharing a performance to students, collaborators or audience.
- creating datasets for analysing movement and study a particular dance genre, culture or type of gestures and expressions.
- recording a performer, as an artist or a living intangible heritage representative.
- preserving intangible cultural heritage, including movement, steps, performer, and expression.

- communicating choreographic practices and share strategies.
- creating material for teaching a dance.

These are only some examples on why one would like to capture, record or document a “dance”, and depending on the purpose the available means of representation or devices for recording might be appropriate or not. For example, one cannot expect to have a satisfactory documentation using scores and notation, if the objective is to capture a specific dancer, as a living archive. The conceptual and symbolic nature of notation might be appropriate to analyse her steps but would not capture her flesh and bone performance in its totality, including expressions of face, personality and energy.

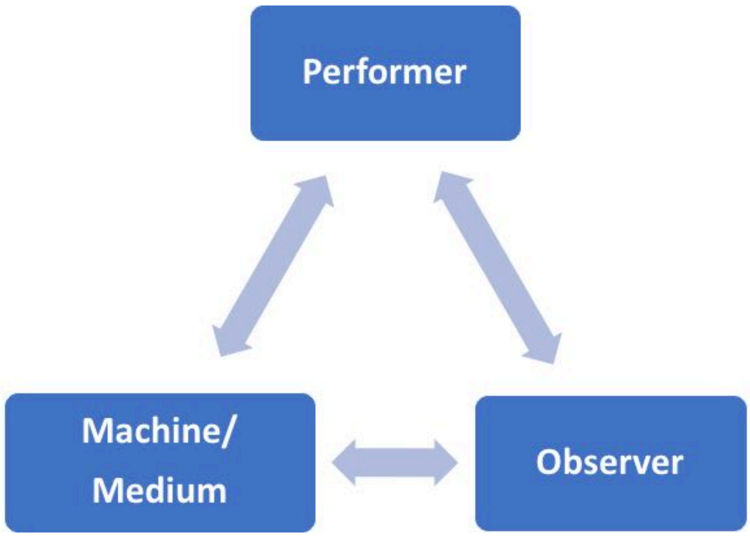


Figure 4: Triadic relationship of Performer, Machine/Medium that captures or represents the Performer, and the Observer who either reads the documentation to recreate or understand the Performance, or Observes the Performer to create a new documentation of the Performer.

Nevertheless, even if we can plan the most appropriate way of recording a dance, we should be aware of the triadic relationship between the Performer, the Observer and Media or Machine (Figure 4), that facilitates the documentation or capturing of this performance.

One of the challenges for designing meaningful tools for dance stem from the fact that dance is primarily an experiential, embodied activity, therefore the intention of the performer in terms of experience, what is actually done on a physical level and can be captured or measured, and what the observer can perceive or see. Loke [140] describes the “The three perspectives in the design methodology.” that occur in a movement based interaction experience. In fact, a similar triangle exists when it comes to capturing, recording as well as representing movement through notation or scores. As the Figure 4 depicts the perspective of the performer, observer and machine or medium can never be aligned.

The following relationships can occure between these three entities.

- The (human) performer acts and experiences the movement (first person)

- The (human) observer describes what the performer does, always limited by their own perception and priorities of focus. (third person) to create a representation using a machine/medium.
- The human (observer) reads the representation of movement as it is captured by the medium /machine, or creates a new representation (e.g., in case of descriptive notation).
- The machine (or medium) captures aspects of movement of the Performer, depending on its technical and expressional limitations
- The (human) performer reads the representation that is created either by the machine/medium alone or through the human observer to re-create a movement. (e.g., In the case of prescriptive notation or learning).

When it comes to describing movement another duality that has been introduced by cultural anthropologists is important: the difference between Etic and Emic [106] perspective on analysing and documenting the structural elements of a language. While in the Etic approach the identification of the important components is done by the observer, the outsider or the scientist, in the Emic approach the distinction is based on the perspective of the community that uses the language. Kaeppler's definition of structural components of dance morphology is based on an Emic approach [124].

2.4 Movement Semantic Representation

The semantic representation of movement includes many challenges, due to a variety of reasons such as the following:

- No unique framework on dance description or standard definition of dance data, format or management technique
- Gap between research and practice, no written language is actually used by practitioners
- Syntactic and semantic heterogeneity of movement data
- Labanotation provides a rich but complex language, that expressive but resembles physical language (it is symbolic and in some cases ambiguous)
- Dance Representation, implies Space/Time Representation
- Segmenting the continuous movement and defining the *Movement Entities*, i.e., the parts that are separable or important
- Diverse provenance of information: e.g., part of Intangible Cultural Heritage, artistic creation, social expression and part of syllabus or educational subject

We will discuss in detail how we address some of the challenges in the thesis, mainly in Chapter 4 and 5.

To what follows we present the main points that make semantic representation of movement challenge even on a conceptual level, independent of other practical or technological issues.

2.4.1 Complexity of the Human Body and its Movement

The human body can create endless different combinations depending on the context. These can vary from functional everyday movements and the execution of specific actions, to various dance techniques, expressive gestures, and non-verbal communication.

To address this challenge, we have adopted a modular approach based on theoretical basis on movement analysis such as Labanotation and Choreological methodologies. In particular, we have developed a core ontology based on MoveOnto, and we develop specific ontologies to describe the terminology of syllabi of different dance genres. More details are given in Chapter 4

We focus on dance genres that allow this modular approach, since they have specific well-defined vocabularies, and structure rules.

The entities of the different ontologies (core and specific) are linked through rules which reflect basic and common knowledge about the movement according to technique and the dedicated literature [99, 152].

2.4.2 Temporal aspects

Movement descriptions imply a temporal description. Motion, as well as stillness, in dance is always connected with a duration, and depending on the orchestration and coordination of the different body parts, the temporal aspects might vary in complexity. This complexity is again related to the dance style and technique and the level of detail which is needed depending on the context.

2.4.3 Segmentation is Not (only) a Computing Issue

In what follows, we present the main issues that make automated interpretation of a dance description (digital or not) a big semantic challenge. For if automation and computing require clear semantics and formal interpretations, standardizing dance and movement descriptions is not a straightforward process.

Imagine that you hear a language for the very first time. How easy would be for the listener to guess where words begin and end, if they find no meaning in what they hear? Dance practitioners of any style have their own concepts, names for steps and moves and while learning or teaching a new choreography, consciously or not, they segment all the time. Sometimes it is easier to learn and remember when they name what they do no matter if those names are simple verbs, terms from specific syllabi, dance specific vocabularies, or even made up words. The segmentation might be measured in beats and reflect the rhythm of the music, or the movement might have its own rhythm. To give another example of a dance and language analogy, studying the structure of dance from motion captured data and physical equations, is similar to study speech (oral language) by signal processing, but completely ignoring the morphological analysis, grammatical and syntactical rules and all the work conducted by linguists for centuries.

Likewise, it is like studying music only through the signal but ignoring notation, and other musicological knowledge. Such a method might provide extremely interesting results on emerging patterns, but if the objective is archiving data of dance descriptions for systematic study it is worth to exploit the existing Choreological and Dance Anthropology tools and methodologies. Last but not least, in selecting movement data, whether digital or not, it is important to distinguish between the Emic or Etic segmentation of movement, as in the first case the practitioners, are the ones who decide how they conceptualize about the movement, while in the second case the observer is the one who segments the movement out of any cultural context.

2.4.4 Segmentation and Discretisation

Semantic descriptions, the construction of concepts and entities, require clear time and space bounds to identify movement entities. Nevertheless, the human motoric usually include complex synchronisations and coordination of different body parts in order to occur in a continuous manner. For example, at the semantic level walking is considered to be a continuous sequence of altering steps from one step to another. On the other hand, if we need to analyze and observe movement there is not always an absolute measure to tell us when exactly the first step ends and when the second step ends.

We address this challenge by providing a usable interfaces where expert users can add annotations by choosing terms from the ontology according to their knowledge and perspective. The terms in the ontology vary from more complex recognized sequences to very simple movements. These annotations are stored in the system for further analysis. First, we base the segmentation, on the notions of *Kinemes*, *Morphokines* and *motifs* as structural, recognisable components of a dance genre, as have been introduced by Kaeppler [125] in an analogous way that phonemes, morphemes and words are the morphological components of language. More details about this methodology is provided in Chapter 3. The challange of annotation from a more user centered approach, and our related solutions are discussed in Chapter 5.

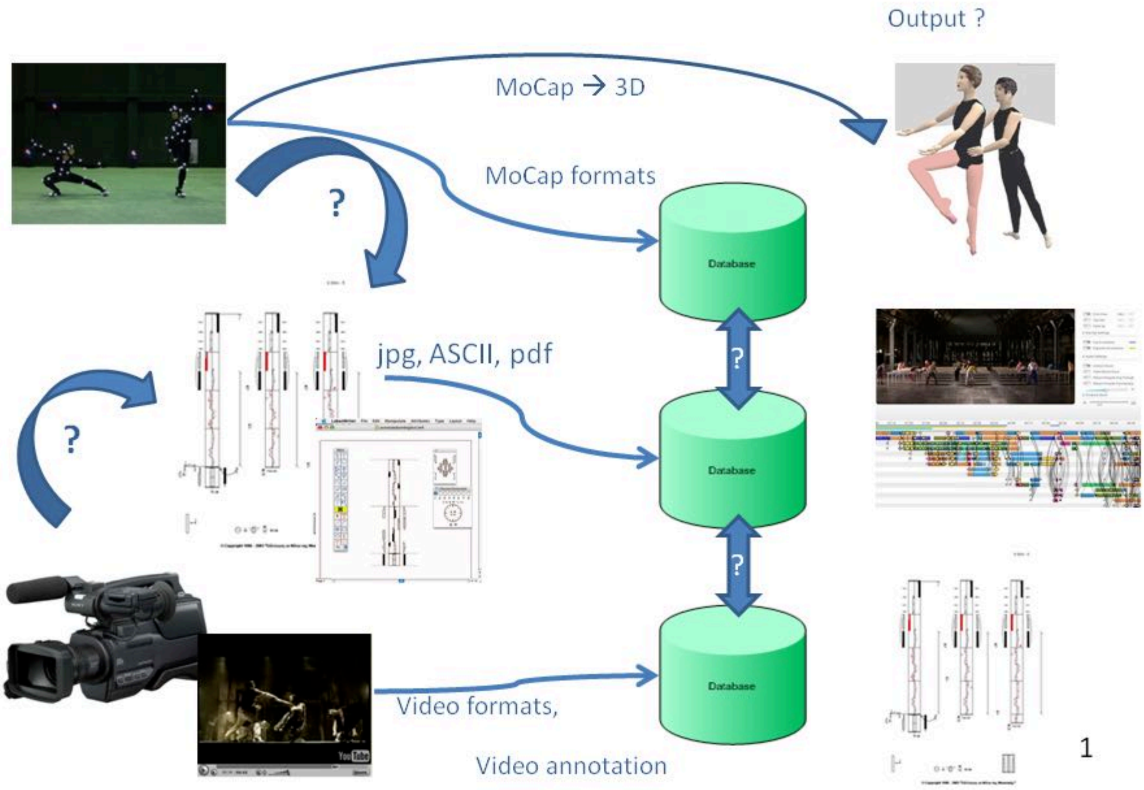


Figure 5: Dance Data "Ecosystem" -a landscape with cultural, semantic but also technical heterogeniety

2.4.5 The Dance Data "Ecosystem"

Another issue that makes the problem of managing, enriching, and representing dance data a complex problem, is that next to the semantic issues that are related to dance and movement representation, the heterogeniety of the formats and syntax of the different files is added to the equation. Figure 5 shows the dance data "Ecosystem". This Ecosystem is characterised by high hetereogenity on many levels and thus requires a lot of effort as well expertise that ranges in different computer science areas (e.g. Data Management, Image and Video Analysis, Signal Processing, Semantics, Human Computer Interaction), as well as, other Dance and Humanities domains. In this thesis, ofcourse we do not cover all this range; however, our contribution is summarized in the investigation and definition of the Conceptual and Experiential for dance, focusing on 1) the semantic representation of movement, and the 2) design of meaningful applications to dance.

While dance data can include of any kind of digital archives including text, video, audio, scores, and motion capture files in any of the formats that is shown in 1. Among others the semantic representation for dance and movement can narrow the gap between physical

Table 1: Different formats of files that are used for representing dance data and carry information about movement. All these files and formats are potentially forms of content for a digital archive or library.

Type	Format Examples
Motion Capture	c3d, bvh, fbx, json
Video	mpeg4, mp4, wav
Audio	mp3, wav
Image	jpeg, png
Text	word, txt
Scores	png, jpeg, lw

(e.g., a motion capture file) and conceptual documentation by contribute to the following:

- Creating metadata schemata for managing dance data or files
- Providing indexical, hierachical or exhaustive annotation vocabularies
- Searching repositories using dance and movement concepts
- Formalizing movement description and similarity definition
- Formalizing rules for composition, and pattern identification
- Defining the features that need to be extracted multimodal analysis of recordings, through the creation of semantic models
- Analyzing verbal descriptions, scripts and scores
- Develop kinetic vocabularies that reflect verbal descriptions and
- Mapping terminology with movement structures on semantic and physical level.

Potential uses of semantic representation for data heterogeneity on the level of connecting information can contribute to the following

- Synchronisation of files.
- Naming and organizing the files (metadata standards).
- Syntactic and semantic Interoperability.

In this context, semantic representations of movement based on existing Choreological, notational, and educational approaches for expressing describing dance movement can contribute to narrowing this gap, providing a language for movement annotation search, analysis, segmentation and composition.

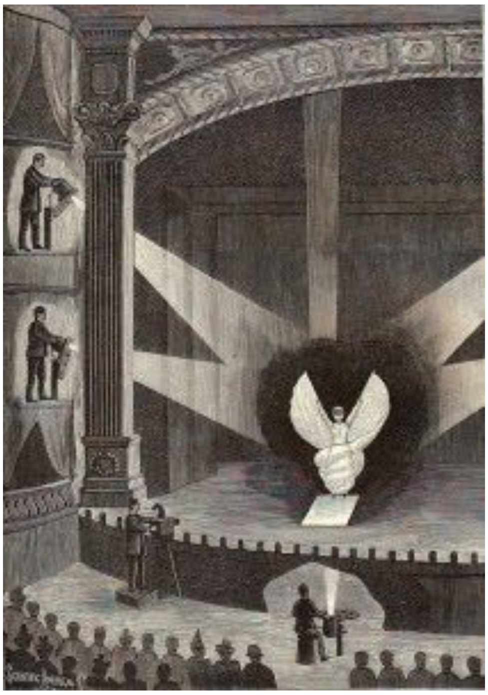


Figure 6: "An unauthorized illustration, originally published in "Scientific American" June 20, 1896, reveals the stage set-up for a Fuller-style dance. From Hopkins, Albert A., Magic: Stage Illusions and Scientific Diversions, including Trick Photography, Munn and Co., New York, 1901)."

2.5 Dance Technologies within the Dance Community

In the following sections, we provide an overview of the state-of-ther art in using technologies for dance.

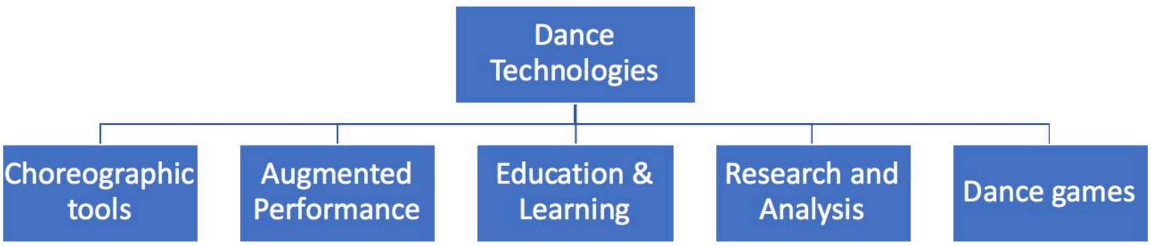


Figure 7: Dance Technologies categorisation depending on the purpose [172]

As it is shown in Figure 7, depending on the purpose of applying technologies to dance we can categorize them as follows:

- Choreographic tools. In this case technology is used as a tool to support the process of Choreography and can include tools such as storing and blending of sequences, creating digital scores, collaboration tools for distant co-creation, tools for stimulating creativity etc.
- Augmented Performance. Here technologies are used as a mean to enhance and augment the staging of a performance and can include tools such as sonification of movement, creation of interactive scenes, etc. In this category it is worth mentioning the historical contribution of Loie Fuller (1862-1928) as being one of the dancers and choreographers who not only used complex lightings and physical props to create the illusion of an augmented body (Figure 6), but has opened an early discussion between dance and science in the begining of the 20th century [93]. An example of such technologies in a recent contemporary production which is implementd by the company Instituto Stocos is shown in Figure 8. [2]. This category can include technologies and settings that can support interactive peformances where the audience can actively participate, such as in the works of director and composer Klaus Obermaier [138].
- Education and Learning. Such technologies can vary from desktop online applications, to mobile apps, and from whole-body interaction experiences, to augmented and virtual reality experiences for training. In our paper [172] we provided a detailed categorisation about these tools.
- Research and Analysis. Such tools can include digital applications for the creation, analysis, and processing of notations and scores, systems that can provide analytics on dance and in all kind of tools that support the observation, analysis and documentation of dance and its related knowledge.
- Dance Games. This category included all kind of interactive playful experiences that mainly aim at entertainment. Some of the examples include “Just Dance” [3].

While the aforementioned descriptions rely on human expert knowledge in the domain of dance describing human movement and its characteristics through high level concepts, a large semantic gap exist between the motion capture data and other multimodal recordings and the aforementioned conceptualisations.

2.5.1 Technology, Contemporary Choreography and Archives

The great choreographer Merce Cunningham [183] (Figure 9) was one of the first to use computers in the choreographing process and since then many others have followed, such as William Forsythe [166, 90] (Figures 10 and 11) and Wayne McGregor [58, 15]. Figure 12)depicts some screenshots from the recent collaboration between GoogleArt and McGregor’s company.

[2] https://www.stocos.com/en/page/the-marriage-of-heaven-and-hell/
[3] https://justdancenow.com/

Figure 8: An example of an augmented performance staging by the company Instituto Stocos from the performance "The marriage of Heaven and Hell" combining sonification with visualisations based on real-time transformation of movement(2018).

In addition last decade many choreographers like Siobhan Davies [12], Emio Greco [95, 2, 86], Deborah Hay [114, 31, 30]) and Bud Blumenthal [32], are collaborating with technology research teams to investigate pioneering methods for capturing and documenting dance. These collaborations result in projects such as Siobhan Davies Replay [12], Inside Movement Knowledge, and MotionBank [114] that are aiming at investigating tailored methods to capture the individual dancing vocabulary of each creator, to document their "idiosyncratic vocabularies", to use a term used by the Transmedia Knowledge Base TKB project team [88], in a process which can lead to new cognitive paths on movement perception.

What is common and worth to mention in some of the above projects are using technologies to create individual or idiosyncratic scores. Nevertheless, the notion of "score" or "notation" is used in a wider, less formal manner. Score in this case is no longer a formal script to be read and interpreted in a specific way, but an individual collection of material and ideas that one uses to take notes during the creating process, and in the same way the score is open to many different interpretations if "read" by another. The second interesting common point is that they are not focused on specific technologies or methodologies that are pre-decided, instead they combine different media and approaches according to the needs of the documentation itself.

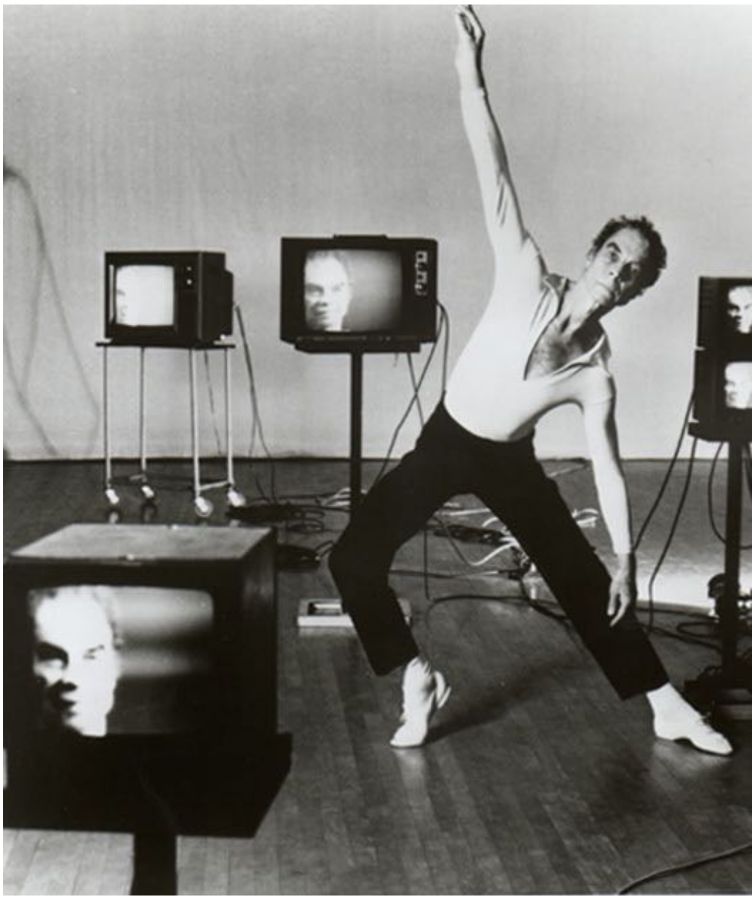


Figure 9: Merce Cunningham, 1981. Photo by Terry Stevenson. Image courtesy of Beth Weinstein.

2.5.2 Digital Tools for Learning and Dance Practice

Motion and its characteristics can be translated into different visualisations, sound and virtual objects that can provide new insights into dance teaching, learning and creation of new movement sequences and choreographies. Synchronous objects [4] by William Forsythe [166] is one of the projects where he and his interdesciplinary team explored such visualisations for transforming queues in choreography into abstract shapes such as the ones shown in 10, creating a new form for digitally annotating dance information.

2.5.3 Dance Learning and Technology

In parallel, in the field of contemporary dance and choreography the notion of the "thinking body" is not new in dance pedagogy and choreography. The results of an assignment on Merce Cunningham work in combination with motion capturing in an experiment have led to the following conclusion. By analyzing movement from both scientific and aesthetic perspectives, students can gain a deeper appreciation of why people move their muscles

[4] http://synchronousobjects.osu.edu

Figure 10: Animated annotations of alignments in William Forsythe's One Flat Thing, reproduced from Synchronous Objects [156]

and bones in a particular fashion [180]. In addition, since dance is an abstract that exists in the memory, teaching the concepts related to form can be significantly enhanced using technology.

Whereas in performance and dance production, technology is being widely used, it is still absent from the dance studios where dancers rehearse, learn and experiment, according to Molina et al. [155]. Designing digital environments to satisfy actual needs of dance practitioners, is a challenge, since there are no mainstream tools or best practices that can guide the development to such experiences, as we also note in our previous work [77]. The low affordability and portability of motion capture state-of-the art technologies, in combination with the fact that few dance practitioners have experienced such technologies, makes the elicitation of concrete user requirements and user-centered design of this type of experience a really challenging task. The need for a multidisciplinary approach and actual involvement of dance experts and practitioners in the process of design is crucial.

A number of recent technologies have explored the concept of an augmented mirror to

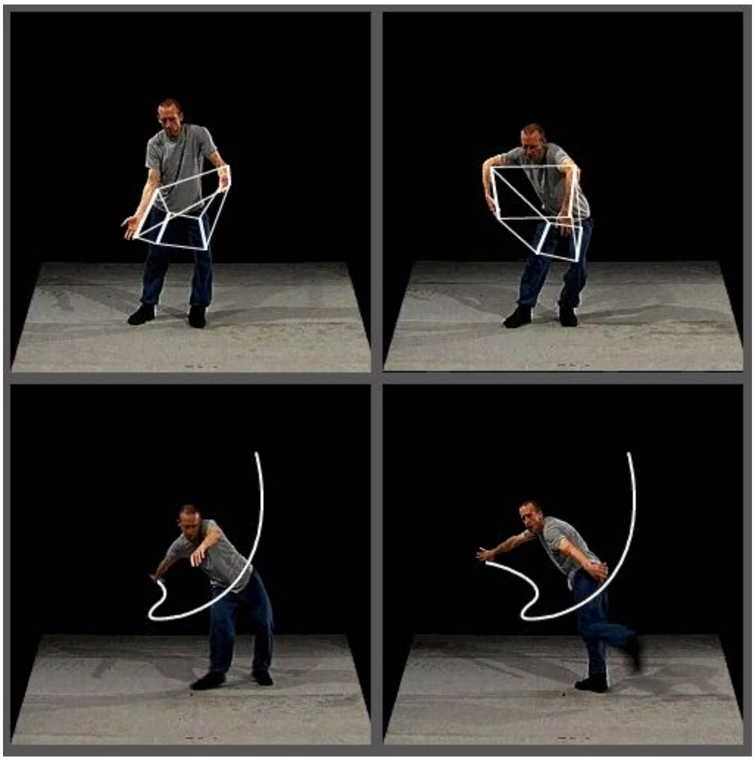


Figure 11: Screenshot from William Forsythe's Choreographic Tools on dance geometry and drawing in space. [90]

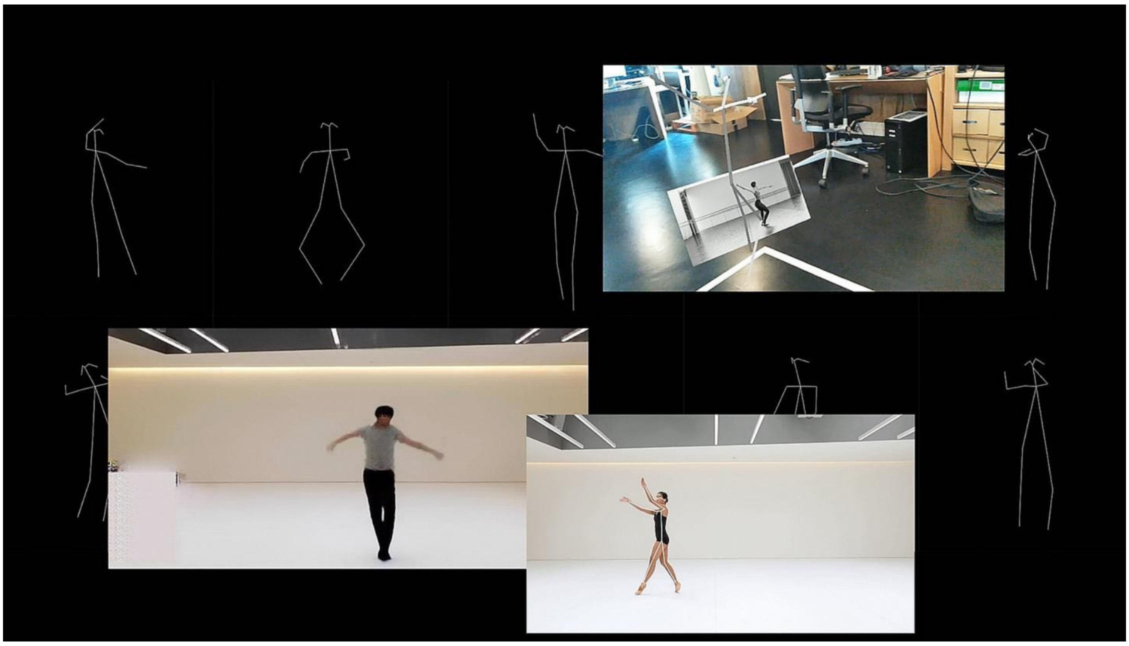


Figure 12: The Living Archive project Wayne McGregor in collaboration with Google Art [15]

enhance the dance learning experience. "Super Mirror" by Marquardt, Zoe, et al. [148] is a Kinect-based system that combines the functionality of studio mirrors with instructional

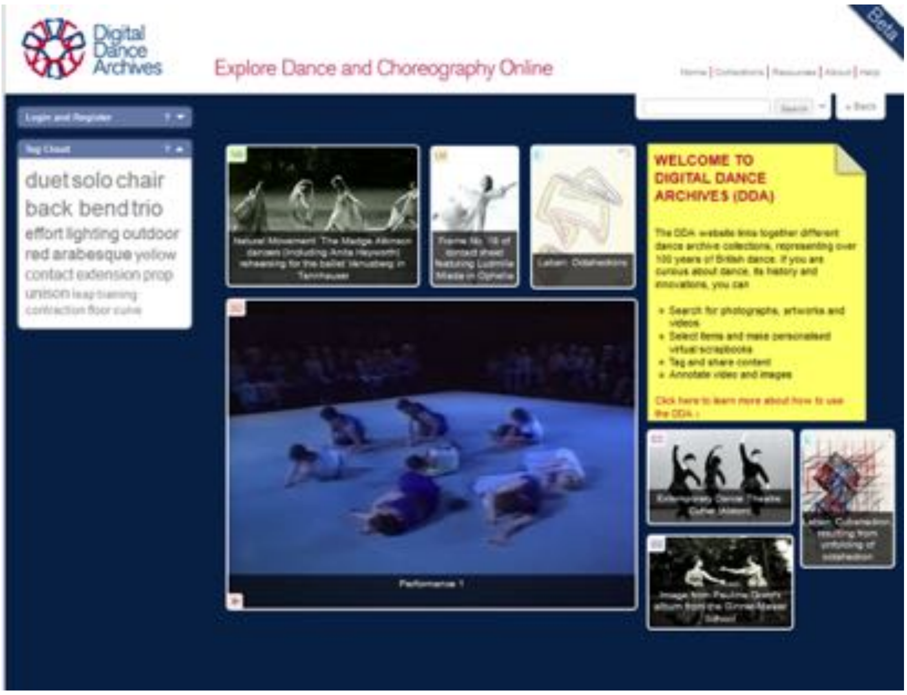


Figure 13: Digital Dance Archive Web Portal

feedback in real-time. The results of its usability evaluation with ballet students [196], has shown a potential for its use in ballet education. Hachimura et al. [102] describe a prototype dance training support system called “Just Follow Me”, with motion capture and mixed reality technologies. Molina-Tanco et al. [155], propose a simple technology setting consisting of a recording mirror which reproduces the image with a few seconds of delay.

Motion and its characteristics can be translated into different visualisations, sound and virtual objects that can provide new insights into dance teaching, learning and creation of new movement sequences and choreographies.

2.5.4 Technologies for Preserving Dance as Intangible Cultural Heritage

Many significant efforts have provided digital descriptions of dance as a performing art such as the Digital Dance Archive [60], the eclap project [24], or as an expression of intangible cultural heritage such as the iTreasures project[62, 63].In particular, eClap [24], a funded Europeana project, has created a platform and data model to collect descriptions of performing arts (theater, dance, performance) and related content and to make archives of different European countries accessible through one unique portal.

The Digital Dance Archives [60] link together different dance archive collections, representing over 100 years of British dance. Siobhan Davies Replay [12] is an example of a Dance Digital Library that is dedicated to the work of a specific choreographer.

The Greek Pandekt, a screenshot of which is shown in Figure 14, consists one example of web-based portals and archives that provide access to video files and organised metadata about the Greek dances. The user can search using key-words such as the name of the dance, the name of the area which the local dance origins from and see related recording of performances and some textual information.

Dance Digital Archive [60], which is shown in Figure 13 is another web platform collecting and organising dance material. One of its goals is to provide the user with a kind of personal digital notebook for “scoring” choreographies”, where he can select material for further inspiration. A very interesting point about this project is the development of tools which allow the user to select a specific part of an image which depicts a body shape or a pose and search for “similar” material by image processing.

Figure 14: Greek pandekt. A snapshot of information about Greek dances from a specific geographical area. The information provided and used as keywords for searrch of images, videos and audio, is related to the name of the dances, the song, the area of origin.

3. AN INTERDISCIPLINARY APPROACH FOR THE SEMANTIC REPRESENTATION OF MOVEMENT

"To understand humans, Charles Darwin recognized it is first necessary to understand how they gather and transmit knowledge in ways similar to and different from their animal forebears. The more we know about dance — its presence, absence and its resurgence in individual and group life — the more we will know about ourselves: To Dance Is Human."
–Judith Lynne Hanna [104]

3.1 Theoretical Background

In this Chapter, we present our methodology which consists an interdesciplinary approach for representing and describing movement. Semantic representation of movement is a challenging problem that can play a great role in managing dance data and making them searchable and accessible for a variety of contexts using digital applications and computing.

We are approaching this question through studying the existing methodologies, and analytical frameworks, that are used in dance research and have been successfully applied independently of new technologies. In other words, we are posing the question of how a dance analyst and or researcher would work if technologies such as motion capture, or even video are in hand?

Thus, our approach for grounding our conceptual model and propose a semantic representation, is based on and inspired by the following approaches:

- formal systems for the analysis of movement, such as Laban Movement Analysis and Labanoation
- Structural analysis of dance movement, as it had been proposed and applied in Choreology and by dance researchers and anthropologists.

For developing our Knowledge Representation models and transfering the aformentioned methodologies into computational languages, we have worked within the domain of Semantic Web Technologies for a number of reasons that we will explain in the following Chapter.

All of the above technological and methodological tools suggest a strong relation and analogy between **Dance and Language** which will present and discuss in this Chapter, along with presenting the theoretical groundings.

The question of developing the tools and methodologies to study the movement of dance either as part of an art form, a social phenomenon or a cultural expression, in a systematic,

Figure 15: Greek women dancing, attributed to a vase in the Museo Borbonico, Naples. From The dance: Historic Illustrations of Dancing from 3300 B.C. to 1911 A.D. London, 1911

universal manner is not a question of the digital age [73], [55]. It is having been a persistent question for anthropologists, sociologists, and ethno-choreologists for many years. It is of no question that dance is one of the least studied areas of communication forms in comparison to language, music and visual arts, a fact that is due, not only to the lack of research interest of the academic world in the past, but also to the intangible character of dance and the lack of methodologies to document and study it in a systematic manner. For the ancient times for example the only visual indications that we could have are illustrations on the wall and other objects, such as the one depicted in Figure 15.

3.2 Dance Notation

Dance notation systems provide a mean to theoretically study the choreography itself, rather than its specific performed versions. Some of the dance notation systems first appeared during 15th century and till now more than eighty have existed [117] although only few of them persisted through time, such as Feuillet [89], Benesh [161], Eshkol-Wachman [82] and Labanotation [119, 35, 39].

Scores using formal notational languages are usually applied for a variety of reasons such as creating a historic archive and support dance analysis with written data that provides detail about the movement. Notational systems can be also applied as an introduction to Choreology, as part of an educational program to enhance creativity and conceptualisation of the aspects of movement.

Another important aspect about notation, is the fact that can be either Descriptional or Prescriptional. In the first case, the score is created by a dance notator, through observing the performer or choreographer. Usually they work together, and observation is cobined with discussion and/or interview. In the case of Prescriptional score, the choreographer uses the symbolic language to capture a sequence or some choreographic ideas that she or he have in mind.

3.2.1 Labanotation: Introduction and Basic Concepts

Labanotation or Kinetography Laban is a notation system for recording and analysing human movement that was derived from the work of Rudolf Laban who described it in Schrifttanz (“Written Dance”) in 1928. His initial work has been further developed by Ann

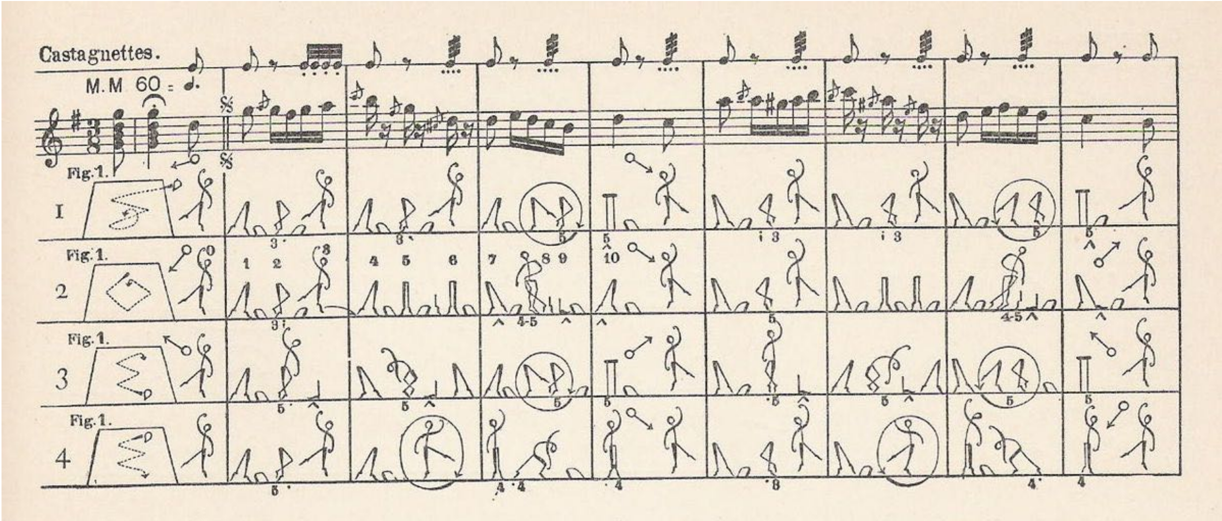


Figure 16: Notation example of La Cachucha by Friedrich Albert Zorn.

Hutchinson Guest [99] and others and is used as a type of dance notation in other applications including Laban Movement Analysis, robotics and human movement simulation. Introduced by dance artist and theorist, Rudolf von Laban in 1928, the Labanotation system, uses abstract symbols to describe movement, providing a well-structured language with rich vocabulary and clear semantics, based on Laban Movement Analysis (LMA).

Labanotation usage for all types of dance style, theatre plays, sports and gymnastics analysis and documentation in academic research, for more than 80 years, makes it one of the strongest notation systems. systems worldwide. In contrary to other systems, it captures not only the directional, but also the qualitative aspects of movement (Dynamics, Effort). In addition, LMA serves as useful foundation not only for designing dance documentation software but also for modeling human computer interaction based on movement and gestures [85, 139, 175].

In Labanotation the symbols are written on the columns of the *Staff* and the progress in time is read bottom up. The Staff, which consists of several columns, as shown in Figure 20 is devised into two parts, representing the left and right parts of the body respectively. Usually the symbols on the Staff represent one choreography for an individual performer or more than one dancer that they do the same thing. In other words, the Staff and the symbols on it represent the movements of a particular dance or sequence. //

The two core columns correspond to the Left and Right Support (where the weight of the body is, usually the feet), whereas the directly external columns represent the Gestures of the Left and Right Legs, i.e., the movement of the legs or feet that are done without taking body weight. Further, outside there are the columns for the Left and Right Arm Gestures. Additional information about other body parts such as Torso, Head etc, are given on the external right side of the staff.

The columns and staff are an analogy of the musical pentagram where music notation is written, while the symbols on them represent the movements, their level, directions and

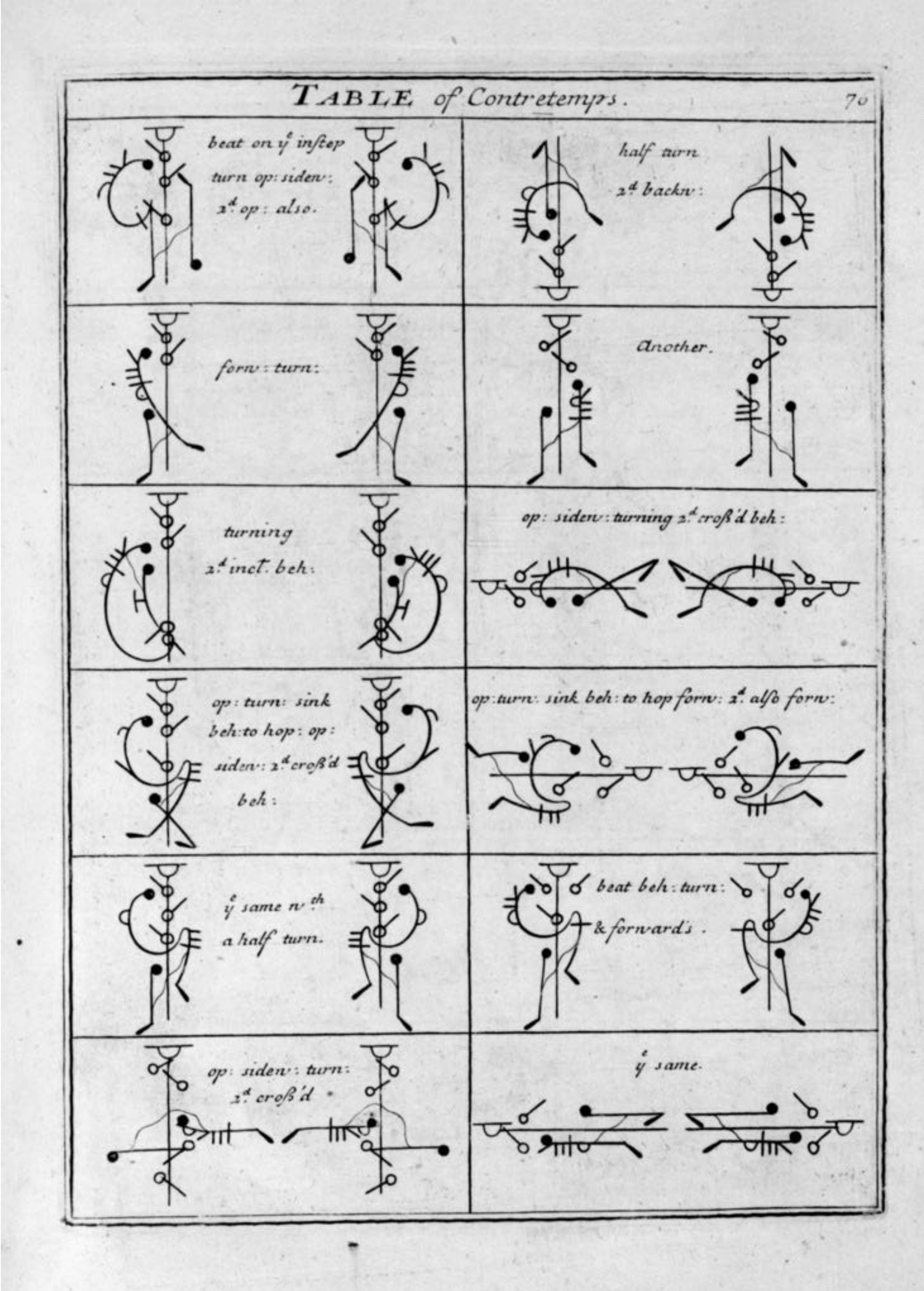


Figure 17: Orchesography; or, The art of dancing by characters and demonstrative figures. Wherein the whole art is explained; with compleat tables of all steps us'd in dancing, and rules for the motions of the arms [11]

Figure 18: Notation example from the Art of Dancing by Kellom Tomlinson 1735 [193]

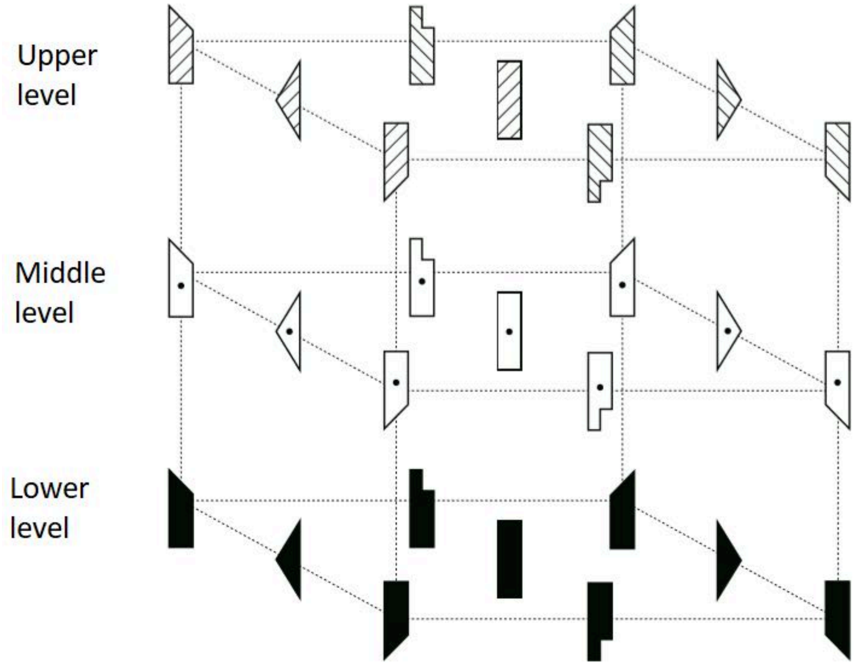


Figure 19: Laban Cube and the 27 directions in space

corresponding body parts.

Thus each symbol represents the following information:

- **Direction of movement**, indicated by the shape of the symbol. In Labanotation there are nine basic directions that are shown in Figure 23
- **Level of movement** The basic levels are three: High, Middle and Low and are represented by the texture of the symbol as shown in Figure 24
- **Duration** The duration is indicated by the lenght of the directional symbol on the column, longer symbols, indicate longer duration (and therefore implying slower or bigger movements).
- **Body Part** The body part is indicated by the column where the symbol of movement is written. In addition to the main columns, there is a number of symbols that are dedicated to represent particular body joints such as the ones shown in Figure 21. These symbols are used when more details are needed in describing the moving body parts, whereas a number of additional symbols and modifiers can be used to describe not only joints but also body parts, surfaces, etc.

Figure 25 depicts some examples of different rhythmic patters of movement using Labanotation.

In the case of couple dances two staffs are used to show the relationship of the two performers and their synchronicity.

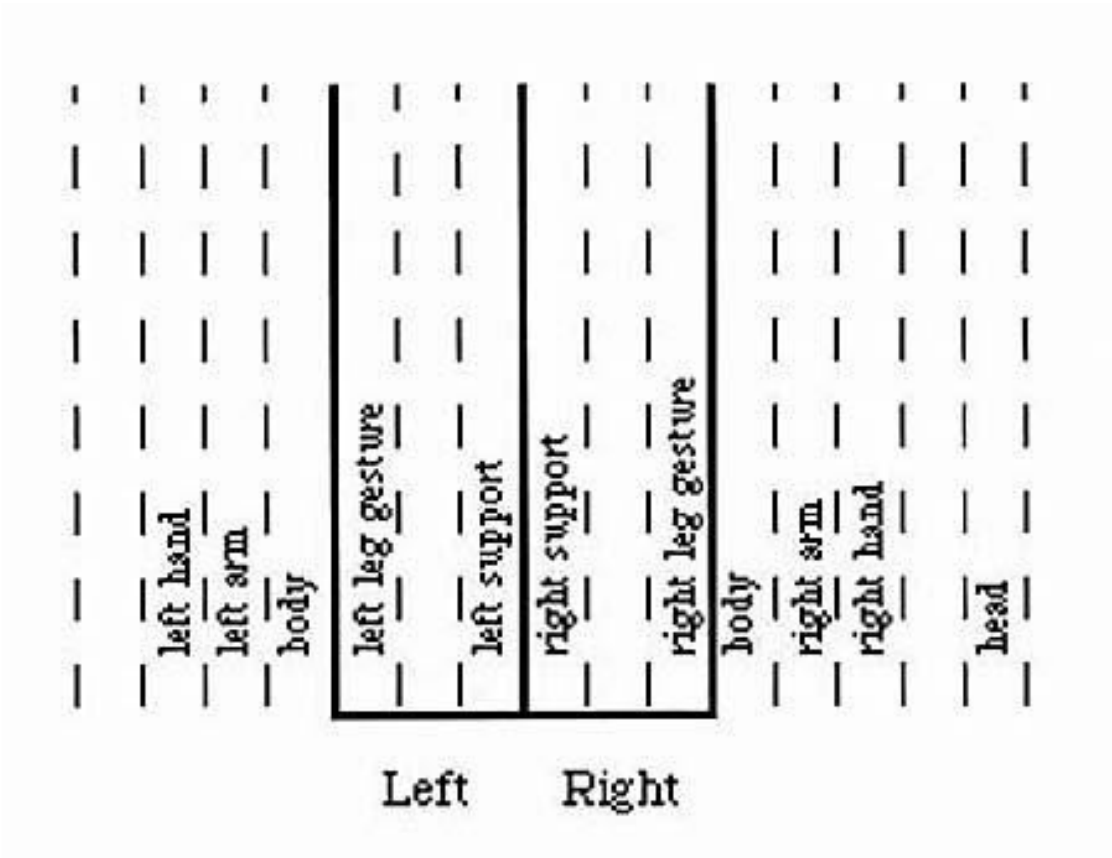


Figure 20: Labanotation Staff symbolising the left and right parts of the body [96]

Also, there is a number of additional symbols for representing particular movements that are not simply directional, such as Bending and Extending, Turning, etc, as well as more complex movements e.g., somersaults, waves, etc. Another subset of symbols and modifiers are dedicated to symbolising the different relationships of body parts of the same body, as well as relationships of different bodies, allowing to express relations such as Crossing, Touching, Grasping. Finally, a set of symbols and modifiers exist to describe the dynamic aspects of movement or more generic information such as the continuity of movement, the Intensity etc.

A significant part of Laban Movement Analysis and Labanotation is dedicated to the analysis and symbolism of the qualitative aspects of movement, i.e., how a movement is performed. Labanotation, as a symbolic language provides the corresponding symbols to describe the Efforts (Figure 27and other aspects of dynamics of the movement.

In the conceptual framework of WhoLoDancE project [81] a distinction between the Movement form and Movement qualities, has been suggested, as follows:

- **Movement form**: the dance form consisting of specific shape of the body and actions which results with a time/space structure, i.e., particular sequence of actions and geometries of the body.

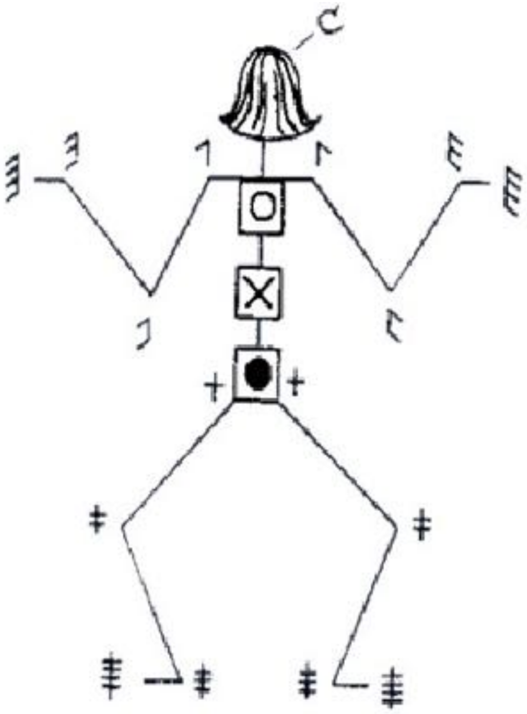


Figure 21: Laban Body symbols

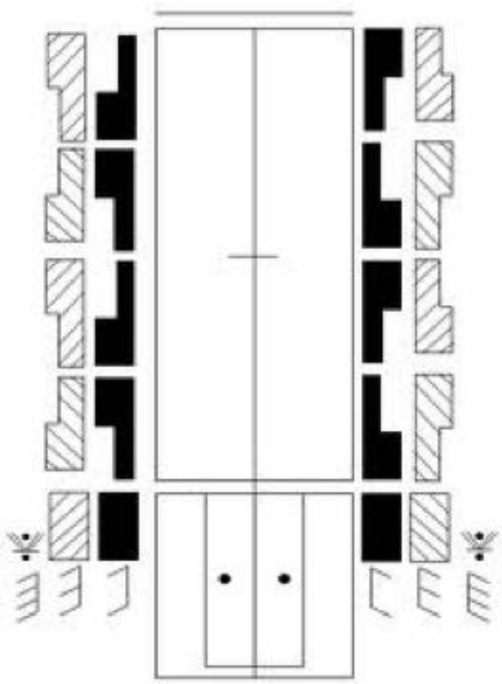


Figure 22: Labanotation Staff representing movement of the hands and arms using additional symbols for the corresponding body parts

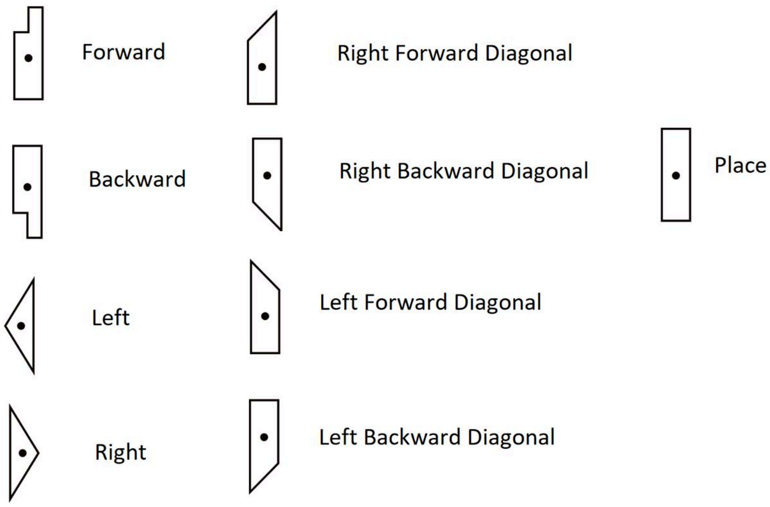


Figure 23: Laban directions and their symbols

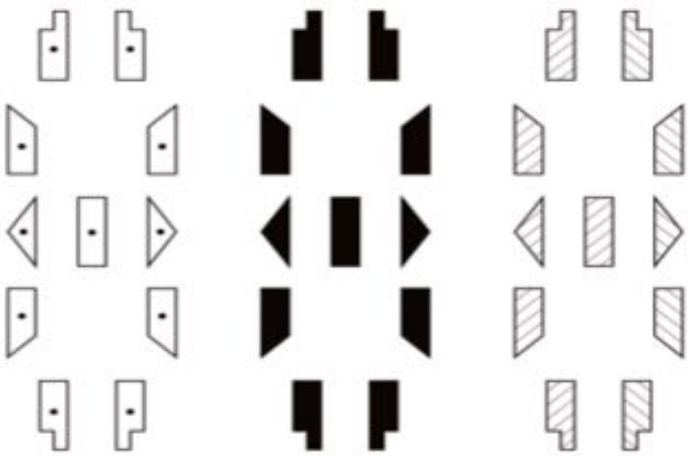


Figure 24: Laban directions symbols and the three level representation

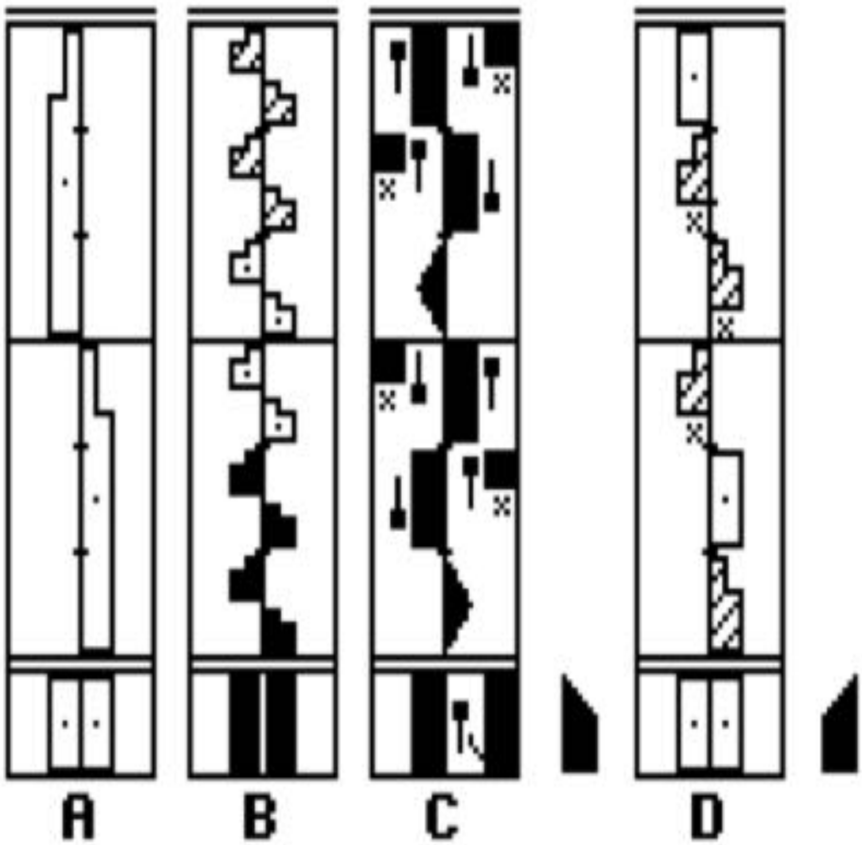


Figure 25: Examples of steps with different rhythmic patterns exressed in Labanoation

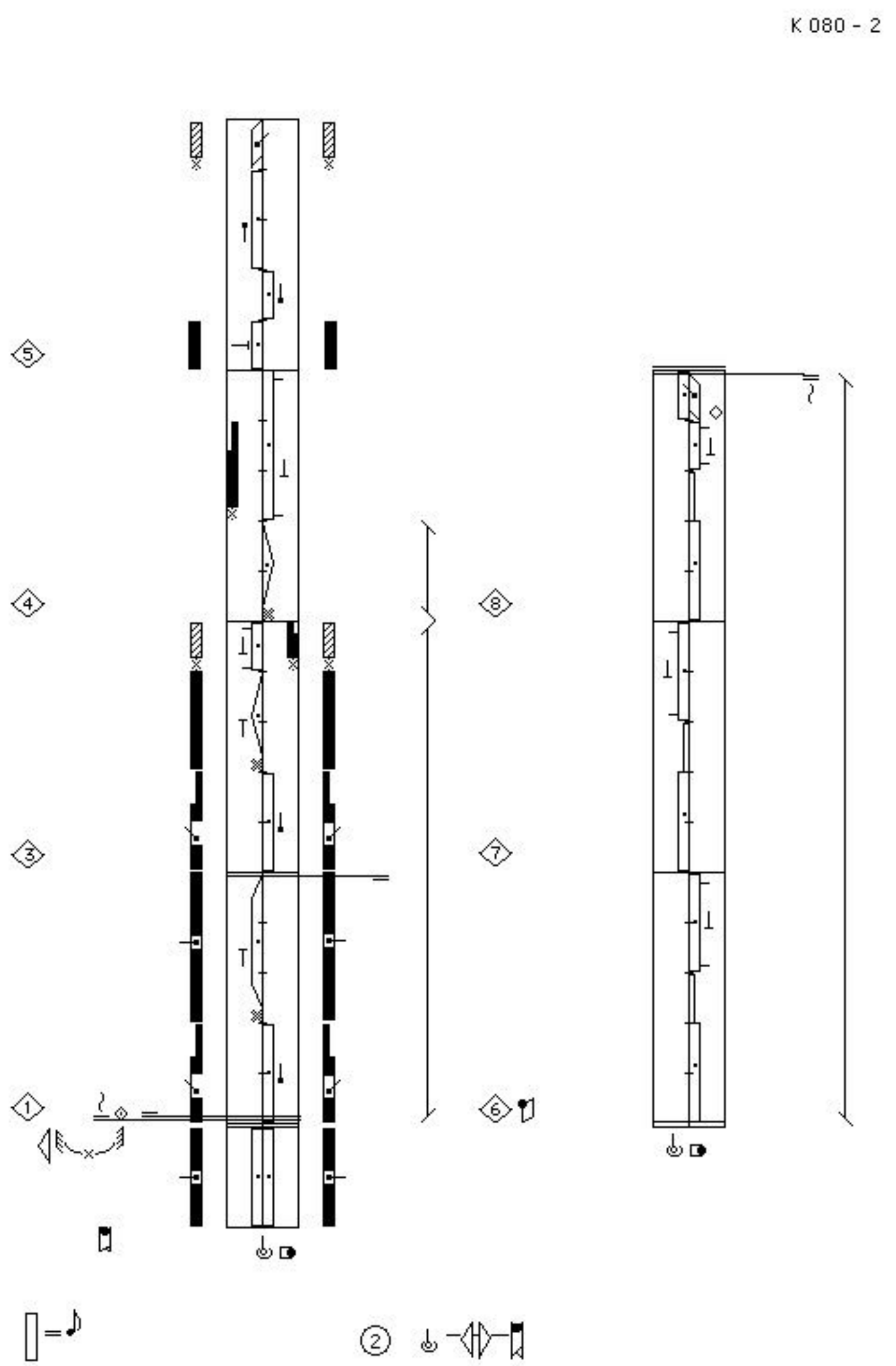


Figure 26: A Labanotation score of one of the documentations of Baytouska dance from the are of Thrace as been documented in the project Thrace for on-site research [162]

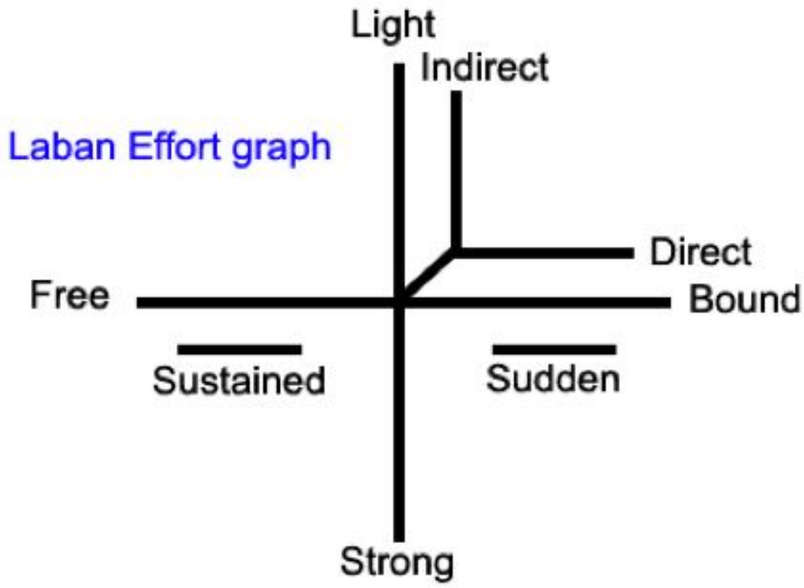


Figure 27: Laban Effort graph

- **Movement qualities**: the dynamics and general feeling of the body rather than achieving particular form. Qualities refer to "how" the movement is executed, what are the dynamics of the movement. (e.g., Laban Movement Analysis Efforts)

On effort (qualitative aspects) vs. form structure body and space Bales [20] suggest the use of Body Effort Space (BES) for teaching creatively different genres. While some dance genres seem to focus on different aspects e.g., precision of the form and technique (implying a more quantitative aspect) terminology itself is within embraces qualitative aspects in the forms of metaphor (e.g., fouetté, brises, batue, etc.)

"Laban analysis can he approached three ways: through study of the body structure and morphology, through study of the paths and spatial tensions of the movement available to the body, and through study of Effort." [20]

At this point it is important to clarify that although qualitative aspects of movement seem to be more connected with the Experiential aspects than the Conceptual, compared to form, this is not the case in our model. Conceptual languages deal with the problem of representing movement i.e., organising and symbolising the concepts that we use to describe dance (including qualitative aspects). Whereas, Experiential languages deal with how these concepts are transmitted to the end user and to what extend the mean itself can transform the perception of both form and qualities.

3.2.2 Labanotation and Digital Applications

To what follows we present some of the most significant LMA-computer based systems, such as Labanotation graphic editors, e.g., LabanWriter[163], Labanatory [154], Calaban, and LED & LINTEL[116], which are used to create scores in digital form. In addition some tools allow the automatic generation of Labanotation from Motion Capture such as GebLaban [50]. Some of these editors have the ability to transform the digitally created scores into 3D animation e.g., LabanEditor [130], LabanDancer [205]. Nevertheless, the problem with the above software is that the user has to be able to produce the symbols of Labanotation, while only few dance practitioners and theorists can read and even fewer can write Labanotation scores. Based on LabanXML [157], Hatol [107] has developed a markup language (MOVEMENTXML) transferring the semantics of Labanotation symbols. In addition, many applications are focused on the creation of automatic Labanotation Generation from motion capture, Semi-automatic Semantic Annotation and Retrieval of Recorded Videos [61]. Nevertheless, in all of the aforementioned examples, the models moved to express movement concepts rather, than the taxonomies of Labanotation symbols vocabulary and their logic on the screen or the paper.

3.2.3 Is Notation the universal language for Dance ?

In what follows we present some of the reasons why Labanotation alone cannot solve the problem of dance semantic representation and especially segmentation and the identification of Movement Entities and their relationships. We explain why although there are some analogies with “physical” written language, and music notation, in the case of dance things are much more complex. This difference is due to two main reasons:

- Dance notation systems are not practically used for long time. What makes a language powerful is its everyday usage and continuous evolution and unfortunately Labanotation (along with other notation systems) is not the language of the majority of dance practitioners and movement creators, but mainly a language of scholars.

- The creator of dance (choreographer, performer, or cultural group) does not necessarily express himself through those notation systems, especially if the movement creators are not traditionally educated in the field of Western dance. With very few exceptions, dance notation has either a prescriptive or descriptive character, as Bartenieff et al. explain [23], which means that the Labanotation score is created before the event of dancing to give instructions about the movement, or afterwards, to describe this event. In both cases, a different person than the performer creates the score. As Hutchinson-Guest [119] notes, Labanotation, as a language, might be a powerful tool, but we cannot say that it represents the written language of dance.

3.2.4 Dance Notation vs. Movement Notation

Labanotation is the written language for Laban Movement Analysis, thus a symbolic language expressing specific concepts for analysing and thinking about the movement. In some cases, the knowledge of the notation affects the perception of movement in practice. As described by Spitzer [190] the perception of movement was influenced by the knowledge of Eshkol-Wachman notational system, as reflected an awareness of a body reference system that relates to all movements as enclosed within a sphere. But not all dance practitioners understand or necessarily think within the context of notational languages. The question that emerges here is how the symbols of Labanotation actually relate to dance segments. Is it a one to one analogy? We are not in any case questioning the major contribution of Labanotation system to the structural analysis of dance and the capability it provides for creating detailed descriptions and many other scientific and creative applications. On the other hand, many unconventional dance styles (like folk) require so much additional notes (or maybe symbols) that the economy of Labanotation diminishes, as Royce states [181].

Labanotation is able to describe every detail of movement such as a finger movement; however, the combination of symbols becomes too complex to understand by local dance communities, thus introducing integrated symbols might improve the usability and desirability of Labanotation as Choensawat et al. prove [51]. As Le Pere explains, [168] informal use of Labanotation system for adapting to particular dance styles, such oriental dances where particular movements of the torso and hips exist in the dance vocabulary, is another example that proves that the knowledge of the system do not automatically make it usable for any kind of dance tradition, at least not for everyday use from the dance practitioners. Some researchers, such as Durr question if Labanotation is a language or just a script [70]. Actually, according to Durr Labanotation is a language, but each score is a script, a recording (prescriptive or descriptive) about movement and it inevitably includes subjectivities and assumptions. As in any language the score is a mean of communication where one needs to decode “who the transmitter is” and “who the receiver of this message”, to decide how much detail is enough to transmit the required message. The emerging question here is that if humans cannot read, or moreover create a Labanotation score without having any knowledge of the particular dance style, how can we create an algorithm to do so?

Dancers can read a notation score because they see something recognizable, the concepts that are represented by the symbolic language and that can be used to develop ontologies that the ones we develop in our work [72, 73, 79] and are also developed by de Beul [55]. We need to decode the process that we follow to read this information, to formally express it in a computer language and eventually reproduce this kind of artificial intelligence.

3.3 Dance and Language

Stating that dance is a language is rather a vague quote. In fact, there is an analogy between Language and Dance. The universal human capacity to express oneself and communicate through means of verbal and non-verbal communication respectively is unquestionable.

The analogy between Dance and Language also extends to the fact that although the human capacity of creating and using Language is universal, there are many humans, written or verbal languages that each one of those has its own rules of syntax, semantics, morphology and meaning. In a similar way, each dance culture, practice, technique, or language has its own kinetic vocabulary, rules, and structure.

3.3.1 Dance is not a Universal Language

It is said that dance and movement is a universal language. However, if we are to methodologically study dance and the morphology of its movement, or design and develop tools to archive this knowledge, the above statement becomes as meaningless, as saying that Language is a universal language, because all people around the world are able to communicate using their phonetic system. In the subsection 3.3.6, we provide the main definitions for the basic notions of structural linguistics, which consist our reference for the Dance Language analogy discourse.

We share Haggerdorn's [103] argument that dance and language share many characteristics at "the formal level of sentence construction, but this analogy breaks at the level of reference, meaning, truth and function."

One can define a number of analogies between the structural parts of language such as phrases construction, specific movement vocabularies that consist a dance system of a particular genre, choreographer or tradition.

On the other hand, there are only a few dance genres where movement plays a symbolic meaning, and where particular gestures refer to specific ideas, concepts, feelings or objects. Although within a particular dance genre, or system has a particular way of constructing its movement sequences, and a finite number of gestures, movements and body postures, these phrases do not carry a particular literal meaning. For example, a combination in ballet, might be wright or not in terms of performance and to what extend is compliant with the technique and valid vocabulary, but we cannot tell if the sentence is true or not [103].

Indeed there are many analogies between dance and language, and one of the most significant is the analogy between the morphology of language and dance structures, as introduced by Kaeppler [123, 124].

This approach has been applied to many dance languages mainly folk dance (Tongan

[124], Polynesian, Hungarian [125], Greek [142] and others).The power of this approach is, simultaneously, its limitation: it is a method that needs onsite documentation, to decide which are the morphemes and Kinemes of a particular dance language. One cannot automatically extract those movement units, unless he is equipped with large, digital datasets that are expressed in a comparable language. Note that in this case the approach is etic (vs. emic) which means that an algorithm actually plays the role of an outside observer who decides what the significant or recognizable units are. The emerging question here is who decides about what's in a movement and what are the concepts to describe it. The one who dances or creates the movement (dancer, choreographer, local person in the case of folk) or the observer?

According to Kaeppler [125]:
"As a system for recording movement, Labanotation can be used in a way comparable to phonetic notation of speech sounds. Just as a linguist working with a living language subjects a phonetic grid to phonemic analysis to obtain an inventory of the basic phonemes in a language, a dance anthropologist can subject an etic movement grid recorded in Labanotation to emic analysis to ascertain which movement have emic relevance and thereby obtain an inventory of basic dance movements comparable to phonemes of a language"

Thus, Labanotation alone is not enough to decide what the words of a language are. Under this perspective, the notions of Kineme and Morphokine [125], as dance segments are analogous to phoneme and morpheme in language. Kinemes are actions or positions, which have no meaning as units themselves, but consist the basic building blocks in a dance tradition. A Morphokine is defined as the smallest kinetic unit that has meaning, where meaning here does not reflect any pictorial or narrative meaning, but it is used to indicate movements that are recognized as units from the people practicing a specific dance tradition. The third level of dance structure is the Motif level. A Motif is frequently occurring combination of Morphokines that forms a short entity in itself.

Most important, what these studies [125] show is that what is an important movement segment for a specific dance culture, could be completely meaningless, or inexistent in another. What it is a Kineme in one dance language it could be a Morphokine, a motif, or unacceptable non-sense in another. To decide about which movement segments convey

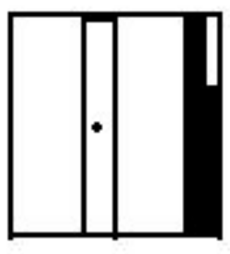


Figure 28: An example of a Leg Kineme represented in Labanotation

meaning, the study and essential knowledge of the particular dance tradition is inevitable. The supplementary relation of the morphological analysis tool to the notation system is also reflected in the glossaries that accompany most studies and serve for the following:

a) Provide the map between a cultural–specific movement segment and the detailed description in terms of movement in a universal language.

b) Provide a useful guide on how to segment a Labanotation score and thus be read easier by applying some simple rules.

c) Connect particular Labanotation description with a cultural context allowing the interpretation of the score in a more consistent manner to the style of this particular dance tradition.

In addition, in literature there is a variety of glossaries and examples for particular dance types (ballet [152], folk [125], contemporary, etc.) expressed in Labanotation scores, which serve to further analyze or explain some of these movements. But most important those movements, are treated as "entities", units of a dance tradition, with their own "meaning" within a particular dance context. In the following paragraph we are attempting to organize these layers of knowledge from a semantic point of view.

3.3.2 Dance traditions and practices are diverse

It is of no question that all type of dance involves some kind of human movement, the question however is if all kind of human movements can be considered as "expressive" or potentially a part of a dance? The answers vary. In the post-modern era of dance through the pioneering work of choreographers' after 60's such as Merce Cunningham, Trisha Brown, and Steve Paxton just to mention some examples the necessity of specific pre-defined forms and shapes in expressive movement have been questioned. Since then many choreographers have given more weight on the intention behind the movement, the exploration of personal movement or the authenticity in expression through dance rather than choreographing predefined patterns. This is the case mainly in contemporary, performing dance. On the other hand, there are many other types of dance like classical ballet, European social and historical, Latin, folkloric that are tightly connected with specific moves or steps that are accompanied with corresponding rhythms of music. Round Balkan dances, river dance, classic Indian, Thai dances, and many other "local" dances, which nowadays are becoming more international through cultural exchange, cannot be examined or learned without understanding the movement vocabulary of such dances.

Therefore, if we are to examine dance as part of intangible, cultural heritage, we cannot ignore the fact that particular dances have their own history that serves as context that is eventually reflected through the evolution of specific movements. Ballet, on the other hand is a dance based on very specific technique, transmitted through the different schools of teaching (e.g., Vaganova, RAD, Ceccetti, French) and the movement is formalized by

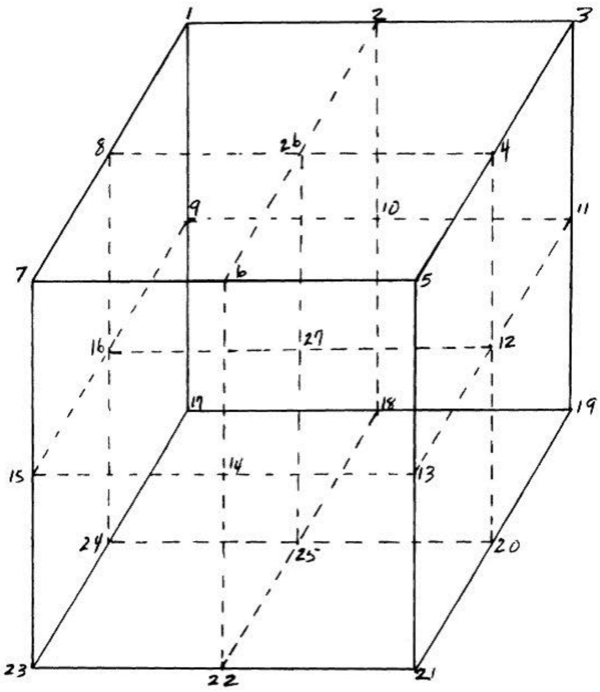


Figure 29: The imaginary cube and its points of reference in Trisha Brown's "Locus"[192]

specific syllabi. Of course, the there is a large school in creative contemporary performing dance which is leaving behind forms, patterns, and specific technique vocabularies, to substitute them with personal idiosyncratic innovative vocabularies. It is indeed a universal human activity, like language.

Each dance languages integrates a specific subset of human movements that are organized, embodied and transmitted within a particular, cultural, educational or artistic context.

The fact that many contemporary choreographers seek for innovation in the way the human body can act and be perceived, extending or inventing new kinetic vocabularies is not contradicting our aforementioned statement. Coming back again to the analogy with language: a writer or a poet uses a specific language to create new meaning and usually feels free to experiment and break the rules of the usual syntax to convey ideas and feelings, but this do not mean that the language that they use is not subject to particular morphology, grammar, syntax and semantics. It is exactly their awareness and deep knowledge of the language that enables this re-invention in a creative way.

One of the historical examples of contemporary dance as field to reform the connection between language, movement form, visual and symbolic representation is the work "Locus" (1975) of Trisha Brown [192, 153]. Some examples of this idiosyncratic language and score are shown in Figure 29 and 30 . In this choreographic score, we see a cube that seems similar of the one proposed by Laban, but serves a completely different role. It is used a mapping between directions in space and letters.

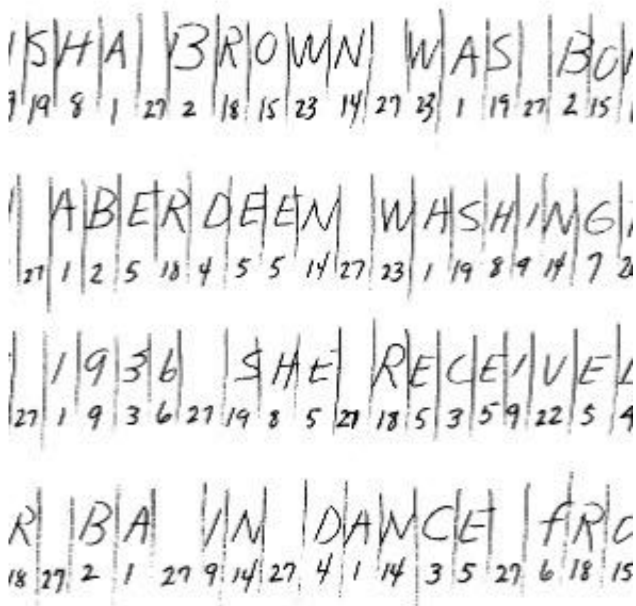


Figure 30: Trisha Brown “Neutral bit of writing ” [192].

The diversity in contemporary dance making and the need of choreographers to invent or create new dance vocabularies, question existing rules and structures is a fact.

The usual argument for handling dance knowledge as a universal language is related to the fact that the main contents of dance is movement and the human body. In addition, it is commonly known that although the main ingredient of dance is movement, the human motion in space and time, it is much more than this.

Depending of the dance itself and whether it is part of a cultural tradition, an artistic creation, or a social expression it usually highly related (or not) with other cultural, artistic and social aspects such as music, costumes, props, gender and social identities etc. In this thesis, we focus mainly on the representation, analysis and transmission of human movement, however, acknowledging that the movement itself is a carrier of a cultural, social or personal identity and signature.

3.3.3 Verbal Descriptions: Semantics vs. Meaning

Another point that suggest a relationship between dance and language on a conceptual and semantic level, is the development and use of terminologies, vocabularies and verbal expressions to describe movement.

We all use language to communicate, but we don’t all speak the same language. The same is with dance. Most interesting, not only different movement vocabularies (ballet, contemporary modern, flamenco, folk, Greek folk, classic Indian, Thai, river dance, Latin, etc.) exist to form what we generally call dance, but dance practitioners built terms, syllabi, words to refer to specific movements like e.g., plié, arabesque, contraction, turn, drop, triplet, to describe a particular move or a way of moving. Those vocabularies or concepts are used within dance classes, and let dance learners, teachers, choreographers and students easily communicate with one another. There are many dances where the movements have also a symbolic meaning or express a particular mood or emotion. For example, in ballet a first position in the arm, has no meaning, whereas “mudras” or “hastas” in Indian dance symbolize specific concepts. Nevertheless, in this work, we are mainly interested in the quantitative and qualitative characteristics of the movement and how they are described. Another very important characteristic of some dance types that distinguishes them from other is their connection or not with music, or songs.

- The importance of verbal metaphors both in the terminology and instructions.
- They can imply or trigger qualitative aspects through using particular verbs. In fact, action itself can be seen as a metaphor for other actions manifested by a different body and in a different form and shape. For example, fouetté is not for referring to the action of whipping literally, handling a whip or beating someone but refers to the action of turning with moving the leg in rapid, dynamic way. As it is the case with Laban Effort the descriptions are again verbs can imply a particular manner of moving in terms of speed or even shape.

“Although movement, including dance, will always exist on all levels or layers at once, we may draw out one or another aspect in order to change it, clarify it, or simply describe it. ” [20]

To this sense verbal descriptions are rather important for many reasons:

a) they are related to a terminology, in this case we are dealing with clear semantics mapping the term with a particular movement, a category of movements

b) at a second level this group of movement or movements is carried with a particular quality-sometimes implied by the term used itself and caries a particular role within a dance genre or a dance system. Thus, the particular movement suggests or implies connections that might be related not only to other movements in terms of structure but also, in terms of function and meaning or placement within an educational or social context. E.g., a fouetté turn is not a movement for beginners or a movement that is done in the beginning of the class.

3.3.4 A Brief Reference to Linguistics

“Linguistics includes such fields of study as: phonology (the study of the sound patterns of language), phonetics (the study of the production and perception of the sounds of speech), morphology (the study of word formation and structure), syntax (the study of grammar and sentence structure), semantics (the study of meaning), pragmatics (the study of the purposes and effects of uses of language), and language acquisition.” [57].

Swiss linguist Ferdinand de Saussure (1857-1913) is considered the father of structural linguistics [57]. The main elements of the system of language according to Saussure, who set the fundamentals for Structuralism in language consist of the following dichotomies:

- *Signifier and Signified*: According to this dichotom*Sign*, i.e., whatever we use to symbolise an object in the real world e.g., a symbol, a word, is based on an arbitrary relationship between the Signifier and Signified object (Figure 31), and this choice is not a natural process. E.g., the word CAT in English implies no explanation for connecting these three letters and sound with the corresponding animal. Another important note is that Signs can communicate through any of the senses, visual, auditory, tactile, olfactory, or taste.
- *Parole and Langue*: Parole in French means speech, and Langue language. This distinction forms one of the theoretical foundations of structuralism. While Langue consists of the systematic structures of language, including its universal components, rules and patterns. Parole is characterised by diversity and is connected with the people that speak the language, their age, their social group etc. For example, the grammar rules, syntax and vocabulary of English Langue is universal for the people who use it, systematic, and documented. On the other hand, Parole, includes the different accents, idioms and disruptions that social groups and individuals introduce when they speak the language.
- *Syntagm and Paradigm*: This dichotomy refers to the relationship of Sign to create greater meaningful structures. For example, the letters C, A, T in the word CAT, and the words THE, CAT, IS, BLACK, in the phrase THE CAT IS BLACK, have Syntagmatic relationship. Letters, numbers or words in a list on the other hand, have a Paradigmatic relationship in forming a sequence.
- *Synchrony and Diachrony*: In a Synchronic linguistic approach, language is studied in a particular moment of time in history, while in the Diachronic approach, the language is studied as a subject that evolves through time. They can be also referred to as *Static* and *Evolutionary* approaches respectively.

Although the aforementioned perspective in Linguistics have been questioned by many other researchers and for some might be considered as outdated, we argue that understanding this perspective in the context of this Thesis, is very important for defining the possible analogies between Dance and Language. Language, as a subject of Linguistics, or as concept used metaphorically to describe other forms of activities can raise discourses that range from Humanities to Philosophy and Mathematics. Nevertheless, understanding the context and perspective in which we define Language when we talk about a Dance-Language-Analogy is critical.

3.3.5 Morphology

Morphology is the subject of studying the word structure and formation.

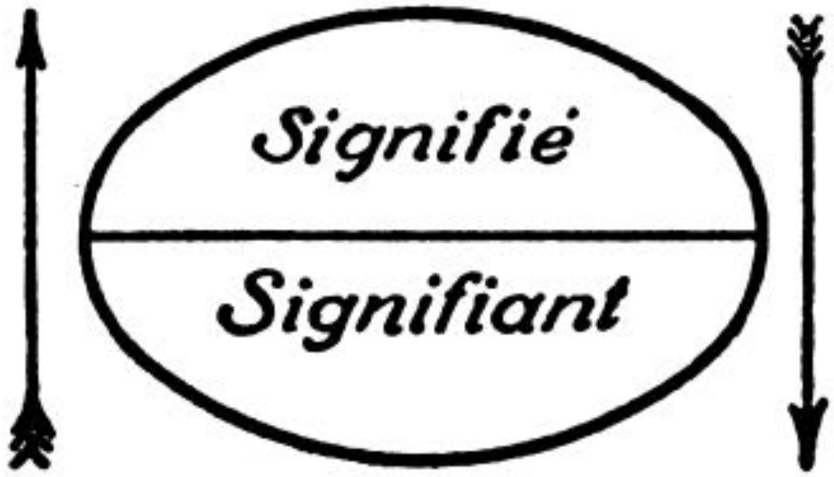


Figure 31: A generic diagram from Saussure's Course in General Linguistics illustrating the relationship between signified (French Signifié) and signifier (French Signifiant) [57]

According to Lyons: "Morphemes are the smallest units of meaning in a language. Phonemes are the smallest units of sound in a language. In Chinese, each phoneme corresponds to a morpheme and each morpheme corresponds to a morpheme. For example, in English we have the word CAT. "CAT" is a complete idea, and it cannot be broken down into smaller ideas based upon the word. "CAT" is also a complete sound. While each letter in "cat" corresponds to a specific sound, separately they are not complete. Every character in Chinese represents a single morpheme and has a corresponding phoneme very similar to the word "cat". On the other hand, English has many cases where more than one phoneme is corresponds to a single morpheme. For instance, in telephone there are two morphemes: tele and phone. In the same word there are seven phonemes: t, e, l, e, f, o, and n." [144].

The system that is developed by Kaeppler [124] offers a tool that is analogous with the ones used in Morphology one of the subdomains of Linguistics, (together with Phonetics, Phonology, Syntax, Semantics and Pragmatology).

An example of the morphology analysis in Linguistics is that for the sound pronounced for TELEPHONE the following facts are true :

- TELEPHONE has a meaning
- It consists of two smaller structural elements, that are called Morphemes that they also have meaning [TELE] and [PHONE]
- Each Morpheme consists of seven Phonemes [T], [E], [L], [E], [F], [O], [N], [E] that are valid in the particular language (in this case English), but that do not have meaning on their own.

- Since Morphemes and Phonemes are referring to speech (the sound of language) there is a correspondence between Phonemes and Symbols or written language.
- it is possible that one phoneme can be written using two symbols e.g., the Phoneme [F] is spelled with the sequence of two symbols “P” and “H”

3.3.6 A Linguistic Perspective on Dance Digital Analysis

In this thesis we consider the following analogies of movement and language:

- Dance and Language (with L capital) are universal human abilities to communicate express ideas, feelings, social values. Dance, in an analogy with Language, describes the capacity of human beings to develop, evolve and practice “dances”, in an analogy that Language defines the capacity of human to construct and use “languages”.
- Continuing this analogy, dances (or dance languages or dance genres), as languages are built with social and cultural systems that define their morphology, function, and meaning. For many reasons that we explain further in the document, the analogy of language and dance language is stronger and valid if we consider language as mainly as speech.
- Each dance language consists of specific morphology, vocabulary, syntax and semantics (this point needs to be further clarified). Vocabulary is the set of elements that carry particular meaning within a dance genre or dance language. See Whatley [16]
- as in any language, in dance languages there are the rules and structures that the language is defined by
- although there are claims that written languages of dance exist and this is notation, we argue that the analogy between a dance language and notation is different than the one of language and its written form for many reasons. First of all, most of notation systems such as Labanotation is a movement representation system that is dance independent and can be applied to any type of movement. Taking the analogy of dance language with an oral language and speech, movement in dance is what sound is for speech. Therefore, Labanotation would serve dance writing in the same way of creating a written language for writing the sound of the language.
- apart from all these analogies, dance has another close connection with natural language in the way words, terms and verbal expressions are used to describe dance elements in every dance system or practice.

What can information technologies offer to dance? In order to develop tools to support dance learning and research we need to understand what are the main attributes of dance movement.

3.3.7 Dance Structures

To what follows we present the structural elements (Kinemes, nes, and Morphokines) as they have been introduced by Kaeppler [123] and we provide a definition about the generic Movement Entity and Movement Sequence.

Kineme
According to the methodology of Kaeppler for analyzing and documenting dance anguages.

“Kinemes are units treated as comparable to phonemes; that is, they are elements selected from all possible human movements and positions and are recognized as significant by people of a given dance tradition. Kinemes are those actions and positions which, although having no meaning in themselves, are the basic units from which all dance of a given tradition is built. The first task of a structural analysis of dance is to locate for a specific tradition the basic movement unit and define the range of permissible variation within these units.”[124] Kaeppler, A. L. (1972).

A finite and specific number of movements can occur into this language, in terms of body parts moving, actions, shape and structure. We are talking about a Dance System (within a Dance Genre with specific Movement Vocabulary, context and functionality)

Allokine The concept of Allokine is very important, as it distinguishes between the slight personal, interpersonal, and contextual variations of a motion or position, which stil consitute the same Kineme, and a completely different Kineme. The analogy with language is again clear. Although in a language system, e.g., English the number of the Phonemes is precise and limited, each speaker can pronounce the exact same phoneme slightly different at different moments, different persons pronounce the same phoneme differently, and finally the same phoneme can vary depending on the context, e.g., its position within a Morphokine or Phoneme.

- Personal Variation. The same person does it slightly different but still not to consider a different Kineme.
- Interpersonal Variation. Different persons do it slightly different but still not be considered a different Kineme.
- Contextual Variation. The same Kineme is performed a little bit different according to the context)

A **Kineme** is a concept, a class it is not every singular movement (move or position) performed but something that is a recognizable (emic vs. etic) by the culture, the dance system and can provide the vocabulary, the inventory of movements.

Here asre some importnat facts about Kinemes:

- A Kineme can be a Position (State) or a Move (Transition).

- A Kineme is an abstract categorisation of movement, it is very interesting how the authors and researchers who apply this methodology decide whether this is a "variation" of the same Kineme or a different one. "What the practitioners of this genre will correct."
- A Kineme and it's symmetrical is the same Kineme
- A Kineme is usually defined by the Body Part (Jumps and Turns are considered Leg Kinemes), so they are actually defined based on a body hierarchy. (Leg, Arms, Upper Arms, Lower Arms, Hands, Fingers, Head, Torso, Hips)
- A Kineme can be directly related with an Action (including stillness, pause or position)
- A Kineme is part of the structure, sometimes a characterisation of the quality, speed or dynamic is given but not always
- A Kineme is defined within a "dance language", a culture and has an emic definition (it is defined and recognized by the people practicing this culture, and not by an outside observer-third party). Note that automatic algorithms play the role of an outside observer.
- A Kineme at least when it is a position can be pictured/ a frame/ focused on a particular body part
- A Kineme can be expressed into Labanotation using, one or more symbols
- A Kineme can be described by and be directly related to a simple anatomic motion
- Since Kinemes and Morphokines are defined within a "Dance System" they can be related to cultural context.
- By using this system anthropologist are in the position to differentiate structure from style and other details, as they are usually more interested in the differenced.
- A Kineme for the system of analysis proposed by Kaeppler is the smallest, however, can be long enough in

Morphokine A Morphokine can be defined as "the smallest unit that has meaning in the structure of the movement system." This does not imply that Morphokines must have narrative or pictorial meaning (although they sometimes do), but only that they are recognized as movements (Kinemes, like phonemes, being largely unconscious as separate entities to the people who perform them). Morphokines are combinations of Kinemes and only certain combinations are meaningful. Morphokines combine Kinemes-whether position or motion-into flowing movements that have a definite beginning and end. A Morphokine may consist of a single Kineme, repeated one or more times, or a combination of Kinemes. These units cannot be divided without changing or destroying their "meaning." These combinations are recognized as movements by holders of a specific dance tradition and may be given names.

Morphokines can be analysed in two ways:

a) With regard to their internal structure (i.e., their Kineme composition-the Kinemes that are used and in what sequence) and grouped into categories or classes.

b) With regard to their external distribution (i.e., the co-occurrence of Morphokines-what Morphokines can occur simultaneously). The number of possible Morphokines in a given dance tradition is theoretically unlimited, just as the number of morphemes of a given language is unlimited."

3.4 Conceptual and Experiential Aspects of Dance

While many digital applications related to movement either focus on transmitting particular movements with precision that are very particular to one dance genre or expression, or analyse movement concepts as a general, in this thesis we attempt to bridge these two approaches through expressing and applying conceptual and semantic models.

We argue that designing and developing tools for analysing, transmitting and transforming dance knowledge, cannot be done effectively, without studying the way dance systems and genres create and understand their structural components.

We acknowledge the fact that each dance language and practice brings different structures, rules and suggests different needs and opportunities in terms of user interfaces. We also acknowledge the fact that these rules, structures and languages present interesting connections. Based on studying existing theoretical frameworks on analysing and representing movement and dance we develop conceptual and semantic models that are hierarchical, linked and extensible.

While many technological solutions have been proposed to analyse and transmit dance knowledge, in the form of digital learning interactive systems [172], and have significantly contributed to the various specific problems of transferring dance knowledge to the digital, we noticed that most of the efforts, provide ad-hoc solutions that are valid within a very specific dance system (approach and technique).

At this point we suggest that one solution to fit all is almost as impossible providing a universal framework to embrace equally all kind of dance languages or languages in general. We argue that a conceptual framework that defines and explains the main characteristics of dance, can effectively contribute to the digital analysis, representation, comparison, and transmision of dance knowledge. In fact, creating tools for analysing dance in general without taking into account its structural and functional characteristics, is analogous with applying natural language processing, and ignoring all the linguistic theoretical systems and approaches, or trying to process speech in general, without taking into account the characteristics of Language in general, or the vocabulary, grammar and syntax of this particular language.

4. DANCE ONTOLOGIES

4.1 Semantic Representation and conceptual modeling for dance and movement

In this Chapter we discuss the main challenges and outcomes that are related to the development of the semantic representation model for movement and the ontological approches to dance description.

In this Chapter we present the process of transfering the semantics of Labanotation to OWL, the resulting ontologies and knowledge bases, as well as the extnended conceptual model as it has been iteratively improved and presented in the corresponding papers [72, 73, 75, 74, 143].

Our theoretical background is presented in the previous Chapters and consists of the following:

- Labanotation System [1] for notating and analysing movement.
- Choreological methodologies that suggest an analogy between Dance and Language in structural analysis.
- Description Logics and Semantic Web Technologies.

In particular in this Chapter, we present the following outcomes:

- The development of a Labanotation based ontology for representing movement using OWL, and building a Knowledge Base (KB) for Greek folk dances. SPARQL language has been applied to express queries that allow to search for particular patterns within the KB. The results of this work have been published in [72] and are presented in details in section 4.2.
- In Section 4.3 we present the outcomes of a use-case that have been published in [73]. In particular, we extend the expression of the relationships between the concepts of dance that are related to its digital preservation, such as recordings, scores, and Movement Entities and descriptors that have been integrated into the initial version of the Dance.OWL ontology. In this part of our work we focus on semantic representation of movement and conceptual modeling for dance from an archival and preservational perspective and we formulate the challenges in reference to exiting conceptual models for intangible cultural heritage, traditional and performative.
.

[1] Note here that the use of the word ”system” does not refer to the computational or digital system, but the the notational system for representing movement

- In Section 4.4 we formulate the semantic challenges for transfering Labanotation into expressive, computational models: such dealing with time representation, negation and ambiguities of symbols interpretation, and we present the development of a multilayered approach for analysing and describing movement. For this use-case we have worked with existing score archives of Greek folk provided by the Trace project. The results of this work have been published in [74].

- In the Sections 4.5 and 4.6 we investigate the analogies of morphological and structural analysis for dance with language, as well as well as the analogies with conceptual modeling of music in relation to scores. The results of this work have been published in [75, 143] respectively.

4.2 MoveOnto: A Labanotation-based ontology for representing dance movement

In this use-case, we present a Knowledge Based System for describing and storing dances that takes advantage of the expressivity of Description Logics. We propose exploiting the tools of the Semantic Web Technologies in representing and archiving dance choreographies by building a Dance Ontology in OWL-2. Description Logics allow us to express complex relations and inference rules for the domain of dance movement, while Reasoning capabilities make it easy to extract new knowledge from existing knowledge. Furthermore, we can search within the ontology based on the steps and movements of dances by writing SPARQL queries. The building elements of the ontology and their relationships to construct the dance model are based on the semantics of the Labanotation system, a widely used language that uses symbols to denote dance choreographies. In this work, we have described a number of Greek folk dances and applied the methodology both for representing and creating the database as well as querying specific motifs. In this work, we use the Labanotation System as the main guideline for developing a Dance Ontology, transferring the semantics underlying symbols into concepts and relationships. This task proved to be quite challenging, as in many cases movements in Labanotation are not expressed by one and only symbol, but by a combination of more symbols and their placement on the Labanotation staff.

Archiving dance can also be achieved using software applications that are based on notation systems. This field has a huge potential to reach, as it combines the established dance knowledge with new technologies.

We create an ontology transferring the semantics of Labanotation into OWL entities, so that representations are both human (at least for the ones that are familiar with basic dance concepts) and machine-understandable. Moreover, in our work, the use of the ontology provides the ability to express complex relationships, restrictions, and rules about the concepts, creating hierarchies and graphs of movement entities and properties, and as a result provides a rich vocabulary for describing dance movements in different levels of detail.

4.2.1 Challenges and the Dance Ontology Approach

In the created ontology, we represent the most important concepts underlying the symbols of Labanotation, and we enrich the ontology with concepts and relationships to enhance the expressivity of the model. It is important to state that our goal is not to develop a Labanotation Ontology, but -a Dance Ontology based on the movement concepts of the Labanotation System. In what follows, we present the main advantages of a Labanotation-based ontology in addressing the main challenges of digital dance archiving:

- To preserve choreographies in an expressive searchable way, we need a strong theoretical basis that allows us to describe the required elements of dance. In dance, we cannot predefine a limited set of specific movements, as the human body acts within the extremities of its movement range, creating innovative spatiotemporal entities and dynamics through endless combinations of possible positions, body parts relationships, rhythms, qualities and also face expressions. Thus naming the type of movement (what) and the main body parts (who), is not enough for describing dance. Timing (when) and quality (how) of movement are equally important. Based on the Labanotation System, our model captures all of the main parameters of dance movements: Time, Space, Dynamics, and Body Parts, as presented by Hutchinson-Guest [119].

- Style in dance is one of the most difficult qualitative features to be captured, as it is associated with structural and qualitative features of the dance itself, as well as other parameters which are not directly related to the dance movement (e.g., social and historical context, music style, costumes) as Koutsouba explains [131]. Aiming at developing a universal model which will be capable of describing a wide range of human movement independently of the contextual parameters of dance, we do not assume a particular style or technique. Instead, we develop the concepts that are required to describe the structural and qualitative stylistic features, as this is important when we need to compare similarities in dances of different eras and areas.

- In the need for a model to implement applications that can be used by non-experts in notation, we must use concepts rather than complicated combinations of symbols and organise these concepts in a higher level of detail. In our approach, we create a hierarchy and taxonomy of movements, by clustering them into abstract categories. This hierarchy supports the scalability of the system by giving the opportunity to search movements in different levels of detail e.g., search for arm gestures or specific dapping movement of extended fingers. As OWL is based on Description Logics, it allows us to express complex inference rules and relationships, enhancing the expressivity of the knowledge-base. Reasoning capabilities support reuse of entities, and allow the system itself to infer new knowledge from the stored dance knowledge, e.g., a gesture is a movement. To examine a detailed example, let's see the case of hop, a specific type of jump. In dance theory, we analyze a jump into three stages: preparation, elevation, and landing (in Labanotation three individual symbols -or group of sequential symbols are used) and we categorise jumps depending on preparation and landing and in particular, if the action is on both feet, on the same or on the other foot. We use the concept (Class Entity) “Hop” for jumps where preparation and landing is on the same foot. The hierarchy of this Class is as follows:

$$Movement \sqsupset Action \sqsupset Jump \sqsupset Hop$$

According to this analysis, the definition of concept “Hop” in Description Logics is the following:

$$SimpleJump \equiv Jump \sqcap \exists hasPreparation.SupportOnBoth \sqcap \exists hasLanding.SupportOnBoth$$

$$\begin{aligned} Hop \equiv Jump \sqcap & ((\exists hasPreparation.SupportOnLeft \sqcap \exists hasLanding.SupportOnLeft) \\ & \sqcup(\exists hasPreparation.SupportOnRight \sqcap \exists hasLanding.SupportOnRight)) \end{aligned}$$

$$\begin{aligned} Leap \equiv Jump \sqcap & ((\exists hasPreparation.SupportOnLeft \sqcap \exists hasLanding.SupportOnRight) \\ & \sqcup(\exists hasPreparation.SupportOnRight \sqcap \exists hasLanding.SupportOnLeft)) \end{aligned}$$

$$\begin{aligned} Sissone \equiv Jump \sqcap & hasPreparation.SupportOnBoth \\ \sqcap(\exists hasLanding.SupportOnRight \sqcup & hasLanding.SupportOnLeft) \end{aligned}$$

$$\begin{aligned} Assemble \equiv Jump \sqcap & hasPreparation.SupportOnBoth \\ \sqcap(\exists hasLanding.SupportOnRight \sqcup & hasLanding.SupportOnLeft) \end{aligned}$$

- By using OWL, we build a knowledge model that is extensible and can be further on integrated with related knowledge, i.e., origin, history and music of folk dances.
- Another challenge stems from the use of OWL itself and is related to the representation of timing and sequencing. We address this issue adopting a methodology similar to the one applied for representing amino-acid sequences in proteins, using OWL [69]. In particular, each dance consists of temporal entities following one another, organised in staffs (kinetographs), phrases, and measures.

4.2.2 The Movement Ontology Classes

The main classes of the created Dance Ontology, within this particular version of our model are the following:

- **Dance**: refers to the abstract concept of dance categories, and not the choreography. Examples of Dance subclasses are Solo, Group, Round, Folk Dance, Greek Folk, Dance etc. Instances of this class are Kalamatianos, Zonaradikos etc. In ontology engineering, expressing a concept as a subclass or an individual usually, is not a one solution problem, rather than a decision which relies on the general context of described domain. For example, Zonaradikos could be an individual of the

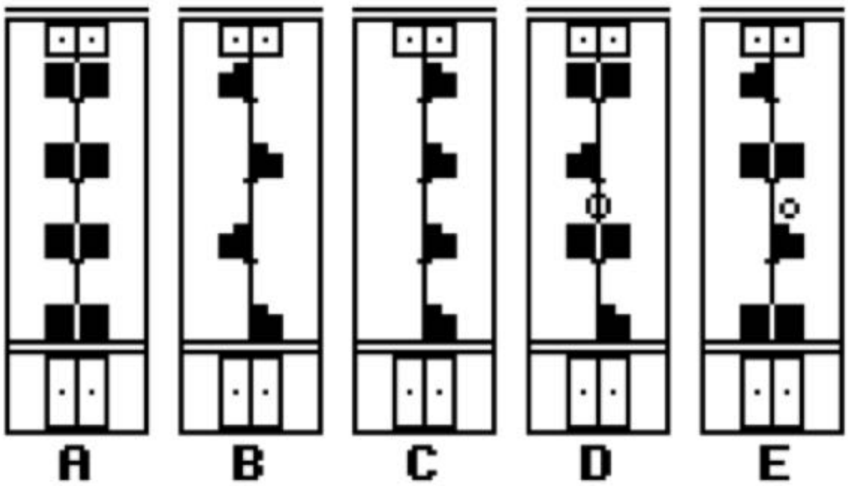


Figure 32: Types of jumps in Labanotatio

ontology if we expect to have only one type of Zonaradikos, but it should be a class if we consider it a category of Dance which has many versions. In this case we would have:

$$ZonaradikoshasOriginThrace \sqcap ThraceisPartOfGreece$$

The intention of this extendable hierarchy, which can be further associated with other concepts such as , is rather indicative and serves to organise general dance knowledge, but it does not reflect a specific study on styles, genres, and dance classification.

- **Movement**: the subclasses of this class and their associated properties form the core schema for the dance movement analysis.

  Subclasses of Movement can either have

  a one- to-one relationship to Labanotation symbols e.g. Contraction, Extention, Step, Support, Gesture, Relationship, Turn and specialisation of them, e.g., Bend, Arm Gesture, Limb Rotation, Forward Step, or

  more complex Actions and Positions e.g., Double Step, Feet Parallel, Jump, Stamp that are expressed by a combination of symbols. In the knowledge base, the individuals of Movement class, the movement instances, represent the building blocks of the "scored" choreographies. These building-blocks usually can be subclasses of more than one class movement, e.g.,

$$Ag1 : ArmGesture \sqcap Ag1 : LimbRotation$$

  In addition, some of the movements classes are defined through DL rule expressions (as Equivalences or Subclasses) e.g.,

$$Clap \sqsubseteq Action \sqcap Touch \sqcap (\exists isActedBy.Hand) \sqcap (\exists hasDynamics.StrongAccent)$$

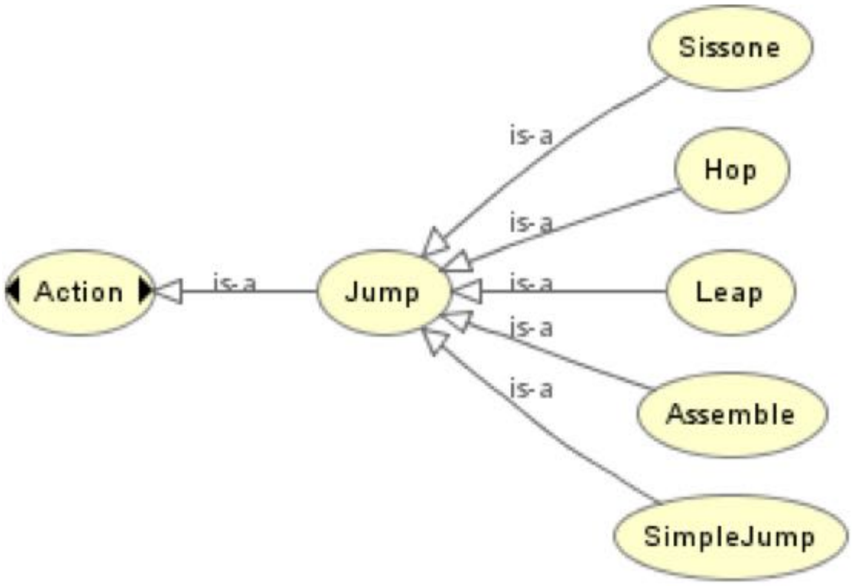


Figure 33: Hierarchy of jumps in the ontology

In fact, we represent only the basic rules; however, it is not effective to exclusively express all possible rules for all possible movements and postures of all dance techniques, and styles, if this would ever be feasible. In addition, OWL tools have some performance issues when using too many complex rules, and the reasoner system responds too slowly. Our goal is to include in the model the required dance parameters of space, time, dynamics and body parts considering them the different "degrees of freedom" of the complex "system of the moving human body".

Thus we do not define classes of default movements, only general types of movements e.g., a Turn class describes an abstract action of turning, however, different versions of turns are represented by different instances of the Turn class, which have specific properties (direction, degree, level, and axis) and optionally consist of other instances of simultaneous movements and sequential stages describing the details (e.g. legs and arms positions or gestures during the turn).

- **MovementChar**: this class includes the space and dynamic parameters e.g., Direction, Size, Accent, Effort etc. that are needed to characterise the Movements instances using object properties e.g.

$$S1 \quad hasDirection \quad Forward$$

- **Stage Object**: refers to any human or inanimate object that may occur on a (real or imaginary) dance stage and has as subclasses the Performers and their Body Parts, Groups of Performers, Costumes, Stage Parts, Stage Areas, e.g., Floor, Stage Points, and Corners e.g., FLCorner.

- **ScoreElement**: this class and its subclasses represent the kinetograph and the staffs that are used in Labanotation to score a specific dance- movement analysis. A Dance instance e.g., Kalamatianos has one or more instances of Score and each Score has one or more Staff (we need only one staff for a group dance where all performers do the same choreography or a solo dance). Each Staff contains Phrases, Measures, Temporal Entities, Start Positions and finally movements. Each Measure individual has properties such as Meter e.g., 3/4 , Tempo and Unit.

4.2.3 Human Body Representation

For analyzing movement which use a skeleton model or a stick figure description, Labanotation offers a wide variety of symbols referring to different parts, joints, areas, surfaces, and other details of a “flesh and bone” body (e.g., eyes, tips of finger), offering a tool with a great potential for dance research as Bartenieff et al. explain [23]. Also note that Labanotation system may be used to describe the same movement shape (at least for the untrained observer), in many different ways, e.g., tilting the head (joint) backwards and moving face (surface) up may produce a similar shape, but the emphasis on different body parts may define a difference in dance style, and demand a different “feeling” on the body of the performer, according to [23]. In addition, a specific usage of body parts in the description, help us recognise familiar movements in a specific technique. For example, a ballet-technique right leg “passé” or “retire” is usually notated as “upper leg has direction right side and has level middle and lower leg has direction left side and level middle” rather than “right leg has direction on place and level low it is contracted 3 or 4 degrees”, although the two description produce a very similar shape. Adding body details to our model allows us to be more specific in description, and be able to compare details later on, in movement search. In our ontology the Performer class has Body Parts, and the Body Part class has the following subclasses:

- Body Joint: e.g., Elbow, Wrist, Ankle, Knee.
- Body Area: e.g., Torso, Chest, Pelvis, Waist
- Limb: e.g., Arm, Leg, Upper Arm, Lower Leg
- Surface: e.g., Face, Back, Palm
- ArmPart: e.g., Elbow, Shoulder, Upper Arm, Hand, Right Hand
- LegPart: e.g., Leg, Left Foot, Hip, Right Knee, Both Legs
- BodySide e.g., Right Side (Right Hand, Right Leg), Left Side

Some body parts are subclasses of more than one class e.g., a Right Arm is a Right Side part, an Arm Part and a Limb Part, this complex hierarchy serves again to search in different level of detail, by actually clustering body parts in many different ways. In Labanotation

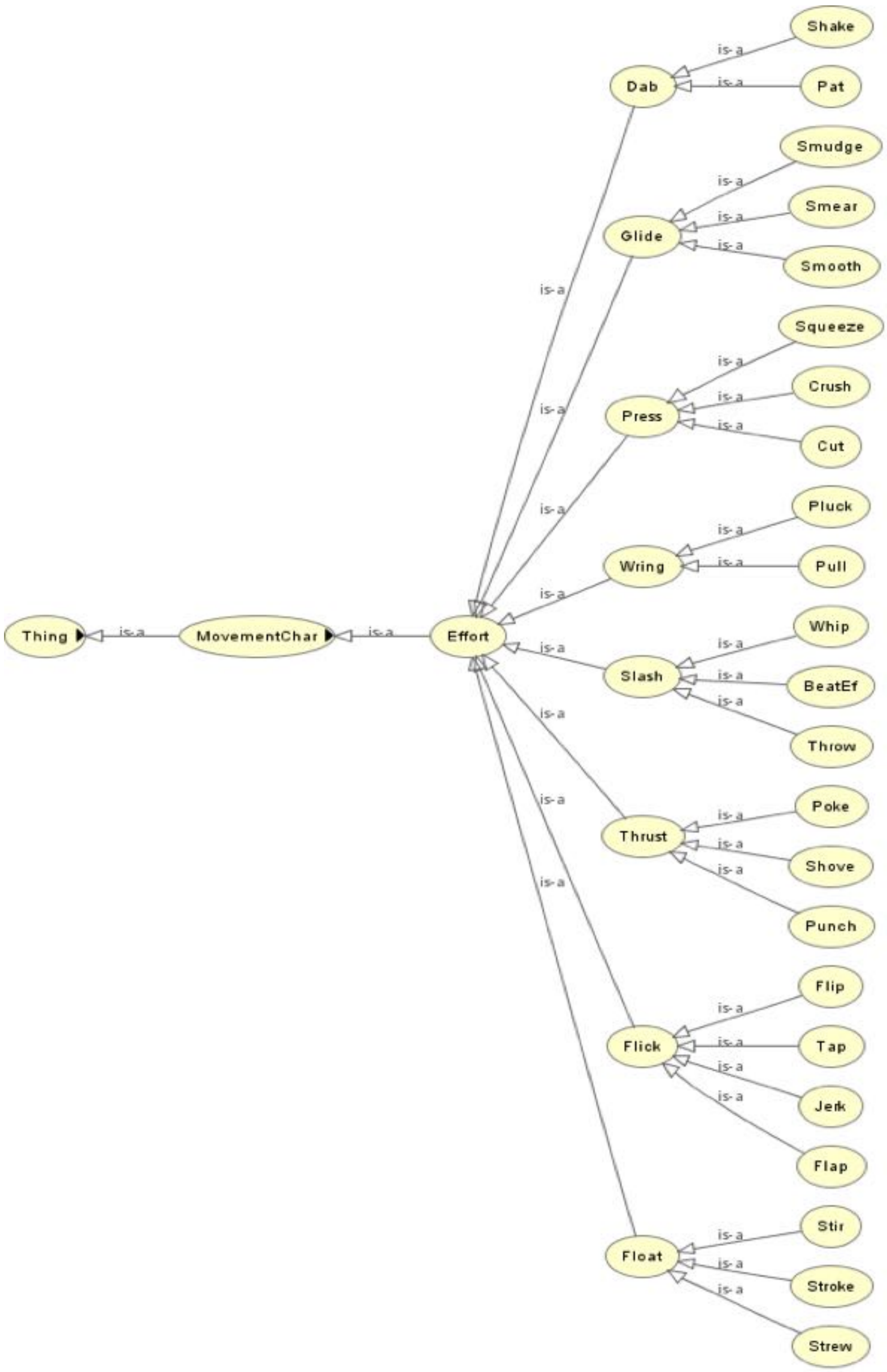


Figure 34: Effort subclasses as they are represented in the ontology

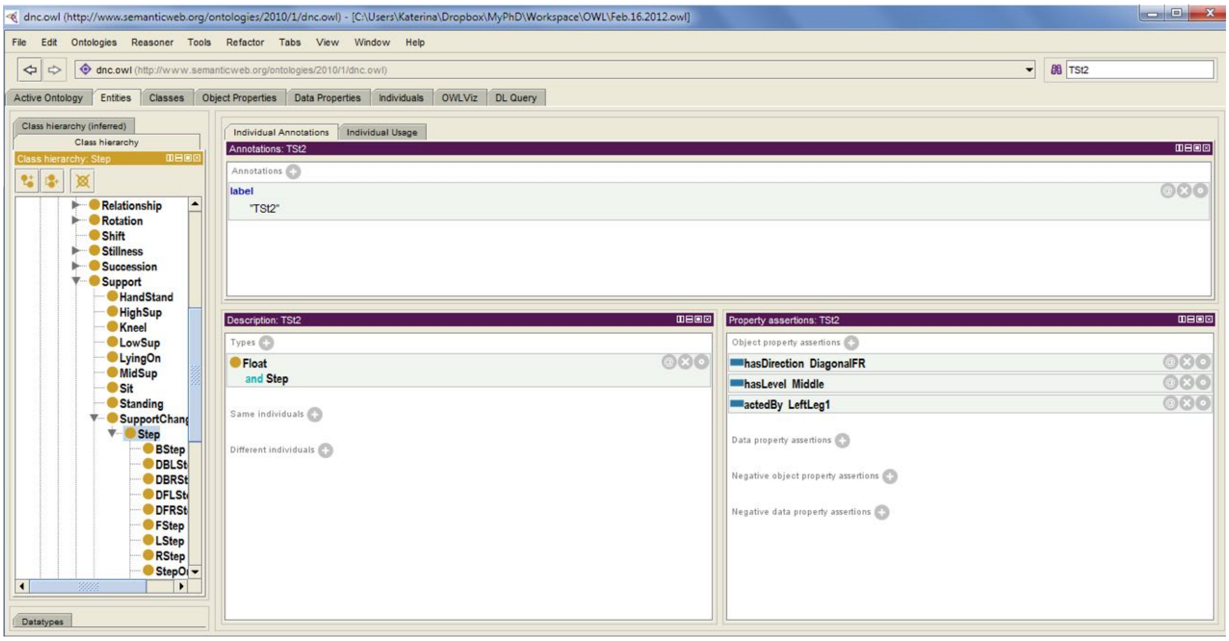


Figure 35: Effort Reasoning in Protegé

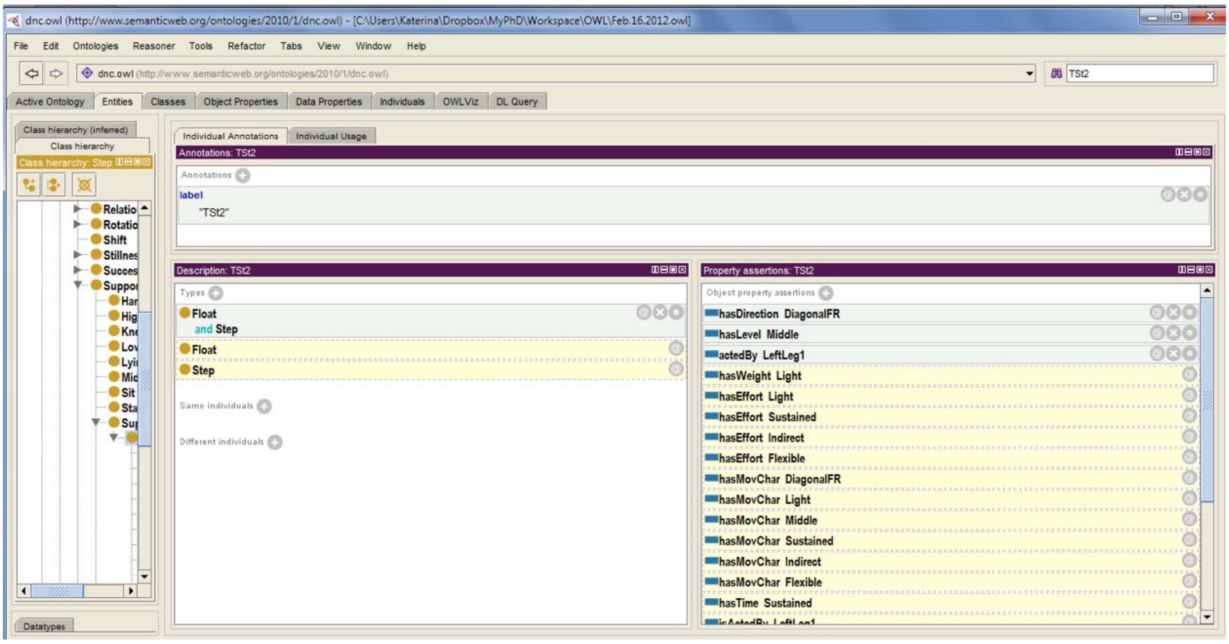


Figure 36: Effort Reasoning in Protegé: The assertions in yellow show the information that is

a single body is represented by a staff and its columns and different bodies by different staffs. In our model, we have Performers class individuals, related to the respective Staff to represent group dances where each individual has his own choreography.

4.2.4 Interpreting Labanotation into OWL

In the process of transferring the semantics underlying the Labanotation symbols to the ontology, the translation into words and phrases of natural language was unavoidable, which is no surprise, as Labanotation is actually a (symbolic) language according to Hutchinson [119] and also some researchers, such as Hatol [107]. Nevertheless, following the general rules of translating physical language into OWL was not always a straightforward task, considering the spatiotemporal nature of movement and all the related philosophical questions expressed on representing processes and change. Ontology engineering recommends translating names into Entities (Classes and Individuals), verbs into Properties and names or adverbs into Values (e.g. Arm1 moves High). To simply use triplets such as “Hand1 Touches Face2” to represent Relationships of Labanotation (expressed with bows, hooks, or pins), would mean that Hand1 touches Face2 forever! To address this, we express a touch as follows:

- *R1 isa Touch (subclass of Relationship)*
- *R1 hasActiveMember (subproperty of isActing and hasMember) Hand1*
- *R1 hasPassiveMember (subproperty of hasMember) Face2*

$$
\begin{aligned}
R1 isa Touch (subclass of Relationship) \\
R1 has Active Member (subproperty of is Acting and has Member) Hand1 \\
R1 has Passive Member (subproperty of has Member) Face2
\end{aligned}
$$

In our case, where we don’t actually talk about body parts moving but about entities of movements, N-ary relationships are represented between each building block of movement , all of its characteristics (BodyParts, Direction, Level, Effort etc.) and also among movements (M1 hasNext M2, A1 hasMov M1).

Each instance of Movement is characterised by the following:

- The type of Movement (e.g., Contraction, Relationship, Step, Turn, WeightTrasfer, LevelChange, Location, Space Facing)
- The object properties describing Space e.g., hasDirection, hasLevel, hasSize
- The object properties describing Dynamics e.g., hasAccent, hasDynamic, hasEffort
- The body parts involving in the movement action or position), e.g., isActedBy, hasMember
- The simplest movements that can be analyzed e.g., a Double Step consists of three small, quick steps, thus hasMov S1, S2, S3.

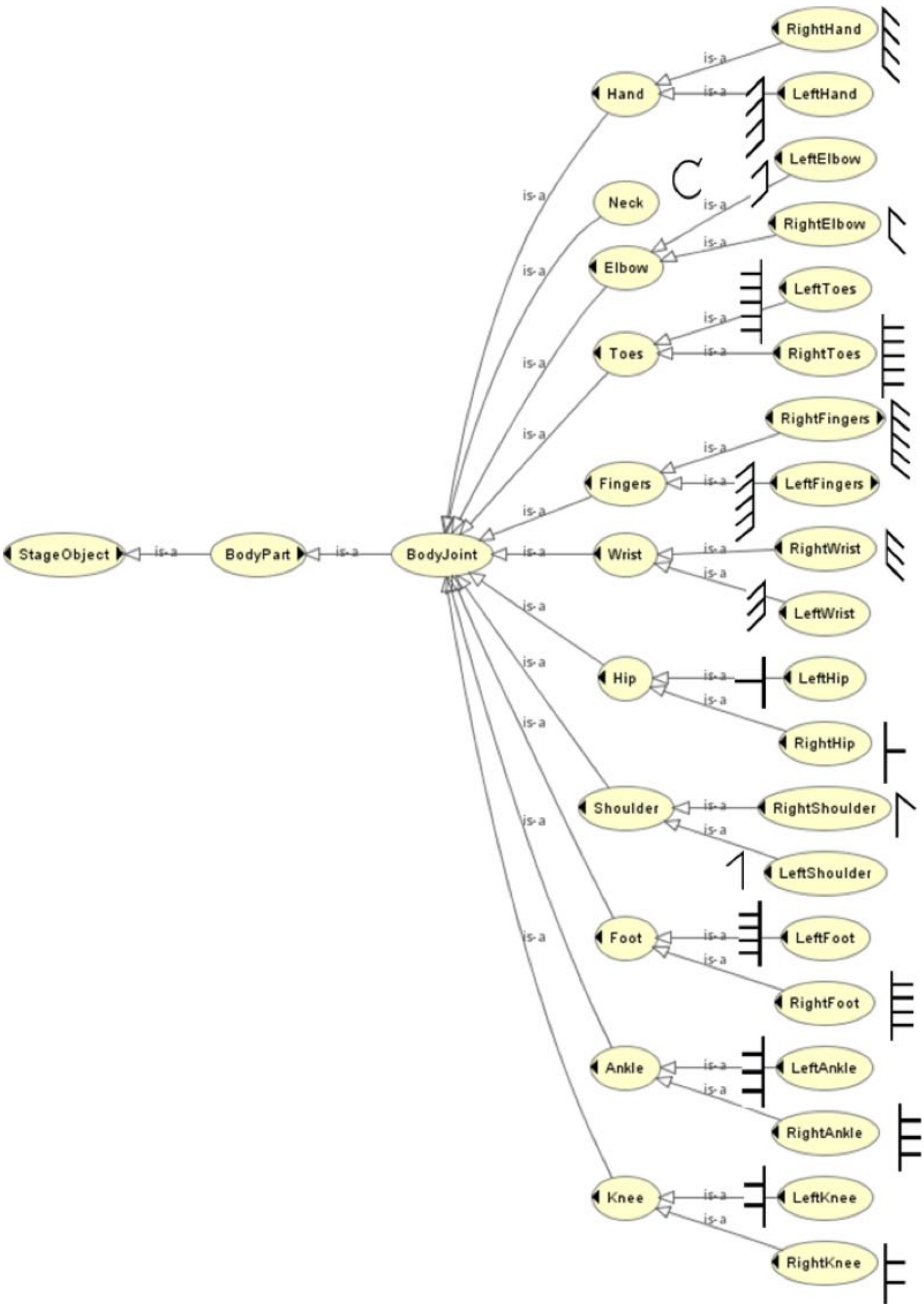


Figure 37: Body joints in the ontology and their correspondand Laban symbols

Also note that OWL is an Open World Assumption language, which means that we expect knowledge to be incomplete. In our case, we do not expect to have values for all the above properties, but we add properties and values only if we have specific information about this aspect of movement. Not giving values to properties could either mean two things:

1. No specific knowledge is available about this aspect of movement, or

2. It is considered insignificant detail, e.g., we don't describe finger positions, or even palm direction in all arm gestures unless this is part of the choreography. Usually, we assume a "standard/normal" position for the rest parts of the body, for example, in a Step, unless the head takes part in the choreography doing an "important or different from usual move", we do not notate anything about the head, thus it is assumed that the head follows the standard position (place-high).

One of the strong advantages of Labanotation is that, in the typed score, the reader has the whole image of the choreography, so the trained eye can catch familiar "word movements" [119] and then focus on the details. In the Dance Ontology approach we represent these different levels of details by the encapsulation of the analysis which consists of a sequence or a combination of Movement individuals, inside the main movement instance. For example, the Labanotation score, in figure 52, represents a jump (J1) with specific details in each of its 3 stages: preparation (P1), elevation (E1), and landing (P2). Next to the figure, we analyze this example as expressed in ontology.

The definition of concept "SimpleJump", in Description Logics, is the following:

$$SimpleJump \equiv Jump \sqcap (\exists hasPreparation.SupportOnBothLegs \sqcap \exists hasLanding.SupportOnBothLegs))$$

In addition the following hierarchy occurs for the Object Properties

$$hasMov \to hasJumpStagehasMov \to hasPreparationhasMov \to hasElevationhasMov \to hasLanding$$

Also hasMov is a transitive property, which means that if a hasPreparation b, then a hasMov b and if a hasMov b, and b hasMov c then a hasMov c, so the new knowledge that results from Reasoning is that J1 isa SimpleJump and hasMov P1, E1, P2, S1, S2, R1, LG1.

Figure 38 shows the example of a jump in Labanotation, whereas in what follows we present the same example in OWL:

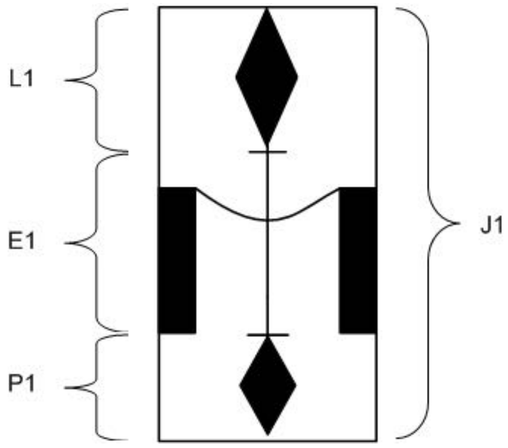


Figure 38: Jump from an open position to an open position and a touch during the lift

- J1 isa Jump
  hasPreparation P1
  hasElevation E1
  hasLanding P2
- P1 isa Position
  hasMov(hasSup) S1
- S1 isa SupportOnBoth
  isa FeetApart
  hasLevel Low
- E1 isa Elevation
  hasMov (hasLegG) LG1
  hasMov R2
- LG1 actedBy RightLeg1 and LeftLeg1
  hasLevel Low
  hasDirection OnPlace
- R2 isaTouch
  hasMember RightLeg1
  hasMember LeftLeg1
- L1 isaPosition
  hasMov(hasSup) S2
- S2 isa SupportOnBoth
  isa FeetApart
  hasLevel Low

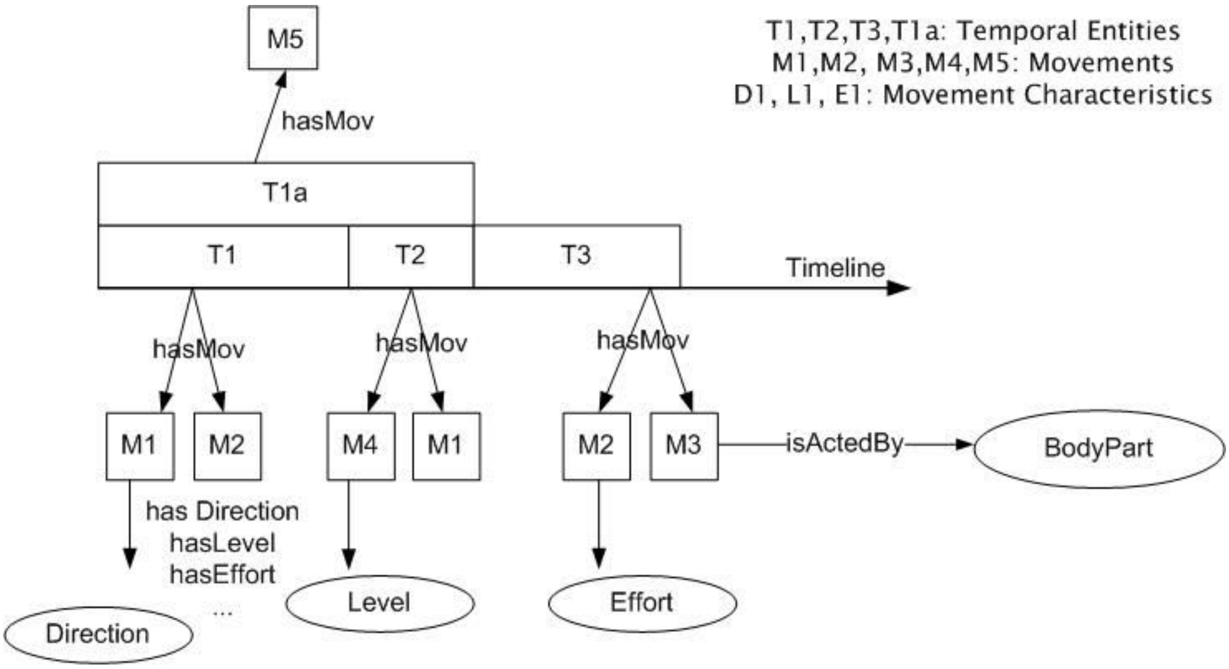


Figure 39: Movement Entities(ME) and Temporal Entities (TE) are the main concepts used to represent time. Movement Entitities are included in Temporal entities through the relation hasMov.

4.2.5 Storing a Choreography- The challenge of time representation

Labanotation scores are read bottom to top, and the duration of each movement is realised by the length of the symbol. Whatever is in parallel is simultaneous, while the sequence of symbols indicates the sequence of movements. Timing can be free or measured (in measures, counts/beats or subdivisions of beats) and usually a metronome indication is included to indicate the tempo. In the Dance Ontology, we need to represent all this information, without applying a tight schema, which would reduce the flexibility. The goal is to represent time and sequence in such manner that if we want to represent effectively both untimed sequences of movements and measured staff, without being inconsistent and thus be able to somehow compare these two representations.

The second question is if the time units that we use, whether they are measures, beats or subdivisions, indicate the start and duration of movement entities. The answer is no, at least no rule can be applied for all cases, and this is why we should be able to represent independently movement entities (that are represented by a group or a sequence of symbols) and rhythmical units such as phrases, measures, beats, and temporal entities that indicate the rhythmic motives. For example, if we say that the measure consists of four beats, this does not mean that we have four instances of movements, one for each beat, bur each movement starts whenever something changes in movement itself (a new Relationship, Position, Direction, Effort etc.) and has its own duration. Nevertheless, we assume that in all cases, staffs are divided into measures, represented by Measure individuals and have tempo and meter.

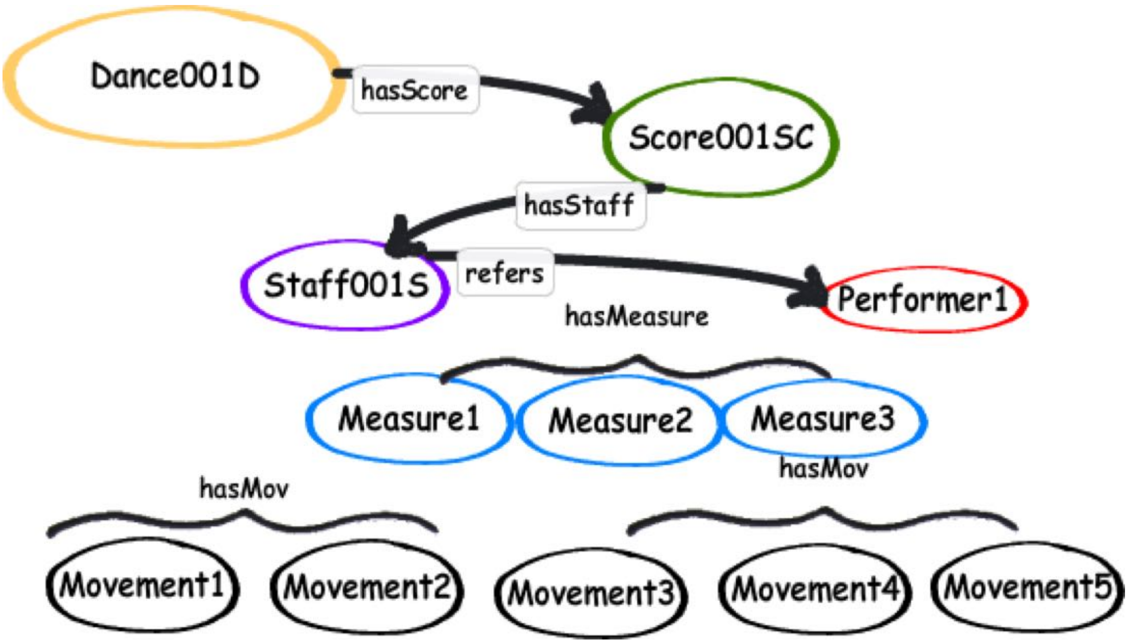


Figure 40: General sketching of representing the timing of movement in the initial version of the ontology

Example:

- Measure 1 isa Measure

    isContentOf Staff1

    hasBeatUnit quaver (=eighth)

    hasTempo 120

    hasMeter 5/8

Where: hasBeatUnit is an ObjectProperty having Measure as domain and Beat as range, hasTempo and hasMeter is a Datatype Property having Measure as domain and a string as range. Then the Measure is divided into Temporal Entities which have duration (hasDuration is an Object Property with Beat as range). These Temporal Entities may have longer, smaller or equal duration of beats and represent the dance count. Movements on the other hand have their own duration (hasDuration) which may be longer or smaller than these Temporal Entities. In this way we have the sequence of counts (Temporal Entities), but without restricting the duration of the Movements. For example in a ¾ waltz triplet where the count is 1,2,3 the feet make 3 steps (one for each beat), but the arm movement may last 2, or 3 counts.

To what follows we give a detailed example of a Greek folk dance that shows the relation of rhythm and movement instances and our approach. Usually dance practitioners use the term “step” to refer to a more complex group of movements e.g., a Double Step, or a skimming Skip, or a Step toClose sequence, but in our ontology a Step has a very specific meaning (means a unique Weight Transfer and a Support Change from one Foot to the other with specific direction). In addition, in the Greek Folk, as in many other dances, the "steps" are always associated with the rhythmic motif of the music.. When teaching the different versions of Tsamikos dance e.g., the one with "16 steps", we actually don't count neither 16 "movement instances" (as in "step 1"a double step occurs and is actually a sequence of three Steps), neither we count 16 beats, (as the 16 "steps" actually represent a rhythmic –dance phrase which consists of 8 measures having ¾ meter, and the rhythmic motif " slow (2/4) – fast (1/4), slow (2/4) – fast (1/4) etc", so step1, 3, 5,7 etc have double duration of step 2, 4, 6 etc.).

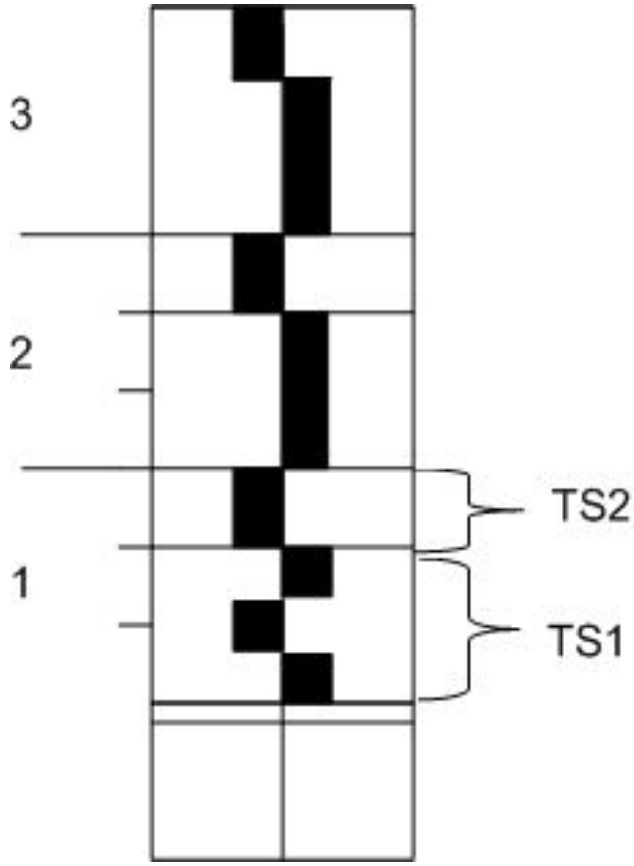


Figure 41: The 3 first measures of "Tsamikos" Greek dance where each measure has 2 temporal entities of different duration.

Example of representing time for the pattern shown in Figure 41

- TsamikosStaff is a Staff
  hasContent Meas1, Meas2, Meas3
- Meas1 hasNext Meas2
  hasContent TS1, TS2
  hasMeter ¾
  hasBeats 3

hasBeatUnit crotchet (quarter note)

- Meas2 hasNext Meas3
- TS1 hasNext TS2
  hasDuration minim (quarter note)
  hasMov DS
- TS2 hasDuration “crotchet (quarter note)”
  hasMov S4
- DS isa DoubleStep and hasMov S1, S2, S3
- S1, S2, S3 isa Step
- S1 hasNext S2
- S3 hasNext S3

So in our approach, trying to add this knowledge but without affecting the philosophy of our model, we divided the Dance Score in Phrases, Measures and in Temporal Entities, which have different duration and correspond to the dance “steps” rhythm. In this case, we have two types of sequences and durations: one between Temporal Entities, and one between the movements. Below, along with the Labanotation representation 41, a detailed analysis of our formalisation is presented. Please note that the Labanotation symbols here have no specific meaning in terms of movement type and direction (shape) or level (color) but only in terms of sequence and duration (length). In the example, note that temporal relationships, e.g., hasNext are expressed both between Temporal Entities and Measures, but also between Movements, as temporal knowledge of these two classes is supplementary.

The idea is that a group of movements, within the same Temporal Entity, does not necessarily form a new “movement instance”, while sequences or group of movements in different sequential Temporal Entities may (but again not necessarily) form a unique “movement instance”, i.e., a movement entity that can be stand alone and can be represented by Movement subclasses (e.g., a Double Step, a Jump, a Skip).

4.2.6 Implementation and Search

The ontology includes about 300 classes, 500 individuals and 80 properties and is developed using Protégé 4.1.0. This version of the software supports OWL-2 with SHOIQ(D) expressivity, and Pellet reasoner [167] . Note here that although the general idea is that the classes and properties provide the schema whereas individuals represent the specific entities of scored dances, however, this is not always the case as many movement characteristics are also defined as individuals (e.g., Forward, Right and so on are individuals of the class Direction although directions are part of the “schema”, i.e., the model description and not the “data”. First, in the ontology we analyzed and stored seven Greek folk dances: Baytouska, Kalamatianos, Chaniotis, Fissouni, Syrtos, Tsamikos, Zonaradikos, that are originated from different areas, creating a pilot knowledge base, however, the sample at this stage is very small to enable any comparative conclusions and evaluation of the model itself. Nevertheless, this pilot knowledge base is considered a first step to evaluate and plan the appropriate process of building the dance repository. At this stage the experiment was to explore how straightforward is to use the system developed to analyze dances not by reading the Labanotation scores, but by following simple description using a Greek dance teacher's book. What came as a conclusion from this process is that, however strong is the theory that the dance model is based on it will not reach its potential, unless the data acquisition is based on the same theory and expressed in a similar language. Developing a model language for dance description does not address the challenge of analyzing and documenting the dance. The second part of the experiments included search of the ontology using SPARQL queries executed within Eclipse framework for JAVA using Jena API and Pellet reasoner. This allows us to search for small sequences of movements with specific characteristics.

SPARQL Example 4.1: *Select all the movement individuals that consist of three movements in a row and the name of the dance which include them*

```
SELECT DISTINCT ?a ?d WHERE {
?m1 rdf:type  dnc:StepWithRight.
?m2 rdf:type  dnc:StepWithLeft.
?m3 rdf:type  dnc:StepWithRight.
?m1 dnc:hasNext ?m2.
?m2 dnc:hasNext ?m3.
?m1 dnc:isOn ?a.
?m2 dnc:isOn ?a.
?m3 dnc:isOn ?a.
?m1 dnc:isContentOf ?t.
?m2 dnc:isContentOf ?t.
?m3 dnc:isContentOf ?t.
?t dnc:isScoreOf ?d.
?a rdf:type dnc:Movement}
ORDER BY (?a)
```

SPARQL Example 4.2: *Select all the dances in the KB and their origin*

```
SELECT ?x ?y ?z WHERE {
?x dnc:hasOrigin ?y.
?x rdf:type dnc:Dance.
?x rdf:type ?z}
ORDER BY (?x)
```

SPARQL Example 4.3: *Select all the name of folk dances that contain a sequence of a "hop on right leg, a weighty step with left, feet together, and a sudden arm gesture*

```
SELECT DISTINCT  ?m1 ?m2 ?m3 ?m4?d ?s
WHERE
{ ?m1 rdf:type  dnc:Hop .
?m1 dnc:isActedBy ?r.
?r rdf:type ?RightLeg.
?m2 rdf:type  dnc:Step .
?m2 dnc:hasDynamic dnc: Weighty.
?m2 dnc:isActedBy ?r.
?r rdf:type ?LeftLeg.
?m3 rdf:type  dnc:FeetTogether .
?m4 rdf:type  dnc:ArmGesture.
?m4 rdf:type  dnc:Sudden.
?t1  dnc:hasMov   ?m1 .
?t2  dnc:hasMov   ?m2 .
?t3  dnc:hasMov   ?m3 .
?t4  dnc:hasMov   ?m4.
?t1  dnc:hasNext ?t2 .
?t2  dnc:hasNext ?t3 .
?t3 dnc:hasNext  ?t4.
?t1  dnc:isContentOf  ?v .
?t2  dnc:isContentOf   ?v .
?t3  dnc:isContentOf   ?v .
?t4  dnc:isContentOf   ?v .
?v   dnc:isScoreOf     ?d .
?d   rdf:type     dnc:FolkDance }
```

4.2.7 Limitations and Future Work

One of the weaknesses of our approach is that by using concepts and entities instead of symbols on paper (or on a screen), we can hardly represent complex shapes that cannot be described in words and thus concepts. In the following example we describe a starting position in space and a simple circular path, but what if the path follows a more complex shape (e.g., non-symmetrical spiral)?

```
P1 isa Circular Path
P1  hasTurnDirection Clockwise
P1  hasTurnDegree ¼

L1 isa Location (Relationship)
L1  hasActive Performer1
L1  hasPassive BLCorner

SF1 isa SpaceFacing (Relatioship)
```

```
SF1 has Active Performer1
SF1 hasPassive FRCorner
```

The same stands for complicated Floor Patterns especially when many performers take place. Another limitation which stems from the fact that we lose the whole image of a printed score is that, if we search for specific movements we can't always guess the shape resulted unless we know what is done in the previous movement. For example, if we search for movement instances where the "elbow is middle, right side", we will get "frames" where the elbow is in the required direction and level, but the whole arm shape is different depending on the previous level and direction of the whole arm. Moreover, in each "frame, whether it is an action, position or temporal entity, we do not describe the shape of all body parts, but only of the parts that move/ change position. In Labanotation, it is assumed that the "inactive" parts hold in a "normal/standard" position according to the context or dance style. Respectively, if we want to have the whole picture of the body shape we have to go back to previous frames, or even try to guess the "normal" position according to the context of dance, an aspect which is not taken into account in our model.

Another challenging issue is raised from the fact that, even if we use the simplest words to describe movements, an essential sense of analyzing movement is required to interpret the description into the imaginary movement For example, the normal place for the chest-rib cage area is not middle-forward as one would easily say (thinking of the rib cage as the front surface of chest), but high on place, following the rule of Labanotation that direction is measured from the "free end" of the body s in relation to the "basis" of the joint which produces the movement). Thus a description of a chest movement or position forward middle means a forward down tilt of the rib cage. To overcome this issue, we are in the process of creating a detailed dictionary which would accompany our system explaining in detail each class and property along with pictured symbols of Labanotation and paradigms. In this subsection, we present a "language": a model for the Dance Representation, but this model cannot substitute the process of the analysis which requires many work –hours of experts such as choreologists, and notators.

The work outlined in this section is only the beginning in a longer-term effort to create auniversal dance repository with advanced storage, indexing, search, and analysis capabilities. In the following sections, will be more focused on adding "data" from existing Labanotation scores and experiment on them to implement more usable ways in searching movement instances, sequences, and patterns. This "data migration" will be held under the supervision of dance theorists and practitioners that we have contacted already. Additionally, in the following Chapters we include enhancements and extensions of the dance ontology, based on a continuous discussion with dance practitioners. For this part of the results we have mainly worked with a dancer/dance teacher and an experienced ethno-choreologist, and we plan to get feedback from more practitioners during the future development phases of applications. Next experiments also include the description of more challenging score examples from different dance styles, as scores of a specific dance style may not provide the variety of movement examples need to evaluate and extend the model.

4.3 Dance in the World of Data and Objects. [73]

In this part of our work, we discuss the challenges that we have faced and the solutions we have identified so far in our currently on-going effort to design and develop a Dance Information System for archiving traditional dance, one of the most significant realms of intangible cultural heritage. Our approach is based on Description Logics and aims at representing dance moves in a way that is both machine readable and human understandable to support semantic search and movement analysis. For this purpose, we are inspired by similar efforts on other cultural heritage artifacts and propose to use an ontology on dance moves (DanceOWL) that is based on the Labanotation concepts.

DanceOWL extends the previous version of dance ovement ontology, (MoveOnto), that was described in the previous section. While the main objective is stil to provide an expressive machine understandable schema to arrange formal and common knowledge about dance movement, in DanceOWL we relate the concepts of Movement with concepts that are needed for describing the process of documentation and digital archiving. The main difference and contribution of DanceOWL, is that it deals not only with the problem of Movement Representation, but deals with the issues that are related with the conceptual modeling of Dance Objects and their relationship with Movement Entities.

In other, words, we are examining the concepts and relationships that are needed to describe movement not only from the Labanotation and Laban Movement Analysis perspective, but also from a cultural heritage and Choreological perspective. Thus, Movement Entitites are related to Dance Objects that are manifestations of ICH objectsWe are thus able to represent dance movement as a synthesis of structures and sequences at different levels of conceptual abstraction, which serve the needs of different potential users, e.g., dance analysts, cultural anthropologists. We explain the rationale of this methodology, taking into account the state of the art and comparing it with similar efforts that are also in progress, outlining the similarities and differences in our respective objectives and perspectives. Finally, we describe the status of our effort and discuss the steps we intend to take next as we proceed towards the original goal.

4.3.1 Dance OWL in the “Dance Data” Ecosystem

In addition, videos are still the main carrier of dance digital content. They can be annotated or processed through image recognition to extract information on dance movement. In fact dance annotation tools can be a poweful tool for education as Brooks [36], and others explain.

Many digital files for Labanotation or other scores, and verbal descriptions of the movement are available worldwide in printed or digital formats in different databases or small digital libraries. Although the collaboration of dance creators, archivists and Information and Communication Technology (ICT) experts is young, usually hard in communication and probably immature, it is also of no question that different forms of “dance data” (and metadata) is created every day.

While working in building and enhancing the DanceOWL, there was the need to locate this approach on the map of current “dance data” ecosystem where inputs for storing and processing techniques and possible outputs of the different forms is depicted in Figure 5. Fact is that although there are some standard “input-processing-output” schemas e.g., from Motion Capture to 3D animation, from notation to 3D animation as Wilke et.al. have discussed [205] or from video recording to annotation and abstract visualisation, the different forms in this map are mostly ad-hoc solutions which lack communication with each other.

The DanceOWL approach is working on bridging one of these links: “from Labanotation Scores to the concepts of DanceOWL”, by representing the semantics of these symbols, to make this description of the movement, its characteristics and synchronisation readable and searchable. At this point the user interface is not designed yet, but one can search by quering (using SPARQL) the ontology and experimental knowledge base, by posing questions like
“Select all dance expressions or extracts that are originated from Kastanies village and include a crossed arms hand grasp, or very small light steps” .

4.3.2 Ontology based Data Modeling

Usually in other cases of ICT solutions for Cultural Heritage or Digital Libraries, ontologies, as formal conseptualisation of a specific domain seems to give the answer to the different syntactic and semantic interoperability issues. Ceusters and Smith [47] state that ontology engineering can play a great role in making digital dance knowledge accessible, searchable and meaningful. As they consider videos to be the main form of “dance data”, they propose to have two ontologies: the first describing real world phenomena relevant for the domain of dancing and the second covering how these phenomena are exhibited in videos through image and sounds. This statement enforces the argument to distinguish between the act of dancing, the performance and the recording media, as when annotating a video about a dance we do not describe the dance we describe the video that records the dance. The creator of the file is the creator of the digitized or born digital media, but is not the creator of the dance or the movement.

In addition, the question that is going to be discussed later on is the following:

Can we say that any kind of these “data” is indeed a digital form of the dance itself, or all these are nothing but data related to dance?

If the answer is the latter, and dance does not exist in any physical (or digital) form once the performance of it is over, maybe we should compromise with the idea that in the case human movement the best we can archive are metadata and related objects, and not the dance itself as a digital object.

As described above one of the aimed functionalities of the Knowledge Base is to query similar movement elements, motives or more complicated units within the different scores, but before searching for “similar” things we need to define what these things are. Of course this stands for any conceptual representation, but dance as been intangible has its own peculiarities. We stressed above on the importance of building bridges between one description, representation of dance to another, but this process is highly challenging, as we are not only translating from one language to another e.g., Labanotation to OWL, but in addition the referent is intangible, is movement.

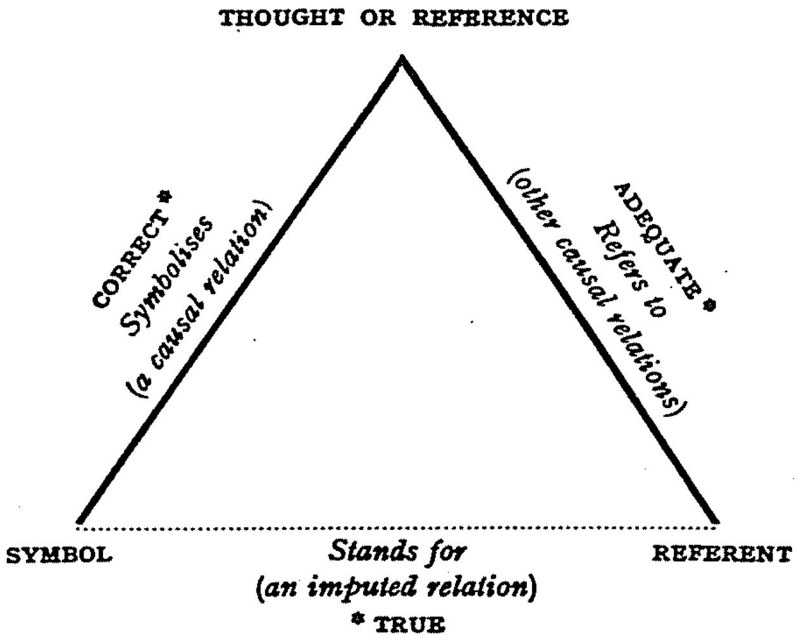


Figure 42: *Triangle of meaning* or *Triangle of reference* which has been introduced by Ogden and Richards (1923) in their work “The meaning of meaning” [164]

At this point, we intruduce a more complex, than the Saussurian Signfied-Signifier dichotomy (that was presented in Section 3.3.4), a triadic relashionship that occurs within any signification process. In any type of writing and symbolism, Labanotation included, the relationship of lingustics symbols and their relation to the object that they represent, can be modeled by the *Triangle of meaning* or *Triangle of reference* which has been introduced by Ogden and Richards (1923) in their work “The meaning of meaning” [164], and shown in Figure 42

The *Triangle of meaning* depicts the relation between the Concept (Reference or Thought), the Object or Referent and the Symbol (Word or Lexeme in Linguistics, or Sign). can be read as follows [3]:

- The matter (Object) evokes the writer’s thought (Concept).

[3]https://en.wikipedia.org/wiki/Triangleofreference

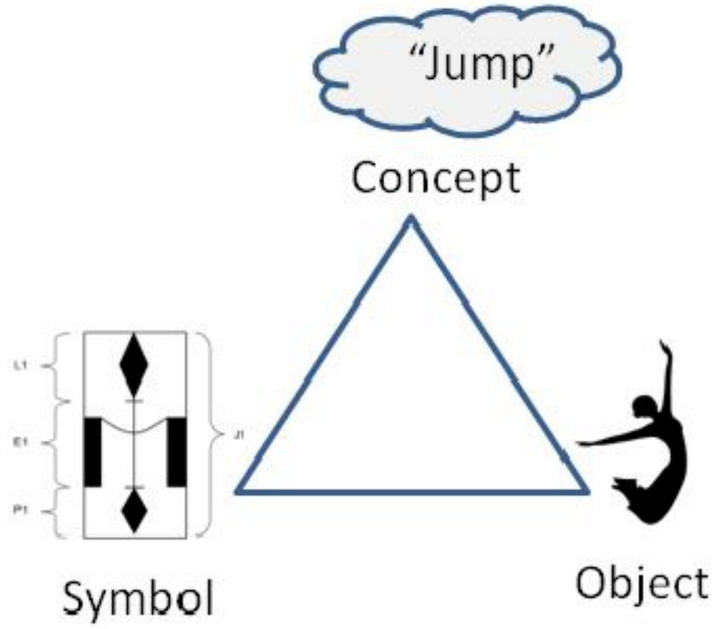


Figure 43: ***An example of applying the Triangle of meaning* or *Triangle of reference* to dance, depicting the relation between the Concept "Jump", its representation using the symbolic language of Labanotation and the referred "object", the action of jumping.**

- The writer refers the matter (Object) to the Symbol
- The Symbol evokes the reader's thought (Concept).
- The reader refers the Symbol back to the matter (Object).

And here comes the tricky point when it comes to dance: the object is not matter nor a real object. The act of dancing and moving is an Event, that after its performance it no longer exists.

In 43 we give an example of application of the *Triangle of Reference* to dance. The relation between an extract of the Labanotation score is shown, in particular we have a Jump with preparation on both feet apart in low level, touch of both feet in low level in the air, and landing in both feet apart in low level, so in this case the reader interprets this as a "Jump" a concept referred to the "object" the act of jumping in this particular way.

Here we need to stress that the concept "Jump" is not the word "Jump" itself (words are symbols as well), but is the Concept, a general class of "jumping moves" one brings in mind when using the word jump or reads related score. If we take into account the different interpretation one can give to concepts, the use of words might be confusing, although unavoidable. For example S. Fdili Alaoui [86] uses the term "jumping" metaphorically to express one specific quality of movement in Emio Greco's dancing vocabulary. Therefore we have same word, but different concept.

This conversation about the eventual nature of dance and movement can be further extended from a philosophical perspective, in this thesis we mainly focus on providing solutions that can contribute to movement computing and can enhance the findability of dance related data. Thus, we address this challenge by basing our model on the Labanotation system and its terminology, writing rules in Description Logics, otherwise a concept (or a Class in a an owl ontology) is not of clear "meaning". Even if we humans can understand the difference from the context, a machine cannot.

For example, in DanceOWL the hierarchy of a Hop is as follows:

```
Movement hasSubClass Action
Action hasSubClass Jump
Jump hasSubClass Hop
```

The definition of concept "Hop", in Description Logics, is the following

$$\begin{aligned} Hop \equiv Jump((&\sqcap \exists hasPreparation.SupportOnLeft \sqcap \exists hasLanding.SupportOnLeft) \\ &\sqcup(\exists hasPreparation.SupportOnRight \sqcap \exists hasLanding.SupportOnRight)) \end{aligned}$$

In DanceOWL, a Jump and its subclasses have specific semantics for the machine, which is also open to integration with other kind of vocabularies, if we of course formally describe their "meaning" in the same language. Coming back, however to the *Triangle of Reference*, no matter how well defined the concept will be, the object itself, i.e., the movement performed in the real world can vary if performed by different people, or even by the same person in different circumstances.

We are aware of the fact that no matter how much detail one can add to a Labanotation score what he gets might be a detailed useful representation, but this is still a script [29, 70] about the choreography. It is not the performance, but only a description or a prescription of it. In addition, no matter how formal or consistent one wants to be in a translation, there is no guarantee that in the semantic triangle of these two languages changing from one symbol to another won't cause a small shift and that the alignment will be perfect, especially now that is about something that is difficult to talk about.

Therefore we quote Z. Brown's comment [37]:
"Labanotation is not a technically rigorous system. A lot of the ideas expressible in notation rely on subtle poetic interpretations. Often the meaning of a piece of notation can only be understood by asking, "what might the author have meant when they wrote this?".

Well, this is true. This is why this translation is very challenging. On the other hand the goal of interpreting Labanotation into XML, RDF, OWL or any other semantic computer language is not to substitute the work of notators, and dance experts [29, 208], is to create tools that enhance and enable the communication between one form of digital dance descriptions and another [37].

Semantics about dance and human movement is not the meaning of the dance or the movement, is simply to add common knowledge on data that otherwise is not searchable or usable. It might be useful for a dance student to search for a specific dance motif, e.g. Right Turn, Fall, then Jump which is available in different dance extracts, although this similarity, on the motif level does not mean that all the above dance extracts are the same or even similar in shape or in qualities. If one wants to go deeper in the similarity of these dance extracts she has to go for the context and the provenance of these dance extracts.

4.3.3 Conceptual Models for Intangible Cultural Heritage

The above is in alignment with the FRBRoo model for performing arts, as well as the thoughts on Dance in the world of data and object. What we are interested about are the digital files from which we can retrieve the information, and they are distinguished in two main categories: Recordings and Scores (a prescription or description)

Having this distinction, it is clear that for dance, as a performative art and part of intangible cultural heritage, there are two types of digital archives from which one can extract dance related information in a way that is done in music again these are

- Recordings (video or other motion capture data techniques)
- Scores (Notations of all kind, descriptions)

4.3.4 Conceptual Modeling for Dance: Existing Schemas for Performing Arts

At this point, we briefly discuss existing Cultural Heritage models, and their possible application in the field of Dance. Although the following models are created for Museum and Libraries, we examine these schemas as a Library shares the objective of our Knowledge Base to help user to find, identify and obtain [37] things.

The *CIDOC-CRM (Conceptual Reference Model)* [97] provides definitions and a formal structure to enhance interoperability between different data and metadata models in cultural heritage documentation.
The *FRBR model (Functional Requirements for Bibliographic Records)* was designed as an entity-relationship model by a study group appointed by the International Federation ofLibrary Associations and Institutions.

The IFLA model distinguishes four level of abstraction from ideational content to the physical (or digital) item: The *Work, Expression, Manifestation and Item*. Nevertheless, in the case of dance the realized and embodied "object" is the last thing one can have in hand: it is not an object such as a book or a file, it's an event. Here there is a kind of paradox when we try to apply this model on Dance, stemming of the fact that Manifestation is defined as "The physical embodiment of an Expression of a Work" [146, 178].

If we want to be semantically correct, the embodiment of an Expression of a dance Work is the dancing process itself, the ephemeral phenomenon which happens in a specific time and place incorporated by the performers. The embodiment of an Expression of a Dance

Work is not the prescription, neither the description, or the digital object that is created by the recording of using video, motion capture or other media.

The FRBRoo [64, 177] is a formal ontology intended to capture and represent the underlying semantics of bibliographic information and to facilitate the integration, mediation, and interchange of bibliographic and museum information. FBRoo is the outcome of FRBR/-CIDOC CRM Harmonisation. In 2008 M. Doerr and C.Bekiari [64], presented an FRBRoo for perforiming arts.

FRBRoo declares therefore three classes:

- F20 Performance Work
- F25 Performance Plan
- F31 Performance

They are interrelated as follows:

- F20 Performance Work R12 is realized in (realizes) F25 Performance Plan
- F31 Performance R25 performed (was performed in) F25 Performance Plan.

In the case of theater as a form of performing art there is also the need to differentiate between Performance-Work e.g., Shakespeare's Hamlet, the Production and the Individual Performance, as C. Doty [68] states.

Nevertheless, in the case of theater, especially if we talk about a famous classic written play, the script exists before any Performance Production or any Individual Performance in physical or digital forms (book, pdf, etc.). This is not the case with dance, which although it might have been documented using notation, usually one does not expect to have the movement of the Dance Work "written". Moreover, in most of the cases the Labanotation or other scores are created after or during the performance for documentation and archiving purposes. So score is rather a description not a prescription, which means that a score is more like a recording (F21 Recording Work) rather than a script (F25 Performance Plan) [64].

Of course, any score which has been created as a F21 Recording Score can also serve later on as a F25 Performance Plan in performance reproduction from the score. In addition, the above discussion is meaningful in the case we are talking about Dance Work(s) e.g., Swan Lake where dance is considered a form of Performing Art, a subcategory of Performance Work.

Nevertheless, another question is if the above vocabulary is appropriate to describe dance as a social phenomenon or a physical form of entertainment, therefore use these vocabularies to describe folklore, traditional or social and popular forms of dance. In common language usually we use simply the word "dances" to describe the different types of dance

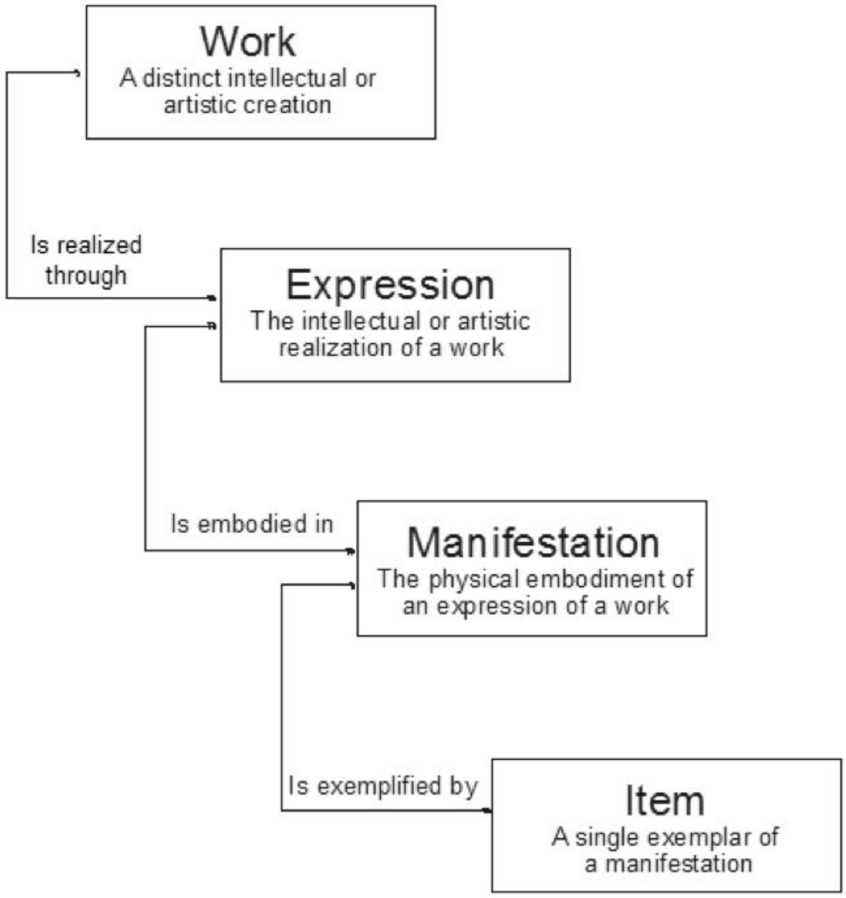


Figure 44: FRBRoo conceptual model [64]

which have specific name e.g., jig, or mambo and specific "steps and variations", referring to specific Dance Types, or Dance Genres. Later on we will discuss the relation between the notion of "dances" with Dance Type and Dance Record, as represented in DanceOWL.

4.3.5 DanceOWL: The Dance Ontology

In MoveOnto, the concepts of Labanotation about movement are used to translate original Labanotation scores into DanceOWL Scores to make them accessible, searchable and subject to further analysis and complex computational processing. The open world assumption of Description Logics fits perfectly to the domain of dance description, as our aim is not to provide a close template to define what dance is, but to build a core data model about the movement that is open to possible integration for different applications, e.g., video annotation, motion capture indexing or wikis enrichment for educational purposes.

The ontology was engineered using OWL-2 [2], within Protégé 4.1 [3] which supports SHOIQ(D) expressivity, combined with Pellet reasoner which is capable for Sound and Complete Reasoning. SPARQL [4] queries where executed within Eclipse framework [5] for JAVA using JENA API [6]. The current edition of DanceOWL, which is in progress and subject to continuous enhancements, consists of 350concepts and rules, 100 relationships , 720 individuals (experimental data) and 4000 axioms.

The advantages of this approach are the following:

- **Reasoning and expression of complex rules**: As OWL is based on Description Logics, it provides a formal language to express complex inference rules and relationships, enhancing the expressivity of the knowledge-base. Reasoning capabilities support reuse of entities, and allow the system to infer new knowledge from the stored dance knowledge, e.g., a gesture is a movement, as being a subclass of the first.

- **Extensibility**: By using OWL, the knowledge model which is extensible and easy to be integrated with related knowledge, i.e., origin, history and music.

- **Searchability**: The Knowledge Base can easily searched by SPARQL queries or browsing within Protégé.

- **Movement Hierarchies**: The ontology allows to express movement categorisation , either by 1) Extension, i.e.,
  Step1 and Step2 isa Step Forward, or by
  2) Intention i.e.,
  Step$\equiv$Step $\sqcap$ (($\exists$hasDirection.Forward),
  therefore any Step which satisfies this condition is a StepForward. [7]

- **Temporal Modeling**: In the DanceOWL time is represented in a similar way with Labanotation as it is expressed in measures, and beats. Movements are modeled as intervals and the synchronisation of them is expressed with properties like “hasNext”, “isSimultaneous”, ismetby” based on Allen’s temporal relations of intervals [7].

[2] https://www.w3.org/TR/owl2-overview/
[3] https://protege.stanford.edu
[4] https://www.w3.org/TR/rdf-sparql-query/
[5] https://www.eclipse.org
[6] https://jena.apache.org/
[7] Intension and Extension, in logic, correlative words that indicate the reference of a term or concept: Intension indicates the internal content of a term or concept that constitutes its formal definition; and Extension indicates its range of applicability by naming the particular objects that it denotes. For instance, the intension of “ship” as a substantive is “vehicle for conveyance on water,” whereas its extension embraces such things as cargo ships, passenger ships, battleships, and sailing ships. The distinction between intension and extension is not the same as that between connotation and denotation.-https://www.britannica.com/topic/intension

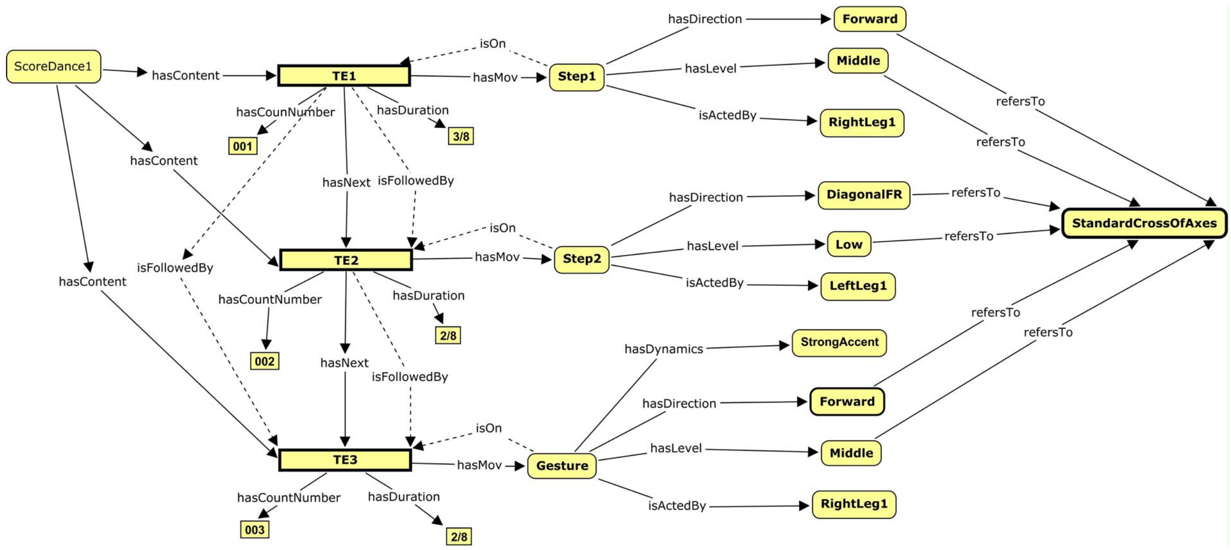


Figure 45: A concept map showing the relationship of Temporal Entities, Movement and the individuals of its SubClass Step their characteristics and the temporal interval relationships between the Temporal Entities to express the syncronisation of movements.

- **Human Body Representation**: Based on the rich vocabulary and number of symbols that Labanotation offers a part of the ontology is dedicated to represent the Human Body and the relations between the various parts and perspectives i.e., joints, surfaces, points, areas.
- **Human Readability**: The terms that are used to describe the movements and their characteristics are simple words, based on the literature of Labanotation system. Although, someone can claim that someone has to be familiar with Laban Movement Analysis to fully comprehend the meaning of these terms, it is far more readable than an ascii file, or any other numeric expressions created by Motion Capture. Moreover, Laban Movement Analysis is an established system used worldwide since the 20's, supporting communications among movement analysts.

4.3.6 Modeling Movement: Linguistic Approaches

As also explained in detail in our previous work [72], the ontology expresses movement by Labanotation characteristics that refer to the following LMA components:

- *Space*, e.g., Level, Direction, Size
- *Time*, e.g., ST01 hasNext ST02, ST01isDuring AGST01hasDuration Quaver
- *Body*, e.g., Right Elbow, Upper Left Leg
- *Dynamics*, e.g., Strong Accent, Tremolo

- *Effort*, e.g., Flick, Float
- *Type*, e.g., Support, Turn, Relationship, Contraction

Nevertheless, when we talk about movement as spatiotemporal entity, or a specific activity, "what's the segment" we refer to?

To this point we will introduce the dance- language analogy as it was presented by A.Kaeppler [125]. This analogy is in the terms that we can use the linguistic morphology analysis tools to study dance structures of a specific area or group of people, i.e., a dance genre's movement vocabulary, as it is shown in Table 3

What it is important in this segmentation technique of movement is that is based on what "makes sense" in a particular dance genre. For example if we consider Ballet a dance genre, one does not expect to find Kineme, i.e., movements of the pelvis in the scores of this genre, as they are not part of its movement vocabulary. This point brings to light the fact that dance segmentation is related to the knowledge of a specific language. For example, a ballet dancer can easily select a "pas de chat" on a Labanotation score and classify the symbols into a larger unit, because the "pas de chat" movement (or Morphokine) makes sense to his dancing language.

To this point, the DanceOWL serves as a dance genre independent "language" to describe the small simple movements and characteristics (at the level of Elements or Kinemes) in a way a score can do. Once the knowledge of the score, is inserted to the ontology, having the sequence and synchronisation of these small movements, this knowledge can be subject to further analysis, by more complex temporal queries and aggregations. Nevertheless this analysis and search for larger movement units requires specific dance genre knowledge. Our future work includes the addition this kind of knowledge, starting with Greek dance expressions from Thrace.

In relation to Kaeppler's linguistic model, we would like to add, that the word Dance is not referring to dance as an art form in general, but to "a dance", a dancing language, genre or type which is danced in a studied area and era. This distinction between the notion of Dance as a general human cultural, physical and artistic phenomenon and dance genres (or "dances" in common language) is analogous to the distinction between Language, the general human capacity for acquiring and using complex systems of communication, and language(s) which is any specific example of such a system.

Ceusters and Smith [47] state that if we want to "represent" dancing, we must have a good insight of what dancing is. In the previous section we described an earlier version of the ontological representation [72] we had developed simple hierarchy under the notion "Dance", as the focus was on Movement rather than Dance Documention, and its totality as a problem. In fact what we were referring to with the word Dance was the Dance Type (IFMC) or the Dance Genre (A. Kaeppler) [125]. In the latest version of DanceOWL, the instances of this Dance Type Class are particular dance "expressions" of a very specific dance type which are scored, e.g., D001D isa (individualOf) GreekFolk as it was performed, recorded and scored at a very specific time and place, by specific people.

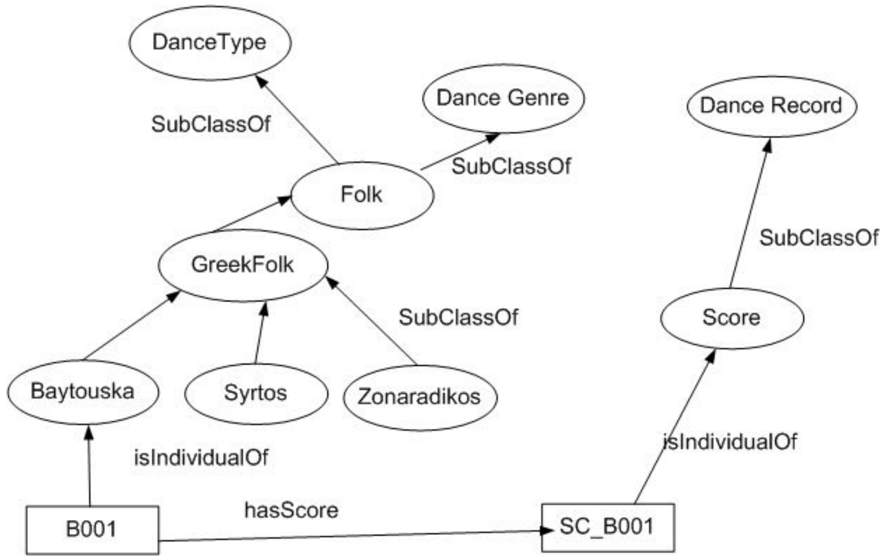


Figure 46: Dance Type and Dance Record

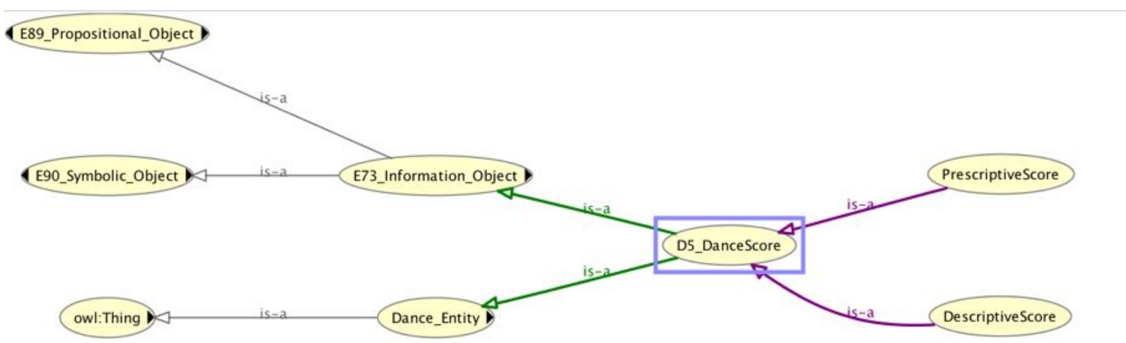


Figure 47: A Dance Score is an Information Object as defined in CIDOC-CRM, and can be either Descriptive, i.e. resulted by the notator observing and notatingor Prescriptive, i.e. resulted by the creator of the choreography to prescribe the sequence.

In the latest version of DanceOWL, Dance Genre or Dance Type is referring to the type of dance e.g., Ballet, Contemporary, Folk, Traditional, Greek Folk, etc. The subclasses of the Greek Folk help us represent a simple hierarchy.

Example:

```
"B001" is an (individualOf) Baytouska
 Baytouska isa (SubClassOf) GreekFolk
 GreekFolk  isa (SubClassOf) Folk
 Folk  isa (SubClassOf) DanceType.
```

In addition

```
 Folk hasOrigin some Region
 B001 hasScore SCB001
 SCB001 is individualOf Score
 Score SubClass of DanceRecord.
```

So in this way:

- we make clear that a scored extract e.g., B001 is not the dance type itself, but only one of many individuals of this dance type, an “expression” of it recorded in a specific place and time,
- we differentiate between the dance expression itself and the score which in this case is a type of Dance Record.

At this stage we are evaluating the ontology and experimenting with scores, from the repository of Thrace Dance as shown in Figure 48 and Figure 49

The interpretation of the scores is added manually according to the specifications –relations to Labanotation. These Labanotation scores are outcomes of anthropological onsite research and have been created on-site, after interviewing the local dancers. They represent different dance expressions of specific dance types and genres of Greek folk, e.g., the “Zonaradikos” dance. It is very important to test with such different expressions in order to later on find the similarities by comparing small amounts of dance reality provided that it is described in the same language (i.e., Labanotation) and by the same team with the same goals (in these case Thrace’s researchers).. The strength of a documentation tool lies on its ability to represent dance knowledge as it is coming from the creators of the movement or the analysts and not to provide a template on what a dance should be.

4.3.7 Conclusion

Since the nature of dance, either as a performing art form, a cultural, social phenomenon, or an entertainment physical activity, is an ephemeral event that exists once it is embodied by the dancers, we can only have tangible items which are related to the dance such

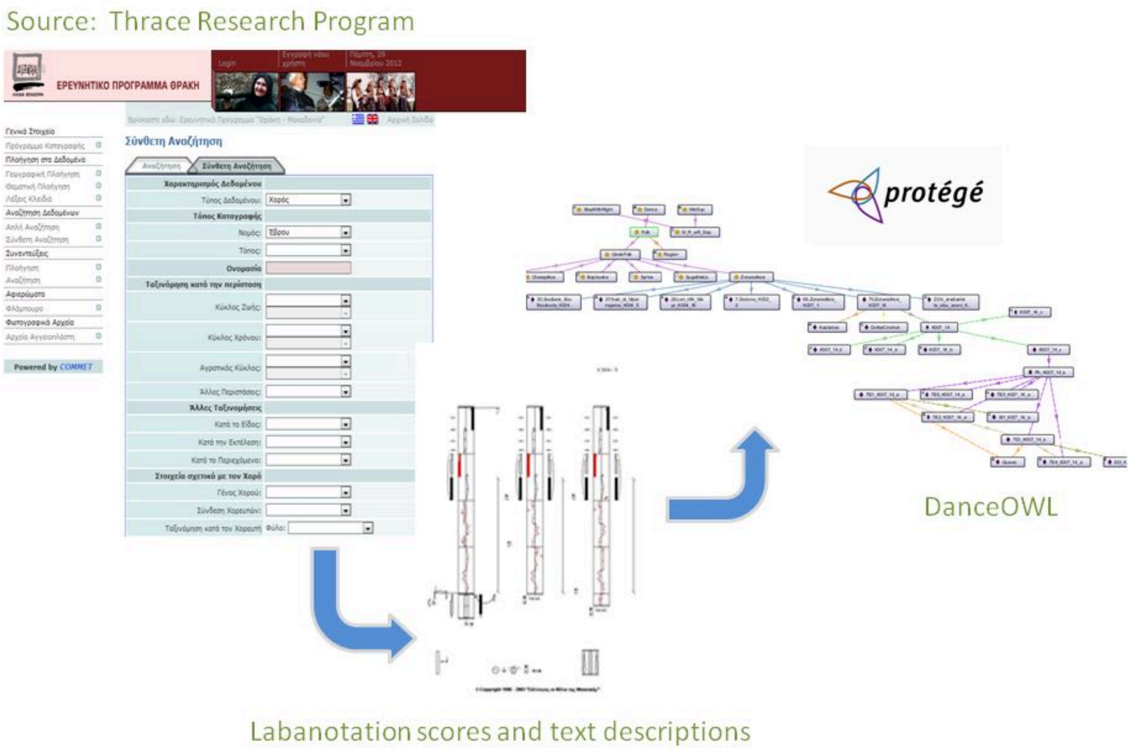


Figure 48: From Labanotation scores to owl

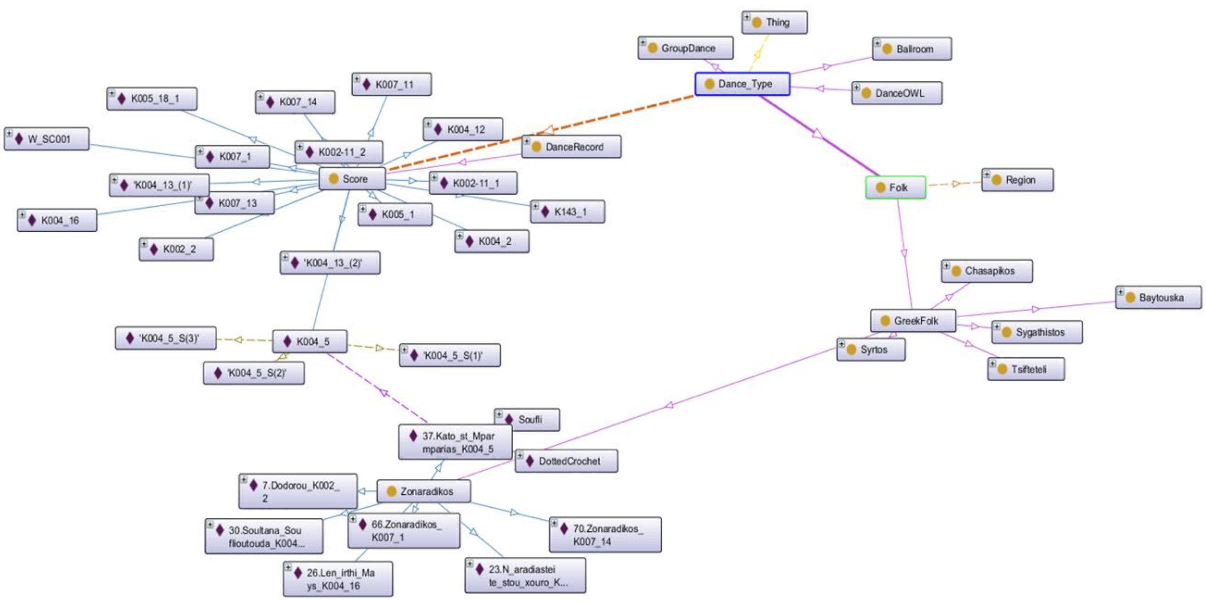


Figure 49: from scores to dance and movement concepts in Protege

as videos, descriptions, printed images, used objects and costumes scores and scripts about the movement in different forms. Nevertheless, “dance data”, including movement descriptions in a variety of forms and granularities are living and growing everyday in the web of things and objects, and recent research assesses the need for data models that are based on formal notation or other scripts, to exploit theoretical and practical dance knowledge. There is high need to organize data and make this knowledge accessible for further computational automated analysis and a basis for building user interfaces and tools for educational purposes such as the work of Brooks [36], research or creative applications.

Having in mind that all notation are partial descriptions and that the different forms of movement descriptions are complementary, we took advantage of the semantic web technologies, to build an extensible data model that can be easily related to other similar models e.g., idiosyncratic vocabularies or history of the dance.

The contribution of this work is making movements of choreographies and dance extracts searchable in different granularities, in a machine understandable way while using terms that have meaning for the user. By developing a core model, based on a formal language such as Labanotation, we are aiming at putting another piece in the puzzle of dance knowledge which is available online in various forms. We envision a future where the dance related knowledge will be interlinked, machine understandable, human accessible and searchable by all users.

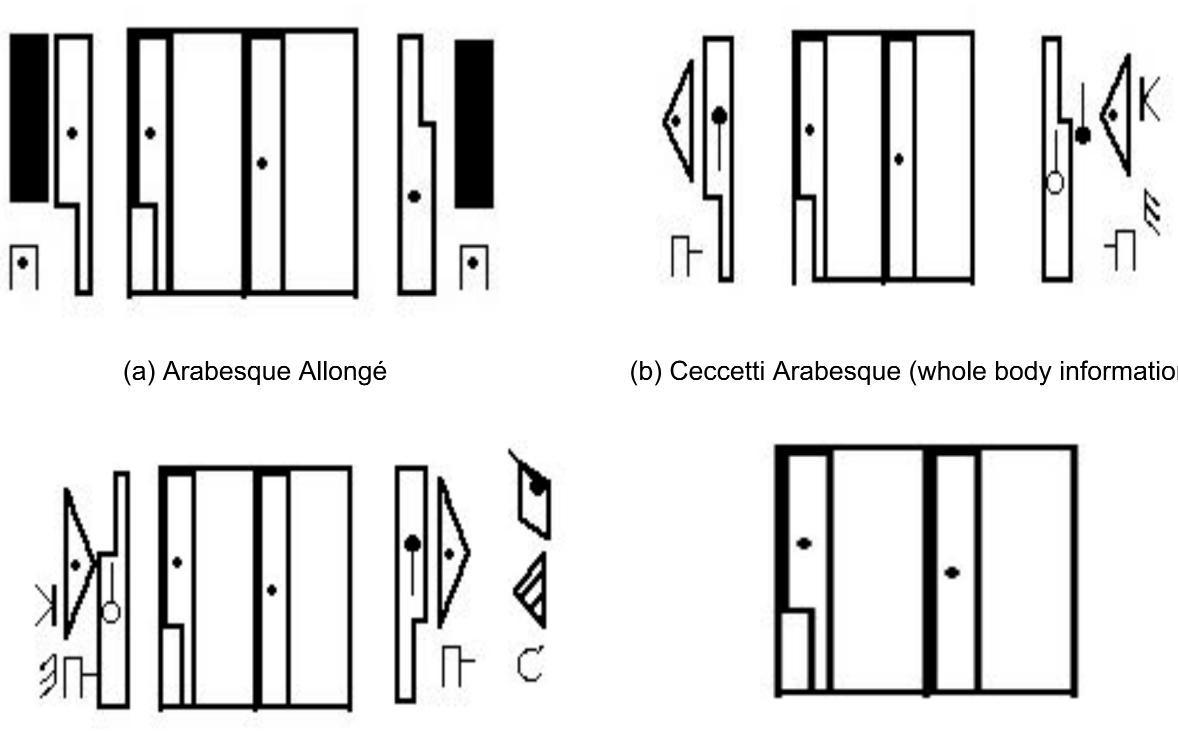
4.4 From Dance Notation to Conceptual Models: a Multilayer approach [74]

In this section, we discuss the key elements of a semantic dance and movement representation model based on rule-based extractions of logical descriptions from existing Labanotation scores [99]. This is part of a larger effort on representing and analyzing dance movement based on choreological approaches and notation systems. The main goal is to develop a Knowledge-Based System that provides functionality

a) to search by movement concepts and characteristics in a meaningful way for dance practitioners, who may not necessarily be specialists in notation or analysis, and

b) to link different manifestations of movement recordings, especially Labanotation scores.

We use examples to highlight the primary and abstract representation model and outline the main challenges in interpreting and segmenting a Labanotation score to transform it in a semi-automated way into a sequence of meaningful recognizable movement concepts. We are not aiming to develop an alternative notation system, but to construct a model and methodology to access existing scores (in digital form) and exploit the underlying information about movement for further computational analysis. We take into account some existing Choreological approaches, which use an analogy between dance structure analysis and morphological language studies, and identify multiple levels of describing dance and movement. Finally, we discuss limitations of our approach as well as potential



(a) Arabesque Allongé

(b) Ceccetti Arabesque (whole body information)

(c) Arabesque Allongé Pose

(d) Generic Right Arabesque (only leg information)

Figure 50: Labanotation Examples of different forms of an Arabesque [152].

uses of the "search by movement" idea and outline some theoretical observations that emerged during this work.

For documenting dance while it is performed, there are as many ways of describing, representing and analyzing movement, as there are researchers according to the anthropologist of dance Royce [181]. It is no question why many current efforts of studying movement, dance and choreography are developed in collaboration with specific choreographers trying to find the emerging patterns of individual creators [32, 95, 201, 114, **?**]. On the other hand, documenting dance is also a digitisation process, where the creation of data is as important as making these data available, accessible, comparable and subject to further analysis and computation [72, 73].

The question we are addressing in this Section is how semantics underlying a notational system, knowledge of Choreological movement analysis, and existing conceptualisation of dance practice, can be related to each other. If a universal (syntactically and semantically) language for dance does not exist, how the different ontologies [47, 72, 55] could be mapped to construct, useful data models, or standards to capture this knowledge under a digital library perspective. Our aim is to examine the Syntactic and Semantic gaps that exist between the various digital manifestations of dance descriptions and provide an abstract categorisation.

4.4.1 A Multilayer Conceptual Approach

In what follows we present our Multilayer Conceptual model which suggests a differentiation not only between the different vocabularies of different dance languages, but between Labanotation (or any other graphical and symbolic notational from the concepts that they represent).

4.4.1.1 Notational vs. Conceptual Levels

In the following paragraph we are organizing these different expressions of dance descriptions from a semantic perspective. We propose a four layers model including the notational or Labanotation symbols (LN) layer and three conceptual levels. The distinction of the levels is according to their relation to formal movement analysis, to common language movement description or to specific movement or dance practices vocabularies. This layering could serve as a useful guide to categorize semantic models for movement. The layers of this model are the following:

- **Labanotation Symbols (LNS) Layer**: This layer includes the various classes of symbols, as they are categorized by Labanotation system for analyzing movement and are implemented in software applications e.g., LabanWriter [18]. Examples of such concepts are DirectionSymbol, Staff, Measure BowSymbol, PinSymbol, TurnSymbol, Body Parts Symbol, Joint Symbol etc.
- **Labanotation Concepts (LNC) Layer**: This layer includes the concepts that correspond to the lowest level of interpreting a symbol based on its location in the score and how it is related to other symbols. E.g., in Labanotation (LN symbol layer) there are Turn symbols, and by interpreting Turn symbols based on their location, the corresponding concepts might be Rotation, Leg Rotation, Turn, Arm Rotation, Twist etc.
- **Generic Movement Concepts (GMC) Layer**: This layer includes movement concepts that are not directly related to Labanotation concepts or Laban Movement Analysis, but are common sense expressions of movement. E.g., Running, Walking, Turning, Jumping, Skimming.
- **Specific Movement Vocabularies (SMV) Layer**: This layer includes specific terms, and notions, movement concepts that come from particular dance languages and constitute the vocabularies and grammar of those dance genres. It could include any of ballet terms (plié, arabesque, pirouette, en dehors, tendu etc), contemporary dance terms (contraction, suspension, fall, drop), or even idiosyncratic vocabularies. They could be Kinemes, Morphokines, Motifs or any recognizable units, named or not, of less known dance languages.

At this point we discuss some of the existing semantic models, presented in related works and examine in which of the layers they belong. LabanXML [157] is a semantic model to represent Labanotation symbol concepts, thus it would be a model of Labanotation Concepts layer. On the other hand MovementXML [107] is a model to represent simple concepts of movement as they are expressed in Labanotation system, thus it would be a model of Labanotation concepts layer. Similar to the above, is the Labanotation based ontology presented in [72], which actually is a model in between the layer of Labanotation concept but also General Movement Concepts layer. Note that in none of the above conceptual models, no formal rules were implemented to directly, map the Labanotation symbols from original scores into instances of the ontology in an automated way. Finally the project TKB [88], was studying higher levels idiosyncratic vocabularies.

Within each of those levels, taxonomies and hierarchies of concepts occur as it is shown in Figure 54.

For example in the notational level (LNS) there are clusters or families of symbols that share some common characteristics e.g., Direction, Bow, Turn (Turn Left, Turn Right, Turn Any side), Pin (Black Pin, Black Pin1-4) and the same stands for each one of those levels. SupportOnLeft The advantages of this separation are the following:

a) Distinct between movements that are different or belong to different sup-domain ontologies but share the same name e.g., contraction in Labanotation Concepts layer is the specific movement of joints indicated by space measure symbols, in Generic Movement Concepts layer it might mean something more generic and in the Specific Movement Vocabularies Layer it might refer to Graham technique contraction. Also what is referred with a single word in a system it might mean something else in another e.g., Jump (an action or a quality of movement? [73]), Arabesque (a ballet or oriental dance term?), Drop (generic term or a Limon technique's term?)

b) Find movements that are close as movement description in any of the three lower levels, but have different names.

c) Once the links between different layers are developed we can "guess" missing information by linking one layer to the other, as described in Example 1.

d) Incrementally build the relations of the nodes from one level to the other and add information and also relate to other forms of description and information, such as pictures, videos, motion caption..

e) The model can be extended, to reflect additional ontologies and notational systems and the relationship between their entities. For example what is described in the paper of de Beul et al. [56] is a transition between a notational layer, Benesh in this case, and a conceptual level based on the systems' description of movement properties. Also the Specific Movement Vocabularies Layer can include endless numbers of vocabularies from more academic syllabi, to particular style and individuals' idiosyncratic vocabularies, or even other movement practices (e.g., martial arts).

Example 1. What is shown in Figure 28, in a glossary of expressing Ballet Syllabus using Labanotation, it is interpreted as "degage devant en l'air" [152], whereas there is no indication on outer rotation of legs, straight legs, or stretched foot (coup-de-pied), because the reader is supposed to know the ballet technique.

On the other hand the motif in Figure 28, can be found in many Balkan round dances to describe a simple raise of the leg where the leg is slightly bent, and relaxed. In both cases the minimum amount of symbols is used to describe the Kineme, and the reader is expected to guess the rest of the details by the context, by knowing the ballet and the folk dance's style and technique respectively.

Using logical expression [72], this description literally says,:

```
SupportOnLeft hasDirection OnPlace AND
SupportOnLeft hasLevel Middle AND
RightLegGesture hasDirection Forward
RightLegGesture hasLevel Low.
```

In this case, knowing the score's particular dance style is essential to correctly interpret the motif in a higher layer of description, and decide if it is a Folk or a ballet Kineme.

It is difficult to say that the aforementioned Kineme in the folk dance is identical with ballet Kineme, just because they share the same notational description as they come from different dance traditions, with completely different technique, style and cultural context. Nevertheless, finding this kind of similarities in some of the layers (notational or conceptual) it might give interesting links and connections for various researches, educational or artistic applications.

Last but not least, if the descriptions in each layer have the required metadata (i.e., where does this description come from, who is the descriptor, etc), more studies can be applied on how we document and communicate movement in dance. For in what we described above, we focused on a specific example, however, one can find others with more detailed descriptions. Therefore, if the mappings in different layers exist, one could compare those descriptions, and understand "why, or where or who describes a movement in one way or another" and how much info should one provide for a satisfying documentation. A related question is when a description is more detailed than another does it mean that in the first case additional details were required for the specific dance style, or it was simply the notator's decision?

4.4.1.2 Example- Moving from one layer to the other

Imagine that you have a large number of digital Labanotation scores and you need to search for particular scores that include specific symbols that symbolize a required movement with specific characteristics, e.g., "give the scores that particular hook indicating the point of the foot touching the floor".

Moreover, decode the symbols into something that gives an insight of what this symbol is about, and ask questions such as "bring me all the Labanotation scores in a database that include something which is similar to an arabesque (ballet)". We propose a methodology

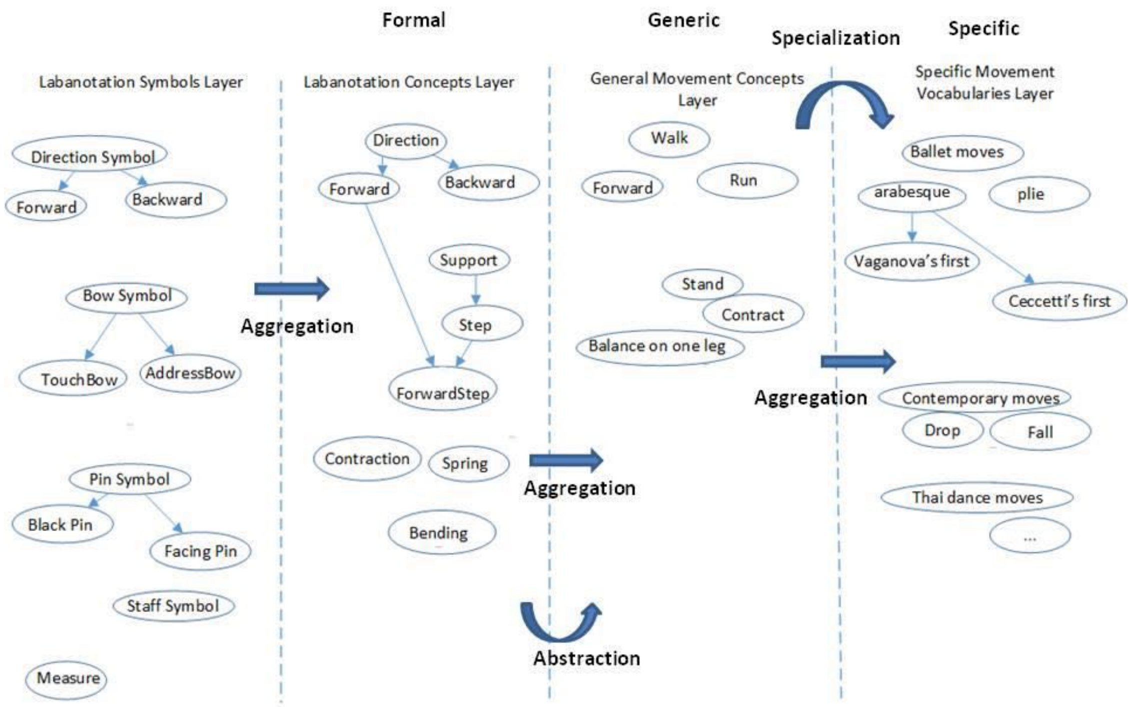


Figure 51: Moving from one layer to another [75]

to apply rules directly on the Labanotation scores and extract basic knowledge from a LabanWriter file.

Example 2. Let's say that we have Labanotation scores that include any of the motifs in Figures 50d, 50a, 50b,50c actually which describe different forms of arabesque [152].

We mentioned previously the fact that the human reader subconsciously "searches" for familiar patterns to read what's in the score as we describe in our previous work [72].

What Figures 50d, 50a, 50b have in common is the motif in Figure 50c.

Motifs in the three first figures are all different forms of "an arabesque", while in Figure 50c , is what a reader would simply describe as a "generic arabesque" without going into details. If we describe the motif in Figure 50c , using a logical description (Labanotation Concepts level) we will have the following:

```
SupportOnRight  hasDirection  OnPlace
SupportOnRight  hasLevel  Middle
LeftLegGesture  hasDirection  Backwards
LeftLegGesture  hasLevel   Middle
```

In a more Generic Movement Concepts (GMC) Layer we would describe this with terms such as Standing on one foot, Standing on one leg, Balance on one leg, Leg is behind body, while in the Specific Movement Concepts (SMV) Layer we simply call this an arabesque (ballet). The following definition can be found for an arabesque. [8]: *"In dance (particularly ballet), arabesque is a body position in which a dancer stands on one leg while the other (the working leg) is extended behind the body, with both legs held straight. The working leg may touch the floor in tendu back (called arabesque par terre) or can be elevated. Common elevation angles are 45° (also called à demi hauteur) and 90 (à la hauteur)."*

So if we need to locate "an arabesque", we need to take the following steps:

- Define what it is in common language: "body position in which a dancer stands on one leg while the other (the working leg) is extended behind the body".
- Express the above notational description in a formal language, in way similar to the aforementioned in the Labanotation Concepts layer.
- Map the concepts of the formal language with the symbols of the score through rules, i.e., map the symbols with each of the conceptual levels.
- By this process we are aiming at artificially reproducing the process of the reader who knows what "an arabesque is" through an abstract definition which gives him the ability to locate the pattern in Figure 50c, in all of those in 50d, 50a, 50bIn addition to the above we can make the Labanotation Concept description richer in order to include the symmetric definition (an arabesque is still an arabesque whether it is on right or leg foot), different levels (arabesque in relevé or in plié) to indicate variations of the same Kineme, and also relate the formal definition of "what could be an arabesque" with generic and ballet specific concepts, e.g., "working leg".

4.5 Modeling abstractions for dance digital libraries.

The description of the human body and its movement is fundamental and a critical part of the content of a Dance Digital Library. It must be captured in an organized way, both for allowing user interaction (browse, search) and computational analysis (similarity comparison) of dances, as well as, for exploring meaningful ways to present content to users. In this section, we present a comprehensive modeling abstraction for such digital libraries, which consists of a multi-layered model that covers different levels for describing dance movement. We address the semantic challenge of organizing knowledge of dance by starting a dance piece or work, going to the characterisation of its structural movement components and their related concepts and standard detailed movement description and notation i.e., Labanotation. In addition, we take into account the existing Choreological research, as well as, related work in other domains, such as music information systems and standards i.e., IEEE 1599 and generic cultural heritage models i.e., FRBRoo. These modeling abstractions have been devised in the context of a more general on-going e ort

[8] $https://en.wikipedia.org/wiki/Arabesque_(ballet_position)$

to develop a Dance Digital Library System and will be instrumental in some critical functionality, i.e., searching by movement concepts and characteristics in a meaningful way for a wide range of users, and linking different manifestations of movement recordings, descriptions, prescriptions or representations.

In this section, we examine how the information that is relevant to a collection of dances can be organized and transformed into high quality content so that a wide range of functionality may be offered to interested users, whether they are scholars, dance practitioners or amateurs . As content of such a dance digital library, we consider not only the metadata surrounding a dance piece (cultural, socio-anthropological, or simply technical e.g., multimedia formats), but also and primarily the descriptions of the actual dance movement so that they may be searchable at different levels.

4.5.1 Movement as Digital Library Content

In the digital age, dance documentation is still an open issue: there is no single standardized way to describe the moves of a dance that can lead to satisfying and complete descriptions of all dance types as we explain in the previous Chapter [73]. Technology have provided with some tools for recording and analyzing movement, i.e., collecting dance or movement data, however these data can hardly be homogenous or even comparable. Although anthropologists, sociologists, and ethno-choreologists have studied dance structures for many years, there are as many ways of describing, representing and analyzing movement, as there are researchers according to the anthropologit of dance Anya Royce [181]. For dance documentation to be optimized, needs to take into account the type of the dance, the context and usually the objective of the documentation itself. This is due to the intangible character of dance as an art form, as compared to visual arts and literature, for example, but also to the complexity of human movement and its dependence on cultural and historical context.

Nevertheless, the objectives of each effort vary significantly and the methodology of capturing and presenting movement varies accordingly. We summarize the means of dance documentations in earlier work as follows:

a) Video recording

b) Motion capture systems

c) Notation systems,

d) Narrative descriptions, and

e) Idiosyncratic scores. Video recording is most widely used across practitioners: it is the cheapest way to capture a choreography in terms of cost and infrastructures, and the easiest in terms of technical knowledge requirements.

Video is the mainstream and most standard way to memorize a dance performance within a dance school or studio or for archiving performances of theaters and dance companies. Motion Capture systems have clearly the advantages of capturing 3D movement in very high quality, and collect data that can be further processed and mainly create 3D animations. In both these cases, “capturing” of the movement is audiovisual (video, 3D animation) or physical (xyz positions or/and rotations).

On the other hand, notation systems, narrative descriptions, as well as idiosyncratic scores are in one way or other conceptual models. They are languages (formal or less formal) to describe the way dance practitioners, dancers, choreographers, choreologists or specific cultures think on movement. Notation systems can be any of the widely known and applied notations for dance, such as Labanotation or Kinetography Laban, Benesh, Eshkol-Wachman.

Narrative descriptions can be based on formal movement analysis systems, such as Laban Movement Analysis, Bartenieff, Conte, or on physical language and common sense concepts of movement. Finally, they can include terms of specific dance vocabularies or a combination of the above.

All of these languages give names to specific **Movement Entities** and define their subject relations. One of the questions we deal with in section, is how to exploit those languages of describing movement to create a framework of organizing the various and supplementary manifestations of dance representations to create more complete documentations. Video annotation, or indexing motion captured data using such languages, notational or less formal, are only two examples of potential applications. In addition, as in any process of digital documentation, making data available, accessible, comparable, and subject to further analysis and computation is as important as the documentation itself [72, **?**]].

4.5.2 Conceptual Modeling for Findability

Apparently dance and human movement documentation lacks universal models, while in parallel using strict, one-to-fit-all standards for representing an expressive, intangible human social and creative activity is rather impossible. These contradictive objectives actually emerge a challenging modeling issue. Another issue we are addressing in this section is how semantics underlying a notational system, knowledge of Choreological movement analysis, and existing conceptualisation of dance practice, can be related to each other.

If a universal (syntactically and semantically) language for dance does not exist, how the different ontologies, emerging in dance knowledge transmition or implemented in information systems [47, 72, 55] could be mapped to construct, useful data models, or standards to capture this knowledge under a digital library perspective. In this section we examine the syntactic and semantic gaps that exist between the various digital manifestations of dance descriptions and provide an abstract categorisation.

To what follows we address the connection of dance and movement entities in relation to the questions below:

- How we describe “a dance”, whether this is an expression of a Dance Genre or a part of a choreographic Dance Work)?
- How we structurally analyze “a dance” and decide what its movement entities are? In other words how we segment a dance into its building blocks?
- How we describe the aforementioned Movement Entities”? What is the vocabulary that we use?
- Finally, how the different languages that we use to describe dance apply a conceptual segmentation on movement?

At this point, we stress that our focus is on the structure of movement in the dance and how these structures are represented and transmitted through formal notation, or more individual manners. Of course when analyzing dance, context, history, style and expression of emotions are very important but these aspects fall out of the frame of the work we present in this thesis.

4.5.3 Dance works, Genres and Movement Vocabularies

Taking into account the relation between specific movements and dance styles, but also existing conceptual models such as CIDOC and FRBRoo [65, 64, 97] we define the following notions to describe the Generic information about a dance and its documenting recordings:

- **Dance Type**: an abstract categorisation of various dance traditions and styles e.g., Ballet, Folk, Greek Folk, Bulgarian Folk, European Dances, Modern etc. [72]
- Dance Genre: a specific family or dances, in a dance tradition, usually folk of similar origin, music or movement rhythm.
- **Dance Piece**: a choreographed or traditional piece of dance which has a beginning and end. Usually accompanied by a dance piece, or song and could be anything from a Ballet Variation, a contemporary solo, or a particular variation (expression) of a folk genre. It represents what in common language usually express as “a dance”.
- **Dance Work**: Its has meaning in the case of dance as performance and represents specific work, e.g., Swan Lake, Sleeping Beauty, The Rite Of Spring. A DanceWork is a subclassof F20 Performance Work, as it is was described in the extension of FRBRoo conceptual model for performing arts [64].
- **Specific Movement Vocabulary (SMV)**: a movement description vocabulary that is connected with a specific Dance Type, e.g, the words describing the different Ballet syllabi. This is one of the Structural Conceptual Levels, within the model we present later on.

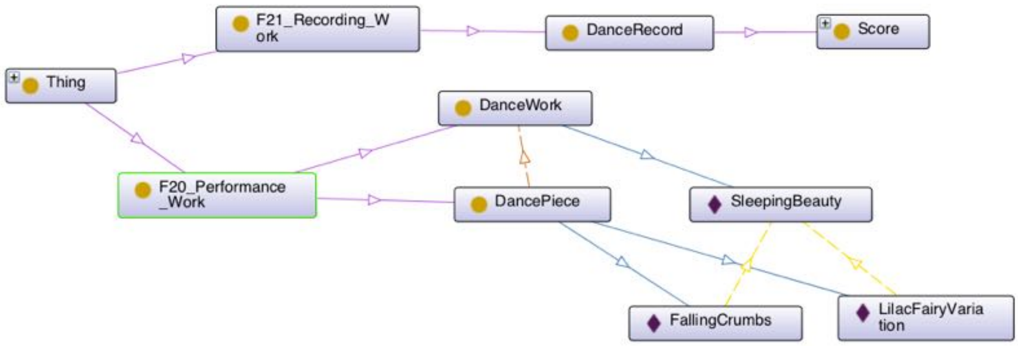


Figure 52: Dance subontology in Protégé

- **Dance Record**: A documentation file of any type and that captures a specific performance of a dance. It is a subclassof F21 RecordingWork, as it is was described in the extension of FRBRoo conceptual model for performing arts [64] .

- **(Dance) Score and Labanotation Score** : It is a subclass of the DanceRecord [73] and indicates a recording of a dance in the form of a score in general, or Labanotation in particular.

  In Figure 52, the concepts and their relationship are shown as an example expressed in OWL-2 and visualized in Protégé. DanceWork hasPart one or more DancePiece (s), which can be of the same or different DanceType (e.g., character dance styles within classical ballet works).

Example

```
Ballet isa DanceType
SleepingBeauty isa DanceWork
FallingCrumb isa DancePiece
SleepingBeauty hasType Ballet.
```

4.5.4 Multilayered Models

A Labanotation score is read bottom-up, and this main column, the staff represents the progress of time, as it is shown in Figure 53 where it is aligned with a music score. Let's note that it is not necessary for a score to be accompanied, aligned with music score as what it is represented on the staff measured or not is the rhythm of the movement itself.

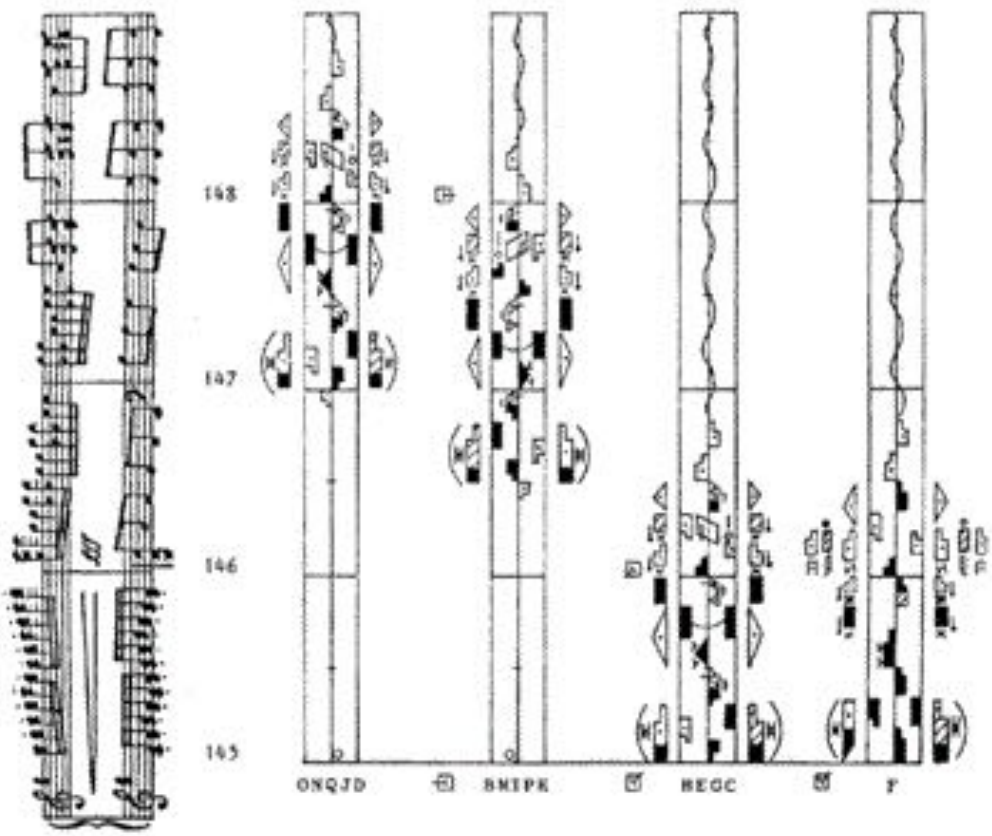


Figure 53: An example of Labanotation score, aligned with the music score

4.5.5 Analogy with Score Following for Music

“Score following in music is the process of automatically listening to a music performance and tracking the position in the score. It is an active area of research and stands at the intersection of artificial intelligence, pattern recognition, signal processing, and musicology”. In our work with Ludovico et al. [143], we have presented an approach for synchronizing different manifestations of a dance piece within the platform of EMIPIU, which is based on the standard of IEEE 1599 format [189]. This synchronisation was implemented by mapping the rhythmic spine, i.e., the axis of the chronological progress in the score of music [189], with the corresponding in the Labanotation score, i.e., the staff. Music objects which exist in both scores (measures, beats etc) were mapped with specific musical events” i.e., points the audio of the video, in a similar way notation scores are synchronized with with the respective audio. We share with this work [143], the aim to link different manifestations of digital objects related to dance and movement through a multilayer-approach focusing on the two layers.

According to the authors, in the case of dance the major open issues, is the representation of Logic and the Structural layers, and are indeed very challenging to represent and standardize.

In Table 2. we compare these layers for music and dance, highlighting the challenging points and clarifying the layers which we further analyze in this section. The IEEE1599 standard has six layers: 1) Generic, 2) Structural, 3) Logic, 4) Notational, 5) Performance, and 6) Audio.

Nevertheless, in the case of dance, additional layers are necessary in between the Notational-Logic and Structural-Logic. In what follows, we do not discuss the three last layers, but we focus on the Logic and Structural part, which we call “Conceptual” layers for describing and segmenting dances in terms of movement in relation to Dance Notation and Labanotation in particular.

Needless to say, that although there is an analogy between music score analysis and synchronisation with audio through the logic and structure of symbols, there are some major differences.

Powerful notation systems exist (Labanotation, Benesh, Eshkol-Wachman), however, there is no comparison with “physical” written language, nor music notation for two reasons. a) Dance notation systems are very young in comparison to music notation. What makes a language, including a notational one, powerful is its everyday usage and continuous evolution and unfortunately Labanotation (along with other notation systems) is not the standard language of the majority of dance practitioners and movement creators, but mainly a language of scholars. b) The creator of dance (choreographer, performer, or cultural group) does not necessarily express herself trough those notation systems, especially if the movement creators are not traditionally educated in the field of Western dance.

A dance creator or a choreographer will not necessarily use Labanotation or other formal dance notation to compose his piece, as it is the case, usually although again not always, the case with music. Going from the Notational layer to the Logic and Structural of a

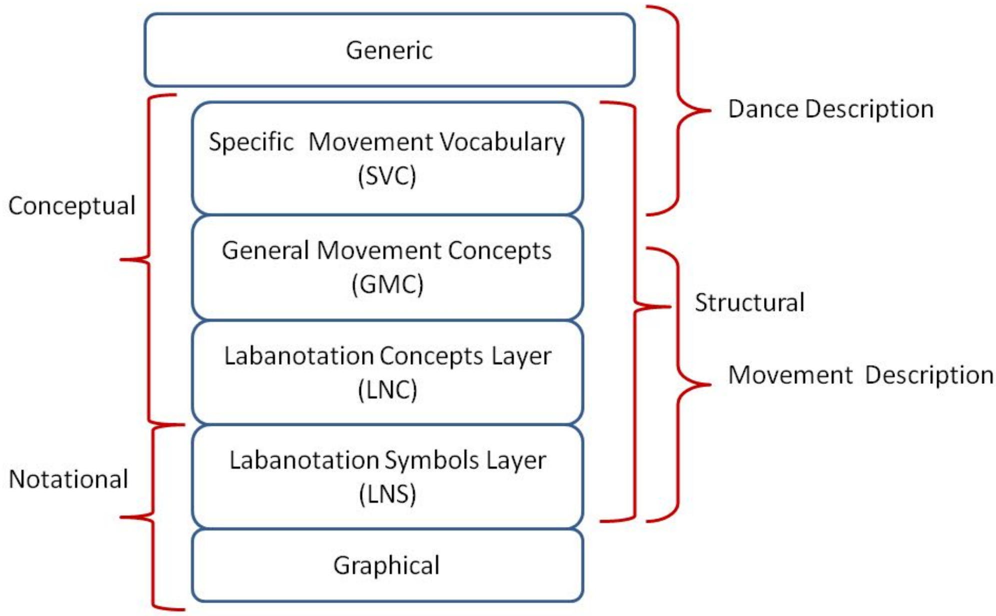


Figure 54: The different layers of languages that can describe or prescribe, i.e., represent a Movement Entitiy

dance piece is not a straightforward process, which can be easily become fully automated. It is hard even for music. "The concept of musical object is left vague, the automated segmentation is very hard, a musical object can be a not or a set of notes" [108]. In analogy with this approach, we deal with the challenge of defining Movement object or Movement Entity in the Structural Layer.

-

4.5.6 Graphical Representation and Organisational Logic of Notation

As described in Table 2, according to IEEE1599 the Notational layer refers to the graphical representation of a score. For dance this layer is about Labanotation score in any graphical format, in the case of dance and the metadata surrounding it (who is the notator, where and when was created). In the aforementioned example of IEEE1599 format "the spine serves as a glue, and in the case of Labanotation this spine is the staff. What in IEEE1599 is described as Logic for Music, in the case of dance is the Logic of the score, it expresses the logical description of the symbols of Labanotation. On the other hand, what is described as Logic in the case of music, for us is a notational conceptual layer, which again consists of two main parts: the spine or the staff in our case, and the Logical Organisation of Symbols (LOS) on paper or screen. In our case, we define this layer as Labanotation Symbols Layer (LNS) as follows:

Labanotation Symbols (LNS) Layer: This layer includes the various classes of symbols,

Table 2: Digital layers of representing Dance and Music

Layers		**Dance**	**Music**
Metadata	What is this sequence (digital object(s)) about?	Generic Dance related metadata, e.g. type of dance piece (Ballet, Folk etc), origin, choreographer part of Dance piece	Generic Music related metadata i.e, catalogue about the piece
Structural conceptual	What are the concepts that describe and consist this sequence?	Identification of Movement objects or Entities and their mutual relationship	Identification of Music Objects and their mutual relationship
Notational logic	How are the symbols representing this sequence organised?	Graphical representation and organisational logic of symbols e.g. Labanotation	Notational (Logic of Symbols)
Notational graphic	How are the symbols visualised	organisational logic of symbols e.g. Labanotation	Notational (Graphic)
Performance	How is the actual performance experienced (visualized, sonified, etc?)	Digital visualisation of the performance e.g. through video, 3D animation, mocap	Performance computer-based descriptions and executions of music according to performance languages (MIDI , MPEG)

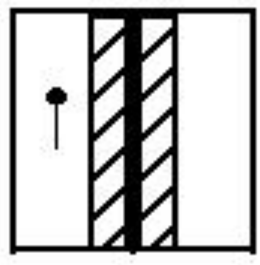


Figure 55: Ballet fifth position in Labanotation [75]

as they are categorized by Labanotation system for analyzing movement and are implemented in software applications e.g., Laban Writer [163]. Examples of such concepts are DirectionSymbol, Staff, Measure BowSymbol, PinSymbol, TurnSymbol, Body Parts Symbol, Joint Symbol etc. In other words, it is the "language", vocabulary and syntax, of Labanotation. The logic is about the architecture of the symbols on the paper and their relationship.

In the notational layer, we take into account not only graphical representations of dance scores (e.g., jpeg, png) but also digital representations that are created with tools such LabanWriter. In case the form of the original score is graphical (e.g., png, jpeg) the only way to define the structural parts, dance movement objects, is to do this manually, as there are no Optical Character Recognition (OCR) applications systems to read Labanotation or any other dance notation formats.

An Example of Notational Layers :from Graphical Notational (Figure 55) to Conceptual Notational

```
DirectionSymbol1 isOn RightCore
DirectionSymbol2 isOn LeftCore
DirectionSymbol1 hasLevel High
DirectionSymbol2 hasLevel High
DirectionSymbol1 hasDirection OnPlace.
DirectionSymbol2 hasDirection OnPlace.
BlackPin1 isLeftOf DirectionSymbol2
```

The critical question here is if we have a Labanotation score how we can search for movement entities that will be interesting for a potential user, to search, visualize, compare, or map with other files The aim of this framework we discuss is not only about synchronizing files but mainly about making the movement as main searchable entitiy in such libraries.

To achieve such results in a methodology similar to score following for music we need to answer the following question: How a pattern of symbols represents a Movement Entity? In Labanotation relative placement of symbols on the 2D of the paper or screen it is important. Some symbols are used as modifiers to others and this modification is context specific (or placement specific literally). Absence of symbols is important and also the size of the symbols and distance between the symbols along the staff is very important as it represents time durations. Once this logic is represented it has to be connected with the "meaning" of those simple patters in terms of Laban Movement Analysis.

They were rather models for the Structural, Conceptual Layer and its sublayers: Labanotation Concepts Layer (LNC) or Generic Movement Concepts (GMC) Layer, which we define as follows:

- **Labanotation Concepts (LNC) Layer**: This layer includes the concepts that correspond to the lowest level of interpreting a symbol based on its location in the score and how it is related to other symbols. E.g., in Labanotation (LN symbol layer) there are Turn symbols, and by interpreting Turn symbols based on their location, the corresponding concepts might be Rotation, Leg Rotation, Turn, Arm Rotation, Twist etc.
- **Generic Movement Concepts (GMC) Layer**: This layer includes movement concepts that are not directly related to Labanotation concepts or Laban Movement Analysis, but are common sense expressions of movement. E.g., Running, Walking, Turning, Jumping, Skimming.

Thus, the example shown in Figure 55, let's name it Movement1 at the LNC level, i.e., in an ontology similar to the one introduced in the previous subsection and published in the correspondant paper [72], it would be represented as follows: Movement1 is a SupportOnBoth, it is a FeetPosition, a ClosedPosition, and also a CrossedFeetPosition. In other words, we characterize Movement1, as an entity, by classifying it into predefined classes from the LNC or GMC layers.

In addition, if we know that this part of the staff is coming from a ballet score, then we can assume that this is a Fifth Position Releve, i.e., to use the Specific Movement Vocabulary concept for Ballet. Note that in none of the above conceptual models, no formal rules were implemented to directly map the Labanotation symbols from original scores into instances of the ontology in an automated way. It comes as no surprise, as forming such rules to do this process full automatically is really challenging. Our work presented in next Chapters is focused on defining such rules expressed as definitions that map the different layers, connecting sets of triples of the LNS with the aforementioned subclasses of LNC and GMC.

4.5.7 Structural –Conceptual: The Challenge of Defining "Movement Entities"

Reading the score and understanding some of the basic concepts that are based on Labanotation do not solve the issue of segmenting a dance into its meaningful building blocks. The second question is how we describe those movement entities? What language do we use? With very few exceptions, dance notation has either a prescriptive or descriptive character [23] which means that the Labanotation score is created before the event of dancing to give instructions about the movement, or afterwards, to describe this event. In both cases, a different person than the performer creates the score. Labanotation, as a language [119], might be a powerful tool, but we cannot say that it represents the written language of dance. Labanotation is the written language for Laban Movement Analysis, thus a symbolic language expressing specific concepts for analyzing and thinking about the movement. In some cases, the knowledge of the notation affects the perception of movement in practice. So the question that emerges here is how the symbols of Labanotation actually relate to dance segments. Is it a one to one analogy? Usually not, as a music object can correspond to a single note or a set of them, a movement entity respectively can correspond to one symbol or a whole pattern of symbols. On the other hand many unconventional dance styles (like folk) require so much additional notes (or maybe symbols) that the economy of Labanotation diminishes [181].

Labanotation is able to describe every detail of movement such as a finger movements; however, the combination of symbols becomes too complex to understand by local dance communities [51] . Informal use of Labanotation system for adapting to particular dance styles, is another example that proves that the knowledge of the system do not automatically make it usable for any kind of dance tradition, at least not for everyday use from the dance practitioners. Dancers can read a notation score because they see something recognizable [72, 181]. We need to decode the process that we follow to read this information, to formally express it in a computer language and eventually reproduce this kind of artificial intelligence.

The Structural Conceptual Layer is the main part of the description of dance movement. It is the layer where the Movement Objects (in comparison to music object) must be defined.

It is the point where the critical questions 2b, 2c, 2d posed in the introduction need to be answered.

The first question is how we define Movement Entities, the building blocks of a dance. Statements such as “dance (or music) is a universal language”, stand true only from a poetic metaphorical perspective, but are extremely vague if we need to systematically study and organize dance knowledge.

Although “Dance is not a real language” [16], there are many analogies between dance and language, and one of the most significant is the analogy between the morphology of language and dance structures, as introduced in by Kaeppler

“As a system for recording movement, Labanotation can be used in a way comparable to phonetic notation of speech sounds. Just as a linguist working with a living language subjects a phonetic grid to phonemic analysis to obtain an inventory of the basic phonemes in a language, a dance anthropologist can subject an etic movement grid recorded in Labanotation to emic analysis to ascertain which movement have emic relevance and thereby obtain an inventory of basic dance movements comparable to phonemes of a language” [124].

Thus Labanotation alone is not enough to decide what the words of a language are. Under this perspective, the notions of Kineme and Morphokine [124], as dance segments are analogous to phoneme and morpheme in language. Kinemes are actions or positions that have no meaning as units themselves but they constitute the basic building blocks of “a dance”, in a dance tradition. A Morphokine is defined as the smallest kinetic unit that has meaning, where meaning here does not reflect any pictorial or narrative meaning, but it is used to indicate movements that are recognized as units from the people practicing a specific dance tradition.

The third level of dance structure is the motif level. A motif is a frequently occurring combination of Morphokines that forms a short entity by itself. Kaeppler proposed one approach of “segmenting” and analyzing movement within a specific cultural context, but is not the only one who proposed movement building blocks: IFMC (International Folk Music Council) [125] proposes another hierarchy of segmentation, a choreologist who analyses choreographic work of a particular choreographer [210] might use another one, while DanceOWL [73] proposes another one.

Nevertheless, some analogies in some of the levels exist, as shown in Table 3. Having the aim to present a generic framework, but also being aware of the context-specific character of such segmentation process, we adopt the one we implemented for DanceOWL [73], as was also explained the previous subsection and published in the correspondant paper [72]. From the Structural point of view, we focus on the notion of Movement Entity (or Object) in analogy with the abstract notion of music object for IEEE1599.

Movement Entity: is an individual of an abstract class Movement, which represents anything from an action or a position, an Element or a Cell of movement (IFMC), a Kineme or a Morphokine (Kaeppler). A Movement Entity has a beginning and an end and has relationship with Temporal Entities, which are time intervals with specific duration expressed in beats [72]. Also a Movement Entity has specific Movement Characteristics (Direction, Dynamics, Level, Degrees, etc). As the Movement Entity can be at the same structural level with various others, Movement Entities can have as parts other Movement Entities. Finally Movement Entities can be expressed in any of the three conceptual layers (Labanotation Concepts Layer, Generic Movement Layer, or Specific Movement Layer). Therefore, a Grand Jeté is a Movement Entity that has as parts a preparation, an elevation and a landing phase, one of which is a Movement Entity too. Also note that, in this example, a Specific Movement Vocabulary term is used to describe the Movement Entity, while at another more generic or abstract layer, we would name the same movement entity as a Jump.

Within the Structural level, one question is how to identify the “movement objects” or the movement building blocks. The second one is how to describe those movement objects. Dance includes building blocks (Movement Entities) that, from a Structural point of view, could be expressed in any of the three conceptual layers LNC, GMC, SMV). Example: A pirouette en dehors is a Ballet specific term is a concept of the SMV layer. It describes something that has meaning within this context, within this dance tradition, therefore it is also a Morphokine, from a structural point of view. If we define and analyze the pirouette en dehors, using concepts of the GMC we will say that it is a “a turn on one foot, where the direction of the turn the opposite of the standing leg” while in the LNC we describe this as a Turn on the RightSupport and Turn has Direction CounterClockwise or Turn is on LeftSupport and Turn has Direction Clockwise. Here we also need to say that what it is an entity in one level consists of many entities in other layers.

To summarize the different layers of describing movement (LNC, GMC and SMV) serve to clarify the relation to formal movement analysis, to common language movement description, or to specific movement or dance practices vocabularies. All of these three layers of describing Structures of Movement, as well as the Logic of the Notational (Labanotation Symbols Layer), are conceptual models that reflect a "specific" language –formal or less formal.

They share the following characteristics:

- **Hierachical**: Within each of those levels, taxonomies and hierarchies of concepts occur as it is shown in Figure 54. For example in the notational level (LNS) there are clusters or families of symbols that share some common characteristics e.g., Direction, Bow, Turn (Turn Left, Turn Right, Turn Any side), Pin (Black Pin, Black Pin1-4) and the same stands for each one of those levels.
- **Extensible**: The model can be extended, to reflect additional ontologies and notational systems and the relationship between their entities. For example what is described by de Beul et. al. [56] is a transition between a notational layer, Benesh in this case, and a conceptual level based on the systems' description of movement properties. Also the Specific Movement Vocabularies Layer can include endless numbers of vocabularies from more academic syllabi, to particular style and individuals' idiosyncratic vocabularies, or even other movement practices (e.g., martial arts).

The advantages of this separation are the following:

- Distinct between movements that are different or belong to different sup-domain ontologies but share the same name e.g., contraction in Labanotation Concepts layer is the specific movement of joints indicated by space measure symbols, in Generic Movement Concepts layer it might mean something more generic and in the Specific Movement Vocabularies Layer it might refer to Graham technique contraction. Also what is referred with a single word in a system it might mean something else in another e.g., Jump (an action or a quality of movement? Arabesque (a ballet or oriental dance term?), Drop (generic term or a Limon technique's term?)
- Find movements that are close as movement description in any of the three lower levels, but have different names.
- Once the links between different layers are developed we can "guess" missing information by linking one layer to the other, as described in the following Example.
- Incrementally build the relations of the nodes from one level to the other and add information and also relate to other forms of description and information, such as pictures, videos, and motion caption.

Table 3: Dance Language Analogy: Structural Segments of Dance.

Language	**Dance (Kaeppler)**	**Dance (IFMC)**	**Foley 2008 Based on IFMC 1972**	**Savrami**	**DanceOWL**
Phoneme	Kineme	Element (smallest structural movement)	Element	Element	Movement Entity
Morpheme	Morphokine	Cell (made up of two or three elements)	Cell (made up of two or three elements)	-	Movement Entity
Word	Motif	Motif	Motif	Motif	Movement Entity
Language Clause	Choreme *	-	Minor Phrase	-	-
Sentence	Phrase	Phrase	Phrase	Phrase	Phrase
-	-	-	Step	Segment	-
-	-	-	Repeat	Unit	-
Larger Grammatical Unit	Larger Movement Structures	Macro-Structures	A Work-Choreography	"a dance", a Dance Piece, Dance Work or Expression of a Dance Genre	-
Language Genre	Dance Genre	Dance Type	Dance (Reel, Jig, Hornpipe)	Dance Genre	-

Example. Combining knowledge of the different layers provides a more accurate interpretation of the graphical notation shown in Figure 28 This pattern of symbols, can be interpreted as a Kineme usually found in round folk dances, but also as a "degage devant" in ballet '[152].

Using logical expression [72], this description literally says: SupportOnLeft (hasDirection OnPlace AND hasLevel Middle) AND RightLegGesture (hasDirection Forward AND hasLevel Low.

In this case, knowing the score's particular dance style is essential to correctly interpret the motif in a higher layer of description, and decide if it is a folk or a ballet Kineme. It is difficult to say that the aforementioned Kineme in the folk dance is identical with a Ballet Kineme, just because they share the same notational description as they come from different dance traditions, with completely different technique, style and cultural context. Nevertheless, finding this kind of similarities in some of the layers (notational or conceptual) it might give interesting links and connections for various researches, educational or artistic applications.

In the Dance Digital Archive or example, there is the functionality of searching for similar pictures or parts of dance pictures through image processing, and while the results might not always be absolutely correct from an ontological point of view, they might provide inspirational new insight on what "similarity" in dance is about. Last but not least, if the descriptions in each layer have the required metadata (i.e., where does this description come from, who is the descriptor, etc), more studies can be applied on how we document and communicate movement in dance.

We need to take the following steps:

a) Define what it is in common language: "body position in which a dancer stands on one leg while the other (the working leg) is extended behind the body"

b) Express the above notational description in a formal language, in way similar to the aforementioned in the Labanotation Concepts layer.

c) Map the concepts of the formal language with the symbols of the score through rules, i.e., map the symbols with each of the conceptual levels.

To decide about which movement segments convey meaning, the study and essential knowledge of the particular dance tradition is inevitable. The supplementary relation of the morphological analysis tool to the notation system is also reflected in the glossaries that accompany most studies and serve for the following:

a) Provide the map between a cultural–specific movement segment and the detailed description in terms of movement in a universal language.

b) Provide a useful guide on how to segment a Labanotation score and thus be read easier by applying some simple rules.

c) Connect particular Labanotation description with a cultural context allowing the interpretation of the score in a more consistent manner to the style of this particular dance tradition.

In addition, in literature there is a variety of glossaries and examples for particular dance types (ballet [152, 143], or folk [125] contemporary, etc) expressed in Labanotation scores, which serve to further analyze or explain some of these movements. But most important those movements, are treated as "entities", units of a dance tradition, with their own "meaning" within a particular dance context. In the following paragraph we are attempting to organize these layers of knowledge from a semantic point of view.

4.5.8 Time Representation: States and Transitions

States and Transitions By definition, Movement is always an event [9]. From a semantic point of view, and for the sake of clearly defining the interpetation of symbols into symbols. We differentiate the *Transition* and from the *State*. The *State* is actually a frame of minimal duration; it is not a pause or a position necessarily neither implies Stillness on its own. An motion capture file , independent of its format, is a set of quaternions, a series of points in time and their correspondant xyz position of each joint that is captured. Each quaternion, each frame describes precisely a State, a position that exists in the shortest of time. We define a State as timeless. A State does not describe motion (although it can imply a motion e.g., a State of the body in the ailr is possibly part of a jump, and implies that it is one of the States that maybe cannot last for two long in the contrary of a standing, sitting for every human or even a complex a balanced position for the skilled). This distinction is also important for representing Stillness, which is not identical with a state, Stillness is always a transition, as it requires time in order to prove its existence.

In the motion capture movement, each very small change is represented by different quaternions and this is how movement happens and is recorded. Transition, however, is always an interval. In motion capture Transition is what happens in between two or more sequential frames.

Web Ontology Language -State and Transitions in Labanotation Labanotation [99] provides the vocabulary for describing movement however it does not make a clear differentiation between State and Transition For example, a very simple combination of symbols might describe an Action or a transition of elevating the leg, or a State where the leg is this specific position.

[9] It is worth mentioning that defining "what dance and movement is " can raise many philosophical questions on many levels. For example the discourse about *Being* (entities) vs. *Event*, and Ontology vs. Praxis, are largely discussed by Alain Badiou both in his book Being and event. (2007), as well as the chapter "Dance as a metaphor for thought" in his book Handbook of ineashtetics (2004). Our objective in this thesis is to define Movement Entities and their ontological relationships to enable their digital representation, computability and findability within digital recordings and scores. Therefore although we acknowledge such philosophical questions especially the ones that are raised directly by the digital representation, are important we will not address them in this document

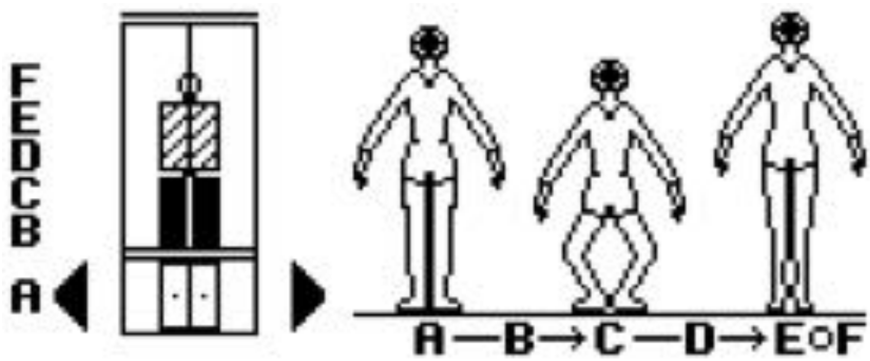


Figure 56: The three symbols correspond to four States (positions) and three Transitions (motions)

In the following, sequence of movement of bending, and extending the legs to the toes of the feet, the Labanotation system uses the sequence by dividing the actions into four ”benchmarks” in space and time:

- Starting Point (A)
- Bended Knees (C)
- Extended Knees (E)
- Hold (F)

So actually, while in the Starting Position there is a one to one analogy between the symbols and the State, the consequent symbols indicate the final next destination implying both the the transition, and the next clear state. The semantics of Labanotation, in order to be translated into a concept it should be translated both as a Transition and a State, indicating the difference of the State: Bended Knees or Standing in Low Level and the Transition or action of ”Bending the knees”. The sequence consists of the following States and Transitions

- State 1: Standing on both feet in middle level
- Transition 1: Bending the needs to low level
- State 2: Standing in low level
- Transition 2: Extending the knees to high level
- State 3: Standing in high level
- Transition 4: Holding the position

Note the difference between the holding transition and the State. The State is a point in time, it has no duration, it is a ”benchmark” in time-space, whereas the ”holding” has duration, it is a transition, a process.

4.5.9 Conclusion

In this section, we presented a framework and a hierarchy of modeling abstractions that are useful in organizing information related to dance, especially descriptions of dance movement. Our objective has been to distinguish between different layers of abstraction of describing movement, starting from a formal, universal, notational layer and moving incrementally towards dance-specific language layers. We have taken advantage of similarities with other fields, such as music and natural language, and have discussed existing related work. A large part of our work has been on how to capture and organize the details of dance movement as required by each dance style or tradition by linking different semantic and digital representations.

While this work is focusing on expressing and implementing mapping rules between the concept hierarchies of the notational and Labanotation layers, subsequently expanding these rules to include links to higher layers as well.

These rules are implemented in the following Chapter 5 Our goal is the develop of a model for accessing dance as a form of a searchable by movement library, offering advanced specialized functionality, such as "search by movement", and exploiting existing knowledge that comes from the research and practice of the dance itself.

4.6 An XML-based Web Interface to Present and Analyze the Music Aspect of Dance.

The use-case investigates the application of the multilayer approach for dance representation to synchronise Labanotation score with the video of classic ballet performance recording. This work explores the representation of music and dance simultaneously, within the framework, of a web-based platform that is available on the Internet [10] and adopts the international standard known as IEEE 1599 to encode music information in XML format. The key issues are two: offering the user an experience of dance performances based on a great variety of recordings (e.g. scores, videos, audio, metadata) and providing the dance student with an educational tool. In the following section we provide a basic overview of the IEEE 1599 standard and how we used our multilayer approach to extend it to dance. The examined use-case is a variation of the Sleeping Beauty.

4.6.1 Synchronising Dance and Music Objects for Enjoyment and Learning

The goal of describing and experiencing music in a comprehensive way, namely taking into account the multifarious aspects it is made of, is a challenging one. Many researches have been done and is currently in progress to achieve such results in the digital field, by using computer-based techniques and formalisms. In this paradigm we explain how an already existing platform for the advanced visualisation of music scores can integrate

[10] http://emipiu.di.unimi.it

other forms of media, and we indicate the correlation between the music and the corresponding performed dance piece. The interface can integrate different forms of materials about the dance, e.g. metadata description about the play, info about choreographer, composer, dancers, music scores, dance notation scores and videos from different productions, demonstrating differences in style and traditions in the production and performance of the same play. In this manner, the tool can designate the music pieces that were written to accompany or are directly connected to dance plays such as suits, ballets, and some traditional dances.

Taking into account the fact that human understanding and learning is connected to receiving and processing different signals e.g., audio, video, haptics putting together different media can help the user deepen the experience of experiencing music in its various representations. In this case, the user can hear the audio and watch the music score, thus is given the chance to correlate the symbolic and logical aspect with the audio rendering (an activity known as *score following*); but the novelty introduced in this use-case is the fact that the user can experience music through seeing dance, which in many cases can be viewed as a visual interpretation or metaphor of the music.

4.6.2 Dance as a Form of Music Visualisation

Music visualisation, long before referring to abstract digital visualisations on screen, is a locution used to describe dance where the movement has equivalents to the timbres, dynamics, and structural shapes of music in addition to its rhythmic base. In the beginning of the 20th century, the contemporary dance pioneering artistic duet Ted Shawn and Ruth St. Denis, introduced the concept of *Music visualisation* as follows:
"In its purest form is the scientific translation into bodily action of the rhythmic, melodic, and harmonic structure of a musical composition, without intention to interpret or reveal any hidden meaning apprehended by the dancer" [185].
Lopukhov makes the distinction between the principles of "dance to accompany music", "dance set to music", and "the integration of dance and music" in choreographing a classic ballet, by discussing the leading, following or equal role one can play to the other respectively [141].Although music and dance are highly related in many people's mind, in Contemporary dance and more recent forms of dance this relation is not to be taken for granted, as it can vary from high correspondence to simple coexistence or complete independence. All kinds of relations to music or even the absence of it are possible and can raise many aesthetical and philosophical discussions. Nevertheless, in this use-case we are examining one classic piece of Ballet repertoire. The use-case that is integrated in the platform shows how combining music, dance scores and video of the performances in various representations can be a useful tool to demonstrate examples of dance-music relationships. In addition, it could take advantage of dance notation scores. In particular, Labanotation [119] is a notation system for recording and analyzing human movement, originating from the work of Rudolf Laban and having been developed and extended by many practitioners, notably Ann Hutchinson Guest. This formalism uses abstract symbols to define the direction and level of the movement, the part of the body doing the

movement, the duration of the movement, and the dynamic quality of the movement. An example is provided in Figure 58. Labanotation is currently supported by the American Dance Notation Bureau (DNB), a non-profit organisation whose mission is to advance the art of dance through the use of that system of notation. In this context, the rhythmic patterns underlying the movement description (beats, meters, phrases) are used to achieve a preliminary synchronisation with the video of the same performance, by synchronizing the music meters and phrases. We will discuss this case later on, including the challenges and ideas for future enhancements.

4.6.3 A Short Overview of the IEEE 1599 Format

IEEE 1599 is a standard internationally recognized internationally and sponsored by the Computer Society Standards Activity Board and designed by the Technical Committee on Computer Generated Music (IEEE CS TC on CGM). IEEE 1599 adopts XML (eXtensible Markup Language) in order to describe a music piece in all its aspects [17]. The innovative contribution of the format is providing a comprehensive description of music and music-related materials within a unique framework. The symbolic score - intended here as a sequence of music symbols - is only one of the many descriptions that can be provided for a piece. For instance, all the graphical and audio instances (scores and performances) available for a given music composition are further descriptions, as well as text elements (e.g. catalogue metadata, lyrics, etc.), still images (e.g. photos, playbills, etc.), and moving images (e.g. video clips, movies with a soundtrack, etc.). Comprehensiveness in music description is realized in IEEE 1599 through a multi-layer environment. The XML format provides a set of rules to create strongly structured documents. IEEE 1599 implements this characteristic by arranging music and music-related contents within six layers:

- *General* - music-related metadata, i.e. catalogue information about the piece;
- *Logic* - the logical description of score in terms of symbols;
- *Structural* - identification of music objects and their mutual relationships;
- *Notational* - graphical representations of the score;
- *Performance* - computer-based descriptions and executions of music according to performance languages, such as MIDI or MPEG4;
- *Audio* - digital or digitized recordings of the piece.

Music events are univocally identified in the encoding, so that they can be described in different layers (e.g. the graphical aspect of a chord and its audio performance), and multiple times within a single layer (e.g. many different music performances of the same event). Consequently, in the multi-layer environment provided by IEEE 1599, one recognizes two categories:

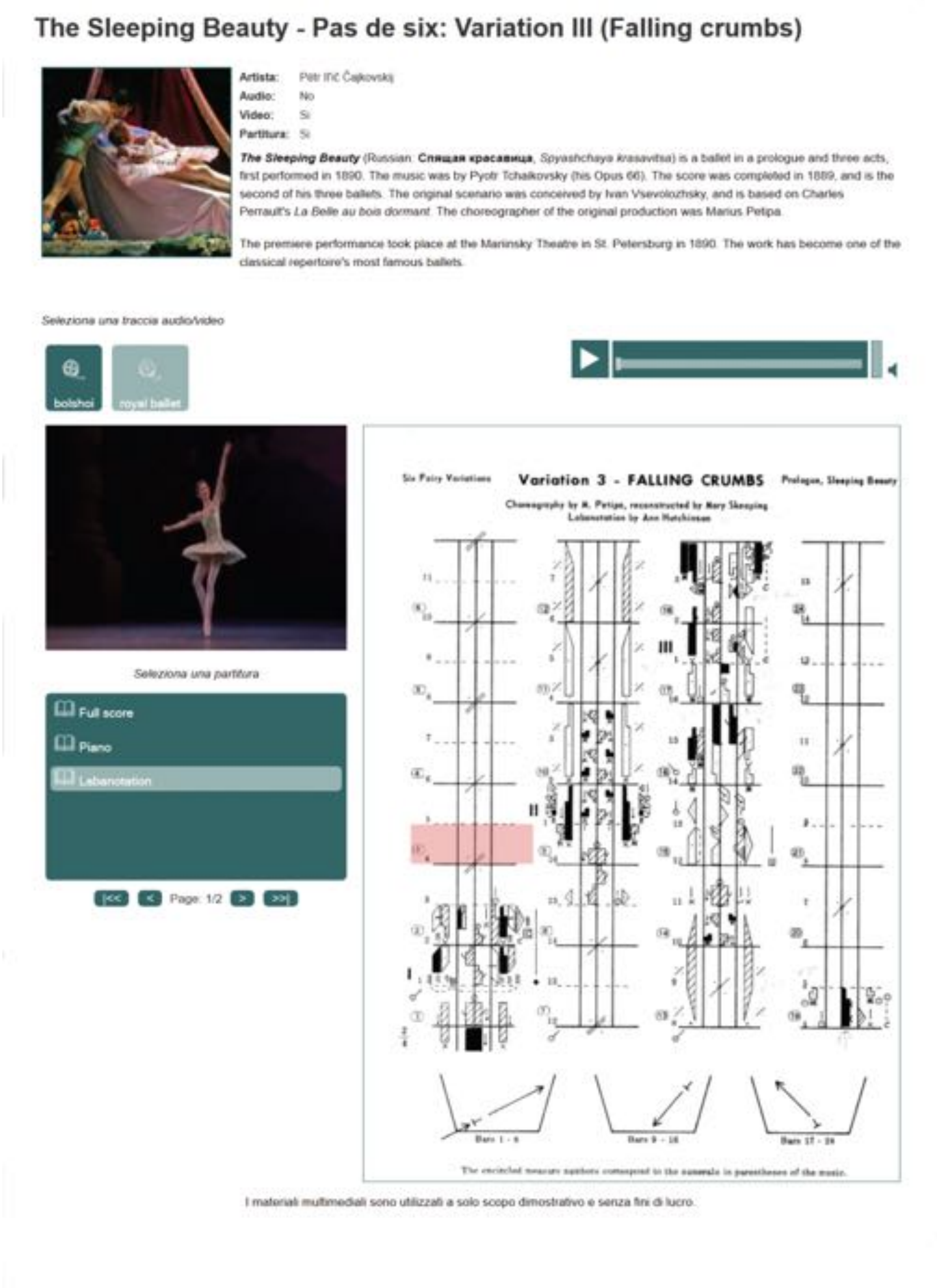


Figure 57: Labanotation score following based on the synchronisation of rhythmic pattern

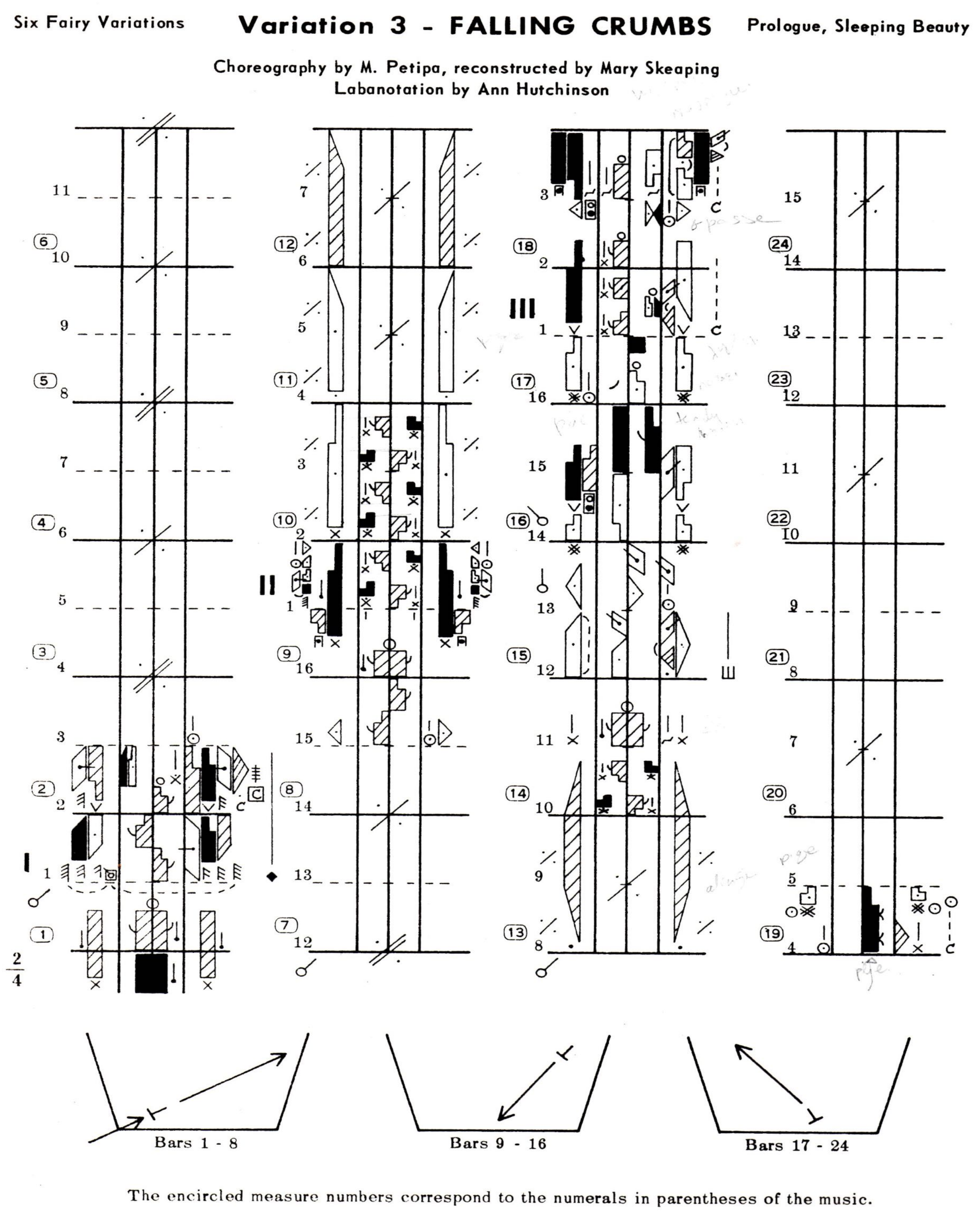


Figure 58: An example of choreography encoded according to Labanotation. Title of dance: "Variation Falling Crumbs" from The Sleeping Beauty, choreographer: Marius Petipa, notator: Ann Hutchinson Guest. Courtesy of the Dance Notation Bureau.

a) *Inter-layer synchronisation*, which takes place among contents described in different layers. Different layers store - by definition - heterogeneous information, to allow the enjoyment of heterogeneous music contents simultaneously, in a synchronized way. Applications involving multi-media and multi-modal fruition, such as score following, karaoke, didactic products, and multimedia presentations, can be realized thanks to this kind of synchronisation;

b) *Intra-layer synchronisation*, which takes place among the contents of a single layer. Each layer contains - by definition - homogeneous information. Thanks to this feature, one can jump from an instance to another instance of the same type in real time, without losing synchronisation.

Coupling the aforementioned kinds of synchronisation, it is possible to design and implement advanced frameworks for music.Further details about the format can be found in the official IEEE documentation [189] or [18]. *EMIPIU* is an acronym standing for *Enhanced Music Interactive Platform for Internet User*. This project aims at applying computer-based technologies to music cultural heritage, in order to provide innovative and advanced ways to enjoy music contents. The technological core is the IEEE 1599 format (see Section 4.6.3), which is described and documented in one of the parts the portal is composed of. However, the most relevant area of the portal is the Music Box, where many examples of music pieces are provided. The purpose is to illustrate the multifarious ways to use the format. As a consequence, music is very heterogeneous as regards genre, style, ensemble, historical period, language, etc. Examples range from Gregorian chant to jazz, from Italian opera to South American tango, and so on. Moreover, the presence and type of multimedia materials is intentionally unequal. In the *Audio* layer some pieces present only audio contents, other pieces are associated to videos referable to live performances, mainstream movies, cartoons, etc. Similarly, the *Notational* layer supports not only traditional scores, but also unconventional graphical representations. This is particularly interesting for a number of cases: contemporary notation [41], Braille scores for visually impaired people [134], etc. Section 4.6.4 will discuss another relevant case study, namely the encoding of dance movements, which is made possible by the features of the *Notational* layer. Finally, the Web portal presents a multilingual interface which accompanies all the stages of the project: design, development, dissemination. This framework has been designed by following the logic of Web 2.0 tools, thus exploiting social software and social networks. Besides, the portal aims at establishing a community to share information and to encourage the discussion on the many issues of the project.

4.6.4 A Case Study from *The Sleeping Beauty*

The purpose of this section is illustrating the advantages offered by IEEE 1599 to the encoding of music for ballets and performance dance. Considering a dance piece from classical repertoire is like adding a “visual” representation of this music, especially if the dance piece is one that its movement rhythm is very close or even identical with the musical. By this manner, the tool of EMIPIU can designate the music pieces that were written to accompany or are directly connected to dance plays (suits, ballets, some traditional dances). The music piece expressly inserted into the *EMIPIU* digital archive is “Pas de six: Variation III” (also known as “Falling crumbs”) from *The Sleeping Beauty* by Pyotr Ilyich Tchaikovsky. The complete example is available in the Music Box section of the *EMIPIU* portal. Tchaikovsky was the first composer to write music specially for ballet (*The Sleeping Beauty*), where with choreographer Marius Petipa he created an example of “dance set to music” principle, although not in a very successful manner, according to Lopukhov, as the symphonic music is more complex, and deep that the choreography itself. Despite this fact, in *The Sleeping Beauty*, Tchaikovsky invariably gave a distinctive musical feature, a musical physiognomy to each of the characters through his musical leitmotifs [141]. The *Fairy Variations* is a characteristic example, as each fairy dances, she bestows a gift on the Princess, and these gifts are physical assets or qualities expressed by the character of each dance [120]. A tool collecting different representations of the material allows the user to see or even question such claims, as he/she can compare the symphonic with the piano score, the choreography, enjoy the qualities of the performance and so on, all synchronized in a unique environment.

Figure 57 shows a screenshot of the Web page containing the variation. It is worth to note that multiple score versions are available, as well as multiple audio/video performances. In accordance with the concepts introduced in Section 4.6.3, these different representations can be enjoyed in a fully synchronized environment. Besides, it is possible to switch homogeneous materials in real time, without making the user perceive a gap. From a technical point of view, the key issue is broadcasting multiple media streams together, so that the browser can minimize the loading time when another material is selected. The problem is not trivial, since the number of media can be high, as well as their quality. However, a strategy to manage them is described in [19], and this technique is the one employed in the *EMIPIU* portal. In the present context, it is particularly relevant to show heterogeneous kinds of score notation, including not only the “traditional” ones - i.e. those conforming to Common Western Notation - but also standard notation for movement. In this case the interface shows three alternative documents: the orchestra full score, a piano reduction and the related Labanotation extracted from [120]. As regards audio and video materials, once more multiple digital objects could be encoded and synchronized. The user could refer to the same performance, showing dance movements from different angles - a useful didactic tool not only for students but also for directors, choreographers, etc.; or he/she could compare different evenings as well as different productions. For the sake of simplicity, the latter case is the one shown in the current example: the user can select either the Bolshoi production or the Royal Ballet one. The Labanotation score shown in the interface is based on the Royal Swedish Ballet version, which is closer choreographically to the Royal Ballet one, but again not identical. As mentioned above, the synchronisation with Labanotation was based on the analysis of the musical aspect of the dance score (meters, beats and phrases), thus the synchronisation with the movement is not always perfect.

Table 4: A comparison between available music and dance descriptions, organized in layers.[143]

	Music	**Dance**
General	Available	Easy to add
Logic	Available	Challenging
Structural	Available	Challenging
Notational	Available	Available
Performance	Available	Available
Audio	Available	Available
Visual	Available (related to audio)	Preliminary

4.6.5 Conclusions and Future Work

This use case we has coupled the comprehensive description of music and music-related aspects offered by the IEEE 1599 format with an example of standard formalism to encode dance movements, namely Labanotation scores. Many aspects strictly connected to music representation, ranging from interfaces for an advanced enjoyment to educational frameworks, have been explored in other papers and scientific publications (for example, see [21] and [22] respectively).

From the dance point of view, the resulting tool can represent *rhythmical aspects* (meters, beats, phrases), *audio* (music which the dance is performed on), *performance* (video recordings of the performed dance), and *notation* (Labanotation score). General metadata (i.e. information about composer, choreographer, etc.) can be easily added, too.

Now the challenging aspect is the structural and logic description of dance. The IEEE 1599 format already supports these elements for music compositions. The future work will be the integration of music and dance descriptions - both structural and logic - within a unique XML document. The current achievements are shown in Table 4.

5. ANNOTATION AND DANCE DATA MANAGEMENT INTERACTIONS

5.1 Movement Annotation Tools

Describing movement and segmenting recognized movement entities that are meaningful in various contexts such as gestural, non-verbal communication, sign language, sports activities, dance, etc, currently remains an important and challenging research area. Two main open issues remain: the first is the automated segmentation of video of movement sequences, based on pattern recognition or other state-of the art methodologies, and the second problem is the development of the semantic models which represent the domain specific kinetic vocabularies.

To what follows, we briefly present previous advancement in the fields. One of worth-mentioning tools in a relevand field is the Anvil interface and the corresponding schema of manual annotation for conversational gestures, which eventually supports the recreation of 2D animation based on time and special descriptions of the gestures on videos [128]. As Bertini et. al explain [26], a typical way to perform video annotation requires to classify video elements (e.g. events and objects) according to some pre-defined ontology of the video content domain, while in the same paper they present pictorially enriched ontologies based both on linguistic and visual concepts and the implementation of solutions for video annotation and retrieval based on these extended ontologies. Ramadoss and Rakummar [174] have presented the system architecture of a manual annotation tool, a semiautomatic authoring tool and a search engine for the choreographers, dancers and students of pop Indian dance to demonstrate how the dance media can be semantically annotated and how this information can be used for the retrieval of dance media objects[173]. In their paper, which they present the semantic models used, it is clarified that the video clips of Indian dance, have been an example of dance videos that allowed the authors to consider the content as narratives. In this case, movements could be easily mapped with particular segments of the song, and the mood described by movement and lyrics [174].

Singh et. al [186], presented the Choreographic Notebook, which is a multimodal annotation tool, supporting the use of text, digital ink, and to be used during the production process of contemporary dance. A similar multimodal annotation tool and approach have been presented by Cabral et. al [40], in the Creation-Tool. The last two examples are applicable in cases where the movement has no narrative or symbolic meaning, and hence the elements of the annotations can be abstract shapes on the video screenshots. Also the purpose of use is different, since it aims mainly at the collaboration and sketching during the choreography process.

5.1.1 Dance and Annotation tools

Annotation tools have been proposed since some decades as tools for manually annotating or transcribing non-verbal communication, with Elan [207] and Anvil [128] being two of the most well-known and used tools in the area. Memo Rekall [1], is an open source video annotation tool as a part of a larger project on the documentation, preservation and analysis of performing arts. Similarly, eClap, was a project focused on creating a platform and managing metadata for performing arts [71], while i-treasures [63] has focused on capturing, managing and automatically analyzing two dance genres (Greek folk and contemporary).

Nixon et. al. [159] have developed an open source movement database, while Alemi et. al. [5], have presented Mova, an interactive analytics platform.

5.1.2 The multipe roles of manual annotations tools for dance

To what follows we describe the different roles of dance annotations, as have been described in our paper [76]:

- **Annotation for enriching performing arts repositories and supporting findability of content.**

  Some efforts are using both manual and automated annotation, focused on particular dance genres in the context of enhancing search in dance archives. Ramadoss et. al. [174] have presented a semi-automated system for retrieving dance performances of pop-Indian dance. Chauldry et. al. [49] have applied classification algorithms on motion captured data aiming at automatically labeling specific segments of Malaisian folk dance sequences, while Ma-Thi et. al. has applied a similar approach for folk Vietnamese dance [145].

- **Annotation as a tool for collaboration and part of the creative process**
  The project Transmedia Knowledge Base for contemporary dance has investigated the process of annotation as part of the creative process using multimodal annotations on the Creation Tool [40], including 2D ”digital ink” annotations, while Ribeiro et. al.[176] have explored the use of 3D annotations. The Choreographic Notebook, by Singh et. al. [186], is another example of a multimodal annotation tool, which was designed to support the collaborative, creation process of contemporary dance choreography. DancePro, is designed to support the creative and compositional processes for accessing dance content and creating extensive metadata [197].

- **Annotation as a way to produce a new dance score**
  Manual annotations in dance can be seen as both a way of generating a score [30], and ”assisting choreographic reflection”[4]. In the description of the Piecemaker2 software, which was created within the Motion Bank Project, the process of annotation has been described as a process of ”scoring video recordings and sharing and this information with others” [59].

- **Annotation as part of the educational process**
  One aspect of the annotation process, which has not yet been extensively explored,

[1] http://www.memorekall.com

is the use of such tools within an educational context. Dos Santos et. al. have proposed an annotation tool for the support of dance teaching [67]. Although, this is not an issue we cover extensively in this work, the process of co-design, using and evaluating the WML tool has bought forth the potential of using the process of annotating, searching and observing other annotations within a learning process. As Jennet states: ”Labels can help remember complex things by giving them a simple name. In addition, things with names can be more easily discussed, shared and related to other things with names.”[121].

In this sense, verbal annotations can become a starting point for not only learning and memorizing specific sequences but also for deepening the knowledge around specific movement aspects, studying differences across a variety of performances and re-thinking the embodiment of these concepts in performance. In the case of WML where these verbal descriptions are connecting different dance genres, there is also the added value of an across dance genres fertilisation.

5.2 BalOnSe: Ballet Ontology for Annotating and Searching Video performances

In this section we present BalOnSe (named after the ballet step balance), an ontology-based web interface that allows the user to annotate classical ballet videos, with a hierarchical domain specific vocabulary and provides an archival system for videos of dance. The interface integrates a hierarchical vocabulary based on classical ballet syllabus terminology (Ballet.owl) implemented as an OWL-2 ontology. BalOnSe supports the search and browsing of the multimedia content using metadata (title, dancer featured, etc.), and also implements the functionality of “searching by movement concepts”, i.e., filtering the videos that are associated with particular required terms of the vocabulary, based on previous submitted annotations. In this section, we present the ballet.owl ontology, and its structure, explaining the conceptual modeling decisions. We highlight the main functionality of the system and finally, we present how the manual ontology guided annotation allows the user to search the content through the vocabularies and also view statistics in the form of tag clouds.

It is no question that dance videos of every kind can be found in large amounts in Internet multimedia and social media channels such as youtube, vimeo, facebook, etc. In parallel, several efforts have been made to organize dance videos as rich multimedia content, such as eClap [71], where the dance videos can be browsed and searched using metadata concerning the performer, the dance company, the title etc. BalOnSe is a web application created with the goal of helping individuals or teams keep better track of the content of a set of videos. Ballet, like any sport, martial art and dance has a very specific vocabulary for its movements and techniques. For the purposes of our project, we used as an example set number of selected videos, of well-known ballet variations, i.e., solo pieces. While a variety of sophisticated technologies exist to analyse and capture whole body movement, the video of dance extracts still remains the most direct medium to communicate, disseminate, and reflect on a dance piece for educational, analytical and research purposes, and also serve as the basis for further automated segmentation and processing. Different groups have explored video annotation interfaces, which can facilitate the communication between different stakeholders, in the past decade, with different degrees of automation and semantic analysis, such as the Choreographer's notebook [186]. In our experiment, we focused on what linguistic terms might be useful for the user considering terminology within the context of the ballet genre, but also through a more generic perspective. We are aiming to facilitate a usable interface that eventually can serve a variety of users and dance amateurs who may be less familiar with the ballet genre.

5.2.1 Dance Representation Models

Though the aforementioned examples of related works share some commonalities, in terms that they all present tools to annotate movement, it is clear that the underlying schemata of the semantic descriptions completely differ due to the different dance contexts and the dance genre they support. Semantic representation models for dance practices is another open research issue, and most of the works are based on the following:

a) Universal systems of analyzing and notating dance such as Laban Movement Analysis (LMA), Laban Efforts, Labanotation, Benesh Notation, Eshkol Wachman, etc. Besides to our work published in [72], Saad, Shatina et. al [56] propose a Benesh based ontology for representing movement.

b) Ad-hoc schemata, which serve the particular content of the application, the dance genre, the purpose of the developed tool and the users, group to whom the interface is targeted. Ontologies as conceptual models can either be 1) upper ontologies, 2) domain ontologies, and 3) application ontologies [40].

In our approach we developed a domain ontology to represent the terminology of ballet syllabus, combined with a Generic Movement Concepts [74]. More details on the ontology is provided in the next section.

5.2.2 Classical Balet Syllabus

Classical ballet is one of the most widespread genres of dance which originates back in the 16th Century in Italy and developed sequentially in France, and Russia in the later centuries to become one of the standard techniques in curricula of most dance schools and academies worldwide. Though in many ballet plays, pantomime gestures exist, ballet in general is a genre of dance with no symbolic meaning of movement and gesture. On the other hand, the segmentation of a dance piece into meaningful entities can be largely based on the clear and well-defined syllabus. It is this aspect of ballet dance we propose to use as an annotation schema for these types of videos. Since, also the education of any ballet dancer relies strongly on the knowledge of syllabus and the corresponding terminology, we believe that such a tool as BalOnSe could support the learning process. The hierarchy of movements is browsable through the application, and provides an easily accessible vocabulary of the syllabus, which associates the terms with examples through the videos, by using the “search by movement functionality”.

Although several schools of technique occur, such as Ceccetti, Vaganova [203], the Royal Academy of Dance, etc., a basic standardized syllabus of movements is common (with some alterations) along with the related terminology. Many terms of the syllabus have become a standard for the communication of dancer, even in other dance genres such as modern dance techniques (Cunningham, Limon), contemporary dance. For example, the five positions of the feet used in ballet, can be considered common knowledge across dancers of almost any dance genre, which is practiced in an institutional arrangement, or independent dance schools. In contrary to other systems of describing, analyzing and notating movement, such as Labanotation [74], the ballet syllabus and terminology consists of a common language among ballet dancers, students and educators, worldwide.

5.2.3 The Ballet.owl Ontology

The BalOnSe application integrates ballet.owl, ontology in OWL-2, which was developed for this purpose. The ontology consists of 151 classes, (512 axioms) which represent a hierarchical taxonomy of ballet syllabus vocabulary. Following the distinction, which was proposed by Elraheb and Ioannidis [74], the top of the taxonomy of the movement terms is distinguished between two main classes:

a) **Generic Movement Concepts**: which refers to the common, everyday language of non-experts about movement including terms such as run, walk, turn, etc. (hasSubClass Generic Actions)

b) **Specific Movement Vocabularies** (hasSubClass Ballet Vocabulary): This refers to any domain specific terminologies coming from particular dance genre practices or techniques. Ballet Vocabulary, which is the terminology for the ballet technique syllabi, is one of the subclasses which have been developed for this application. Nevertheless, there are many more Specific Movement Vocabularies one can develop, e.g., for contemporary dance techniques, other dance genres or martial arts.

In our investigation, we included twelve Generic Actions, which can summarize dance or stage movement activities. The Generic Actions included in the applications are the following in alphabetical order: Arm Gesture, Balance, Bend, Extend, Fall, Jump, Leg Gesture, Position, Run, Stillness, Turn, Walk. These Generic Actions, are used to categorize the different types of movements that exist in ballet syllabi, as shown in Figure 62. For example: Assemble (and all of its subClasses), Brise, Jete, Tour en l’air etc. are subclasses of the Ballet Vocabulary since they are part of the syllabus, but also subclasses of the Generic Action Jump.

The axioms which are expressed about TourEnL’Air which a type of turn is done in the air while jumping are the following:

- TourEnL’Air SubClassOf Jump

- TourEnL'Air SubClassOf Turn
- Jump SubClassOf GenericAction
- Turn SubClassOfGenericAction

To this point note that the application is developed for the annotation of ballet performances, however, the Generic Movement Concepts should cover terms that can describe actions, beyond any techniques, or dance specific knowledge. In the interface, the Generic Actions aim at helping the user choose from a very specific list of movements that are easily understood also by any non-dance expert. For this reason, we limited the Generic Actions only to a very short list, while the Specific Vocabulary Movements includes more than 100 classes. Short definitions are given for the terms, in the form of help comments, and the ontology can be also be browsed. The Generic Actions list, which is used in this version, is a result of a thorough investigation of possible basic movement categories.

One of these candidate categories are the "seven movements" of ballet, as historically have been introduced in "Lettres sur la danse et les ballet" in 1760 and are theories which are valid in ballet practice until now:

a) plièr- to bend,

b) sauter- to jump/leap

c) tourner- to turn

d) etendre- to stretch

e) relever- to rise up

f) elancer- to dart

g) glisser-to glide.

As Guest clarifies: *"Viewing the seven movements of dancing through Laban Movement Analysis, five of the categories identify forms or structures, and two identify effort qualities. The five movements that address forms are basic to human movement and appear in most dance styles. These are plier, etendre, relever, sauter, and tourner. This sliding technique is the impetus for the arc-like leg gestures in the terre a terre, adagio, allegro, and grand allegro movements of ballet. The gliding movement quality manifests in adagio and in the soaring leaps of grand allegro. The darting quality is explicit in allegro and grand allegro movement. Gliding and darting qualities symbolize the dynamic image of ballet. In summary, plier, etendre, relever, sauter, and tourner identify forms and are common to basic human movement and most dance styles; whereas, glisser and elancer are salient effort qualities specific to ballet style"*[100].

This explains why the list of the ballet seven categories of movement, did not seem appropriate to be used as is, since some terms (glide and dart) seem to be genre specific qualities of movement, rather than common activities easily understood by a variety of users. Besides the very high level concepts of Laban Movement Analysis (LMA) for actions, we considered the basic alphabet of the Language of Dance [98] by A.H. Guest. The alphabet includes basic actions, which are derived from LMA and are used in movement practice for both adults and children. The LOD consists of the following actions which are organized also in categories: (initial statements) 1) Action (any action), 2) Stillness, (anatomical possibilities) 3) Flexion, 4) Extension, 5) Rotation, (spatial aspects) 6) Travelling, 7) Direction, (supporting) 8) Support, 9) Spring, (center of gravity) 10) Balance 11) Falling. Although many similar lists of actions can occur in other systems, it is obvious that there is a basic core of actions, which exist in the different high-level lists of actions, in both theories and practices of dance and is this core that we adopted in our ontology.

In the following section, we discuss the actions we propose, commenting commonalities and differences with some of the aforementioned lists of actions.

1. Arm Gesture: The action of moving the arm(s) in any way. Actually, both Arm Gesture and Leg Gesture are under the class Gesture.

2. Leg Gesture: The action of doing any movement with the leg, while the leg is free of weight and not supporting the body. Using the Laban definition for Gesture, we define as such, any movement that occurs without bearing or supporting the weight [99]. Both Leg Gesture and Arm Gesture, are subcategories of Gesture.

3. Turn: The action of (continuously) changing the direction of the body. The action of turning (tourner-to turn) is also in the core of different lists

4. Bend: The action of bending any part of the body, such as bending arms, knees, curving the torso, backbending etc.

5. Extend: The action of extending any part of the body. Bend/Extend, or Flexion/Extension or Ettende/Plier, are two actions in the core of any movement actions.

6. Jump: The action of elevating the whole body from the ground. Also seen as “spring”, is one of the movement actions in the core of all basic lists (sauter-to jump). It is usually analysed in three stages: the preparation (with bending the knees), the elevation, and the landing (again the knees bend). There are five main categories of jumps: 1) From one to the same foot, 2) From one to the other foot, 3) From both to one foot 4) From one foot to both 5) From one foot to the other. This definition is based on the practice an analysis of jumps in dance, as also expressed in Labanotation the main notation system for analyzing and notating movement [119] and is also used in other movement ontologies [72].

7. Balance: The action of balancing in one or more supporting body parts. E.g., Stand one foot, Handstand. These terms could be substituted by the term “Support”, to be more consistent with the Laban/Labanotation terminology; however, we have realized that this word seems to be clearer for the non-expert user.

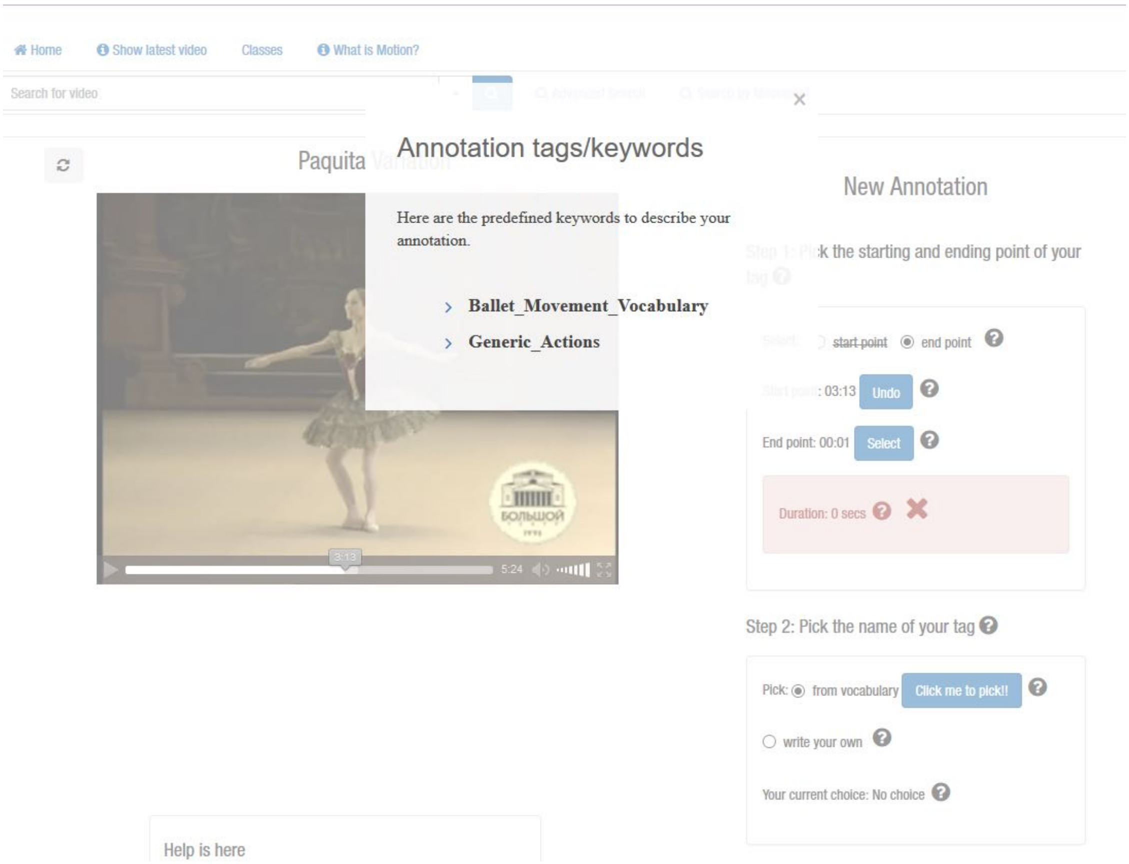


Figure 59: BalOnSe Interface: vocabulary as annotation suggestion hierarchy

8. Fall: The action of dropping-giving one body part or the whole body into gravity. Though this action rarely occurs in classical ballet, we included the term, as it is one of the fundamentals actions, as forming a unit with Balance in LOD [98] and many dance theories and practices of modern and contemporary dance.

9. Walk: The action of changing the support from one foot to the other while progressing in space. Walking can be in any direction.

10. Run: The action of running. Continuous changes of support from one foot to the other, with complete transfer of weight, while between these changes there is a moment where the whole body is off the ground.

11. Position: The action of giving into the whole body or a particular body part a particular shape. The ballet syllabus is reach in positions: the positions of the feet, of the arms of the body in relation to space (croise, efface, en face), etc.

12. Stillness: The action of pausing, remaining still, or holding.

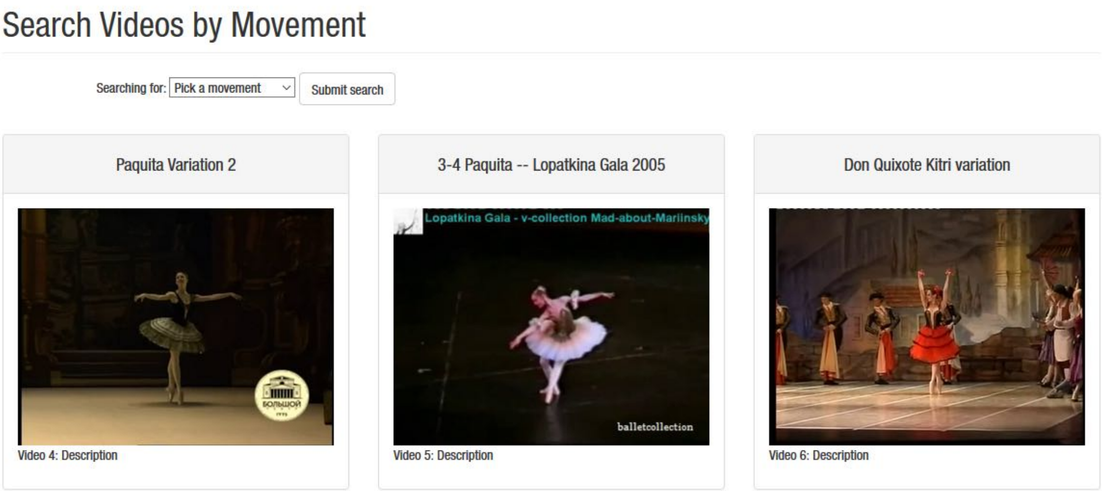


Figure 60: BalOnSe Interface: search videos by movement

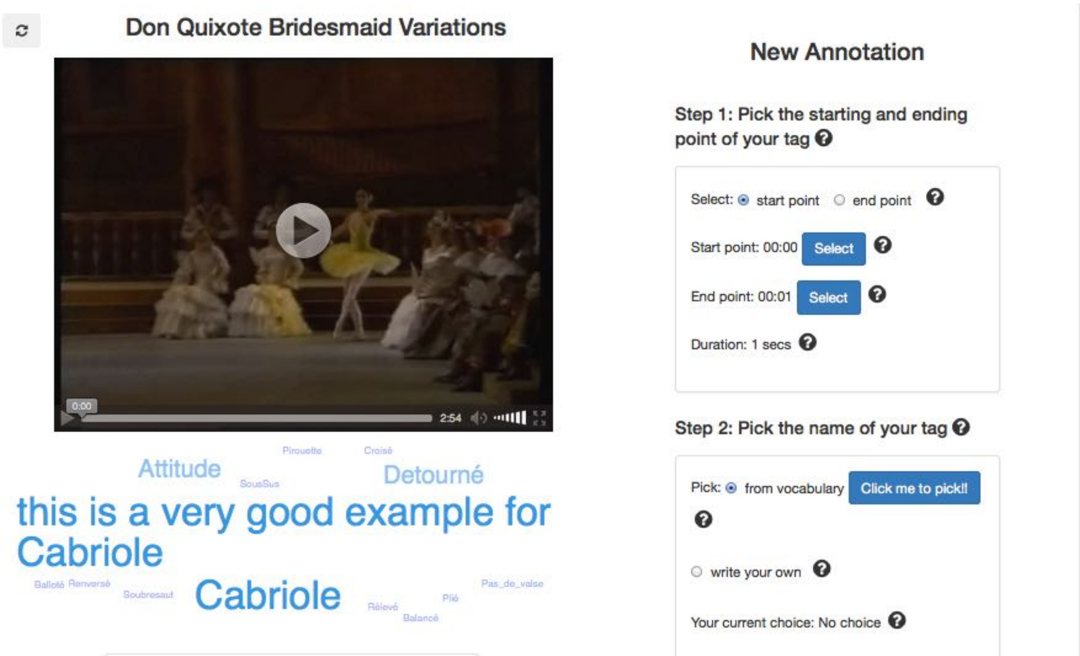


Figure 61: Searching for particular movement

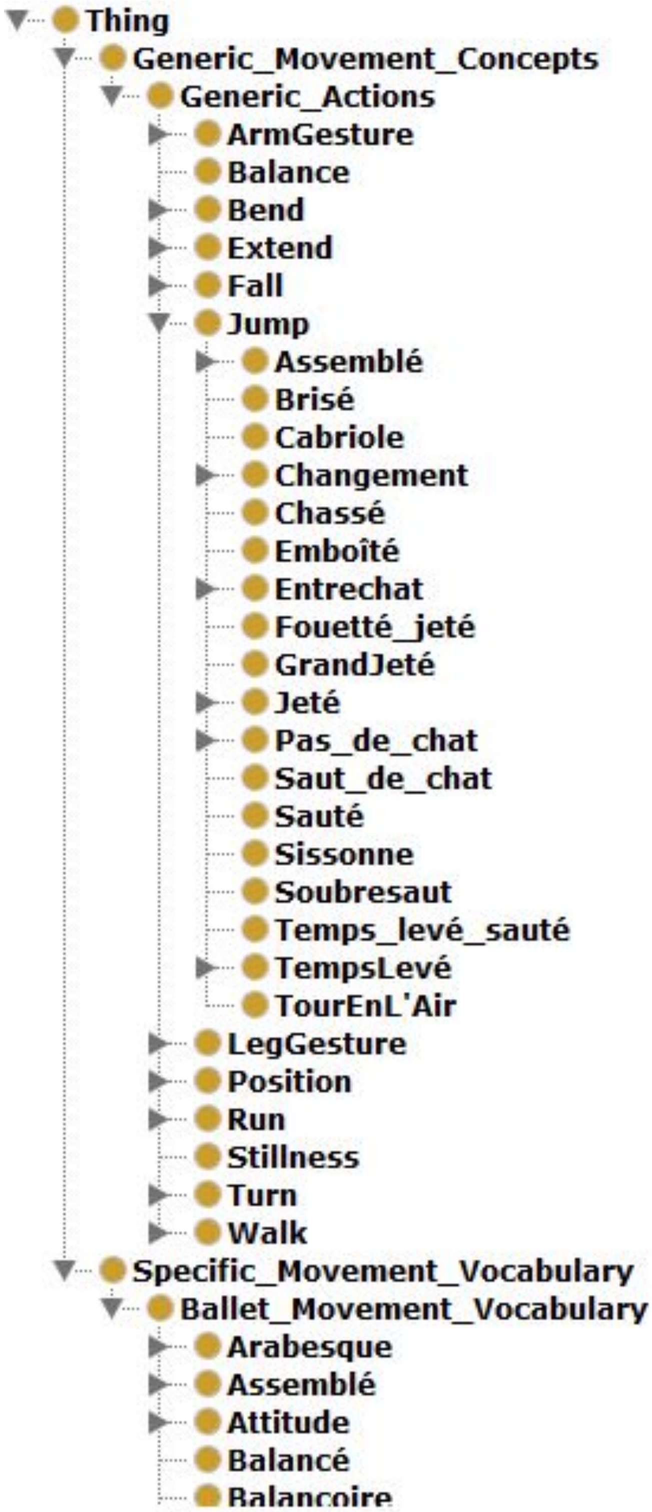


Figure 62: Ballet Ontology expressed in OWL2 in Protégé

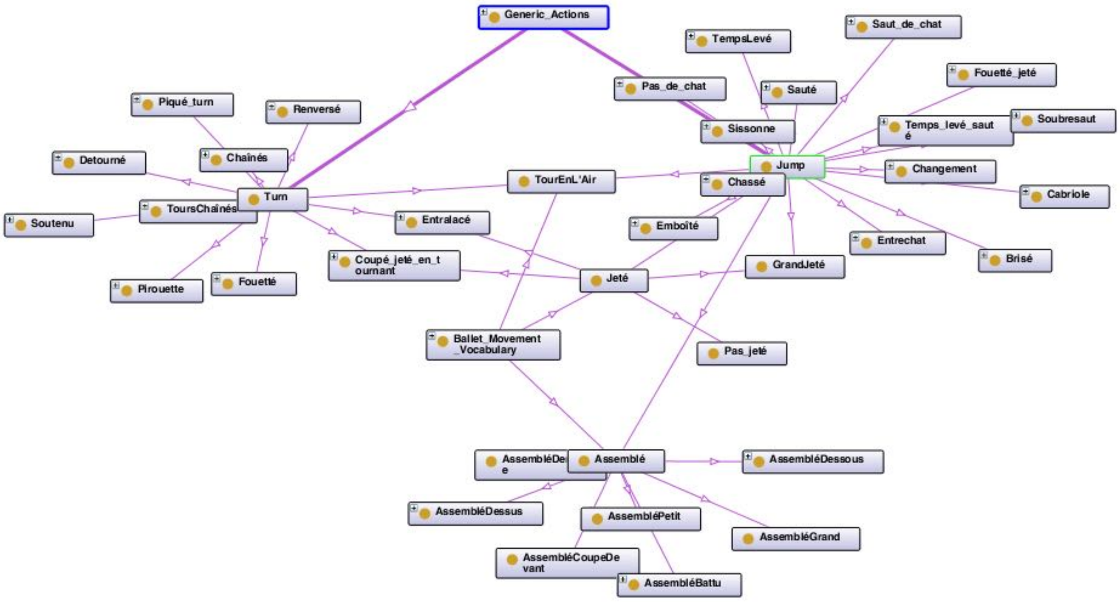


Figure 63: Ballet Ontology -Relations of Ballet and Generic Movements

5.2.4 Annotation and BalOnSe functionality

In this section, we briefly present the functionality of the application and the interface, which we developed taking into account the fundamental principles of usability, and the recent trends in web design. The main characteristic of our system include the following features:

- Simple web-based interface for users with varying degrees of technological expertise.
- An archival system of videos for both the metadata and the annotations
- Context-related video navigational tools with semantic reasoning and search functionality
- Domain specific organized vocabulary When presented with the application the first thing a user is going to observe is the navigation bar. The navigation bar consists of five options: Home, Show latest video, Vocabulary, Advanced Search, Search by Movement:
- The Home page is the first page a user is going to see. Iits purpose is to give the user a general feel of the application and to show him/her the videos.
- The Show latest video page is just a quick way for the user to redirect to the latest video. This option leads to the main annotation page of the videos (Figure 65). In

this screen the vocabulary is actually used a menu, this is why in the design we tried to achieve a good balance between the rich semantic hierarchy of movements vs. what is usable (many choices at one level vs. less choices in more depth levels).

- The Vocabulary page displays the Ontology Tree, also by clicking on the tree nodes after the 0th depth information about the selected class will appear. In this screen the user can browse through the different classes and see definitions and comments about each one of the terms.
- The advanced search page contains all the ways a user can search for a video by using information regarding the video metadata, such as title, featured dancer, etc. More specific about the different attributes a video can contain are given in the Database Structure segment.
- Finally the Search by movement.

In BalOnSe, we have implemented the functionality of “searching by movement”, which allows to search the videos available in the database, by the movements that are performed in the video. For example, the user can search for classical ballet performances that include jumps (using generic terms for describing movement), or “grand jetes”, using the ballet specific vocabulary for describing specific types of dance. The vocabulary which is used in this case is hierarchical, which means that if the user asks for videos containing “jumps”, the interface will show the videos containing any subclasses of the term jumps, including annotation of more genre specific terminology (like grand jetes or any other jumps in ballet syllabus).

5.2.5 System Architecture

The application provides an archival system for the videos while both the metadata of the videos and the annotations of the users are archived in a relational database schema. In this section we briefly present the database schema, which implements a basic entity relationship model with three main entities: (User) Account, Video, and Annotation. In more detail each table has the following attributes: Account holds the data that have to do with a specific user account. The data that the table holds are: The name, which is the username, the account password and finally the email, though this attribute is not currently being used.

Video holds all the data regarding the application’s videos, plus al corresponding metadata, which are following:

- Title of the video
- Genre, (in the current version the only possible value is Ballet, but we consider adding more dance genre videos and vocabularies in future versions of the application)

- Dancer contains all the dancers' names featured in the video.
- Dance-work field might contain info like the Name of the play, the scene that is featured and the act of the play. For example, "Don-Quixote, Kitri variation, Act 1".

Annotation is the table which stores the user's annotations. It has the following attributes:

- The name of the annotation. A record is saved for each tag that is chosen by the user for a specific segment in a video. If the annotation is chosen from the vocabulary then it's a reference to an ontology class name, otherwise it's the custom tag that the user inserted.
- Comment is a user defined characterisation of the annotation the user just created.
- PostTime is the time the user made the annotation OntologyInfo is the ontology URI to the referenced ontology class name or null otherwise. This attribute provides the opportunity to have log history of tags added by the same users in different times.
- StartTime is the time the annotation starts being observed in the video.
- StopTime is the time the annotation stops being observed in the video. StartTime and StopTime are expressed in seconds of the video time. The corresponding tables of the database schema are connected with one another in the following ways:
- The Account table has a 1-N relationship with the Video table and with the Annotation table.
- The Video table has a N-1 relationship with the Account table and a 1-N with the Annotation table.
- The Annotation table has a N-1 relationship with the Account table and with the Video table.

Therefore for each video all the annotations provided by different users are stored, as well as different annotations of the same users provided in different times. The database stores the multiple tags of users, and stores the information of which user have provided these annotations. In the current version of the application, where videos and users are limited, this information is not exploited. Since, however, the objective is to provide a tool for groups of people to keep track of video archives, for a variety of reasons e.g., exchange, research, education, the systems foresee the need of indicating what annotations are provided by whom. In the current version, the annotations of users are stored and each time the video appears, a tag cloud shows all previous annotations.

As shown in Figure 64, the tag cloud under each video, includes both tags that have been selected from the defined ontology, but also free text "this is a very good example for Cabriole". The tag cloud shows all the terms that have been used to annotate the different segments of the video, while the size of the fonts represents the frequency each

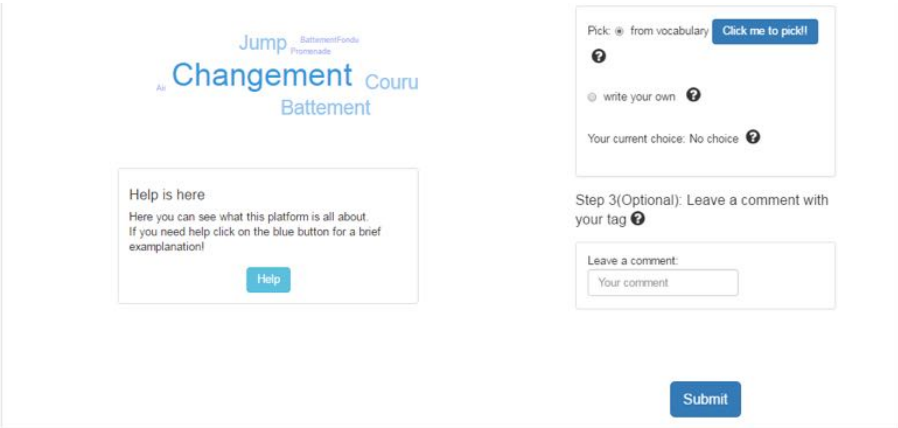


Figure 64: The tag cloud view in BalOnSe

term occurs in this video. Note that one term can be used several times by the same or different users to annotate different segments of the video. This means that if a user annotates three different segments by picking the term “cabriole” (which is a specific jump with beating the extended legs in the air, in front of the body), then all of the three recordings count in the tag-cloud calculations. Eventually, the tag cloud shows the dominance of some terms over others. This might mean that the specific performance contains many |”cabrioles”(if this is the dominant term) or that most people have observed or noticed or decided to annotate this for their own reason. In our work, so far, we are not in the position to answer which of the above should be the case, as this requires extended users experiments. The application, however, is appropriate for supporting this types of experiments, which are eventually interesting questions related to how people use specific terminologies, observe dance, and recognize specific parts of standard syllabi according to their backgrounds. Finally, the application has been developed using mainly open-source technologies aiming at a sustainable, reusable and extensible system. Some of the technologies used for the are for the interface is JavaEE, Spring MVC framework, Apache Maven, Hibernate ORM, H2 database, AngularJS, Twitter Bootstrap CSS. For the integration of the ontology open-source Jena API and Pellet Java based OWL 2 have been used.

5.2.6 Evaluation and Future directions

At the moment we have done an initial round of expert evaluation of the tool and the results are taken into account for the next version, which will be ready to be evaluated by users. An issue is the extensive use of expert ballet syllabus terminology in the vocabulary and the effect that this may have on users not familiar with it. On the other hand, it is important to identify the main user groups for this tool, as ballet dance enthusiasts, even non-expert ones, are bound to be familiar with ballet terminology In our future work we plan to further evaluate our application in terms of usability, and user experience, and do further experiments to get more feedback from a variety of user groups about the way

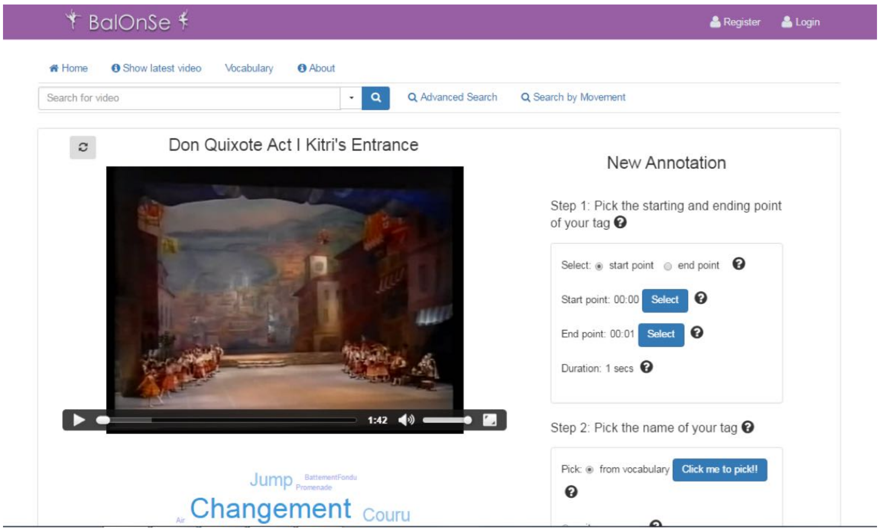


Figure 65: The BalOnSe annotation interface

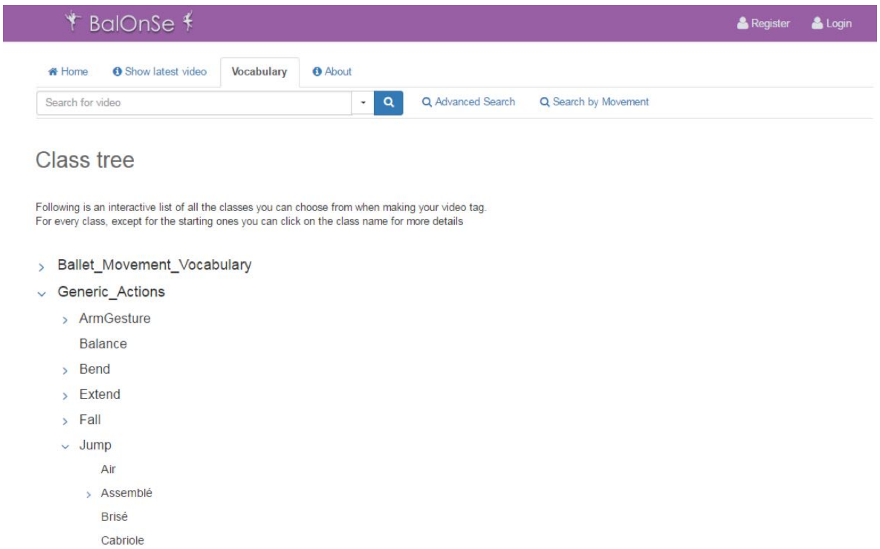


Figure 66: The BalOnSe hierarchy interface

the ontology and terms are used in action. There are some indications from the internal evaluation that the fact that the ontology includes if –not all- a big percentage of the ballet syllabus terminology, this might cause frustration to less experienced users with this terminology. The application, as well as the ontology, which can be used independently can be used in a variety of contexts, including exchange between research or studying groups, educational purposes, and also as a way to gather users observations on videos online. Nevertheless, although the current version is built upon the usability principles of error prevention, help, and error recovery, in terms of annotations, we did not implement any algorithms to validate and check the semantic correctness of the annotation.

5.2.7 Conculsions

In this section we presented a web-based application, which allows the user to annotate dance videos, using both free text tags, and terms from a predefined ontology of ballet syllabus terminology, while providing video archiving functionalities. The interface is designed and developed using recent principles of usability (help, error prevention, feedback, etc) while the generic movement vocabulary supports the users who are less familiar with the vocabulary, or just desiring a more abstract description of movement. In this work, we have also developed a domain specific vocabulary for representing hierarchies of ballet syllabi and shown some examples of uses of the application.

Our main contribution of this work is the following:

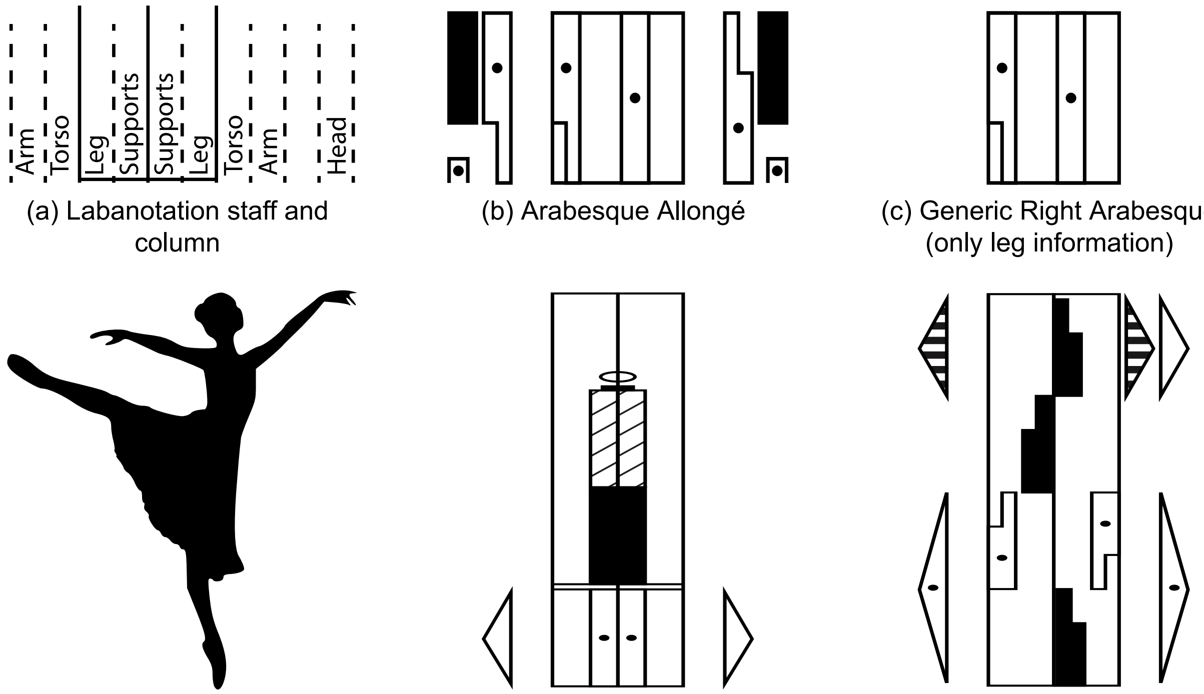
a) the development of a web-based user interface and application which is completely dedicated to the creation of small content-oriented archives of dance videos,

b) the introduction of the functionality of searching videos by dance terminology keywords which are provided by the users,

c) the implementation and presentation of a ballet syllabus ontology, which can be used in other applications, be extended or integrated with other similar ontologies. The application can potentially work with other similar ontologies and sets of videos, e.g., for other dance genres.

5.3 BalOnSe: Temporal Aspects of Dance Movement and Its Ontological Representation

In this section, we propose an approach to describe the temporal aspects of ontological representation of dance movement. By nature, human movement consists of complex combinations of spatiotemporal events, a fact that creates a big challenge for representing, searching, and reasoning about movement related content, such as movement annotations on video dances. We have defined MoveOnto, a movement ontology whose expressive power captures movements that range from body states and transitions based



(a) Labanotation staff and column

(b) Arabesque Allongé

(c) Generic Right Arabesque (only leg information)

(d) Arabesque Allongé Pose

(e) Plié-relevé sequence

(f) A jete jump followed by one step

Figure 67: Labanotation Examples

on the semantics of Labanotation, to generic actions or specialized vocabularies of specific dance genres, e.g., ballet or folk. We combine the ontology description with temporal reasoning in DatalogMTL, based on temporal rules of the movement events. Finally, we present the and requirements for dance exploration from a user's perspective and describe the architecture of BalOnSe, a specific system that is currently under implementation on top of MoveOnto according to them. BalOnSe consists of a web-based application with semantic annotation, search, and browsing on the movements, as well as a backend with archival and query processing functionality based on temporal rules.

We address this challenge by using DatalogMTL [34], a language for representing temporal ontologies. The language allows both temporal representation and reasoning.

Dance multimedia data such as videos can be found in large volumes in multimedia channels, but also in dedicated archives and collections. Various recent efforts are aiming at developing and bringing state-of the art information technologies to the area of digitisation, archiving and preservation of intangible cultural heritage and performing-art content [25, 71], as well as investigating bodily knowledge and widening the access to such content through enhanced experiences in various contexts, e.g., education. The question is how to facilitate *findability* and provide usable ways to access, search and browse multimedia content, based on the information related to the movement itself through concepts that are interesting for the users. This information could vary from generic concepts regarding actions e.g., step, turn, jump to specific terminology of dance syllabi e.g., pirouette, arabesque, as well as any verbal descriptions that convey something about the form or the quality of movements.

Semantic information about movements in a video can be added in two ways: automated extractions of patterns and movement recognition and manual annotation of experts. Even in the case of automatic annotation, the experts' annotations are needed as ground truth data to validate an automated algorithm. In addition to the above, explicit information can be inferred by reasoning if we add to the system rules to represent common and expert knowledge about movement.

To put our ideas into practice we have developed *BalOnSe*, a system that allows to add semantically rich temporal annotations about movement on multimedia content, *store* these annotations, and *search* the content based on the annotated metadata. The *BalOnSe* platform is build upon the *MoveOnto* ontology, a movement ontology whose expressive power captures movements that range from body states and transitions based on the semantics of Labanotation, to generic actions or specialized vocabularies of specific dance genres, e.g., ballet or folk. We combine the ontology description with temporal reasoning in DatalogMTL, based on temporal rules of the movement events.

The architecture of the BalOnSe platform is designed to allow modularity and extensibility, i.e., the integration of different rules and ontologies, including more details about the movement, terminology of other dance genres, context of the performance or the recording. To sum up, the current version of BalOnSe platform provides the following characteristics: *(i)* Annotation with archival functionalities and user moderation; *(ii)* Semantic-domain specific search (search the content based on movement and dance terminology); *(iii)* Rich predefined vocabularies for key-word search; *(iv)* Usable user interface including video streaming, and preview of statistics of annotations; *(v)* Temporal Reasoning; *(vi)* Modularity and extensibility.

Through the BalOnSe interface, the user may *(i)* employ ontological assertions to annotate a dance video recording using a rich ontology that contains both temporal and non-temporal predicates; *(ii)* browse through dance-multimedia content by querying the ontological video annotations; *(iii)* preview the rich multimedia content that resides in the BalOnSe deposit. A key characteristic of our system is that it allows further development and integration of other dance-specific ontologies in order to describe different dance genres. By extending our core ontology, that is designed in order to describe sequences of movements, we have built dance-specific vocabularies for different types of genres, i.e. ballet. Thus, a user may query a ballet repository using movement sequences that are defined in the ballet syllabus.

We now identify some key-usage scenarios of our system:

(S1) Annotate segments using vocabularies: In this scenario the user annotates specific segments on the video, using specific movement descriptions and terminology by choosing from the defined entities of core (movement) and domain-specific ontology (ballet syllabus terminology). The information which is related to each video can be subdivided to static and temporal. Static characteristics involve metadata information concerning the recording, the performer, the dance company, the title etc. Temporal characteristics are the annotations added by the users which hold the information of a start time and end time on the video.

(S2) Semantic search based on movement descriptions In this scenario the user wants

to access dance-performance content, either by key words or querying metadata knowledge bases, through advance search by movement concepts. For example the user might want to search video recordings that include jumps in general or specific jumps of the ballet syllabus. The semantic representation and reasoning will allow the user to see all the subclasses of a jump, even though in the initial annotations of the videos might include only the ballet terminology was used, since this information is inferred through the semantic and temporal reasoning.

(S3) Preview of existing annotations: The third scenario involves the viewer watching seeing next to each video the previous annotations which were created by other users. The Preview component allows to preview the video along its corresponding tag cloud, as shown in Figure 64 the tag cloud under each video. The tag cloud shows all the terms that have been used to annotate the different segments of the video, while the size of the fonts represents the frequency each terms occurs in this video. Note that one term can be used several times by the same or different users to annotate different segments of the video.

5.3.1 Specifications

To what follows, we outline the different technical functional and non-functional specifications resulting from the aforementioned scenarios, based also on similar approaches [127].

Integrated Data Access: One of the features of the BalOnSe platform, is its ability to incorporate annotations that have been already made on dance-performance content. These annotations may be stored in a relational database endpoint and can be easily accessed. This is due to the datalogMTL translator that follows an Ontology Based Data Access (OBDA) [169] approach as a means to enhance end-user direct data access to relational databases.

Utilising Implicit Information: In databases it is typically assumed that only explicit data matters, i.e. the explicit data that are stored in the system. Nevertheless, our system aims at inferring additional information by utilising the initial annotations and some domain-specific knowledge related to dance and movement analysis. This could be reflected by logical formalism, that allows to derive implicit information from the data stated explicitly, typically using some forms of background knowledge, via a reasoning procedure. The use of implicit information can greatly increase the practical benefit of the BalOnSe system.

Temporal Data Processing: Our applications requires for the existence of a temporal component that will allow to correlate annotations representing movement sequences of a dance-recording video. Existing languages, such as the OWL 2 language are not designed to represent temporal information. Thus we should adopt a language that allows for an expressive temporal component. We identify the specific refined characteristics for the underlying temporal language: *(i)* It should provide for a natural way to annotate movements within a dance video recording of a performance. The annotations of video sequence should refer to an absolute time component, i.e. its event should be mapped to a specific time interval within the video that describes its starting and ending point in seconds or subdivisions of seconds. The user should be able to annotate in absolute time intervals of events within a video sequence. *(ii)* It should provide for a natural way to describe movement patterns and sequences in terms of recognised movement forms for the dance genre. In contrast to the absolute time that applies when annotating a dance video recording, a movement pattern description, even if expressed in notation, does not depend on absolute time-intervals. Instead, similar to music scores, dance sequence descriptions are expressed on beats, i.e. temporal ratios instead of specific time intervals. This means that a mapping is needed between the time expressed in beats in patters and the absolute time intervals coming from the annotations. *(iii)* The corresponding language should allow to have a temporal component when describing the background knowledge of our domain. The later will allow to effectively encode complex dance sequences via simple predicates. *(iv)* Finally the corresponding formalism should allow for an expressive query component. The latter will allow to query our metadata for specific events and the time intervals that these events occurred.

Modular Ontological Representation: Ontology modularisation can be interpreted as decomposing potentially large and monolithic ontologies into (a set of) smaller and interlinked components (modules) [1]. An ontology module can be considered as a loosely coupled and self-contained component of an ontology maintaining relationships to other ontology modules. In our domain of interest, we have the core dance ontology that is used to describe basic human body motion (based on Labanotation) and domain specific ontologies that describing specific dance genres, e.g., ballet. The latter provides users of ontologies with the knowledge they require, reducing the scope as much as possible to what is strictly necessary.

Usable Query Interface: The BalOnSe platform should provide end-user query formulation support to construct complex ontological queries on temporal aspects of the underlying knowledge. Target users, such as dance students and educators, choreographers, and dance amateurs, cannot be expected to learn formal query languages like SPARQL. Instead the BalOnSe platform should provide them for the corresponding interface to describe complex expressions. The appropriate user interface is essential since it allows for fast and easy data access for non-experts to state-of- the-art technologies. The BalOnSe interface is subject to continuous enhancements and iterative evaluations with users.

The BalOnSe platform allows users to enrich multimedia content such as videos with annotations by choosing specific terms from the MoveOnto ontology. MoveOnto includes terminology of movement on different levels of abstraction. To represent choreographies in an expressive searchable way, we need a strong theoretical basis that allows to describe the required elements of dance (grammar and syntax). The theoretical basis for the MoveOnto representation is based on the Labanotation system for describing movement [119] and Kaeppler's choreological approaches that analyse the structural parts of dance in Motifs, Morphokine and Kinemes. Under this perspective, the notions of Kineme and Morphokine [125], as dance segments are analogous to Phoneme and Morpheme in morphology linguistics. Kinemes are actions or positions, which have no meaning as units alone, but constitute the building blocks of a Dance Genre.

A Morphokine is defined as the smallest kinetic unit that has meaning, where meaning here does not reflect any pictorial or narrative notion, but it is used to indicate movements that are recognized as units from the people practicing a specific dance genre.

The third level of dance structure is the motif level. A Motif is a frequently occurring combination of Morphokines that themselves form a short entity.

5.3.2 MoveOnto

In order to provide a more human readable and computer understandable format, MoveOnto was developed to capture the semantics of Labanotation [72], a notation system for recording and analyzing human movement and is presented in detail in Chapter 4.2.

It is a symbolic language which allow to create dance notations on paper. The symbols are put in specific columns on the staff which is read from bottom to the top. The vertical axis represents time, while different columns of the staff are dedicated to different body parts. The reader interprets the different symbols based on their shape (movement type, directions, and other symbols), their color (level of movement) and their size (duration). A Labanotation score, as in Figure 67f, can be seen as a complex timeline with parallel slots.

The main objective of MoveOnto is the interpretation of symbols into entities that are both human- and machine-understandable. Moreover, in our work, the use of the ontology provides the ability to express complex relationships, restrictions, and rules about the concepts, creating hierarchies and graphs of movement entities and properties, and as a result provides a rich vocabulary for describing dance movements. In fact, in a Labanotation score, since the different movements are represented as events, related to time intervals, all Allen's interval relationships [8] are possible to be found on a dance score, to represent the relative synchronisation of states and transitions of movement.

MoveOnto considers three different levels of describing movement [74, 75]: *(i)* a *Labanotation Concepts* level based on Labanotation; *(ii)* a *Generic Concepts Movement* level that is used to describe terms such as turn, step, slide, and *(iii) Specific Vocabulary Concepts* level that is used to represent the terminology related to a specific dance genre, such as the Ballet syllabus.

In the following subsections, we provide some examples of the semantic and temporal relations between the syllabus (specific movements that are meaningful for the genre), and their representation in Labanotation and MoveOnto. In our approach, we create a hierarchy/taxonomy of movements, by classifying them into abstract categories. This hierarchy supports the scalability of the system by giving the opportunity to search movements in different levels of detail. As MoveOnto is based on DatalogMTL, it can express complex inference rules and relationships with a temporal component. Reasoning capabilities support reuse of entities, and allow the system itself to infer explicit knowledge from the stored dance knowledge, e.g., "a Gesture is an Action".

5.3.3 Time representation and DatalogMTL

In our previous approach in order to represent time and synchronisation in the core ontology, we adopted a reification strategy. Time intervals were represented as OWL2 individuals called Temporal Entities [72] and in order to represent the sequential order between time points, the functional property hasNext was adopted. Each time interval corresponded to a set of facts representing the dance movements, while the duration was expressed by the datatype property hasDuration, relating each time-interval individual to a specific duration.

In this work we propose the use of DatalogMTL to represent our knowledge. DatalogMTL is a language for representing temporal ontologies. The advantages that the DatalogMTL language provides, compared to our previous approach, are the following: *(i)* It provides for a natural way to represent time in dance movements, since it does not demand the introduction of individuals that corresponded to time intervals and a datatype property to represent duration. *(ii)* DatalogMTL allows having a temporal component in complex rules. Thus complicated dance combinations can be effectively encoded via simple predicates. For example, a jeté is a complex ballet jump (Figure 67f) that involves a set of different body movements that take part on time. *(iii)* DatalogMTL provides for an expressive query component, which allows querying the dance ontology for specific events and the time points that these events occurred. This provides for very interesting capabilities since it allows to search for specific movement sequences and find similarities between different types of dance.

5.3.4 Movement Representations and Rules

In the following section we describe some examples of simple movements, expressed in verbal descriptions, Labanotation, and DatalogMTL and we show the different levels of complexity that might occur in temporal representation. A DatalogMTL *program*, Π, is a set of rules about our domain, and a *data instance*, $\mathcal{D}$, is a finite set of facts, i.e., in our case video annotations.

The MoveOnto ontology makes the following assumptions: *(i)* Simple and more complex movements are represented as unary predicates that are used to characterise video segments. For example an assertion in $\mathcal{D}$ such as

$$Left\_Leg\_Gesture\_Middle\_Back(:Video1)@[12\,\text{sec}, 13\,\text{sec}]$$

means that a left-leg-gesture-middle-back movement occurred in Video1 during the $[12\,\text{sec}, 13\,\text{sec}]$ time period. *(ii)* The time in Π (rules) is represented in beats, in a similar way time is represented in dance notations, and expressed in practice when a dance sequence is taught and analysed. *(iii)* The time in $\mathcal{D}$ (facts) is represented in seconds of each video file. *(iv)* In the system, the durational value of the beat is mapped into seconds or subdivisions of seconds for each video file according to its tempo, in a similar way the tempo is given in beats per minute (bpm).

Example 1 *In Figure 67b we give an example of an Arabesque Allongé pose, a Morphokine that makes sense for a specific dance genre, in this case ballet. The Arabesque Morphokine, either as a pose or action Figure 67d, is a case of describing a single pose or movement with no complex temporal relationship of its integral parts. It consists of different simple kinemes that (i) are happening at the same time period, simultaneously; (ii) share the exact same duration. The DatalogMTL definition of the Arabesque Allongé pose is the following:*

$$\begin{gathered}\boxplus_{[0,1]}Arabesque\_Allonge(x) \leftrightarrow \boxplus_{[0,1]}Right\_Support\_Midde\_Place(x) \wedge \\ \boxplus_{[0,1]}Left\_Leg\_Gesture\_Middle\_Back(x) \wedge \boxplus_{[0,1]}Right\_Arm\_Gesture\_Middle\_Front(x) \wedge \\ \boxplus_{[0,1]}Left\_Arm\_Gesture\_Middle\_Back(x) \wedge \boxplus_{[0,1]}Right\_Palm\_Facing\_Place\_Low(x) \wedge \\ \boxplus_{[0,1]}Left\_Palm\_Facing\_Place\_Low(x)\end{gathered} \tag{5.1}$$

Based on the previous rule, the occurrence of the separate simultaneous movements (involving the legs, arms, and palms) of an $1\,\mathrm{sec}$ *duration implies an Arabesque Allongé movement of the same duration and vice versa.*
Within our knowledge we may have different levels of details. In Figure 67c, a more generic Arabesque is represented where only information about the legs is specified. The more generic movement is represented into MoveOnto by the following DatalogMTL rule:

$$\begin{gathered}\boxplus_{[0,1]}Right\_Arabesque(x) \leftrightarrow \boxplus_{[0,1]}Right\_Support\_Midde\_Place(x) \wedge \\ \boxplus_{[0,1]}Left\_Leg\_Gesture\_Back(x)\end{gathered} \tag{5.2}$$

while we may also add rules for basic movement details:

$$Left\_Leg\_Gesture\_Back(x) \leftarrow Left\_Leg\_Gesture\_Middle\_Back(x) \tag{5.3}$$

DatalogMTL allows to query our knowledge using the different levels of detail. Thus an assertion $Arabesque\_Allonge(:Video123)@[23,24]$ *in* $\mathcal{D}$*, along with the rules in Equations 5.1,5.2,and 5.3 imply that*

$$Right\_Support\_Midde\_Place(:Video123)@[23,24] \text{ and } Right\_Arabesque(:Video123)@[23,24].$$

Example 2 *In Figure 67e we give an example of a Plié-relevé movement, a more complex Morphokine that includes sequences of simple kinemes: (i) the complex movement is described as a set of sequential movements that are all happening during specific intervals; (ii) all movements overlapping in time, share the exact same duration and are happening simultaneously. In other words, all parallel movements are happening in sequential intervals. These sequential intervals might be equal in time or not.*

$$\begin{gathered}\boxplus_{[0,3]}Plie\_Releve(x) \leftrightarrow \boxplus_{[0,1]}Right\_Support\_Middle\_Place(x) \\ \boxplus_{[0,1]}Left\_Support\_Middle\_Place(x)\ \boxplus_{[1,2]}\ Right\_Support\_Low\_Place(x) \\ \boxplus_{[1,2]}Left\_Support\_Low\_Place(x)\ \boxplus_{[2,3]}\ Right\_Support\_High\_Place(x) \\ \boxplus_{[2,3]}Left\_Support\_High\_Place(x)\end{gathered} \tag{5.4}$$

DatalogMTL allows to infer interesting facts that are happening within a Plié-Relevé-movement interval (similarly with the previous example):

$$\begin{gathered}\boxplus_{[0,1]}First\_Position\_Middle(x) \leftrightarrow \boxplus_{[0,1]}Right\_Support\_Middle\_Place(x) \wedge \\ \boxplus_{[0,1]}Left\_Support\_Middle\_Place(x)\end{gathered} \tag{5.5}$$

$$\begin{gathered}\boxplus_{[0,1]}Plie\_in\_First\_position(x) \leftrightarrow \boxplus_{[0,1]}Right\_Support\_Low\_Place(x) \wedge \\ \boxplus_{[0,1]}Left\_Support\_Low\_Place\end{gathered} \tag{5.6}$$

as well as expressing information that involves sequential movements:

$$\boxplus_{[1,2]}Support\_Bending(x) \leftrightarrow \boxplus_{[0,1]}Right\_Support\_Middle\_Place \wedge$$
$$\boxplus_{[0,1]}Left\_Support\_Middle\_Place(x) \wedge \boxplus_{[1,2]}Right\_Support\_Low\_Place(x) \wedge$$
$$\boxplus_{[1,2]}Left\_Support\_Low\_Place(x) \tag{5.7}$$

What the above rule says is that if the description starts with an interval where the dancer is in normal position, followed by an interval which defines a low level as a destination, this should allow us to subsume that the dancer has bend his/her knees, so there is an action of bending there. Thus by combining the rules in Equations 5.4,5.7 we infer that the Plié-Relevé movement implies a Support-Bending movement as well.

Example 3 *In Figure 67f we give an example of a Jeté jump where parallel and sequential movements occur in combination, thus more complex synchronisation needs to be represented: (i) the complex movement is described as a set of sequential movements that are all happening during specific intervals of the same or different durations; (ii) movements might occur in equal intervals, overlap, start with or end with, so all combinations of intervals relations are possible.*

$$\boxplus_{[0,4]}Jete\_Jump(x)\boxplus_{[0,1]} \leftrightarrow Right\_Step\_Low\_Place(x) \wedge$$
$$\boxplus_{[1,2]}Right\_LegGesture\_Middle\_Back(x) \wedge \boxplus_{[1,2]}Left\_LegGesture\_Middle\_Forward(x) \wedge$$
$$\boxplus_{[2,3]}Left\_Step\_Middle\_Low(x) \wedge \boxplus_{[3,4]}Right\_Step\_Middle\_Low(x) \wedge$$
$$\boxplus_{[0,2]}Right\_Arm\_Gesture\_Middle\_Right(x) \wedge \boxplus_{[0,2]}Left\_Arm\_Gesture\_Middle\_Left(x) \wedge$$
$$\boxplus_{[3,4]}Right\_Arm\_Gesture\_Middle\_Right(x) \wedge \boxplus_{[3,4]}Left\_Arm\_Gesture\_High\_Left(x) \wedge$$
$$\boxplus_{[3,4]}Torso\_Gesture\_High\_Right(x) \tag{5.8}$$

BalOnSe is an integrated system that consists of multiple components to support end-to-end annotation and provide access on ontologies about dance. From a user perspective, the BalOnSe system allows to: *(i)* create temporal ontological annotations of multimedia content; *(ii)* search by movement predicates; *(iii)* preview the existing multimedia content that satisfies the queries. Query evaluation is done via the system's query enrichment, unfolding, and execution modules that allow executing complex temporal queries on relational databases. In this section we give some details of the BalOnSe components that address the challenges and specifications described in Section 5.3.1.

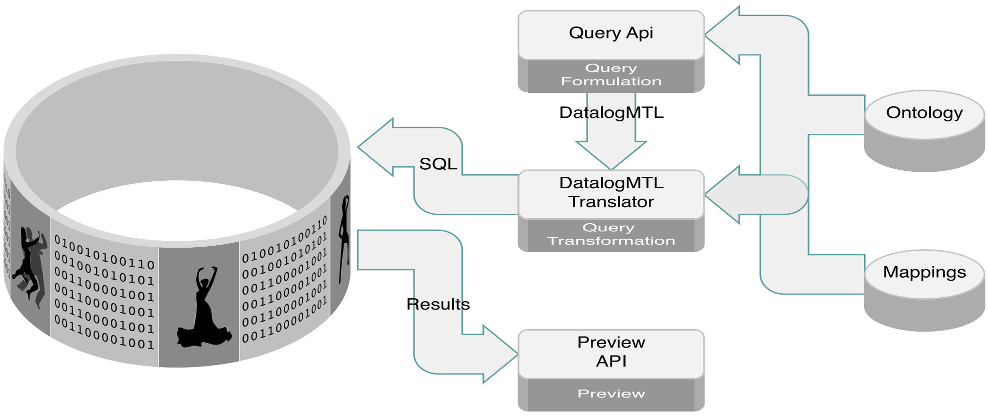


Figure 68: BalOnSe Architecture

5.3.5 BalOnSe Components

The application provides for the following components in order to perform the intended actions:

1. *Multimedia Content Annotation:* the application provides for an archival system for the videos, along with the corresponding user interfaces (UIs) that allow users to annotate video content and store the corresponding annotations in a relational database system.

The query formulation, transformation, execution, and video visualisation procedures are performed in a sequence of stages presented in Figure 68:

2. *Query Formulation:* Data sources can be explored using a query formulation tool that allows the user to navigate through the ontology and the corresponding temporal component. The current version of out query formulation tool is based on DatalogMTL queries. Future work involves the adoption of faceted browsing techniques that allow end-users to explore a collection of information by applying multiple filters.
3. *Query Transformation:* The aforementioned expressions are sent to the corresponding query transformation engine for processing. The processing includes rewriting against the ontology and further unfolding into relational SQL queries based on the corresponding mappings [34].
4. *Query Execution:* SQL queries are executed by a relational database management system.
5. Preview: The results of query execution are video fragments corresponding to the complex movements that were queried. The user is able to preview the corresponding video fragments.

5.3.6 User Interface

A key characteristic of the BalOnSe platform is its simplicity for annotating video content and search. The platform's web-based interfaced is illustrated in Figure 69 and can be logically divided to 5 basic interfaces. The user is able to perform annotations using labels of predefined vocabularies on the core ontology and Morphokine on domain-specific ontologies (Figure 69D). Each annotation has a starting and an ending time point. For formulating queries, we have adopted a transparent approach where the user asks only for specific labels corresponding to the terminology of □□(morpho)kinemes (Figure 69B). Finally the user can directly search for multimedia objects based on there titles (Figure 69A), and furthermore preview multimedia content (Figure 69C).

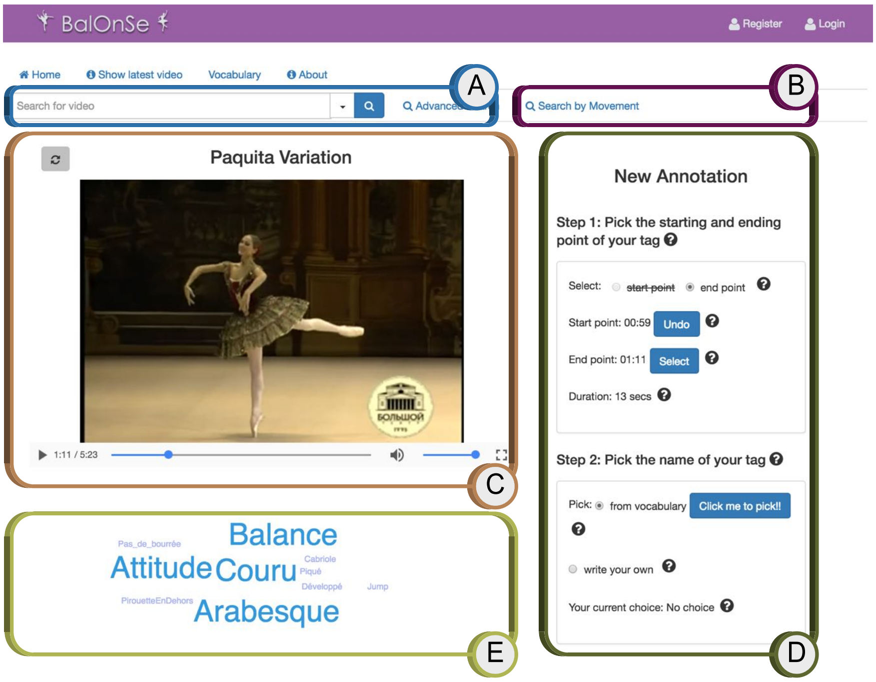


Figure 69: BalOnSe User Interface

5.3.7 Annotations storage and management

The application provides an archival system for the videos while both video metadata and user annotations are stored in a relational database. By taking advantage of the modular characteristics of our ontological representation, the Multimedia Content Annotation Interface allows the user to annotate a dance video either by adopting simple movements (kinemes) on the core ontology, or by using predefined combinations of simple movements (Morphokine) on the domain-specific ontology (e.g. the ballet ontology).

Example 4 *The dance expert may annotate by using the core ontology, that in Video_123 a Right_Support_Midde_Place movement took place during the period* $[25\,\text{sec}, 26\,\text{sec}]$ *and a Left_LegGesture_Back movement took place during* $[25\,\text{sec}, 26\,\text{sec}]$*. Alternatively, the dance expert may assert that a Right_Arabesque movement was performed between* $[25\,\text{sec}, 26\,\text{sec}]$*. Based on the definition of Right Arabesque in Equation 5.2, the two annotations are equivalent.*

Database Schema: We will briefly present the database schema, which implements a basic entity relationship model with three main entities: (User) `Accounts`, `Videos`, and `Annotations`. We focus on the `Annotations` table, which stores our temporal information:

`Annotations` is the table that stores the experts' annotations. A new record is saved for each annotation that is chosen by the user for a specific video segment. It has the following attributes: The `VideoId` contains an identifier that is unique for each video file. The `Movement` attribute represents either a kineme in the core ontology, or a Morphokine in some of its extensions. `Comment` is a user defined characterisation of the annotation the user just created. `PostTime` is the time the user made the annotation, this attribute provides the opportunity to have log history of tags added by the same users in different times. `StartTime` is the time the annotation starts being observed in the video. `EndTime` is the time the annotation stops being observed in the video. StartTime and EndTime are expressed in seconds of the video time.

Example 5 *Based on Example 4 for the core ontology, the user will make the following annotations: a right-support-middle-place movement took place between* $[25\,\text{sec}, 26\,\text{sec}]$ *of the specific video and a left-leg-gesture-back movement took place between* $[25\,\text{sec}, 26\,\text{sec}]$ *of the specific video. The two annotations are stored as displayed in Figure 69.*

Therefore, for each video all the annotations provided by different users are stored, as well as different annotations of the same user. The database stores the multiple tags along with the information of the user that provided them. In the current version, the annotations of users are stored and each time the video appears, a tag cloud shows all existing annotations.

5.3.8 Query Transformation & Execution

This section is dedicated to the enrichment and unfolding stages that occur during a query execution cycle. The DatalogMTL translator is responsible for transforming DatalogMTL conjunctive queries and their temporal component, to relational SQL queries.

Ontology Mappings: The relationship between the ontological vocabulary and the schema of the data is maintained by a set of mappings. Intuitively, a mapping assertion consists of a source (an SQL query retrieving values from the database) and a target (defining RDF triples with values from the source). The DatalogMTL translator exposes relational databases as virtual Datalog assertions by linking the terms (predicates) in the ontology to the data sources through mappings. The W3C standard for expressing customised mappings from relational databases to RDF datasets is R2RML (R2RML: RDB to RDF Mapping Language) [54].

DatalogMTL translator extends R2RML mappings, so that they incorporate both predicates of higher arity, as well as temporal information. For the technical details of these extensions the reader may refer to [34]. We will try to explain with a simple example how R2RML mappings work for our use cases.

Rewriting, Unfolding, & Execution: DatalogMTL a uses two-step approach to answer the user queries described in what follows: *(i)* First, an initial DatalogMTL query Q_1 together with the ontology is rewritten into a query Q_2 over the virtual relations that represent temporal data in conceptualised form. Example of mapping Arabesque concept with its corresponding rule, demonstrated a query that populates one such relation, namely, `Right_Support_Midde_Place`, which has columns `VideoId`, `StartTime`, `StopTime` to represent temporal information. *(ii)* Q_2 is then combined with all the relevant mappings to obtain the final query Q_3 that can be evaluated over the raw data.

The process to obtain the query Q_3 involves the computation of *temporal joins* and *coalescings*. To give an idea, for two tables T and S with columns $\texttt{from}, \texttt{to}$ both containing intervals, temporal join is a table with the same columns that contains all the non-empty intervals i, such that $i = j \cap k$, for some j from T and k from S. On the other hand, coalescing, for a table T as above, is a table T' which contains only one "covering" interval $[i_1, j_n]$ for a sequence of (right-)overlapping intervals $[i_1, j_1], \ldots, [i_n, j_n]$.

Example 6 *A simple DatalogMTL query asking for the videos that contain a Right-Arabesque movement and the time that this movement was performed has the form* $Q_1(x, \delta) = Right\_Arabesque(x)@\delta$ *where* x *corresponds to the video file and* δ *corresponds to the time interval that the movement was performed. By taking into account the definition of the right-arabesque movement in Equation 5.2 and the mappings in corresponding example, the rewriting and unfolding procedure will execute a complicated query* Q_3 *over the table* `Annotations` *of the relational database. For space limitations, we won't provide the full rewriting and unfolding of the initial query, instead, the interested reader may refer to [34] for more information on the corresponding procedures. The query answer will be the tuple* $(: Video\_123, 25, 26)$ *meaning that that* $Video\_123$ *contains a* $Right\_Arabesque$ *during the* $[25\,\text{sec}, 26\,\text{sec}]$ *time interval.*

5.3.9 Conclusions & Future Work

We have proposed an approach to describe the temporal aspects of ontological representation of dance movement. Our approach is based on the MoveOnto ontology that adopts the DatalogMTL language to represent movement in time. To put our ideas into practice we have developed the BalOnSe platform, the first platform that allows to store and query performing-art content containing complex temporal information.

Future work involves extending our platform with faceted browsing techniques, a suitable paradigm for querying ontology repositories. Moreover, we intend to examine DatalogMTL extensions that will allow us to infer conclusions when there is no perfect synchronisation between sequences of movements. Therefore, we want to extend the DatalogMTL semantics with fuzzy values to express the degree of similarity between movements.

5.4 A Web-based system for annotation of dance multimodal recordings by dance practitioners and experts

Recent advances in technologies for capturing, analyzing and visualizing movement can revolutionize the way we create, practice, learn dance, and transmit bodily knowledge. The need for creating meaningful, searchable and re-usable libraries of motion capture and video movement segments can only be fulfilled through the collaboration of both technologists and dance practitioners. Towards this direction, manual annotations of these segments by dance experts can play a four-fold role: a) enrich movement libraries with expert knowledge, b) create “ground-truth” datasets for comparing the results of automated algorithms, c) fertilize a dialogue across dance genres and disciplines on movement analysis and conceptualisation, and d) raise questions on the subjectivity and diversity of characterizing movement segments using verbal descriptions. The web-based application presented in this work, is an archival system with, browsing, searching, visualisation, personalisation and textual annotation functionalities. Its main objective is to provide access to a repository of multimodal dance recordings including motion capture data, video, and audio, with the aim to also support dance education. The tool has been designed and developed within an interdisciplinary project, following a user-centered, iterative design approach involving dance researchers and practitioners of four different dance genres.

Motion capture can significantly transform the way digital dance archives are created, analyzed and preserved. In parallel, the production of new types of dance recordings, creates new requirements for dance data archiving in various formats, in order to make these data accessible, findable and re-usable within a variety of research and practical contexts. Nevertheless, the diversity of what are the types, and formats, of data which are considered as “dance data”, combined with the open issue of movement representation [43] and the lack of standard conceptual models for managing movement archives, emerges as a complex interdisciplinary [74] and technical issue. As a result, the role of dance experts and movement practitioners in the process of creating, managing and enriching movement libraries is crucial. Experts’ annotations can play a great role in both enhancing such libraries, and drafting further specifications and research questions.

The process of manual annotation in particular can play a four-fold role towards this direction: a) To enrich the repository of recordings with metadata through tag annotations, b) to select “ground-truth” data, based on observation of experts to compare with automated annotation and feature extraction, c) To offer an analytical tool for the experts in the context of education, choreography and composition, movement research and analysis, through movement analysis and conceptualisation and d) highlight the subjectivity and diversity of characterizing movement using text-based tags, depending on dance practice background and purpose.

The Web-based Movement Library (WML) application, which we describe in this work, has been designed and developed within the framework of an interdisciplinary EU funded project [2], aiming at investigating and creating tools for dance education.

One of the first outcomes of our work has been the creation of a large library of movements through multimodal recordings, including motion capture, video and audio. The process of capturing and recording movement sequences from four different dance genres, including contemporary dance, ballet, Greek folk and flamenco, aimed at selecting the main building blocks to become the learning material within different educational scenarios. One of the first challenges of the project was to organize these data so that they can be easily accessible, searchable and subject to enrichment through manual and automatic processes. The main goals of the WML is to provide an intuitive interface for accessing the more than 750 recordings and gather “ground truth” data on how the dance experts characterize dif-

[2] www.wholodance.eu

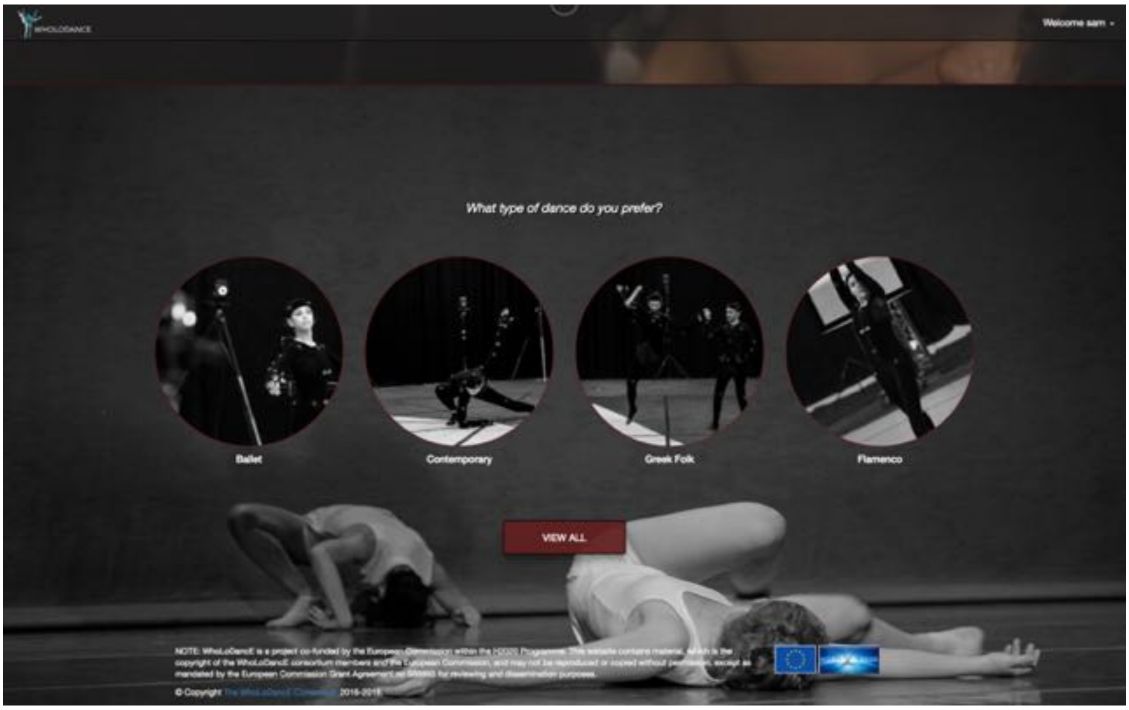


Figure 70: WML home page

ferent segments of the recordings regarding their movement aspects. More specifically, the user can browse the recordings by dance genre, and search by using keywords that are included as metadata or in the annotations of the recordings and refer to different aspects of movement (principles, qualities, actions, etc.). A player has been developed so as to allow the synchronized playback of a video, as well as its corresponding motion capture file. The synchronisation of the two types of formats [38], as well as the development of the 3D visualizer, falls out of the scope of this thesis and is not reported here.

The main objective of WML (Figure 70) is to provide the end-users, including dance educators, choreographers, movement and dance practitioners and experts a tool to browse, search, observe and reflect on particular movement descriptors and characterize them using a variety of semantic descriptors referring to general movement principles, movement qualities and actions. The first step was to enrich the repository with “ground-truth” data regarding the movement aspects of the various segments. The process of co-designing, evaluating and using the tool with the dance experts, brought to the surface a number of research issues on text-based annotations in movement analysis and highlighted its potential within a variety of contexts such educational, creative and research domains.

5.4.1 Movement Library and Annotator

The WML is a web-based application, compatible with any browser that supports WebGL, designed and developed as a means for searching, browsing, editing, viewing and annotating dance recordings, which may include a motion capture segment and/or video.

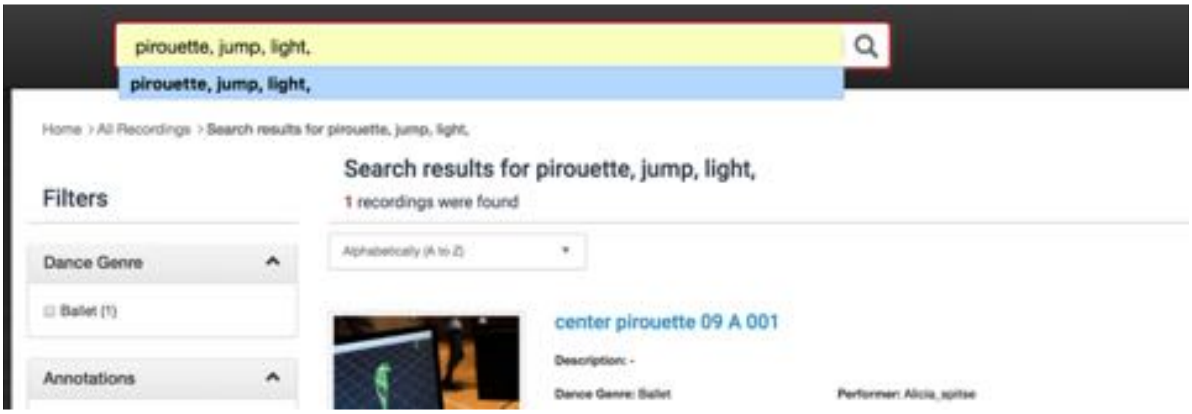


Figure 71: Search by movement functionality

The user is able to explore the rich library of recordings through an intuitive interface that requires minimum training even by the less experienced users. The WML allows exploration of the recordings, grouped into four dance genres, as well as searching that takes into account the rich metadata associated with each recording.

More specifically, the recording metadata description includes the dance genre, the motion capture venue and time, the performers, the dance company, as well as information on the related movement principle(s). Recordings of Greek dance motion capture segments have additional information, such as the name of the dance in the local language, the region, the gender and the type of segment.

Furthermore, WML serves both as a viewer and an annotation tool and a custom player has been developed, in order to support the simultaneous playback of the video and the 3D skeleton (or “stick figure”) of the motion capture that are related to the selected recording. During the process of viewing the recordings, users are able to track the recording annotations, through a Timeline structure as well as through a Table structure, both located beneath the player and enhanced with annotation functionalities.

5.4.2 WML Functionality

The WML offers a variety of functionality to the user, which presented briefly in this section.

Search by keywords or browse using dance genre
The WML home page combines a search bar with the possibility to browse recordings organized by dance genre. The search functionality uses the recording metadata and annotations to locate recordings relevant to the input of the user in the search field (Figure 71). After searching or browsing users are redirected to the “results” page where they can sort or further filter the results and view detailed characteristics for each. Search includes the option of using movement descriptors or free text as keywords, offering the option of searching the repository using terms related to movement.

View recordings

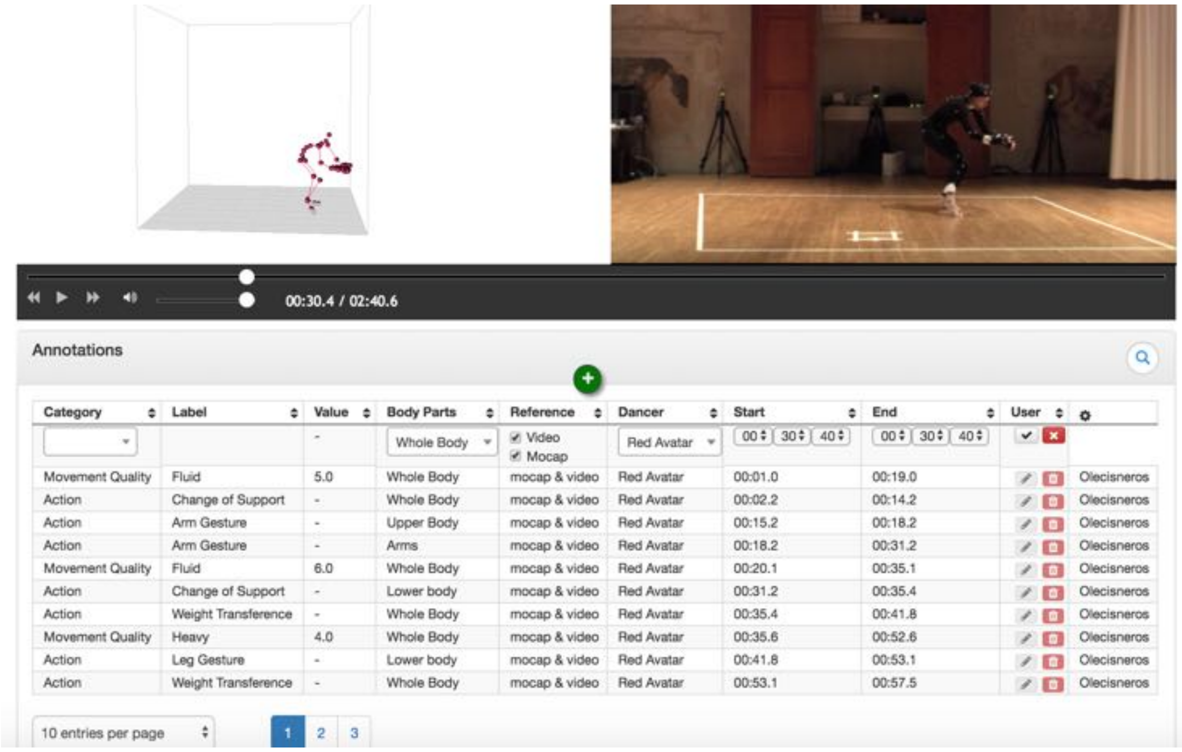


Figure 72: WML Table view of annotations

A specialized, custom player has been developed, in order to offer the possibility of viewing the recordings. The player's structure allows the synchronized playback of a video alongside with the corresponding motion capture file (Figure 72).

5.4.3 Manage and view annotations

Annotations on the recordings describe and analyze the dancer's motion. As Jennet indicates: "Annotating should be an iterative process: add, more annotations than needed, remove and refine later."[121]. The need for managing annotations was covered by developing a specialized table structure. The "Annotation Table" allows users to quickly add or alter annotations. Furthermore, WML offers a timeline structure which is synchronised with the media player (Figure 73). During the playback of the recording, a vertical, red line moves through the timeline segments, in order to present the annotations that correspond to each time point. The tool allows the editing of the annotations directly on the Timeline. Since manual annotation can be a time-consuming and complex process, it is important that the users can re-visit the annotations at a later time to edit and refine them.

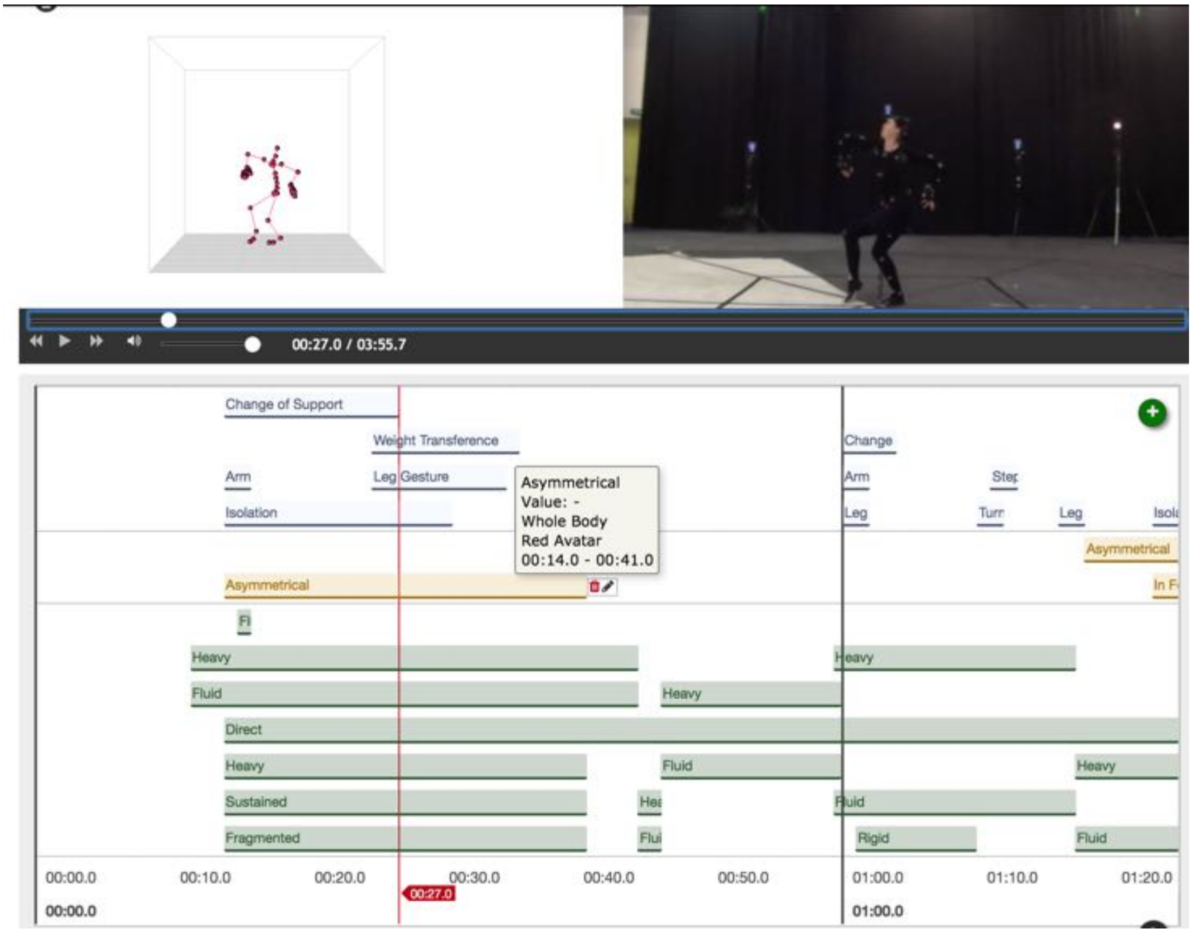


Figure 73: WML Timeline view of annotations

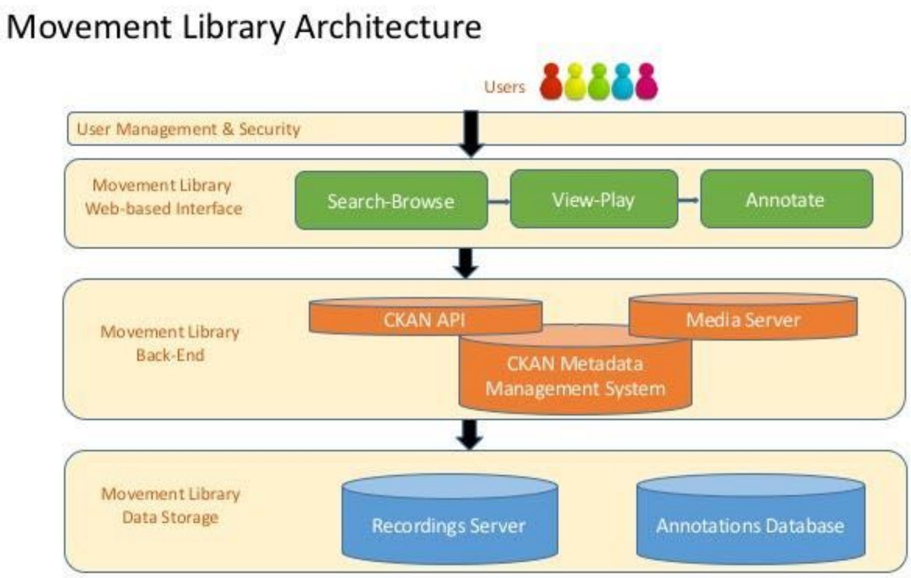


Figure 74: WML architecture

5.4.4 Create personal channel and playlists

WML has integrated personalisation functionality for the users to select recordings and create playlists. More specifically, users can create their own personal playlists with specific name and settings, as well as save playlists with public rights. Through their channels, users can view and edit their personal info and also locate created and saved playlists. By selecting one of those playlists, users can either begin the recordings playback or view the playlist's details.

5.4.5 Architecture

The WML storage layer is based on a server where the recording files are stored along with a database used for the user generated recording annotations. On top of this server, the backend is implemented through a CKAN data and metadata management system that provides tools for sharing and finding the data that are stored in the archival server as well as a search engine that is used in the WML. The WML also features a User Management system to support, among others, the personalisation features of the tool, including user annotations and playlists.

The WML tool is a web-based application, compatible with every browser, based on the principles of a Model-View-Controller (MVC) software design pattern, implemented with the Spring Web MVC framework. The view component has been developed by utilizing the JSP script based templating system, Bootstrap and AJAX to send and retrieve data from the server asynchronously (in the background). Figure 74 provides an overview of the WML architecture.

5.4.6 Movement descriptors and vocabularies

In WML, the type of annotations allowed is text-based, providing a controlled vocabulary which is based on the conceptual framework adopted by the project. The conceptual framework provides a number of specific movement descriptors which are independent of the dance genres and can be used as labels or tags, to characterize a particular segment. These descriptors are categorized in three main types: movement qualities descriptors, movement principles descriptors and actions, and are shown in Table 5.

Movement principles descriptors are related to Movement Principles, which are high-level concepts that all dance practitioners deal with regardless of the genre and practice, such as: Symmetry, Directionality, Rhythmicality, Coordination [46, 81].

Movement quality descriptors are related to movement qualities such as fluid, rigid, light et., derived from a subset proposed by Camurri et. al. [46]. Movement qualities have been adapted to the needs of the project through the co-design focus groups and interviews sessions with internal and external dance experts.

Finally, the Actions descriptors consist of a list of basic, generic actions such as jump, turn, step, arm gesture etc., which are also aligned with the basic actions in Laban Movement Analysis [119] and used in other works [72, 79]. It is true that finding and applying one and only conceptual model or ontology for describing human movement is a challenging issues. While, Laban Movement Analysis and notation systems such as Labanotation [72] and Benesh [56] provide a theoretical basis for doing so, they are not part of everyday language of all dance practitioners, independent of the dance background and genre.

At this point, we should stress that the vocabulary which is provided is more indexical than exhaustive, and serves to limit down the options into specific descriptors to study as use-cases juxtaposing the manual annotations with the automated algorithms within the project. The indexical vocabulary, shown in Table 5 include a subset of the LMA efforts, Movement Qualities as have been defined by Camurri et. al. [46] and Actions, as they have been selected in the Conceptual Framework through a user-centered approach [81] As Jennet indicates, “Finding the appropriate labels or names for each annotation is important. An ‘inside out’ process where the material teaches the names and ‘outside in’ when one arrives with a set of names are both valid approaches and have their own strengths.”[121].

In this sense, within the tool we provide the option of choosing one of the proposed descriptors and also adding free text to reflect additional annotations the user might find relevant. In addition, during the annotation process the user has the option of indicating if the annotation is based on observing the 3D stick-figure of the motion captured segment, the video, or both, and also provide a value for the descriptor on a range of 1-10. Finally, the user can indicate the performer (there are maximum two performers in the recordings currently in the library) and body part to which the annotation refers. The conceptual framework used, which is not reported in this work, highlights yet another benefit of creating tools for manual annotations: Distant collaboration and observation of movement recordings. Even when the framework used is an established system like Laban Movement Analysis

Table 5: The concepts used as indexical vocabulary for annotation

Category	Label
Action	Arm Gesture
Action	Leg Gesture
Action	Pause
Action	, Step
Action	Weight Transference
Action	Fine Motoric
Action	Gross Motoric
Action	Isolation
Action	Jump
Action	Turn
Movement Principle	Symmetrical
Movement Principle	Aligned
Movement Principle	Asymmetrical
Movement Principle	Coordinated
Movement Principle	Misaligned
Movement Principle	In Balance
Movement Principle	In Focus
Movement Principle	Out of Focus
Movement Principle	Out of Balance
Movement Principle	Isometric
Movement Principle	Still
Movement Qualitiy (LMA)	Direct
Movement Qualitiy (LMA)	Indirect
Movement Qualitiy	Fluid
Movement Qualitiy	Rigid
Movement Qualitiy (LMA)	Sudden
Movement Qualitiy (LMA)	Sustained
Movement Qualitiy (LMA)	Heavy
Movement Qualitiy (LMA)	Light

and the observation is held by trained experts in the same system, coming to “consensus doesn’t mean that every person will see the same thing” but rather opening a discussion towards a “more reliable and valid observation”[87].

5.4.7 Iterative design and Evaluation

This section focuses on the formative and summative evaluation activities organized for the beta version of the tool, which implemented the functionality described in the previous subsection These included on-going co-design and formative evaluation activities with dance practitioners as well as an organized usability evaluation event which involved usability and user experience (UX) design experts and a user workshop where external dance practitioners were invited to interact with the tool.

5.4.8 A User-centered Design Approach

The WML tool development has followed, since the early requirements and design phase, a user-centered and iterative design approach. The development team has been in constant interaction with the internal user group of the project, which consists of 12 dance professional practitioners with expertise in different genres and in some cases in the more theoretical, research and also cultural heritage aspects of dance. At the early stages, the dance experts participated in regular co-design and formative evaluation sessions, individualy or in small groups, where they were able to provide their insight and ideas on the direction the development should take. When the first working prototypes were available, the user group was asked to interact with the tool and offer feedback to the development team in the form of brief reports and through interviews and focus group sessions. This process has informed all aspects of the tool, including the offered functionality, the design and also the underpinning conceptual framework.

For the usability and UX evaluation of the WML tool, a task-based user evaluation in a laboratory setting was organized. Seven usability and UX experts were invited to participate in the evaluation. After a brief introduction to the project and signing of consent forms, without initially making clear the objective of the platform, the users were asked to freely navigate in the platform and to express their opinion as to what the objective of the platform is. Our goal was to verify whether the interface makes clear the objective of the tool. The evaluators to this end asked the participants questions like: “What do you think this tool is used for?”, “What would you expect to be able to do with it?” After the discussion that followed, the users were introduced with more details about the platform and presented with its main functionality. They were then given a series of tasks to perform following a think aloud protocol, while they were observed by the evaluators and their reactions video-recorded. The users were given a series of multiple step tasks in order to be able to interact and experiment with all the aspects of the main functionality of the platform. These included:

- Search and browse by dance genre and specific metadata
- Search for specific recordings and annotations
- Work with the timeline
- Add new annotations

After the evaluation, the users were briefly interviewed and then asked to fill in a questionnaire, which is based on the User Experience Questionnaire (UEQ) . The UEQ evaluates user feedback in 5 dimensions, which result from 26 questions likert-type questions in a scale from -3 to 3:

- Attractiveness: Overall impression of the tool.
- Perspicuity: Is it easy to get familiar and learn how to use the tool?
- Efficiency: Can users solve their tasks without unnecessary effort?
- Dependability: Does the user feel in control of the interaction?
- Stimulation: Is it exciting and motivating to use the tool?

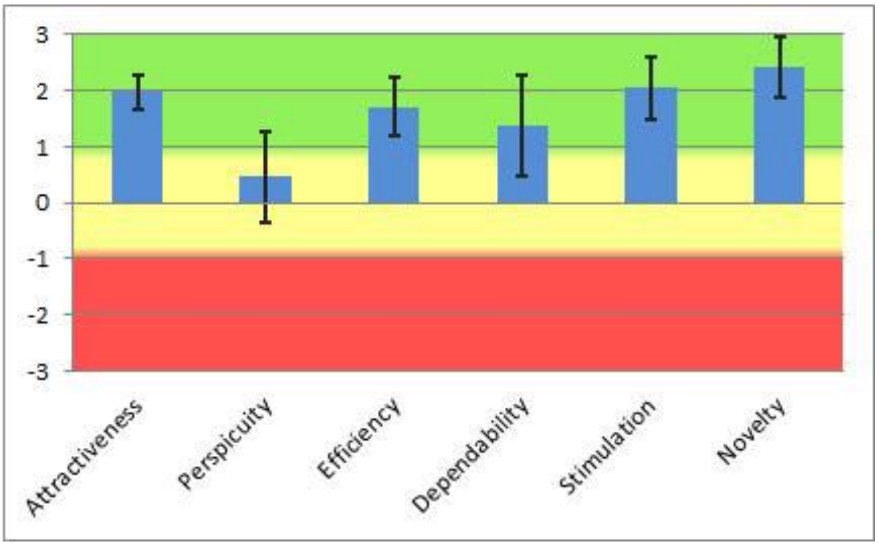


Figure 75: UI/UX Evaluation Results

Table 6: Results on the five selected UEQ scales, in the range of -3 to 3. Average values are presented UEQ Scales

	Average
Attractiveness	1.972
Perspicuity	0.458
Dependability	1.375
Efficiency	1.708
Stimulation	2.042
Novelty	2.417

5.4.9 Results

The results of the evaluation, including user observation and notes during the testing, interviews and questionnaires have been analyzed leading to qualitative and quantitative results.

The dimensions of the UEQ can be grouped into pragmatic quality (Perspicuity, Efficiency, Dependability) and hedonic quality (Stimulation, Originality). Pragmatic quality describes task related quality aspects, hedonic quality the non-task related quality aspects. Table 7 presents these aspects for WML.

Results confirm the success of the tool in all dimensions except perspicuity. This is to be expected as the tool is complex and it can be initially daunting to the inexperienced user, requiring some time to get familiar with it. However, even with this initial impression, in general, users were very positive with the platform in terms of the usability aspect of the functionality. Taking into account the complexity of the functionality offered by the platform, users were able with instructions to navigate and complete simple tasks. They felt that the

Table 7: WML results grouped in pragmatic and hedonic qualities

Pragmatic and Hedonic Quality	**Value**
Attractiveness	1.97
Pragmatic Quality	1.18
Hedonic Quality	2.23

Table 8: WML Workshop-summary of questionnaire results

Question	**Average in a scale 1-5**
Clarity of the recordings metadata description	3.6
Would you suggest WML to other professionals in your field?	4
Ease of use	4
Need of support during use	2.2

design is aesthetically attractive and they were all able to understand the objective of the tool. The users proposed several improvements, both in terms of enhancing usability and extending the offered functionality. The analysis of the evaluation results has informed the re-design of specific features of the tool towards a new, improved version.

5.4.10 WML workshop with dance practitioners

The WML has been evaluated in a targeted Workshop organized in September 2017. The WML Workshop lasted two hours and was addressed to dance experts and practitioners. Nine participants attended with the following profiles: 2 choreographers and dance teachers, specialized in contemporary dance and improvisation, 3 dance researchers focusing on digital technologies related to dance, 1 dance anthropology researcher with extended knowledge in Labanotation, 1 director of dance theatre and, 2 professional level dancers (Greek folk dance). After a presentation of the WML overall approach and the objectives, the participants were asked to freely experiment with the tool individually or in pairs for 45 minutes, with the support of the organizers when requested. During this session, comments and questions of the participants were recorded and interesting discussions were issued between them. After this session, the participants were asked to fill in a questionnaire and another 45 minutes were dedicated to focus group discussion about the platform.

Table 8 summarizes the participant outlook for WML. The participants felt it was usable, clear and useful and proposed extensions and improvements. For example, they pro-

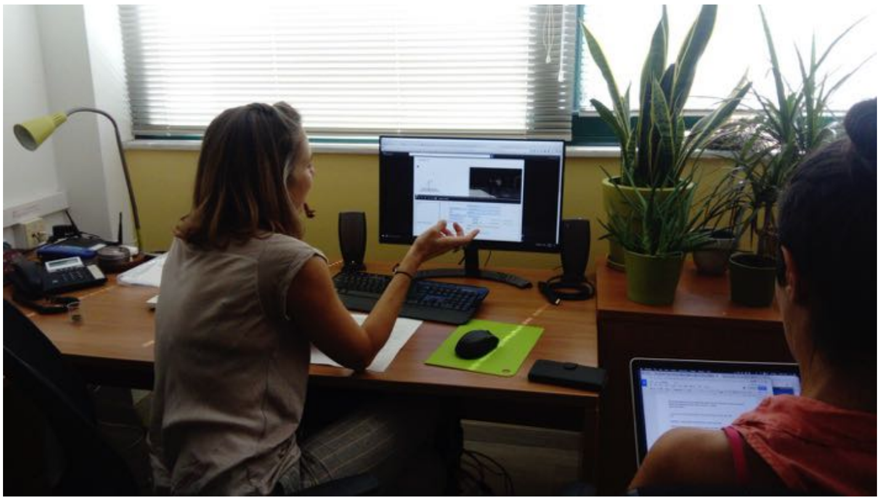


Figure 76: WML user evaluation

posed extending the filters in the search results page with additional metadata of the recording, including body parts, joints, and additional movement qualities, etc.

5.4.11 Annotation and dance research

Dance practitioners both during the ongoing co-design sessions and the evaluation activities proposed different uses of the WML tool based on their expertise and needs in relation to the domain of dance and offered different perspectives as to how the WML functionality could accommodate these needs.

A tool for dance movement analysis and expert collaboration
The WML offers a complete framework for dance movement viewing, examining and annotation. Dance experts with an interest in movement analysis recognized the potential of the tool in the context of their work. Firstly, WML gives the option of advanced search based on specific movement characteristics within a rich library of content, and, secondly, allows the user to focus on the details of selected movement segments by viewing at the same time the movement itself through different perspectives through the interaction with the avatar and also to observe existing annotation in particular parts of the movement segment. The expert is also able to use this tool to communicate her approach for the analysis of a specific segment, by adding her own annotations. In this way, the practitioners felt that WML has strong potential as a tool for academic research in dance movement and for communicating the expert's perspective to other colleagues in the field. A suggestion by the experts was to use the full vocabulary developed within the project conceptual framework to support the search and filtering of annotations.

A tool for advanced dance movement visualisation
WML offers at the moment the possibility to view and interact with the motion capture stick figure avatar and at the same time view the video of the performers. The practition-

ers found the combination of these two perspectives very interesting as a means to study movement and proposed the use of additional avatars for the presentation of the motion capture recording. They felt that there is strong potential in investigating how these different avatars could be employed to highlight and reflect specific movement qualities and they would like to see this direction investigated in order to be incorporated in a next version of the tool.

A tool for dance education and choreography
Those practitioners who are involved with dance education felt that the tool has educational potential and the possibility to be used to prepare and share choreographies with colleagues. The WML offers a rich library of movement segments that can be used to:

- Prepare a list of movements to be used during dance class or a performance
- Share these movements with students and colleagues to comment on or rehearse them

The aforementioned user needs led to the inclusion to the WML of the playlist feature, which was not initially foreseen for the tool. The playlist can be used for the users to save and share their own playlists. Some of the practitioners felt that it would be useful for them to upload their own motion capture segments and videos. Some of the dance educators also noted that the tool could be used by the students themselves to practice on more theoretical assignments, like studying specific movements in depth as to their qualities and using the annotation tools to share their perspective with their teacher. Lastly, as the tool offers material from different genres under a unified framework for search and annotation, it can promote cross-fertilisation between different genres.

A tool for preserving and disseminating intangible cultural heritage
Practitioners from traditional dance genres like Greek folk dance highlighted the strong potential of the tool in terms of preserving, researching and disseminating intangible cultural heritage. The tool allows access to a library of different folk dances that allows the presentation of the dance to different audiences in high quality along with other genres. The more experienced practitioners are also able to study the movements and compare with different variations of the same dance, keeping annotations for their own benefit or for colleagues to review.

The annotation process within a multidisciplinary research context
The Annotation tool has been used for the duration of one year, as a tool to select “ground truth” data to be compared with the results of automatic feature extraction annotation algorithms. The idea is to select data concerning the textual characterisations of the segments in relation to higher level descriptors such as movement qualities. Interestingly, the difficulty for experts to reach a common agreement, even amongst experts of the same dance genre, as well as the difficulty of providing one and only mathematical definition for these movement aspects, lead to the investigation of other methodologies for automatically analyzing the data, apart from until now used rule-based techniques. The results of these methodologies are out of the scope of this work, however, we would like to highlight the importance of providing tools for gathering the dance experts’ views, in the form of data, and

analyzing whatever these data imply, before choosing the best techniques for movement computing methodologies.

5.4.12 Conclusions

In this work, we have presented an annotation tool, which is integrated in an archival system, including also other functionalities such as browsing and searching using metadata and annotations and personalisation features. The movement library consists of more than 780 recordings (motion capture and video) coming from four different dance genres. Whatever is added by the users, depending on their access rights, can be seen by other users, on a timeline, and also can be searched using keywords which matching both metadata (dance genre, place and date of recording, performer, company, etc) and user annotations (movement principles, qualities and actions) through an intuitive interface. The process of designing and using the tool highlights the emerging impact of the use of annotation tools based on verbal descriptions on rethinking movement concepts and characterisations, exploring common understanding and perception of these concepts amongst different practitioners and dance genres. As many of the dance practitioners commented, this re-thinking on movement conceptualisation and use of text-based descriptions can lead to a creative exploration of the limits of “objectively” performing such concepts, which is a useful process for both choreography and education. In that sense, annotation tools, can play a multiple role ranging from collecting data about experts’ observations, to promoting the discussion amongst different dance genres and disciplinarians, to creating applications which can support the dance practice and research itself, as well as dance experts through educational and creative collaborative processes.

6. WHOLE-BODY INTERACTIONS: WORKFLOW AND EXPERIENCES

”When analytic thought, the knife, is applied to experience, something is always killed in the process.” — Robert M. Pirsig, Zen and the Art of Motorcycle Maintenance: An Inquiry Into Values

In this Chapter we discuss the problem of designing and tools that can support the transmition of dance for learning but also for creative experimentation. While in the previous Chapters we mainly focused on the **Conceptual** aspects of movement using digital technologies, in this part of our work we deal with the Experiential aspects of dance. While in the previous Chapters we focused on how the form and structure of dance languages can be represented, analysed, managed and enriched, in what follows we study how the design and develpment of a digital or virtual experience can consist an experience that can transmit the qualitative aspects of movement and dance as a whole.

6.1 Experiences Informed by the Conceptual and Experiential Languages

The focus on conceptual aspects of dance, the morphology, structure and syntax of movement seem important for dance languages that have established kinetic vocabularies and patterns such as traditional, folk, ballet, or particular modern and contemporary techniques that consist of specific syllabi e.g., Graham, Cunningham, Limon, etc. Building tools that support the analysis and transmition of these Conceptual aspects, can have a large contribution to preserving dance as part of the Intangible Cultural Preservation, archiving and providing tools for the humanities research, as well as, transmitting, and teaching a dance language for the next generations (always in combination with physical training).

However, the question that comes right after the recording, management and archiving of dance is how this can be transmitted and experienced by the end user, such as a dance practitioner, performer, student or teacher. How a choreographer that wants to be inspired by existing recordings, archives, or Conceptual aspects, such as Movement Entities and their relationship for constructing a choreography.

6.2 Dance in Digital Environments

A common characteristic of the existing digital dance practice environments is that their approach follows the paradigm of learning by ”seeing and doing” as Harbonnier-Topin and Barber note [105], a teaching approach which is also known as mimesis. In this case, these systems approach the use of interactive technologies for dance learning by teaching a choreography through an avatar, asking the learner to follow and provide feedback on the ”correctness” of the movements.

Anderson et al. [9] introduce ”YouMove”, a system for learning full body movements, comprised of a Kinect-based recording system, and a corresponding training system. Aristidou et al. [14] introduces a prototype virtual reality simulator in which users can preview segments of folk dance performed by a 3D avatar and repeat them. Alexiadis et al. [6] describe a prototype system that automatically evaluates dance performances against a dance professional performance and provides visual feedback to the performer in a 3D virtual environment.

In dance learning, which is by nature multimodal and diverse, using visual, kinaesthetic or even poetic imagery and metaphors to enhance the performance of an exercise is a very common practice, even in genres were the kinetic vocabulary and technique is very precise, such as classical Ballet. Franklin in his book ”Dance imagery for technique and performance” [91] presents hundreds of examples which can be used during dance technique and improvisation classes to enhance performance, while some of them have been evaluated by Heilend and Rovetti [109, 110] in order to measure if and how they affect the performance of dancers in a real-life context. In contemporary dance, the use of visual metaphors is widely used to inspire new kinetic material in the contexts of improvisation and creativity. Merce Cunningham, Trisha Brown, William Forsythe, and Wayne McGregor, ” are only some of the well-known choreographers who focus on the creation of innovative movement through the use of mental imagery related to sensation, space, meaning and emotion” as May et al. report [149]. In addition, some somatic practices, such as ”Skinner Releasing TechniqueTM” [187, 188] which are still applied and have inspired contemporary dance learning practices, fully rely on the use of kinaesthetic and even also poetic metaphors. These have also been investigated in digital and virtual spaces by R. Gibson [94].

Contemporary dance approaches and learning techniques focus not only on the produced shape of the movement, but also on the movement qualities, the dynamic or the way the motion is performed. Fdili Alaoui et al. has explored the relationship of movement qualities and physical models, through a long-term collaboration with the choreographer Emio Greco [86]. Camurri et al. [46] have developed a computational framework for movement qualities applied both on dance and other forms of non-verbal communication.

While several digital environment systems have been introduced for dance practice, and while some valuable contributions have been made the last years in investigating the relation between abstract movement visualisations and movement qualities such as those by Bisig et al. [28], Camurri et al. [46], and Fdili et al. [3], little discussion has been dedicated to the use of anthropomorphic 3D avatars and how their characteristics could affect the experience of dance improvisation or teaching.

Summarizing the above we identify two types of systems: one extending the paradigm of ”augmented mirror”, and one where the scenario of use relies on seeing and following a prototype movement on an avatar -teacher. In parallel to the two aforementioned types of systems for practicing dance, there are two points of using avatars 1) showing the teachers’ movement, 2) seeing oneself as an avatar for self-reflection, while moving.

Although Choreomorphy system can be applied for both types of avatars, the co-design and evaluation with users have been mainly focused on the latter perspective. As defined by Loke et al. [140] in such interactive digital experiences the body can be seen through two perspectives: the mover's, referring to the perspective of "first person experience of the moving body" vs. the observer, referring to the " the view of the body from the outside". In the experience of seeing one's self as an avatar while moving the user becomes a mover and an observer at the same time.

6.3 HCI challenges in Dance Education

Dance learning is by nature multimodal, while dance practice presents a wide diversity across genres and contexts. Choreography and artistic contemporary dance performances have been using interactive technologies to support their creative process for several decades. Nevertheless, the use of interactive technologies to support dance learning and education is still relatively immature and raises many challenges and interesting questions when it comes to choosing the appropriate human computer interaction methods. We present the characteristics of dance teaching and learning in relation to interactive technology and we highlight the points/feedback that dance, as a field of mastering expressive movement, can bring to the design of whole-body interaction experiences. The first question we need to address in a user-centered design approach is "who are the user groups" of the technological system we are developing. Dance practice presents a wide diversity across genres and contexts. Dance varies from social physical activity and intangible cultural heritage expression (within the wide range of folk, traditional and ethnic), to creative performing art. This means that learning objectives in dance include a wide range from improving kinetic and sensor motor skills, to cultivating musicality, improvisation and creative abilities, to cognitive analytical skills and enriching concrete knowledge about the technique and context of the dance.

6.3.1 Interactive Technologies for Dance

Having said this, interfaces for dance education might vary from traditional screen tutorials, to innovative multi-sensory representation, and from whole-body interaction to Augmented and Virtual Reality Environments [10, 27, 94]. Interactive technologies have been widely used in the context of artistic performance and creativity [27]. Co-operation-co-creation with practitioners is very important.

Merce Cunningham and William Forsythe, are two of the well-known choregraphers who have not only used technologies to support the choreographing process but are considered founders of projects tools such as LifeForms [**?**], Improvisation Technologies [90], Motion Bank [114] and Synchronous Objects [166]. Although "economy of movement" (meaning to move in an efficient, functional and simple, non-stylized manner), might be one of the principles in some approaches to dance techniques, movement in dance does not play a functional or a symbolic role. The concept of usability or functionality of the interface has to be re-thinked. Usability implies an interface which is easy to use in order to achieve an objective, but in this case the movement –as opposed to gesture- based interaction - is not a way to communicate a specific message or task, but our main focus.

6.3.2 Characteristics of Dance Learning

Dance learning can also take place in informal settings as well as in formal dance education institutions. Systematic learning can be hard, demanding and also requires the development of critical, analytical skills on one's own movement and knowledge. Dance is also a field of mastering movement literacy and creativity. Different techniques apply different learning objectives, teaching approaches, and often philosophies on movement. On the other hand, if there is one field where education and learning needs to be continuous this is the field of dance. There is no advanced or professional dancer who quits practicing, attending classes and seminars in daily or frequent basis if she/he wants to remain active.

6.3.3 Dance Learning Approaches

Although for physical education in general several models have been applied, according to Harbonnier [105] in dance we can summarize the following teaching approaches, which are also described in the first outcomes of WhoLoDancE project [**?**]:

a) Mimesis – imitation/copying (the teacher is teaching the student a specific movement or sequence of movements);

b) Generative – the teacher gives the student an exercise/phrase/sequence as a starting point to achieve technical and creative goals;

c) Reflexive – the student is given a movement task/image/to work with, improvising without trying to achieve a specific phrase/sequence and the teacher provides feedback.

d) Traditional method (command style teaching), where the teacher makes all the decisions and the learner follows these decisions. The method requires precision and accuracy of performance.

6.3.4 Cultivating sensory-motor, cognitive and creative

The different teaching styles are usually adopted by specific practices, which sometimes have to do with the tradition or culture in the dance genre rather than a deliberate choice. Nevertheless, different teaching approaches can cultivate different motor, cognitive and creative skills. Dance learning requires the development of both open and closed skills.

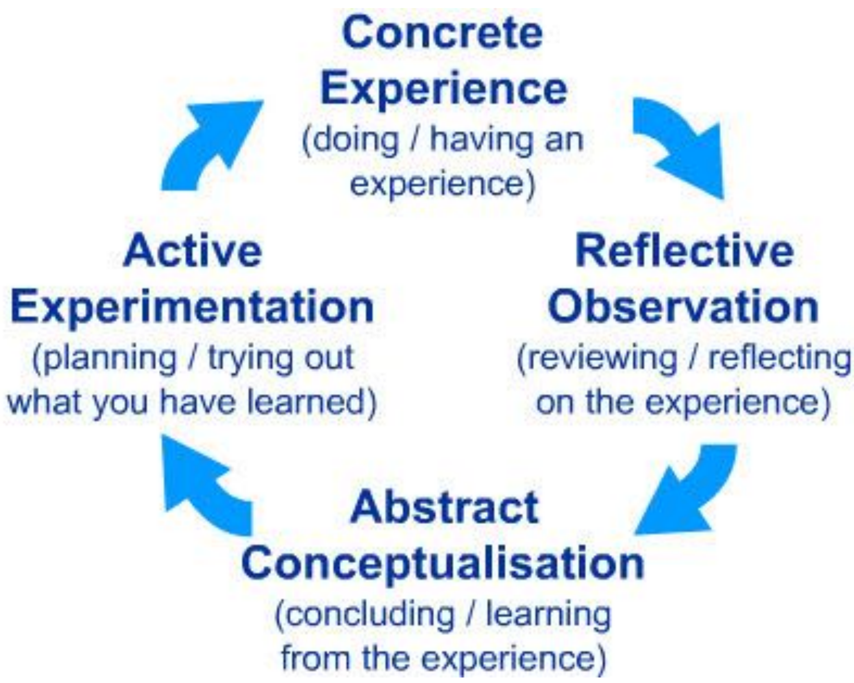


Figure 77: Kolb's learning cycle

When practicing in studio or class specific sequences or choreographies the dancer performs in a highly predictable environment, and doesn't have to consider external, environmental changes and challenges (closed), while in improvisation, dancing with a partner, or a group, or performing in front of the audience the dancer is challenged to move in an unpredictable environment (open). Also depending on the context the dancer can be internally paced, e.g., if she improvises alone or externally paced e.g., when she has to follow the music or a dance partner. The last two examples (open vs. closed and internally vs. externally paced) inspire different learning scenarios for interactions.

In the field of dance education, many researchers question the effectiveness of mimicry or mirror model of teaching, which is also known as "demonstration-reproduction" model. The "demonstration-reproduction" model, however, though it is not the only approach or always the best choice for dance learning, it is much more complex than a simple mimetic process, as the authors explain in their field research with the title -statement "seeing improves doing – and doing improves seeing" [105]. In this traditional of "see and do" approach the assumption is that dance should rely mainly in Active experimentation and Concrete experience (Kolbe's learning cycle shown in Figure 77). On the other hand dance as any other complex field of learning should cover all the learning cycle, including developing the ability of both Reflective Observation and Abstract Conceptualisation. Even if the "demonstration-reproduction" model is adopted, a good teacher leaves time for questions, discussion, and choses the right words and voice to describe while she demonstrates.

6.3.5 Specific Challenges of Digital Dance Learning

In this section we describe some of the major challenges of designing and developing HCI experiences for dance education. • Terminology - how to avoid verbal descriptions ambiguities • The movement has no goal, it is itself the goal • Creating meaningful scenarios - why bring the digital medium in? • Aesthetics issues of movement and human body representation

6.3.5.1 Terminology –how to avoid verbal descriptions ambiguities

Starting from the basics, a simpler interface for dance education would be a screen-based traditional environment for searching and browsing dance content (video, image, audio, text etc.). Here comes the first issue: what is the appropriate language to communicate non-verbal communication? “Match between the system and real world” the second principle of Nielsen would suggest: “The system should speak the user’s language, with words, phrases and concepts familiar to the user, rather than system oriented terms” [158]. When it comes to dance there is no standardized language or terminology across dance genres and learning practices. On top of this many choreographers and dance practitioners use their own idiosyncratic vocabularies. These individual dancing cultures informally define the movement units as meaningful segments or content components in each case. How therefore could we search a repository of dance content using “the user’s language” on movement? Two possible solutions: a) Develop context specific vocabularies; b) get rid of language and verbal descriptions. If we want to design an interface that speaks the user’s language, we should realize that in this case the “language” is the movement itself. An example of this approach would be the option to search and browse a repository of movement (video, motion capture data etc.) using the movement of the user, rather than key words.

6.3.5.2 Movement in the Focus of Interaction

In addition, whole-body interaction in dance is different from gesture-based interaction. In dance, with an exception of very specific genres, the movement does not convey a symbolic message. And neither does it normally consist of movement units with clear start and ending points, to serve a specific task or goal, e.g., pressing a key or catching a ball. This aspect of continuity, which is very clear in the case of dance (unless it is required for a choreography to imitate a more “robotic” or “fragmented” quality), highlights a mode of interaction and is important to other aspects of life as well. In addition, the diversity of contexts in dance provides a very wide range of movements and motor skills. For example, in contrary to some other sports and physical activities, most of the dance techniques require mastering both fine i.e., using smaller muscles to achieve precision e.g., precise hand or finger movements, and gross motor skills, i.e., using larger muscle groups or parts of the body as a whole e.g., running, or jumping. Gesture based interaction, apart from conveying particular meaning, is based on Discrete motor skills, i.e., movement units that have clear start and ending point, whereas in physical activity in general and more specifically in dance discrete motor skill are only one option, e.g., doing a pirouette, among many. This is the case when one needs to master one specific move or step usually at early stages of learning. Dance, on the other hand depending again on the style and context is a combination of Series or Sequential and Continuous skill. For example, in choreography, a combination of specific motives (sequential) vs. dancing or improvising with no clear, discrete movement units. Whilst unpredictability, fluency and freedom of movement are some of the principles in contemporary dance, at the same time economy and efficiency, as well as clarity of movement are required also. Scenarios of using interactive technologies to explore the movement as functional, goal oriented tasks in a gamified, creative, personal or collective experience [10, 170] opens new perspectives for both education and choreography in relation to modes of interaction. In addition, since dance inspires many whole body interaction scenarios but not gesture interactions in the manner of communicating specific meaning it adds another argument of how “natural are natural user interfaces” a question having been posed by D. Norman [160] but also reflected in artistic setting [1] . As the video of Privieux implies, gesture based interaction, actually imposes stillness and discrete movements, and requires from the user a very specific and restricted choreography to achieve his goal.

6.3.5.3 Co-design with Dance Experts as a Necessity

In other fields of “book” education (or even presentation) of technology, digital interaction brings the element of entertainment, creativity, and enhances the experience through engagement. Dance is by nature, multimodal, a whole-body activity, by itself considered entertaining. In addition, although props are used in specific dance styles, in general it is one of the artistic forms that require nothing but the human body and space. Bringing a new medium in the studio, on the body of the learner, can be considered a significant intervention in the kinaesthetic experience. Although dance requires a combination of sensor, motor and cognitive skills, which can be supported not only by the kinaesthetic, but also the visual and audio channels, the design must be focused on what the digital interaction can add to the learning experience, without shifting the weight to the analytical skills, e.g. through a visual channel. Finding the impact of the used digital interaction for each context is the key. Going back again to the basic ten Nielsen’s principles of usability the solution lies in “bringing analogies from real world examples”[158]. This is achievable through the close collaboration-if not co-design sessions between dance educators, practitioners and interaction designers. This point creates a challenge for designing “seamless” [53] and “transparent” technologies [33].

[1] What Shall We Do Next? (Sequence #2) by Julien Prévieux-https://vimeo.com/111013619

6.3.5.4 Transforming the Experiential Languages

Although the visual quality of a 3D model, VR environment or avatar construction is a technically challenging issue, the decision of what representation is appropriate for the transmission of the movement is key. Every dance genre and style usually brings (consciously or not) a whole culture, and philosophy on the perception of the body and its fragmentation. For example, in classical ballet, there are the limbs, legs, arms, the torso, the head, but traditionally the dancer does not think about isolating movements of the spine, hips, and abdomen, but as reference points for the body alignment. In folk, chain and round dances, most of the focus is on the feet, and since dancers hold each other's hands, arm movements are very limited to a secondary role. The costume imposes a quality of movement and reflects a body image of a whole area and era. In contemporary dance, the fragmentation of the body is challenged, as it is not fixed. Dancers are asked to be innovative in their movement, and perception of the body. This perception varies from biomechanical descriptions to poetic imagery. Dance as a performance creative art raises aesthetical, philosophical and perhaps political questions. Having all this variety of perspective creates the question what is the appropriate avatar or human body representation to teach dance in a virtual environment? Do we need to convey these perspectives or leave some parts to the imagination of the user-student? How realistic do we need to be in the representation of the human-body, and how this implies a body image or in a worst-case, a stereotype? It is true, however, that these issues existed before the use of avatars, thus one can claim that technology here can play a powerful role. Using stick figures side by side with anatomical details about one's movement, or abstract visualisation can transmit the quality or the essence of the movement. Using abstract visualisation as body extensions [27], sonification or virtual landscapes [28, 2] opens new perspectives on perceiving movement and explorations through various scenarios.

6.3.5.5 HCI: an analogy to HHI

In the following section we employ an analogy of Human Computer Interaction to Human – Human Interaction to identify the core aspects of interactivity for dance learning environments. In particular, a dance learning scenario can be viewed as an interaction dialogue between the dance teacher and the student. Learning objectives and teaching approaches, as the one described in previous section, in combination with specific categories of motor skills, can define a mode and degree of intervention. The four factors are the following:

- Way of intervention
- Frequency of intervention /Timing /Initiative
- Continuous vs. Discrete
- Correction vs. Reflection

Way of intervention. The way of intervention provides the answer to what is the modality chosen (Audio, Visual, Haptic, etc.) to give the required feedback to the student.

The choice depends on the learning objective and scenario itself, as well as the learning style of the student (audio, visual, kinaesthetic, multisensory), but it is independent of the teaching style (mimetic, traditional, reflexive, or generative) Frequency of intervention /Timing /Initiative. This parameter defines how frequently the teacher intervenes or not to provide feedback to the dancing student. In the traditional and mimetic teaching styles, in contrary to the reflexive and generative the learning experiences are basically lead by the teacher, thus the interaction is mainly initiated by the system, which asks the student to do something in a very particular way. Continuous vs. Discrete/asynchronous. Another point that we need to decide for the interaction is whether the feedback is continuous or discrete. For example, sonifying one's movement in real time is a way to provide feedback continuously, without interrupting the sequential or continuous skill of the dancer. In the discrete mode of interaction, the user does a movement or a short sequence and the system replies with feedback. Correction vs. Reflection. This parameter differentiates the feedback given by the teacher (or system), depending on the inclusion of semantic meaning. Correction, which occurs in the traditional model, means that the system has set a codification to tell you how close you are to the "right" movement or manner of movement. In Reflection, however, the feedback does not imply "right or wrong" semantics; the system (or teacher) just provides open feedback on what you do. This is usually the case when the Reflexive or Generative teaching approach is applied.

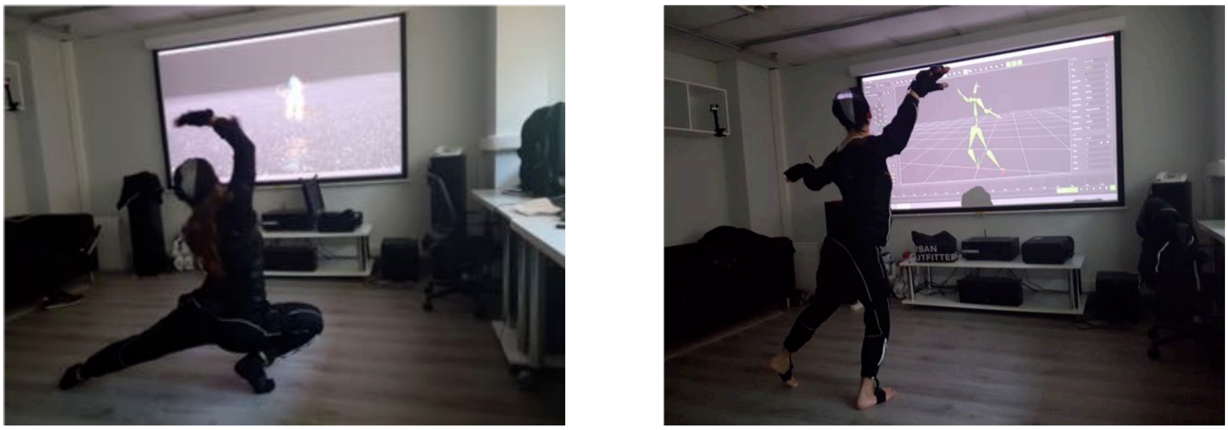
6.4 Choreomorphy: a Whole-body Interaction Experience for Dance Improvisation and Visual Experimentation [80, 199]

In this work, we describe the iterative design, development and evaluation of a whole-body interaction interface for exploring different visualisations of movement, using real-time motion capture and 3D models, to apply in dance learning and improvisation within a creative, gamified context. A full inertial motion capture system is used by the performer while a simple user interface provides the option to the user to experiment with different avatars, and visualisations e.g., trace of motions on different parts of the body and to interact with virtual objects. The 3D simulation provides a real-time visual feedback for the movement. The interaction follows the paradigm of moving from mimicking kinetic material into a self-reflection teaching approach. The interactive avatar is the reflection of the performer, but on the same time the avatar depicts a character, a dance partner which can inspire the user who moves to explore different ways of moving. Either within the framework of artistic experimentation and creativity, or in the context of education, the visual metaphors of movement shape and qualities consist a powerful tool and raise many scientific and research questions.

Visual metaphors and imagery are widely used in dance education, and creation. Motion capture and comprehensive movement representation technologies, if employed appropriately can become valuable tools in this field. Choreomorphy, is a system for a whole-body te experience, using Motion Capture (mocap) technologies in real-time, while it can be also used to visualize pre-recorded movement sequences. The system applies different avatars and 3D model visualisations of movement through an intuitive interface which allows the dance practitioner to switch between different avatars and customize a variety of visualisations of movements such as traces, trails and other effects, in real-time. Professional dance practitioners' sessions have been held in the lab, to investigate the influence of the different visualisations on movement qualities, as well as the perception of the avatar as an augmented mirrored self or as a co-dancing creature which inspires and leads their movement into creative pathways through real time interaction.

6.4.1 Introduction

One of the questions that this use-case investigates, is what would be the appropriate avatar or body representation to visualise a third persons dance recording, or one's own body in an Augmented Mirror setting?



(a) Participant 1 (b) Participant 2

Figure 78: Professional contemporary dancers exploring visualisations in lab setting

Wouldn't this choice affect the observation of the qualitative aspects of movement and guide user's focus into particular aspects? Whereas interesting efforts have investigated the role of abstract visualisations, a little attention is given so far to the body representation. On the other hand, body representation for dance, especially within a virtual or augmented environmet is highly related to body ownership, i.e., to what extend the user feels that the virtual body representing their movement is their own. In addition, in dance practice is a field that is really reach in body metaphors and has always played with the shape of the body, either as an "ideal" resulting from hard practice, or as way of visualising the dancer's identity, usually enhanced with costumes or props.

One historical example of designing costumes that challenge the shape of the dancers' body and its relationship to space is the Triadisches Ballett (Triadic Ballet), a ballet developed by Oskar Schlemmer, premiered in 1922 during the Bauhaus era (Figure 79).

Recent design of digital interactive dance costumes has been also inspired by Schlemer's work [126]. Many other choreographic examples can be given where the body is reshaped on stage using costumes, masks, or other props and physical or digital extensions [27]. In Choreomorphy intallation and experiments we do not focuse on one particular examples of these body representations, however, we investigate the opportunity of using such digital body representations in real time while dancing and imporvising. The digital environment allows the change from one of this representations (avatars, effects and scenes) real-time by simply chosing the next avatar in almost zero time, ideally in a studio setting where dance practitioners improvise.

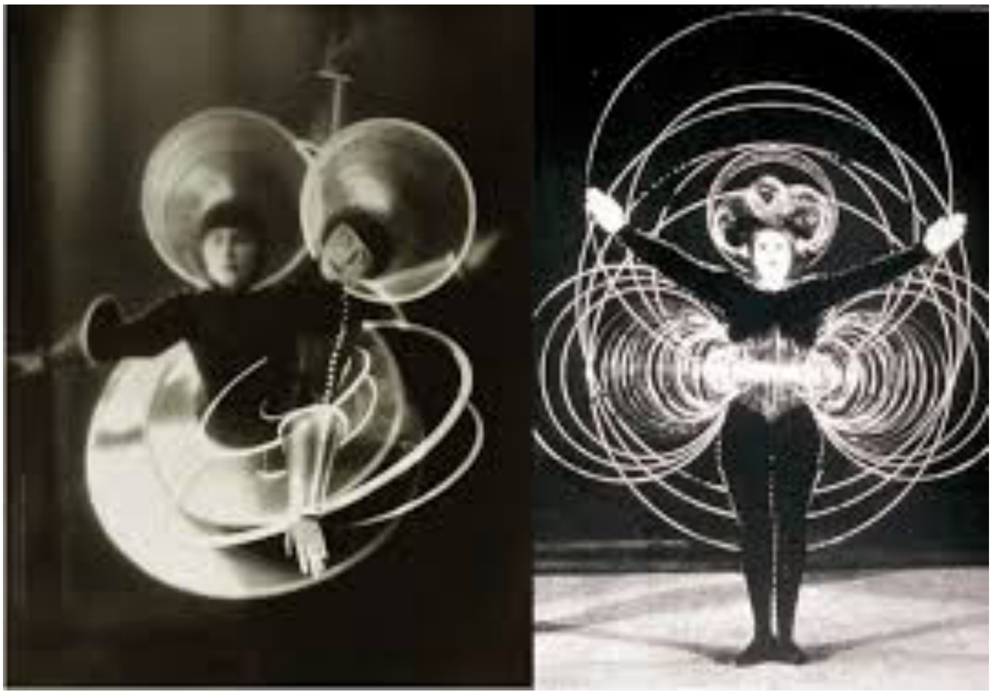


Figure 79: Costumes by Oskar Schlemer's Triadic Ballet (1922), an example of re-shaping the human body through the use of physical extensions and costumes.

Interactive motion capture technologies create new opportunities for reflecting on movement through different modalities. In particular, the use of full body motion capture and 3D display of the movement allows the dance practitioner to view the movement in its full 3D dimensionality. The Choreomorphy interaction system offers 3D display of the movement in real-time, as well as the option of viewing recorded motion captured sequences. Through a simple interface, the users themselves or an any assistant independent of technical background, can alter the environment and avatar and add special effects such as trails and traces, customizing characteristics like fade-out duration time, allowing the dancer to focus on specific aspects of movement such as shapes in space and trajectories.

Choreomorphy provides an interactive virtual environment which gives the possibility to select and customize the visualisations of the dancer's body and her movement, facilitating self-reflection and experimentation with different visualisations and avatars. According to the feedback from the dance experts who participated in the co-design and iterative evaluation sessions, the interactive experience allows self-reflection, stimulates imagination and raises many questions related to body perception, such as if and how they identify the avatar as their own reflection or as another ”partner” or ”creature”, depending on its shape and figure.

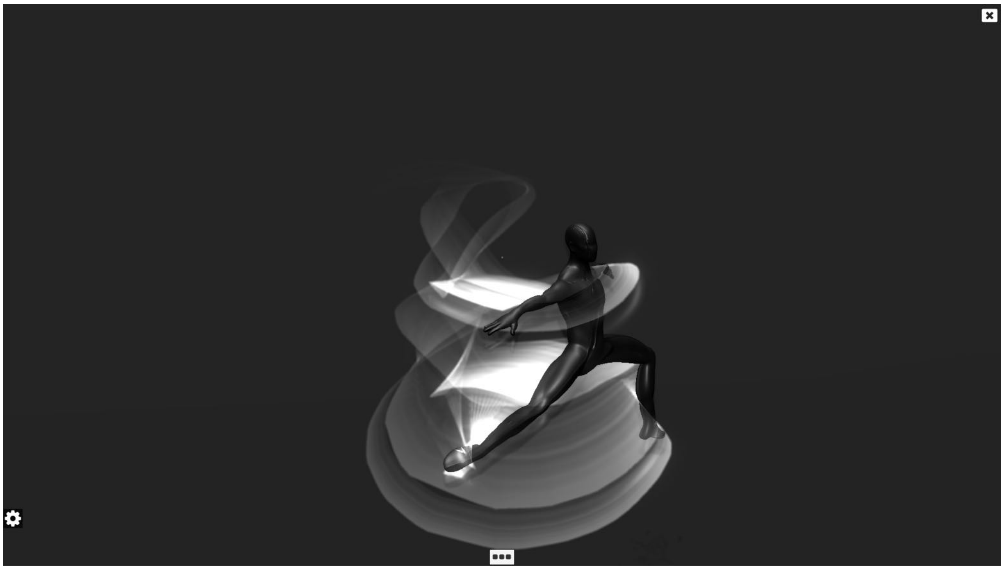


Figure 80: Ghost avatar with trails effects: One of Choreomorphy's scenes showing trace effect combined with an "invisible" avatar

Firstly, we frame the Choreomorphy system, in the context of the state of the art in the field and relevant work and we highlight its contribution. Then, we describe the experience and present the technical aspects of the setting and the system. We present the co-design and formative evaluation process with dance practitioners that we have followed. We describe the characteristics of dance practice, and in particular contemporary dance and improvisation. Next, we explain why the visual representation of the body and movement in digital spaces is important and how we took this into account. In the same subsection we describe the virtual environment and different options given by the system, and we present the user requirements which are derived from the co-design and evaluation sessions. Finally, in the last subsection, we discuss the outcomes of the process, including open issues and future work.

6.4.2 System and Setting

For this exploratory research we focused on the effect of "seeing oneself, as a moving digital body". Thus, the pipeline setup of Choreomorphy resembles a real-time inertial motion capture session. Independently of the venue where Choreomorphy is deployed, the setting should be a darkened room with space layout of at least 12m^2, so that the user can move freely. It is recommended to use a projector or a monitor of at least 24" for display purposes. The bigger the screen or the projector used, the more the avatar becomes closer to a life size figure and the whole experience becomes more immersive.

The user firstly has to wear the motion capture suit and calibrate it and then she is able to move freely in space. The system live-streams the motion to an avatar which simulates the movement on the screen (or projection), as shown in Figure 78a. The user can customize the visualisation settings (avatar, scene, effect etc.) or ask an assistant to do so. The user can initialize and fine tune different visual parameters including avatar textures, particle systems, motion trails and motion traces, and even the virtual environment itself. The user can also switch between several viewpoints of the avatar, including a first-person perspective.

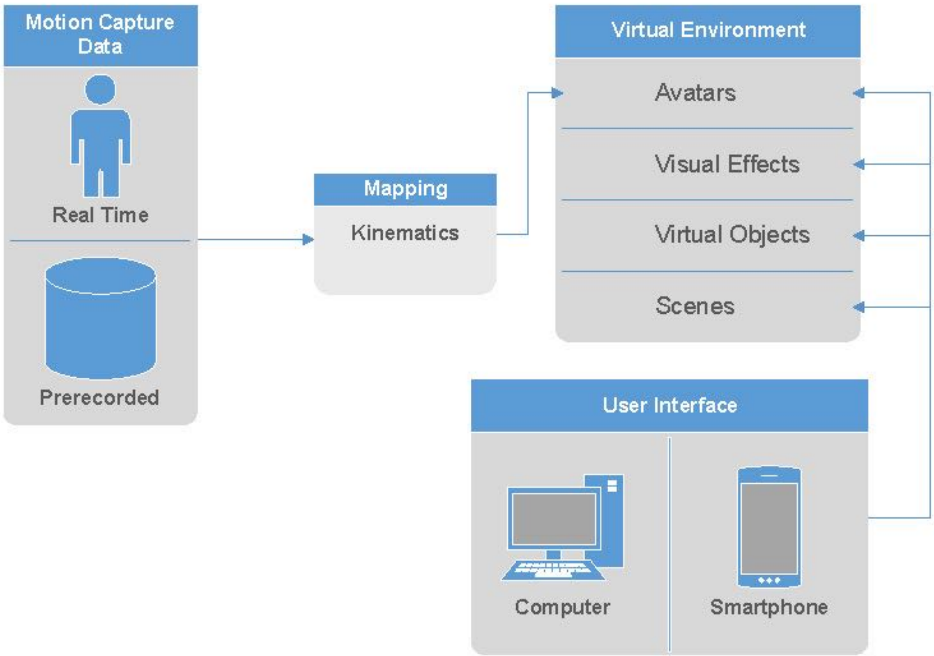


Figure 81: Choreomorphy Pipeline

The interface is available through the pc, as shown in 80 and 81, or a mobile device and has been inspired by a typical character customisation interface.

Choreomorphy as a system is developed to be interoperable with a number of input and output devices. As input we consider the following:

- the motion data coming from the motion capture suit, and
- the user input from the controls.

During the co-design sessions Synertial's "Cobra IGS C-420" inertial motion capture suit was mainly used as the input for motion data. Other motion capture devices have been tested and can be used, including the Microsoft Kinect .

Choreomorphy can also be used for displaying pre-recorded movement sequences, thus providing a desktop experience of seeing the motion recording in the different visualisation options the tool offers for real time visualisation. The architecture of the system is shown in Figure 81. More intuitive and less disruptive ways of controlling the visualisation parameters are being considered and tested, including voice and/or gesture recognition.

6.4.3 Co-Design and Evaluation

The design and evaluation of the Choreomorphy tool follows a user-centered iterative approach. Taking into account the exploratory research aspects of the approach and the need to investigate the complex relation of the dancer and her virtual body in an improvisation, but also an educational context, the team worked closely with dance practitioners, both members of the core Choreomorphy research team and external ones. The tool, from its early requirements and design phases, has been informed by constant interaction with experts, initially in the form of design ideation interviews and focus group sessions and later through interactive sessions both in the lab and in other settings, where testing the current version of the tool became the stimulus for more concrete input and insights by the practitioners. The co-design sessions were organized with the following main objectives: a) to provide an insight about desired features for the interface and avatars (human vs. non-human shape, human vs. non-human articulation, face characteristics) and b) to explore the potential and impact of such a tool in an artistic, creative, and also educational context for dance practitioners that wish to experiment with visual metaphors and imagery, c) to evaluate the experience as whole, since motion capture technologies are not widely used by dance practitioners and for the majority of them this was a completely new digital experience. During this process, the team collected feedback also on the more technical interaction aspects of the tool, constantly improving thus the interface and interaction paradigm to better serve a whole-body interaction experience with movement being its main objective.

The co-design and evaluation activities organized can be roughly divided in three main groups:

a) Laboratory sessions with 3 dance practitioners that closely collaborated with our group and were able to provide continuous feedback. These included a professional ballet and contemporary practitioner, also experienced in other dance genres, one ballet/contemporary practitioner and one contemporary dance performer. They regularly experimented with different versions of the system and offered their input in the form of informal interviews and on-going commentary while using the system.

b) Presentation and interactive sessions in three science fairs where the system has been presented interactively to a wider audience, including children. These sessions included the professional performer who demonstrated the use of the system while members of the audience could try it through a Kinect device. Feedback was gathered through brief interviews.

c) Two Workshops with dance practitioners have been organized, with a total of 12 participants. In this case the participants had the chance to experiment with the tool at length and then provide their feedback in the form of a questionnaire and semi-structured interviews. The next paragraphs present in more detail the two Workshop participants profile and setting.

6.4.4 Choreomorphy Co-design Sessions

The first Workshop group, part of it shown in Figures consisted of 5 female and 2 male dancers, all with extensive experience in contemporary dance and improvisation. In particular, the participants were: one female contemporary teacher, choreographer and professional performer, one male professional performer and choreographer, two (male-female) graduate dance students and professional performers, two female advanced, amateur dancers with experience in contemporary dance, ballet and dance theatre, one female professional performer/actor with background in contemporary dance and somatic theatre.

Figure 82: Users trying Choreomorphy interface, changing avatars in real time, during the third workshop. The traces on screen demonstrate the path of the movement in space [80]

The second Workshop group, part of it shown in Figure 82 in a different venue, consisted of four female participants, and one male. In particular, the group included one experienced dancer and educator in Greek folk, one choreographer and certified Skinner Release TechniqueTM teacher, one professional contemporary dancer, choreographer and ballet teacher, two contemporary performers one of the with background in visual arts. Only two out of the twelve participants in both sessions had some experience with motion capture before. The participants were firstly briefly introduced to the purpose of the experiment and asked to sign a consent form agreeing to be recorded through video, motion capture and/or audio. After wearing the mocap suit, each participant individually spent on average 60 minutes experimenting with the tool through movement improvisation. No music was used in order to avoid additional bias and influence on movement. After the movement sessions a face-to-face interview followed with each of the participants and they were asked to complete a questionnaire to provide additional input.

For the user experience and usability part of the questionnaire, we used the UEQ - User Experience Questionnaire which foresees 6 scales measured through 26 questions (seven-point Likert-scale from -3 to 3). For our evaluation we used the five of the six scales as most relevant, Attractiveness, Perspicuity, Dependability, Stimulation, Novelty. Attractiveness is a pure valence dimension.

6.4.5 Results: User Experience and Usability

As it is shown also in Table 9 presenting the UEQ results, users were enthusiastic with the UX aspect of the tool. As one them noted:
“I felt interest and curiosity, it was a completely new experience!”. As it will be shown later in this section, the participants felt the experience was engaging and attractive, absorbing them in a novel way of experimentation through interacting with a virtual altered and augmented self. Again, as shown from the results, the users, although positive were more reserved with the pragmatic aspects of the tool (perspicuity and dependability), due to two main reasons, identified in the interviews. Firstly, the environment of the lab and the idea of performing with the evaluators present, to them an audience not focused in the performance itself but on the technology was to a certain degree daunting and did not make them feel at ease.

Secondly and most importantly, the users did not feel in complete control of the experience. With the objective to have them focus in the performance, the evaluators were handling the controls of the experience, with the participant’s instructions. Most of the participants would have liked to be allowed to control the experience themselves and have some “alone time” with what was for them an exciting new piece of technology. Impact and potential for dance performance As already mentioned, the main strong point of the approach was that the different avatars were seen as an augmented mirrored-self that allows the users to see their movement but at the same time to distance themselves from their own self, emerging thus as a new character or moving creature. Therefore, as we expected, the different avatars created for the dance practitioners a creative, immersive experience which stimulated their movement improvisation. Most of the participants explained that this marginal perception of the avatar as their own self was a motivation to new movement patterns.

It was interesting that a kinetic relation was forming between the physical and virtual self,

Table 9: Results on the five selected UEQ scales, in the range of -3 to 3. Average values and standard deviation is presented UEQ Scales [80]

	Average	Standard deviation
Attractiveness	2,514	0,435
Perspicuity	0,571	1,367
Dependability	0,583	0,736
Stimulation	2,571	0,460
Novelty	1,476	0,964

as sometimes they felt that the avatar was leading and vice versa, although in fact it was always their own movement that was reflected. One of the participants noted:
"At some points I felt like the avatar was not me, but rather that I was just initiating its movement. I became more and more curious about moving in different ways and trying to affect the visualisations." Another participant adds,
"I was surprised when I saw myself through the avatars. I was trying to move according to the shape which I was seeing every time. Each avatar triggered me in a different way. So, my movement was affected by the avatar. I really liked it, because I was discovering all the time new movements." An interesting aspect to investigate further is the perception of the "empathic" relation gradually forming between the dancer and the avatar. As one of the performers notes:
"At the beginning the emotions where not connected at all between the avatars and me. We were kind of separate, the avatar and me. But then, very empathic, narcissistic, playful and equal emotions started to trigger between the avatars and me." Some participants reflected on how the Choreomorphy interactive experience allowed them to move in a new body, with different size or different gender. One of the professional female performers, who is also a choreographer and dance teacher, notice: "I'm a small shaped dancer, so seeing myself as a bulky avatar with big volume, was an interesting experience and triggered me to move in new ways". While a young male choreographer and dancer comments: "Seeing myself dancing as a female avatar was an interesting and strange feeling. It was amazing! I like the fact that most of the avatars were gender neutral. I was mostly intrigued by some avatars where the human shape was distorted. I would like to play more with this aspect". In addition, dance experts commented on the way the visualisations allowed them to actually see, what in the real world they can only imagine through imagery techniques: "It was great playing with the traces and the trails. Usually in the dance studio you get instructions of trying to imagine the shape of your movement traces, the trajectories, but with this tool I could actually see them!" The moment of changing from one avatar to another was always a moment of excitement and a focus of attention for the dancers. Last but not least, it was interesting to see how the usage of the system by each one of the individuals, revealed something about her/his dance practice. For example, one of the performers who never uses the mirror in his practice, preferred to not look directly on the screen while dancing but to use more his peripheral vision. The performer who had also an acting background, improvised with voice and speech and explained that

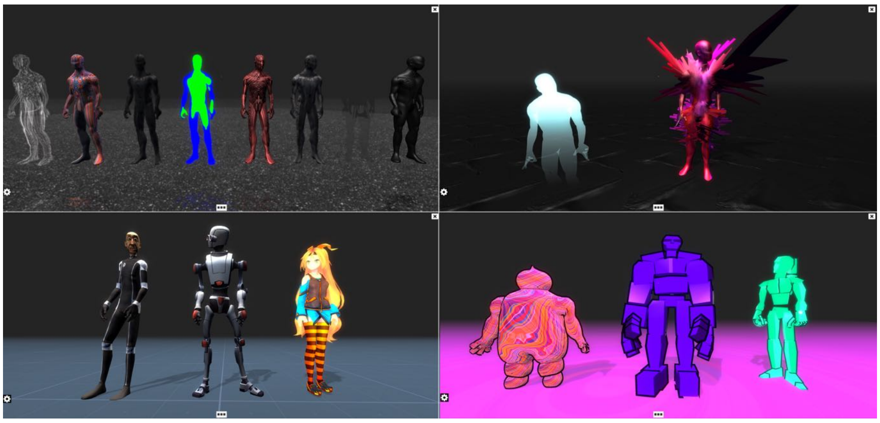


Figure 83: Some of the avatars that have been tried during the sessions and can be characterised as a) Abstract Anthropomorphic (Static and with animated textures, b) Distorted Anthropomorphic, c) Cartoonistic and d)Abstract Cartoonistic)

she would like as an additional feature to be able to produce different voices and sounds while moving through the avatars.

6.4.6 Digital Body Representations and Virtual Environments

Through the co-design and evaluation sessions, the use of a variety of avatar types, environments and visual effect characteristics is being explored resulting in new visualisations added to the system.

6.4.7 Avatar Variations

As the co-design sessions confirmed, avatars are not simply digital-virtual bodies, but also graphical representations of identities. In this case the avatar not only conveys the movement, but depending on its shape, size, anthropomorphism vs. abstractness, gender, articulation, color and texture, it may convey particular movement and character qualities. In the case of the dancer seeing her/himself as a moving avatar, instead of his/her real physical body in the mirror, may create a novel and captivating experience as the kinesthetic feedback is matched with a brand new visual feedback. Taking into account the deep connection between body representation and dance practices, and also the need to go beyond the stereotypical representations and explore the potential of moving in a different body, the question of designing appropriate avatars for such experiences becomes critical. Through the constant interaction with users, different avatar types and variations have been explored in an on-going effort to categorize them and identify patterns as to their suitability for different contexts and practitioners.

The Choreomorphy avatar library at the moment contains two main avatar groups, a) Abstract Anthropomorphic and b) Cartoonistic. The first category can be distinguished by the lack of face characteristics combined with humanoid body shape, as shown in Figure 83

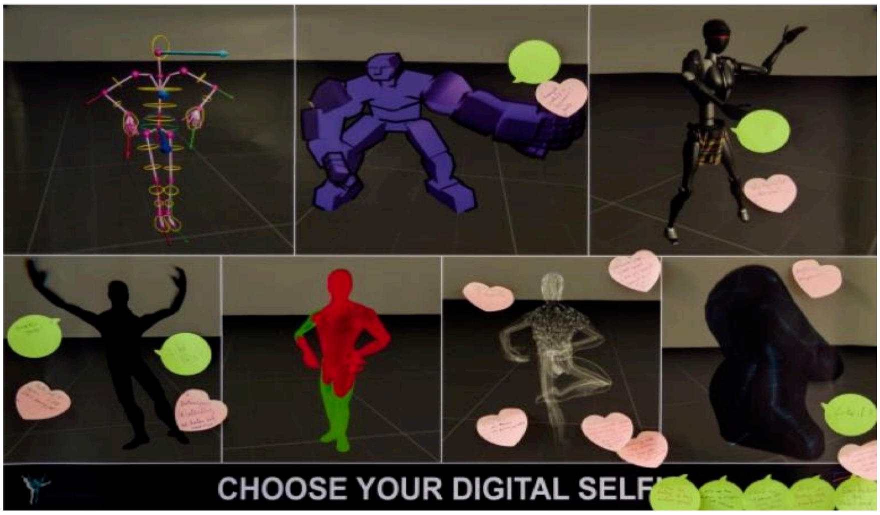


Figure 84: Chose your digital self: participants were able to provide feedback on a poster including a variety of avatars

The basic characteristic of the second category is the resemblance to a cartoon character that maintains the familiarity of the human body shape but also abstains from realism. Both basic avatar categories cover a wide range of character representations that could match the user's preferences for their dance improvisation. It is worth mentioning that, despite the fact that the avatars share the same basic characteristic of the category that they belong to, they differ in other features. As a result, we divided them to subcategories according to more detailed qualities.

During the workshop the participants were able to provide their feedback on a poster including a variety of avatars, as shown on Figure 84

6.4.7.1 Motion and Scene Visualisations

The scenes are divided in themes and each one of them stimulates the imagination of the user to choose it according to their aesthetics and current needs. Some of the scenes are pictured in Figure 85. The strength of the system is that by combining the different features such as the avatar, scene, trails or traces, the resulting environment can effortlessly offer a very different atmosphere and aesthetic, transforming from a colorful, pop, cartoonistic, to a more abstract and poetic one.

For the purpose of experimentation and evaluation there have been implemented several types of visual effects such as particle systems, motion trails and motion traces. Particles systems, motion trails and motion traces are considered to contribute to a better understanding of the user's movement trajectories and motion through space. Similar examples have been applied in augmented performance [27], visualisation of movement qualities [86], while visual metaphors for analyzing space have been used by various choreographers, from Rudolf Laban to William Forsythe. In fact, they can work as an extension of the body limbs and clearly depict the path of the motion and the virtual shapes that the

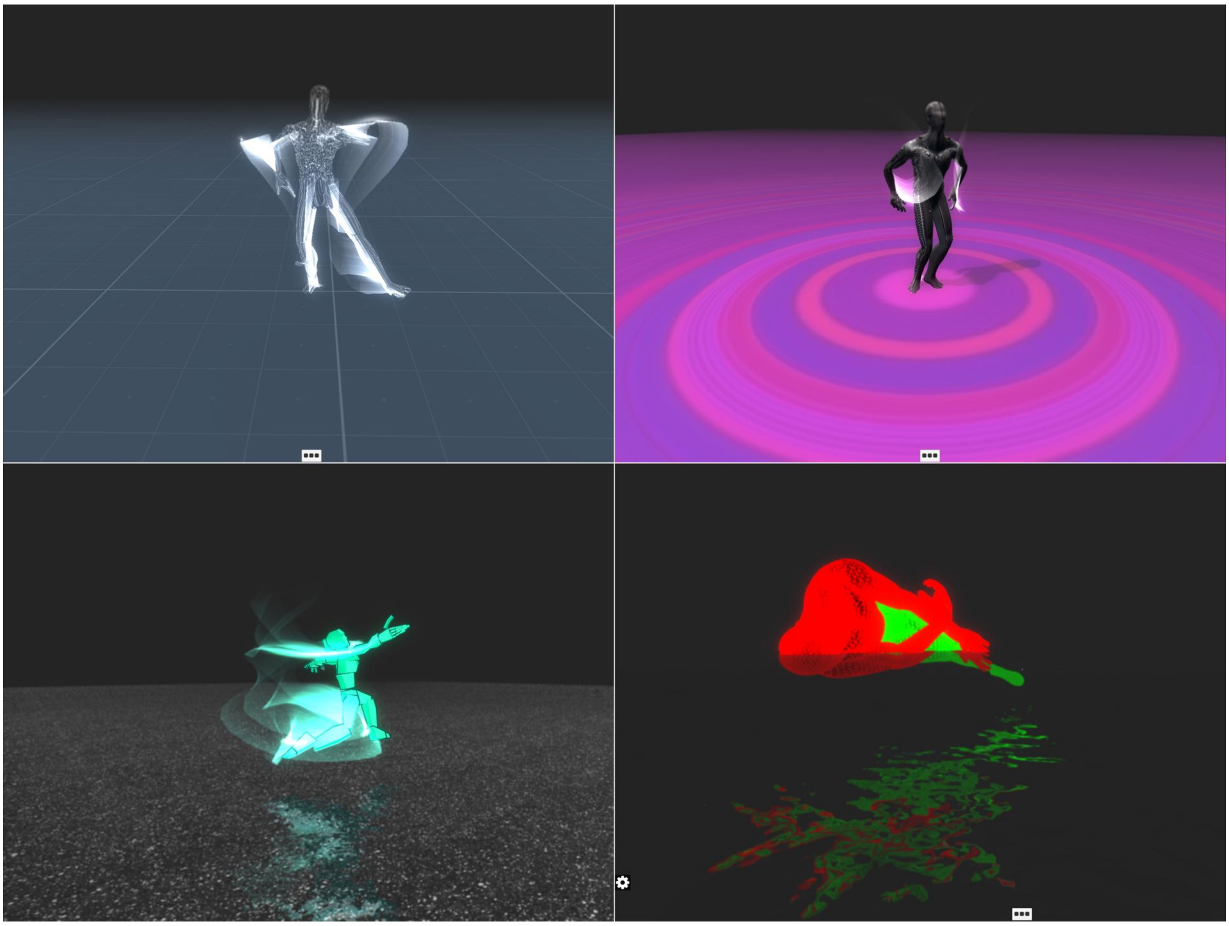


Figure 85: Different scenes used in Choreomorphy during the sessions with the dance experts [80]

mover draws in space. This metaphor has also been used in other artistic and research installations. This effect has been characterized as highly interesting and useful by the majority of the participants throughout the various sessions and co-design activities. The motion trails and traces, combined together, enable the dancer to obtain full feedback of their movement trajectories and speed and emphasize the feeling of motion. The trails help the user to keep track of the visual information about the previous positions her limbs, while the traces provide visual information about the rotation and position of each limb. The user can adjust the time that the motion trails remain rendered in the scene before they fade out. For each avatar there are specific color-themed motion trails as shown in Figure 80 and 82 The co-design sessions with users, not only highlight the importance of the graphical representation of the body in digital environments for dance learning and creativity, but also show the possibility for an emerging tool for artistic creation and exploration of movement beyond the conventional ways of moving, which are deeply rooted in the way we perceive our own body with its particular shape, size, gender characteristics, etc. All of the participants felt that they would possibly or definitely use such a tool in their practice if they would have the chance to deal with the practicalities (hardware availability and cost). The interactive avatar is the reflection of the performer, but on the same time the avatar depicts a character, a dance partner which can inspire the dancer to explore different ways of moving. Both within the framework of artistic experimentation, performance and creativity, and in the context of education, visual metaphors of movement, shape and qualities can be a powerful tool and raise many scientific and research questions.

Through the dedicated sessions with dance professionals in the lab, all participants commented on the fact that each avatar inspired them to move in particular form or quality, and overall their mood has been largely influenced by the avatar chosen at the time in the way they moved and improvised. Nevertheless, during the co-design and evaluation sessions, it was hard to identify any particular patterns of movement related to the avatar on the visualisation, neither to the preference towards a very specific avatar. Another interesting outcome was that the majority of the participants commented on the fact that each avatar created different emotions and that depending on the avatar they would identify with the avatar as a “mirrored-self” or not. According to the feedback received, the abstract anthropomorphic avatars were closer to being identified as a reflection, or shadow, rather than a separate entity. Taking into account the analysis of the video recordings, and also the feedback during the interviews, the abstract anthropomorphic avatars created a more mysterious and esoteric mood which was usually reflected through smaller, cautious movements and stillness, while it also made the users wonder “what is this, is it my shadow?”. In the case of the cartoonistic avatars, they frequently led to laughter, bigger and more rhythmic movements and a more relaxed and playful mood, while most of the participants had the feeling of moving or puppeteering another creature, different from themselves. The moment of transformation was always a very intense moment in terms of reaction, a fact which might be connected with a surprise of seen it for the very first time. We are continuously investigating different interactions and metaphors which will take advantage of this movement of transformation in a more meaningful way. The Kinect version of the tool which has been used in a performance session for wider audience including children, indicates a big potential to be explored in this direction. Finally, another interesting part of the user feedback, is the wider discussion on whether the experience of seeing oneself as a digital avatar different from one self diminishes or amplifies the “narcissistic” effect of the mirror, i.e., the obsession of constantly seeing one’s own reflection on a two-dimensional surface (mirror, screen or projection).

6.4.7.2 Discussion and Open Challenges

In this section, we presented Choreomorphy, a novel interactive system which is compatible with a variety of motion tracking and capture systems and allow to explore time. The system is in its prototype form and has been resulted from a long-term co-design process and experimentation with experienced dance practitioners and also demonstrated and used in events for the wider public of different ages. This process led to the definition of a number of design decisions, based on user requirements.

As a digital environment for dance practice, Choreomorphy satisfies the following principles:

- Allow the dance practitioner (user) to deepen the understanding and perception of movement through self-reflection and multimodal exploration.

- Follow a teaching approach which goes beyond the traditional or mimetic teaching approach, where the teacher or choreographer makes all the decisions. Since digital learning and practicing environments have the advantage of allowing the practitioner to self-practice without the anxiety of being judged by an austere dance teacher or choreographer, it is important that the feedback provides rich material for self-reflection and goes beyond the “right/wrong” paradigm.

- Inspire the dance practitioners to generate their own kinetic material and embody the different principles and concepts of movement based on their own sensorimotor abilities, learning or artistic objectives and self-expression potential.

- Provide tools to explore and enrich their movement vocabulary, movement qualities and expressivity range through imagery, instead of mimicking particular steps and movement forms and structures.

- Create an experience that would not be possible in the real world. One way to address digital dance environments for learning and practice is by implementing a digital environment which aims at simulating the real studio experience. On the other hand, there is a dynamic potential in stimulating dance practitioners’ imagination through designing experiences where the dancers can test with whatever is unfeasible in the real world, extending the physical limitations of the body, space and time. Consequently, creating digital environments and prototypes, where dance experts can explore a wide range of visualisation options, experiment with them and then reflect on the experience becomes a necessity in order to take interactive digital dance improvisation and education tools closer to the actual needs of advanced dance practitioners.

In addition, taking into account the importance of imagery in dance practice, Choreomorphy can be applied to digital improvisation sessions to advance research on dance movement by exploring the impact of body and movement representation in digital environments and draft requirements regarding the avatar characteristics (anthropomorphism, textures, shape, gender, etc.) and their influence on movement improvisation. Our on-going work is focused in the visualisations themselves, to understand which characteristics are more interesting to the practitioners and how they affect their practice. It is also focused in exploring alternative ways to make the interface between the dancer and their digital counterpart, the avatar, even more transparent, through the use of different interaction paradigms and possible VR and or AR equipment. Finally, we plan further user sessions with dance experts.

6.5 Dance Interactive Learning Systems: A Study on Interaction Workflow and Teaching Approaches [172]

Motion Capture and whole-body interaction technologies have been experimentally proven to contribute to the enhancement of dance learning and to the investigation of bodily knowledge, innovating at the same time the practice of dance. Designing and implementing a dance interactive learning system with the aim to achieve effective, enjoyable and meaningful educational experiences is, however, a highly demanding interdisciplinary and complex problem. In this work we examine the interactive dance training systems that are described in the recent bibliography, proposing a framework of the most important design parameters, which we present along with particular examples of implementations. We discuss the way that the different phases of a common workflow are designed and implemented in these systems, examining aspects such as the visualisation of feedback to the learner, the movement qualities involved, the technological approaches used as well as the general context of use and learning approaches. Our aim is to identify common patterns and areas that require further research and development towards creating more effective and meaningful digital dance learning tools.

6.6 Interactive Dance Learning System Workflow

Focusing on recent advancements and state of the art on Dance Interactive Learning Systems, using both Whole-body Interaction Technologies and/or AR/MR/VR technologies, we can identify a specific, common workflow which exists (sometimes) partially to facilitate the interactive, learning experience. The general workflow presented in Fig. 4 consists of four phases of user interaction with the system: 1) Student Moving, 2) Capturing Student's Movement, 3) Processing Movement Data, 4) Feedback

As Figure 86 shows, for each one of the phases, which can also be seen as individual components of a system, the designer needs to answer several questions before proceeding with an implementation. Depending on how the critical questions are answered in every phase the detailed workflow might lead to different experiences, where some phases are more prominent than others, depending on the teaching approach, the trade-off between cost, complexity and effectiveness, and the actual needs of the dance teaching example. Based on this a DILS can vary from a very simple, low end application to a more sophisticated lab setting. However, not all DILS necessarily fully develop all the phases of this generic workflow as it will be demonstrated in Section 5. Depending on the design decisions, there are DILS which seem to skip one or more of these phases. In fact, they all phases are implemented in a less prominent manner for the student and without necessarily being less effective as learning tools. For example, an Initialisation phase might be less obvious for the user, in a Generative approach, where the Student is not shown of particular movement to mimic, but leave more freedom to the user to do what they will, making the system less intrusive. Another example would be a system which do not necessarily evaluate the student's movement through comparison, but only maps the movement into another modality e.g., sounds with similar quality providing self-reflection.

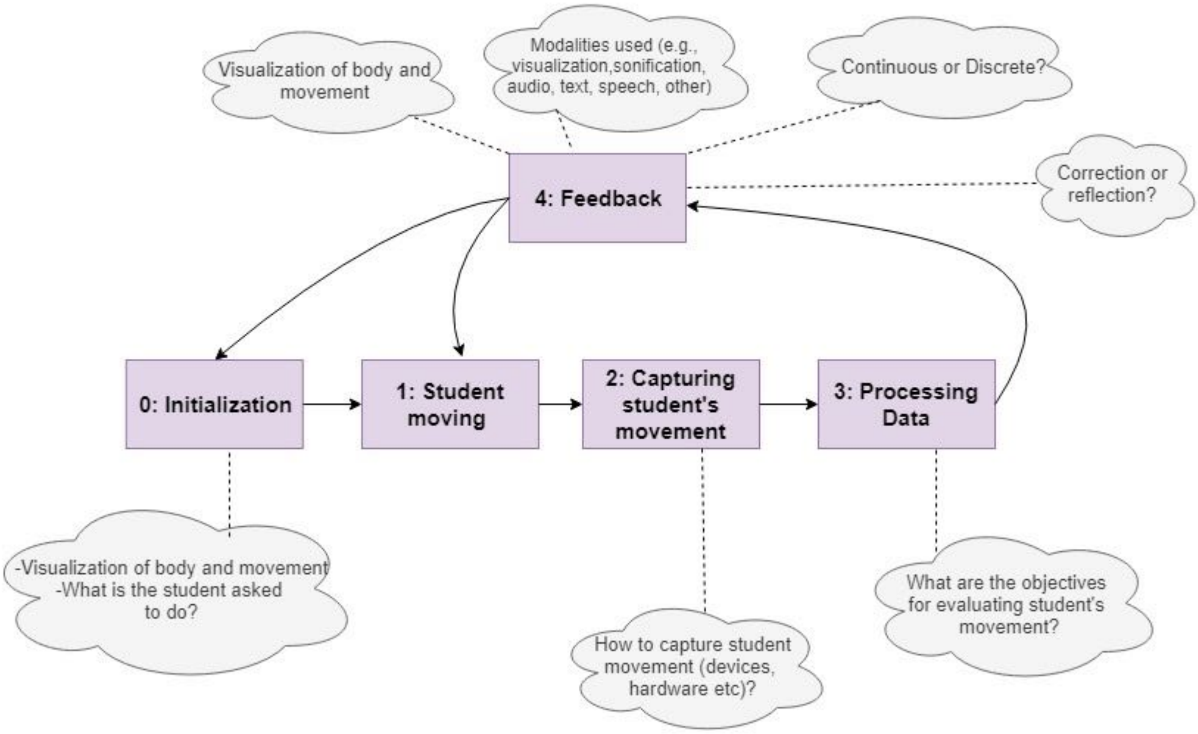


Figure 86: Interaction Workflow

The rest of the section focuses on the definition of each, as shown in Figure 86, and presenting the main design questions which are connected with each one of them. These questions constitute complex Human Computer Interaction challenges, some of which are presented in our the previous section. As we will also demonstrate in the next section, with examples of existing DILS, the most important factors which define a DILS in regards with dealing with those questions are the following: Initialisation: How the experience starts?

- Initiative (Frequency of Intervention/Timing) -What is the student asked to do?
- Visualisation of body and movement.
- Capturing the Student's movement: How to capture the student's movement?
- Equipment and setting (devices, hardware, etc.) Processing (Movement) Data: What are the objectives for evaluating student's movement?
- Movement parameters to evaluate
- Feedback Phase:

  Visualisation of body and movement

  Modalities used (e.g., visualisation, sonification, audio, text, speech, other)

Continuous vs. Discrete

Correction vs. Reflection

Phase-0 Initialisation. In every interactive dance learning system, this is the pre-phase where the content presentation takes place. In this phase, the system invites the student to move, usually, but not always, through a demonstration of a prototype movement performance with an avatar. The movement of an expert, which is considered to be the "ideal" or "correct", is captured by a motion capture system and is used in order to animate an avatar. We will from now on, refer to this avatar as the teacher's avatar, since it is used to demonstrate the movement to the student, and sometimes also to compare the student's movement against it. However, there might also be other ways of providing the student with instructions, such as using abstract visualisations, or even other modalities, promoting thus a more Reflective or Generative approach on dance learning. Therefore, the presentation phase does not necessary imply the demonstration of a specific movement, but rather the way to stimulate the student's reaction and invite the student to start the experience.

Initiative.

This point focuses on the initialisation of the digital learning experience. In our previous work [33], this point was also described as Frequency of Intervention/Timing/Initiative. The initiative is related with how the experience is triggered and to what extent the students lead this experience or expect from the DILS to guide them with specific tasks. If this can be seen as an analogy between the Human to Human Interaction experience of teaching, the approach can vary depending on the teaching approach. So, for example a DILS which is designed after a Generative or Reflective approach is expected to leave the initiative to the student, through providing choices, and flexibility, whereas a DILS following the Traditional or Mimetic approach is expected to ask from the student to perform specific movement sequences and activities.

Visualisation of body and movement.

The question of how to visualize the initial move is present in both the Initialisation phase and also during Feedback phase. The way of presenting the student's and/ or teacher's movement, is another characteristic to take into account at the feedback stage. The representation of the student's move individually, or in combination with the correct move (the teacher's move) is a very common way of providing corrective feedback as we will see in the next section. The way chosen for this visualisation is also a characteristic to be examined for each system. Amongst the most common visualisations is a realistically rendered avatar or a skeleton avatar. This particular phase can raise many research and design decision question, as the representation of the body using 3D offers many opportunities for augmentation and abstraction of the body, as well as the risk of falling into the uncanny valley in case of using photorealistic anthropomorphic avatars. In addition, as we point in the previous sections the visualisation can never be neutral, and it always somehow affects the qualitative aspects of movement. On this point, we should also differentiate between the visualisation of the virtual teacher body and movement, vs. the visualisation of the students' body and movement. In the different DILS, there are cases where only the teachers' body and movement are visualized for giving instruction, cases where both teachers' and students body and movement are visualized side by side to provide visual comparison, and finally there as some DILS that only provide visualisation of the student's body and movement for self-correction and reflection.

Two additional points on which we focus later on in this work are how the teacher's ideal movement has been captured (or generated) and how the different choices (e.g., selecting what to learn) are provided to the student.

Phase 1-Student Moving:
The part that follows the initial presentation is the phase where the student reacts and starts moving. The student usually, but not always, depending on what they are asked in the initialisation phase, they are trying to mimic what they see in the presentation. Therefore, another aspect to be examined is the "teaching approach". The teaching approach that is applied in each interactive system can be Mimetic, Reflective, Generative or Traditional (See Section 2). It is possible that there is a visualisation of the student's movements already in this phase, although this mostly takes place in the feedback stage after the movements have been captured. For example, there may be a reflection of the student's image on a mirror. Some of the existing systems stop at this stage, repeating the loop of presentation and re-action and exhibit limited interaction possibilities in comparison to the ones that cover the full cycle of the interaction workflow.

Phase 2- Capturing the Student's Movement.
The next phase, which is implemented in some of the existing educational systems, is the part where the motion of the student is captured through motion capture devices. The technology for capturing the student's motion is an important parameter to be examined for each system. The technologies for capturing the student's movement can vary from full optical or inertial Motion Capture technologies, to lower-end technologies such as gyroscopes, accelerometers, Microsoft Kinect devices, etc. Most interactive systems, use capturing mainly for real time processing in order to provide feedback. Nevertheless it is important to note that this is also a mean of recording movement, and potentially create personal archive for a dance practitioner or student, either to reflect on it later, compare their progress across time, or re-use in a variety of applications that require study of human movement.

Equipment and setting.
Another factor relevant with this phase is the type of equipment used and setting of motion capture, in relation to what is expected from the student in a task. Different equipment and settings present a variety of advantages and disadvantages, as Hong et al. report [112]. Several DILS described in the next section are using full optical motion capture technologies. This allows collecting high accuracy and quality data, but requires a specific laboratory setting and expensive, sophisticated equipment handled by expert personnel. On the other hand, lower cost and complexity equipment such as an individual or a combination of Kinect devices, inertial motion capture equipment or other depth cameras offer an easiest more cost-effective way to capture the students' movement, although they might present some limitations in terms of accuracy. It is also worth mentioning that each type of equipment can be considered appropriate or not, not only based on accuracy and ease

of use, but also based on the characteristics of the dance genre and learning practice to be applied.

Phase 3 -Movement Data Processing.
After capturing, the processing of the data is the next possible stage. There, in most cases, the movement performed by the student is compared with the one of the teachers. The most common way for movement comparison is by measuring the Euclidean distance between the two body parts and determining whether the divergence is within desirable limits. The method of comparison that each system uses is presented in the following sections. Nevertheless, depending on the context, equipment, teaching approach adopted, the aspects of the movement to be analyzed might vary (shape of movement, sequence of steps, rhythm, qualities, etc.). This particular phase, as well as the initialisation phase in case pre-recorded data are stored, present a number of data related computing problems such as storage, management, semantic search, pattern recognition and similarity search, etc. Another critical question of this points is how and when the data of students are stored or shared. Monitoring one's movement across time or just record to reproduce later can offer a variety of benefits not only for dance, but also in other related to movement applications also for teachers or physicians e.g., it might be a tool for identifying common mistakes in data becoming from different users.

Movement parameters to evaluate.
What are the objectives for comparing the students' movement vs. the ideal movement? Motion accuracy, rhythmicality, body balance, weight distribution between two feet, expression, effort, fluidity etc. can be some of the qualitative and quantitative aspects that describe a dance performance. We consider that the aspects of evaluation are the qualitative objective of the feedback, or in other words, what the feedback refers to, so we incorporated them in the feedback category in order to give the reader a holistic understanding. It is also worth mentioning that this aspect can be highly related to the specific scenario and context of use of a particular tool (dance genre, learning objective, age, level of expertise, etc.) as well as to the technologies used to capture the students' movement since they create a limitation. If for example the ideal movement is produced through a full motion capture optical system, with high accuracy, it is not very meaningful to compare the accuracy of movement while the students' movement is captured through a depth camera, with much lower accuracy.

Many aspects are involved in describing system feedback since it is a crucial stage for the system usability and efficiency. The "visualisation of the correct initial movement in the initial demonstration", if there is one, can be considered the ideal movement that its characteristics are to be examined next and compared to the students' performance. Last but not least, this phase can also include a presentation, through more traditional means such as video, audio, oral instruction, texts or any other output of the system which will evoke the student to start the learning experience workflow.

As mentioned above, in the phase of feedback some of the most important design questions are related to when and how to provide feedback to the student. In other words, the "Frequency timing-initialisation" as well as the "way of intervention" that are also presented in the previous section, can be further analyzed into the following main aspects:

- Visualisation of body and movement
- Modalities used (e.g., visualisation, sonification, audio, text, speech, other)
- Continuous vs. Discrete
- Correction vs. Reflection vs. Judgement

Continuous vs. Discreet feedback.
Another feedback categorisation describing the interaction is whether the feedback is continuous or discrete. For example, visualizing one's movement in real time is a way to provide feedback continuously, without interrupting the sequential or continuous process of dancing. In the discrete mode of interaction, the user performs a movement, or a short sequence and the system responds with feedback [33]. An interactive system can use all tools that are used in corrective feedback in a continuous or a discrete way or even in a combination of both.

Correction vs. Reflection.
A distinction is whether the system provides corrective or reflective feedback. This question is related mainly with the Feedback but the answer to it also affects the Processing of Data stage. Correction, which occurs in a traditional educational model, means that the system has set a codification in order to show to the students how close they are to the "right" movement or manner of movement. Another important point regarding corrective feedback is to differentiate between providing an overall score or judgment and providing specific corrective instruction suggesting improvements on particular body parts or aspects of movement, as Trajkova highlights [195]. The corrective feedback can be either explicit on body parts, by using techniques like color coding on body parts, overlaid avatars, etc. to provide visualisations useful for indicating the student's mistakes, or an overall evaluation of the student's performance by providing scores in numeric or graphical format. These characteristics are explained in detail in the next section.

According to the recent, and contemporary approaches to dance, especially following the Reflective and Generative approach, feedback does not necessarily need to be in the form of a "correction" or a numeric "score" [2] comparing student's movement with an ideal one, especially if the tool is addressing advanced, experienced dancers and dance genres where the right and wrong way of moving can be very subjective, as is the case of contemporary dance. An interactive tool can also facilitate an effective learning experience if it provides structures and modalities for self-evaluation and reflection. This parameter differentiates the feedback given by the system, depending on the inclusion of semantic meaning. In Reflection, however, the feedback does not imply "right or wrong" semantics; the system provides open feedback on what the students do. This is usually the case when the Reflective or Generative teaching approach is applied.

[2]Please note here the different meaning in the word "score", as in this case we are not refering to a movement dance score created by the notator or dance practitioner but to the numeric score used to evaluate once performance within a gamified experience.

Apart from the aforementioned characteristics which are generally relevant in most of the interactive systems in this review, there are other characteristics relevant in some of the systems, including the technical means for motion capture of the teacher's movement, devices, context of use, target group, portability, online vs. offline use, commercial or academic usage and the overall system architecture approach. These features are also very important for the description of an interactive dance training system. The type of dance, target group and whether the system is commercial or academic will be presented in the summary Tables 10 and 11.

In Tables 10 and 11 we present characteristics of existing Dance Learning Interactive Systems (DILS) based on how they relate to the defined workflow. We examined in detail 21 DILS based on literature research.

6.7 Survey Results

To what follows we present the outcomes of our survey based on literature and examining exisiting systems in relation to the proposed Workflow. Dance Interactive Learning Systems (DILS) and experiences can definitely enhance and improve dance learning and teaching as well as dance performance. Moreover, interactive dance training systems can contribute a great deal in researching bodily knowledge, innovating the teaching of dance, preserving cultural heritage, revolutionizing choreography, widening the access and practice of dance and augmenting the experience of performing. All of these fields are very promising and merit further research. Therefore, we have collected the interactive dance training systems that could be found in bibliography, and we have categorized the characteristics that describe them.

After examining each system in terms of the aforementioned aspects, the findings suggest particular trends in this field. Each dance training system offers a different degree of interactivity, with the ones that provide feedback to be considered as highly interactive and the ones that do not as less interactive. The majority of the systems were found to be highly interactive, as they provide feedback to the users by evaluating their performance or indicating their mistakes. Feedback is a very crucial characteristic for the student's progress and with the current state of the art in motion capture technologies, we expect that motion capture will soon be much more accessible also in low cost solutions than it was in the past. Moreover, all the systems examined, provide real time feedback allowing the student to have an immediate understanding of their performance and their mistakes.

In terms of the system workflow, the majority of the interactive systems choose the following model: First there is an initial demonstration of the correct movement, the student's move is captured, this move is directly compared with the correct move (teacher's move) and feedback is provided. Some systems use variations of this system's workflow, but this is the most common scenario. The most popular and yet obvious way of comparing the two motions is by measuring the Euclidian distance between the joints.

Concerning the technological means of capturing the motion we have come to the conclusions that optical motion capture is usually used for capturing the expert's (teacher's) movement whereas, MS Kinect is used mostly for capturing the student's movement. This is only natural, since optical motion capture is much more accurate but also much more expensive, so it is normally used once (for capturing the exemplar, ideal movement) and in that way, the quality and accuracy of the demonstrative movements are high. Ideally, the student's movements should also be captured by optical motion capture. Some of the interactive systems do so, however it is understood that this is not yet a cost-effective solution for a product to be made available to this consumer target group. New motion capture systems are expected to offer more accuracy in low cost.

The devices (hardware) that are mostly chosen as equipment apart from the motion capture devices, in most cases are simple 2D screens, as shown in Figure 88. Although quite a few systems try to increase the level of immersion and interactivity with augmented reality devices (head mounted displays, augmented reality mirror, etc.), most interactive systems that are presented in this work, use a simple screen as an interface of interaction. Despite of the two dimensions, these systems offer a 3D interaction since the users can change their point of view, so that they can observe the teacher and themselves from different angles.

6.7.1 Modalities and Body Visualisation

Visualisation of student and teacher is met in all interactive dance training systems. The modality chosen more often for visualizing the teacher in the initial demonstration as well as the correct position (teacher) in feedback is a realistically rendered avatar. The same applies for the visualisation of the student in feedback. There are also a few cases that a skeletal avatar is chosen instead of a humanoid avatar. However, the ghost metaphor used in the interactive system "Just Follow me" [209] , is a quite different scenario. The results from Yang et al.'s work [209], suggest that the ghost metaphor would be very useful in slow motion training of a movement. This is quite interesting, since practicing of a movement in very slow motion is often a pre-condition for being able to execute this movement faster.

Generally, designers have not been experimenting much with the modality of visualisations, probably because the majority of the systems are designed for dance genres that require precision in movement, like ballet. For other kinds of dances which are more abstract, like contemporary dance, experimenting with other types of visualisations, abstract or not, is an interesting direction, at the moment investigated in the Choreomorphy tool. Experimenting with visualisations is a common technique used in whole body interaction augmented performances and maybe with the proper research it can contribute a great deal in dance learning and training as well. As a teaching approach, mimesis is the one applied in most of the systems.

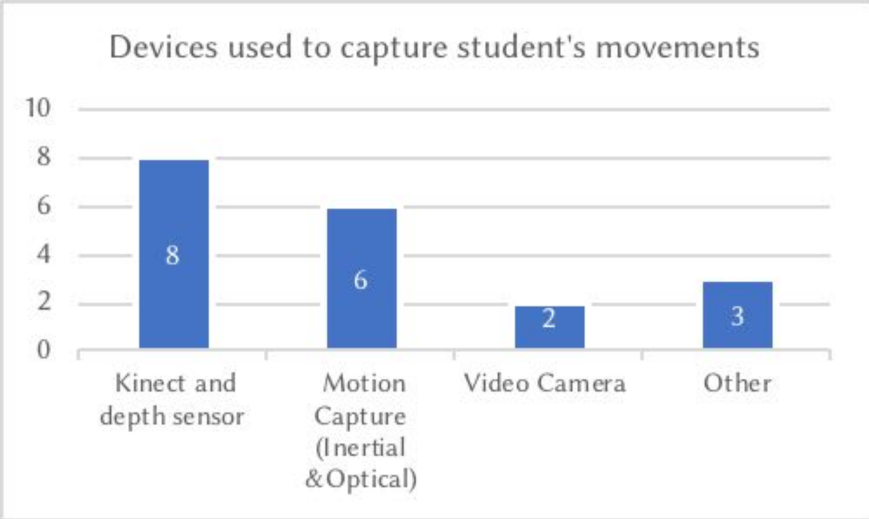


Figure 87: Number of examined DILS using per devices used to capture students' movements

6.7.2 Evaluation and Feedback

The aspects of evaluation are mostly motion accuracy and rhythmicality, when there is an initial demonstration to compare timing. There have been some attempts of evaluating more qualitative aspects of dance like expression, including a variety of movement qualities as they are considered essential for dance performance and training. In terms of feedback, correction, but also overall judgement in the form of a score or a value, is mostly applied. Corrective feedback is provided through color coding, showing the teacher's and student's avatar side by side and by overlaying them. Providing scores is also another very popular way of feedback used by almost every system. The score can be given in the form of a number, percentage or chart for overall performance, or for each body part separately. According to the study, the way the system provides clear and valuable feedback is still an open issue which needs further investigation, considering also different modalities (visual, audio, verbal, tactile, etc).

6.7.3 The Metaphor of Augmented Mirror

Many of the systems examined above follow the metaphor of an augmented mirror. Although this analogy is valuable since it follows a real -life example, it brings the risk of perceiving movement mainly through a visual, two-dimensional perspective, whereas technologies such as, sonification of movement, Cave, AR, MR and VR can offer new opportunities in widening this perspective and only a few examples have explored the potential of three dimensionality as shown in Figure 88.

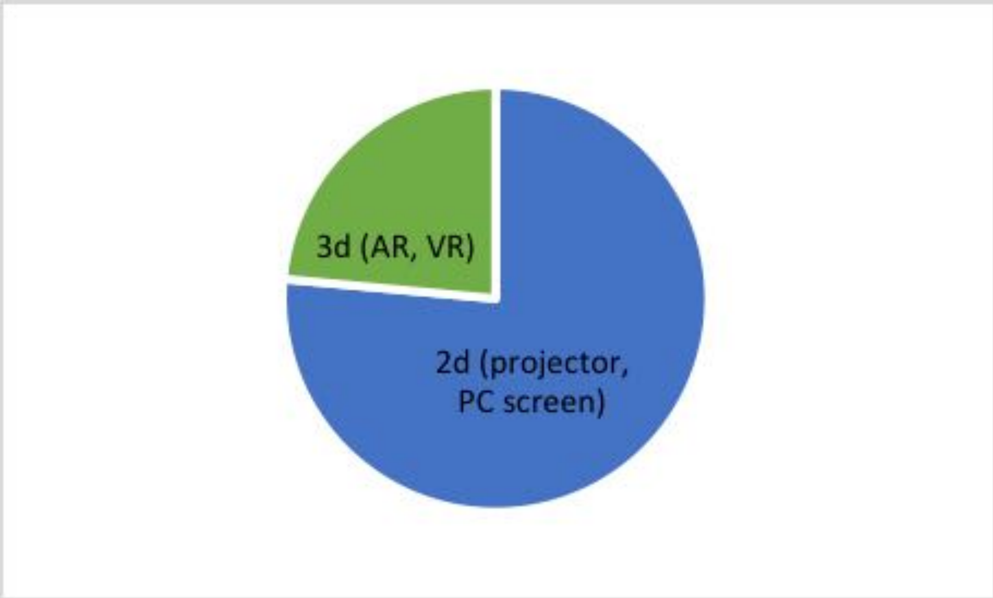


Figure 88: Number of existing DILS using 2D and 3D perspectives to visualize students and teachers' movement

6.7.4 Portability and Context

Another outcome from reviewing the interactive systems for dance training is that approximately, 50% of them are considered highly portable whereas the other half cannot be considered as such, since they demand complex or heavy equipment for their use.All systems suggest that they can be used either for home training or for classroom training and few imply that they can substitute the role of the teacher.

6.7.5 Opening and Sustaining and Interdisciplinary Dialogue

Future designers of interactive dance learning systems can use the various examples of other existing interactive systems as a source of inspiration. Collaboration in virtual environments has a lot to offer in dance training. The main conclusions regarding the open issues in the domain can be summarized as follows:

- Research for an effective DILS is an interdisciplinary process. Comprehensive representation of movement needs further investigation, exploring a variety of modalities (visualisation, sound, verbal descriptions, metaphors, etc.), looking also into what is been explored by choreographers and researchers in the field of dance and technology in general. Dance Interactive Learning Systems should most of all aim to be tools for transmitting bodily knowledge thus the way of representing the body and movement should be aligned with the philosophy and aesthetics of the practice nowadays. Designing an effective DILS requires both deep understanding of the dance practice, and requires interdisciplinary perspective including technologists of various expertise, educators, and artists.

- Bringing a DILS into the dance practice requires close collaboration with the dance community. Understanding the dance community requirements and apply not only user-centered design but also co-design where dance practitioners will bring their perspectives and needs early in the project are critical. Especially in creating tools for real-life and use in the studio where dancers learn, practice, rehearse, it is important to document early what a digital tool can add to a practice, or teaching and learning experience, always in relation to the context of use.
- To this point, it is necessary to stress that designing tools which introduce functionalities but also use of hardware to a bright new community of users it is a huge challenge. Since needs and specifications are defined from scratch it is very important to work with the dance practitioners rather than for them. In addition, evaluation is a huge challenge not only because of the complexity of technology but also due to the novelty effect which occurs when users react positive to the new experience not due to the experience itself but due to their enthusiasm of using cut-edge, novel technologies for the first time. Involving dance practitioners and experts in the early stage of design is key.

6.7.6 Dance Diversity Requires Diverse Solutions

There is no one solution to fit all. What works for ballet or Greek folk, does not necessarily work for flamenco or contemporary. Practices vary in the way the learning approaches are applied, in what are the learning objectives and on how they deal with specific movement vocabularies and forms vs. improvisation and qualities of movement. This is the first questions to answer for designing the tool: What is the most important factor in this particular dance genre or style: Precision? Form and shape of the body? Foot work? Relation to Rhythm? Movement qualities? How are they defined and could be measured? To what extent does this dance practice involve and rely on Improvisation and creativity? Collaboration? Communication and interaction? Tradition and other aspects of cultural heritage?

6.7.7 Going Beyond Mimicry and Judgement

Going beyond a score as feedback is critical. In relation to this, how and when the system provides feedback beyond a score value, giving comprehensive and clear feedback for both correction and reflection needs further thorough investigation. The student does not only need to know “how well they did” but to understand exactly how they moved their body parts and what they can do to improve in terms of trajectories, movement qualities, rhythm, and other aspects which seem important to this particular dance genre or practice. The existing DILS, according to literature show impressive achievements in terms of examining accuracy in time and motion and indicating the exact mistakes of the student. However, there is much more to conquer in order to make these systems efficient and meaningful for use in the day to day practice of dance education. Currently the majority of DILS adopt the Mimetic learning approach and the paradigm of mimicking a pre-recorded movement to learn, which is only one part of dance education. (Figure 87).

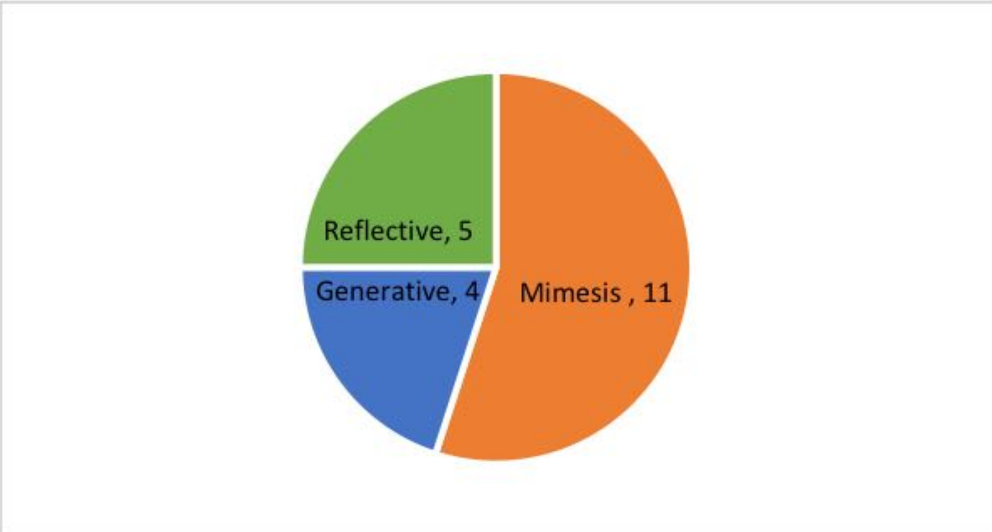


Figure 89: Most common Learning Approaches used in existing DILS

6.7.8 Learning Dance in Immersive VR Environments

Building simple prototypes to test how they work in real environments is important. While there are several interesting DILS in the recent literature, exploring state of the art technologies such as Motion Capture, VR/AR, Cave, digital tools for learning have not yet reached the studios apart from a limited experimental context. It is unknown if the reasons for not reaching wider audiences are only practical such as complexity, non-portability and cost of such installations, or the unwillingness of dance practitioners. Further research on actual needs and experimentation with simple devices and settings can help to understand the needs and narrow this gap between experimental research and practice. Although the aforementioned efforts show a great potential for effective dance learning, evaluating the long-term learning effectiveness of DILS is still an open issue. Most of the existing systems in literature, especially those using motion capture, AR and VR have been evaluated in terms of usability and user-experience in laboratory environments or during workshops. Nevertheless, these conditions are far different from actually using the tools in real-life environments (home, studio, dance class) and scenarios. Ideally, the users (students, practitioners, teachers) should be able to use the tools in real-life conditions for longer periods of time, which at the moment seems like a challenging issue due to the low portability, complexity and high-cost of the majority of DILS. By taking advantage of the possibilities offered by virtual reality platforms like Second life, more interactive concepts can be applied. In combination with the already presented technologies and methodologies, collaboration in virtual worlds can offer the possibility of an online real time class with students from all over the world while meaningful feedback can be obtained from the system for each one of them.

6.7.9 Dance as Field to Inform Embodied Interactions

Dance educators and practitioners, as experts in bodily knowledge can play a great role in human computer interaction design and revolutionize the concepts of co-design, embodied interaction and research through practice. We believe that designing and evaluating tools for artistic and cultural domains, can largely contribute to the computing domain, not only for the technological challenges they emerge. This intersection of disciplines poses the question of how we chose objective functions for evaluating expressive human behaviors; a critical question especially if we impose the "right/wrong" paradigm for integrating technologies such as AI, machine learning, etc. Inspired by M. McLuhan [151] we would question ourselves: what are the values and the behaviors that we are amplifying through expecting a technological tool to evaluate a complex, expressive and creative human activity?

Table 10: DILS characteristics in relation to the interaction workflow phases [172]

	DILS	Initialisation	Capturing student's moves	Movement Parameters to evaluate	Student vis	Ideal vis	Correction, Judgment, Reflection	Continuous vs. Discrete
1	Chan [48]	Demonstration of a movement by expert (3D avatar)	Optical motion capture	Motion accuracy, Musical Timing	-	Skeleton Avatar	Correction and Judgment: Side by side, Color coding, Score as number for each body part, slow motion	Both
2	Kyan [136]	Demonstration of a movement by expert (3D avatar)	Kinect	Motion accuracy, Musical Timing	Avatar	Avatar	Correction and Judgment: Side by side, Color coding, overlay, slow motion playback, score as number, score as graph, use of a metronome	Both
3	Camurri [44]	Student performs on their own or along with the teacher	Kinect	Movement Qualities: Dynamic Symmetry, synchronisationg	-	-	Reflection,auditory feedback –musical rewarding Value feedback	Discrete
4	Choremorphy [80, 199]	Depends on mode	Optical-Inertial Motion Capture, Kinect	-	3D avatar	-	Reflection: different avatar visualisations	Continuous
5	Delay Mirror [155]	Student performs	Video camera	-	Video image r	-	Reflection: delay of student's image	Continuous
6	e-Ballet [196]	Student performs specific movements	Remote real teacher	All aspects	Video image (augmented mirror)	n/a	Overlaid Dots on students' body parts.	Descrete
7	Alexiadis [6]	Demonstration of a movement by expert (3D avatar)	Kinect	Motion accuracy Timing	Avatar	Avatar	Correction and Judgment: Avatars side by side, Scores	Continuous
8	Usui [202]	Student performs a move (no teacher visualisation)	Motion Capture	-	-	Stick figure	Reflection	Discrete
9	Aristidou [13]	Demonstration of a movement by expert (3D avatar)	Optical motion capture system	LMA component: Body, Shape, Effort, Space	3D Avatar	3D Avatar	Correction and Judgment Qualitative ribbons, Side by side, pass-fail evaluation	-
10	Fujimoto [92]	Demonstration of a movement by expert (video image)	Kinect	-	Video image	Video image	Reflection: students watch themself performing like the teacher	Continuous
11	Kitsikidis [129]	User performs specific movements	Gyroscopes in limps	Motion accuracy, Rythmicality	3D avatar	-	Correction	Discrete

	DILS	Initialisation	Capturing student's moves	Movement Parameters to evaluate	Student vis	Ideal vis	Correction, Judgment, Reflection	Continuous vs. Discrete
12	Essid [83]	Demonstration of a movement by expert (3D avatar)	Depth sensors, multiple, cameras, inertial motion capture	Motion accuracy	3D avatar	-	Judgment score 1-5	Discrete
13	OpenDance [147]	Demonstration of a movement by expert (3D avatar)	-	-	-	-	Mimesis	-
14	SuperMirror [148]	Student performs a movement of their choice (no teacher visualisation)	Kinect	Motin accuracy	Stick figure	Stick figure	Correction and Judgment: Side by side skeletons, Color coding, “hits” or “misses”	Continuous
15	WebDANCE [148]	Demonstration of a movement by expert (3D avatar)	-	-	-	-	Mimesis	-
16	Whatever Dance Toolbox [170]	System presents a task that the user has to go through -performing a task using their body	Video Camera	white silhouette, video image	-	-	Correction: pass/ fail to the next task Reflection: Delay and reverse mode, Capture and replay and appear and disappear modes	both
17	YouMove [9]	Student watches teacher perform as a video	Kinect	Motion accuracy, Timing	Stick figure	Stick figure	Correction and Judgment: Overlaid figures, Color coding, Vocal instructions Scores	both

Table 11: Other non-functional characteristics of existing DILS [172]

	DILS	Capturing Teacher's Moves	Other devices	Learning Approach	Dance genre	Portability	Target group
1	Chan [48]	Optical motion capture	Screen, VR, Head-mounted display, Fully immersive environment	Mimesis	not specified	no	Amateurs
2	Kyan [136]	Kinect	-CAVE Virtual Environment -Stereoscopic glasses, -eye trackers	Kinect	Mimesis	Ballet	All levels
3	Camurri [44]	Gyroscopes on limps	2D screen	Generative	Contemporary	yes	Adult amateurs and professional dance practitioners
4	Choremorphy [80, 199]	Optical and Inertial Motion Capture, Kinect	2D screen, HoloLens	Generative, Reflective	Contemporary, Improvisation	yes	Adult amateurs and professional dance
5	Delay Mirror [155]	-	Short range projector and projection screen.	Generative, Reflective	Ballet	yes	All levels
6	e-Ballet [196]	n/a	Projector, pc	Mimesis	Ballet	yes	Ballet students of all levels
7	Alexiadis [6]	Kinect	2D screen	Mimesis	Salsa dance	yes	Salsa dancers beginners and intermediate level
8	Usui [202]	Optical motion	capture	2D Screen	Mimesis Cypriotic Folk dance	no	All levels
9	Aristidou [13]	Optical motion capture	2D screen	Reflective	Any	yes	Mostly amateurs
10	Fujimoto [92]	Optical motion capture	tablet	Reflective	Hula dance	yes	Hula dancers All levels
11	Kitsikidis [129]	Multiple Kinect sensors	2D screen	Mimesis	Greek Folk (Tsamiko)	partly	Dance researchers

	DILS	Capturing Teacher's Moves	Other devices	Learning Approach	Dance genre	Portability	Target group
12	Essid [83]	Optical motion capture	Synchronized audio rigs, multiple cameras, wearable inertial measurement devices, depth sensors	Mimesis	Salsa dance	no	Experienced dancers
13	OpenDance [147]	Optical Motion capture	2D screen	Mimesis	Traditional dances of various countries	yes	Adult all levels
14	SuperMirror [148]	Kinect	2D screen	Mimesis	Ballet	yes	Pre-professional ballet dancers
15	WebDANCE [148]	Optical motion capture, videos	2D Screen computer	Mimesis	Folk dances (Greek, British)	yes	All levels
16	Whatever Dance Toolbox [170]	Depth camera, Video camera	projector computer	Generative, Reflective	Contemporary, Improvisation,Any	yes	Amateurs, experienced dancers, choreographers
17	YouMove [9]	Kinect	Augmented reality mirror, projectors, controlled lightning	Mimesis	Not specified	no	Any level of students, beginners

7. CONCLUSION

In this thesis, we have studied the problem of semantic representation and conceptual modelling of movement targeting some of the main issues of dance documentation and digital dance archiving, design of interactive experiences. We have contributed to the definition of meaningful models and applications for movement computing research.

As the title implies, we worked on giving an answer to two main questions:

- What are the Conceptual Languages that we can use to represent dance and define its movement components in a way that make these subjects to semantic computation and management?
- What are the Experiential Languages that suggest meaningful digital interactions for dance that are directly targeting the dance practitioner or researcher?

In other words, we suggest this separation between the conceptual and experiential aspects of dance, and we are discussing how we can transfer this to the digital.

7.1 Main Outcomes and Results

First, in Chapter 2 we presented, our motivation and the problem of dance documentaition, and the need for semantic representation models we positioned our work in the field of designing and developing technological approaches to dance preservation, search and interaction.

In Chapter 3 we present our theoretical background and methodology, which consists of the notation system of Labanotation and Choreological methodologies that suggest an analogy between Dance and Language in many levels. In the same Chapter we define, how we use this analogy for defining movement entities and formalizing structures of dance.

In Chapter 4 we present our first contribution which consists of the semantic model and ontological representation for describing the Conceptual aspects of Dance. We have explored existing notation system, and Labanotation in particular, and created an ontology that uses the Semantic Web technologies for representing movement and dance. We describe the multilayer approach that resulted for the transferring of semantics (from Laban to OWL) and the iterative approach of extending and enhancing the ontological representation. In the Chapter, we present the different versions of the ontologies (MoveOnto, and DanceOWL) and we discuss an analogy between dance with language and with music scores. We also examine the relationship of our model with conceptual models for CH, and define the role of the Recording, Score, Dance Entities, and Movement Entities and their relationship. Finally, we formalize the most challenging parts of movement representation and discretisation, such as body and temporal aspects. The use-case for creating the knowledge base deal with examples for Greek traditional and folk dances.

In Chapter 5 we introduce the potential and challenges of manual annotation for dance and its application in various context of use (education, practice, choreography, research, analysis). We present concrete use cases, of designing, developing and evaluating annotations tools. The first of this tool is the BalOnSe, a tool for semantic annotation and search of ballet movement and vocabulary. We present two versions of its development. During the first we created an extension to our ontology presented in Chapter 4 for representing Ballet syllabus, which we incorporated in web-based system and interface. In its second version of the system, we have extended the rules expressed in the ontology and used DatalogMTL to deal with the challenge of temporal representation and reasoning. Finally, the Web-Movement Library, is a use case where we have used and extended the semantic model to manage and annotate a large number of both videos and motion capture archives coming from four different dance genres (Greek folk, Ballet, Contemporary and Flamenco). In this C, we present not only the semantic issues that related with movement representation and dance vocabularies but also with the HCI challenges that emerge in co-designing such annotation tools with dance experts. Such challenges are only conceptual and semantic challenges related to segmenting and naming movement but extend to the experiential domain posing design questioned such: how the user selects annotations, how the body is visualised, and how to deal with annotations subjectivity.

In Chapter 6, we focus mainly on the Experiential and HCI challenges that are related to designing digital interactions for dance. Bringing a connection with 2, where we introduced the triadic relationship of Performer, Machine and Observer, we define what are the answers that one needs to take into account to deal with this triad in a meaningful way. We present the outcomes of a Survey on existing Digital Interactive Learning Systems, that use motion capture and virtual experiences. We also present one of such applications, Choreomorphy that is used as body and movement visualisation tool in real time, and we present the results of user study with dance experts. Finally, we present a workflow that can be used as a guide for designing and evaluating embodied experiences for dance.

7.2 Future work and Open Issues

The work that has been held during the thesis, has inspired many directions of future work for the applications of both the Conceptual and Experiential Languages to dance, as well as to other fields where movement is important.

To the direction of further studying and designing embodied and virtual experiences, we can envision the investigation of interactive experiences for dance practice and learning focusing on particular aspects that are not covered in the thesis such as dances that require the contact of two or more bodies. Such experiences could offer a lot in the scenarios where distant collaboration is needed.

In terms of extending the ontological representation of movement and dance, and since our proposed model and methodologies are extensible one of the future works includes the inclusion of other dance genres, than the ones examined. This extension is also possible to other contexts such as education, including information about the process of learning, interrelations that are meaningful for teaching particular dance genres and syllabi.

In addition, the conceptual framework, in combination with the workflow can be used as way to inform interactive virtual experiences based on particular categories of dance. Such ontological perspective applied to the actual digital experience that can implemented using motion sensing camera, and or VR/AR experiences. Technology and digital representation can reshape the form and take apart the morphology of the human body. This enables a huge amount of possibilities in terms of transformation not only of forms, and shapes but also of the qualities, amplify or diminish particular aspect and their transmission.

Many open challenges both on manual and automatic annotations of movement can be discovered. On one hand there is the open challenge of automatically annotated movement and apply machine learning techniques or computer vision to discover patters and similarities. On the other hand, designing tools that can gather reliable datasets of annotations that can work as ground-truth data to train algorithms is a complex HCI and semantic challenge on its own. These challenges are due again to the fact that there are no agreed vocabularies for describing and analysing movement, and even if systems like Laban Movement Analysis are used and experts are involved [87], these subjectivity of describing movement cannot be erased. This is also due to the triadic relationship that we mentioned between the Performer, Observer and Medium/Machine 4.

Finally, one of our future works in includes the application of the semantic representation and hierarchies as decision trees, to define the states in Machine Learning algorithms in order to discover movement motifs and patterns in higher level from big motion capture datasets.

7.3 Conclusions

In the core of this thesis in the analogy of Dance and Language, as a methodological tool for analysing, managing, representing and transmiting movement knowledge using information and communications technologies.

This analogy, extends the methodological tools of Choreology and Dance Anthropology that has been applied for studying the morphology and structure of dance. This analogy suggests handling the different dance practices and genres as diffrent languages that they have their own syntax, semantics, grammar and vocabulary.

Different methodological tools originating from Choreology and Dance Anthropology integrate this analogy of language and dance to define the structural movement units of dance. What is characteristic of Kaeppler's model that we focused on is that the structural analysis, is Anthropological rather than Choreological. One of the reasons why we focused on this particular perspective is that it aims at creating an inventory of Movement Entities. So in this approach, the Movement Entities are defined first, and the the characterisation of them as structural elements of the Dance Genre into Kinemes, Morphokines, Motifs, etc, comes at a second stage. This is very interesting for us for two reasons: 1) this methodology starts by identifying these entities with the consideration that these entities have an existence and life on their own. These methodology suggest that movements exist firth then they can then be furthered organised to form the dance, rather than start with a particular dance and analyse it or segmenting it. This way, each of the recognisable movement entities has its own existence withn the language system, and can be re-used, or even belong to other movement and gestural languages, besides dance. 2) The definition of these movement entities relies on an *Emic* approach, which means that the identification of a movement as a meaningful entity, its categorisation into the structural hierachy and distinction from other entities, is done by the community of those who speak or dance this language, rather than the observer or the researcher (*Etic* apprach).

Both characteristics are very important when it comes to translating this methodology into a model for digital representation and analysis of movement, as the first puts in the center the idea of an inventory of movement entities that can be re-used, composed, tranformed or come together to form a bigger sequence. The second characteristic of Kaeppler's methodology, related to Emic approach, highlights the importance of the community's perspective and understanding of movement elements not only when it comes to designing the final interface, but from the very begining of representing movement. In other words, it answers to the question of what are the movement entities that we can find within a movement language based on the practitioners perspective, the people who use and develop the language.

The focus on language has also been introduced on another level. When defining a Movement Entity as a smaller or bigger unit of a dance practice, there are many (Conceptual) languages that one can use to describe the exact same motion or position. These Conceptual Languages can include verbal descriptions, terminology of the specific dance vocabulary, idiosyncratic key words, or formal notational languages such as Labanotation, as well as symbolic, abstract or specific scores. In this thesis, we proposed a multilayer apporach for distinguishing these languages, formalizing them using Semantic Web Technologies (OWL) and other computational languages (DatalogMTL).

On the other hand, the exact same Movement Entity, not only can be described and represented using different Conceptual Languages, but can be implemented and embodied creating different Experiential Languages. Within an interactive learning or creative experience the exact same Movement Entity can change its Experiential characteristics, expression, meaning and functionality depending on the purpose, context, visualisation, body representation, mode of interaction.

Although in practice the Conceptual and Experiential aspects are in seperable, this dualism allows to handle the challenge of documenting, recording and digitally transmiting dance information related to movement. Taking advantage of the Conceptual Languages we can organise the explicit knowledge that exists within any dance practice, while the Experiential Languages can guide the creation of new digital experiences acting as an analogy of human-human interaction to human-computer-interaction.

Dance is usually seen as the ephemeral art, and its lifecycle starts and ends with the event of the human performer embodying the dance. Motion capture and video can record the performance in a digital form but this is not an extension of this lifecycle, but rather a transformation of it. Conceptual Languages such as scripts, notations, verbal descriptions terminologies, abstract scores, or grammar and syntax of the language can provide the description, prescription or in the best way a kind of trancription of the dance. Experiential Languages, i.e., all the embodied knowledge that is developing on the dance floor, in the studio, or dance classroom can be used as a guide to evaluate all the fragments of the actual dance have remained in the aformentioned transformations and descriptions of dance. If organised appropriately they can create a new meaningful experiences for observing, analysing, or learning dance through the digital medium.

This interelation between the actual dance, its representation, recording and trasmition through the digital, although will never recreate the original, embodied experience of dancing can open a numerous options for re-experiencing dance in its digital environments.

One of the main conclusions of this thesis is that semantic representation for dance, as well as the design of dance applications, is a challenging interdisciplinary domain, that requires collaboration between computer scientists, dance experts, as well as other domains.

While the need of applying technologies for recording, analysing and transmitting dances that are considered cultural heritage that requires research and preservation, is obvious, the integration of state-of the art technologies in the embodied practice, poses many HCI challenges.

The lack of a universal written language or system that is applied for the conceptualisation of dance in general, as it is the case with the western music notation/theory, makes digital dance research a very challenging domain. This lack of standards, and written languages, combined with the diversity of dance practices and genres can largely benefit from prototyping, iterative user-centric approaches, as well as participatory and co-design methodologies for drafting requirements and specifications. In addition, dance practitioners can play the role of movement experts, contributing to the field of HCI and especially the field of embodied interaction in very fruitful manner.

As Schacher [182] describes, the analysis of movement with computing tools is a paradox that can be turned into a productive dilemma only under an interdisciplinary lens. Not surprisingly, McBride [150], argues that dance research is the sister discipline of information system not only for its practice-based nature compared to other scientific fields, but also for its deep connection with cultural aspects.

Last but not least, when dance and computing are put together with the question of creating a meaningful application, more than one field of computer science domains need to be mastered in order to solve this problem in its totality.

Computer science, as most of STEMs, relies on particular measurement, quantification and discretisation that are hard to be answered all at once about such a rich, complex, multi-layered, embodied human activity. Therefore, the dialogue between computer science and dance can be either considered as a strange dichotomy, or it can be seen as an opportunity cross fertilisation in many ways. This discussion can contribute to the discourse of rethinking embodied interaction, as well as, the use of the technology itself in a meaningful way.

ABBREVIATIONS - ACRONYMS

AR	Augmented Reality
CH	Cultural Heritage
DILS	Dance Interactive Learning Systems
DL	Description Logics
KB	Knowledge Base
KR	Knowledge Representation
ICH	Intangible Cultural Heritage
MR	Mixed Reality
OWL	Web Ontology Language
RDF	Resource Description Framework
SPARQL	SPARQL Protocol and RDF Query Language
STEM	Science Technology Engineering Mathematcs
VR	Virtual Reality

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