AniAge Ontology for Movement Classification in Vietnamese Dance

Abdelmoutia Telli
Computer Science Department
University of Biskra
Biskra, Algeria, 07000
tellimoutia@gmail.com

Ma Thi Chau
Computer Science Department
University of Hanoi
Vietnam
ma.thi.chau@gmail.com

Mustapha Bourahla
Laboratory of Pure and Applied Mathematics
Computer Science Department
University of M'Sila, M'Sila, Algeria, 28000
mbourahla@hotmail.com

Karim Tabia
CRIL CNRS
Artois University-Nord de France
UMR 8188, Lens, France
tabia@cril.fr

Salem Benferhat
CRIL CNRS
Artois University-Nord de France
UMR 8188, Lens, France
benferhat@cril.fr

ABSTRACT

This paper proposes an OWL ontology called "AniAge", to define taxonomy of dance movement classes and their relationships for the traditional Vietnamese dance taking into account the semantics of its art and its cultural anthropologists. The "AniAge" terminology can be used to describe elementary movements (poses) as a dataset ontology importing "AniAge". These poses are results of dance sequences segmentation (using segmentation techniques). The ontolgy "AniAge" is supported by classification rules, which are developed with the OWL complementary language SWRL (Semantic Web Rule Language) to entail movement phrases, which are basic movements with complete meaning. The dataset ontology containing poses descriptions can be queried using the query language SQWRL (Semantic Query Web-enhanced Rule Language), which is extension of SWRL to retrieve implicit dance knowledge. Then, the query answers can be used for computer animation.

Keywords

Semantic Web Technologies, Ontology, Description Logics, Dance Notation Labanotation, Traditional Vietnamese Dance.

1. INTRODUCTION

Computer animation technologies have grown considerably and they have been widely used for movies and video games. These technologies require a lot of effort and manual work and they are very expensive. It is essential to use these technologies in applications such as archiving and simulation or reproduction of contents to propose effective and less expensive animation solutions. On the other hand, ontologies have been developed in many domains and studies, thanks to their capacity for representing the knowledge bases, and for facilitating knowledge sharing. We can find ontology studies in the domain of multi-media with different goals as annotation and information retrieval.

In addition, it is important to preserve cultural (dance) heritage using web technologies. Dance choreographies can be archived by motion capture, video recording, and dance notation. Dance notation systems such as Feuillet Notation [25], Benesh Notation [1] and Labanotation [26] provide theorey to study the dance choreography.

Introduced by dance artist and theorist, Rudolf von Laban in 1928, the Labanotation system [26], uses abstract symbols to describe movement, providing a well-structured language with rich vocabulary and clear semantics, based on Laban Movement Analysis (LMA) [15]. LMA serves as useful foundation not only for designing dance documentation software but also for modelling human computer interaction based on movement and gestures [21].

In this paper, we develop a searchable knowledge base that enables us to search for specific movements in dance, which describes traditional Vietnamese dances. The constructing elements of the ontology and their relationships to construct the dance model are based on the semantics of the Labanotation system [5], a widely applied language that uses symbols, which are identified by concepts and relationships created with the language OWL [13] to denote and reason on dance choreographies.

The description of these dances will allow us to express complex relations for inferring on the domain of human movements to extract implicit knowledge from explicit one. These complex relations will be described as SWRL (Semantic Web Rule Language), which is a OWL complementary language [14]. These SWRL rules represent additional description for the dance OWL ontology, to entail implicit knowledge as movement classification.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.

PRAI 2018 August 15–17, 2018, Union, NJ, USA

© 2018 ACM. ISBN 978-1-4503-6482-9…$15.00

DOI: 10.1145/1235

This ontology called "AniAge", will be used by developed applications for the project AniAge (High Dimensional Heterogeneous Data based Animation Techniques for Southeast Asian Intangible Cultural Heritage Digital Content) [1]. During the process of capturing the dance, the collected data can be used to produce movement (poses) description using the terminology of "AniAge" ontology. This description is represented as a dataset (assertions) ontology, which imports the terminology ontology "AniAge". However, the collected data can be issued from different sources (different cameras). This multisource knowledge represented as assertions can be incoherent. Before querying the dance knowlegde, this incoherence should be resolved by repair techniques [23, 2, 3].

The ability to extract information from OWL dance ontologies is a basic requirement. While SPARQL and its extensions are being used as an OWL query language in many applications [20], their understanding of OWL's semantics is at best incomplete. We specify queries on dance ontologies using the language SQWRL (Semantic Query Web-enhanced Rule Language) [19], which is based on the SWRL rule language and uses SWRL's strong semantic, where set of operators can be used to perform closure operations as failure, counting, and aggregation. Then, a SQWRL query can be specified to retrieve particular dance information using inference on the dataset ontology, which imports the "AniAge" ontology and its classification SWRL rules. The query answers can now be used by a matching animation process of the AniAge project.

1.1 Related Works

Recently, different works have been proposed to use ontologies for video processing. For instance, [6] makes a collective consciousness of dance into an ontology. The authors in [8, 9, 10] created an ontology transferring the semantics of Laban notation into OWL entities. Other authors in [4] assess the ontological impact of computer programs designed to visualize certain components of dance movements and to show their performance. Moreover, [7] used the BMN (Benesh Movement Notation) system for building Video Movement Ontology (VMO).

In our proposal, we use the Description Logics (DLs) to represent different human movements, in particular the movements in dance. This representation is based on techniques for representing the Laban and the Benesh movement notation, where the result is an ontology of Vietnamese folk dances.

This paper is organized as follows. Some concepts about the Vietnamese folk dances are presented in Section 2. The development of the ontology "AniAge" is presented in detail with examples in Section 3. A set of rules for the movement classification is explained and added to the ontology "AniAge" in Section 4 with presentation of a method to introduce dance datasets (assertions) to be queried for extracting knowledge. Finally, a conclusion and future works are presented in Section 5.

2. VIETNAMESE FOLK DANCE

In Vietnam, 54 ethnic groups have their own folk dances, which express cultural knowledge, spiritual life, reflecting Vietnamese people's creativity and talent. Ethnic groups, geographically closing together, have similar customs. Therefore, folk dances of Vietnam's 54 ethnic groups can be classified regionally into 7 main groups: Highland-Midland Northern, Red River Delta, North Central, Coastal South Central, Highlands, South East and South West regions [24, 16]. In addition, Vietnamese folk dances express 3 groups of messages [16]: (i) daily life activities, (ii) festival activities and, (iii) human spirituality.

Through dances, people want to pass on an experience of productive labor, hunting and show the behaviour of human beings, such as sailing dance (mùa chéo thuyên), weaving dance (mùa dêt cùi). Festivals, reflected alive popularly in dances, are always composed of two parts: the ceremonial part, giving homage to the local genies and deities, and the festival one to entertain the whole village. Drum dance (mùa trông), Thài spreading dance (mùa xóe Thài), for example, are performed in local festivals. Châu dance (múa châu), Hâu dông dance (múa hâu dông) are typical examples of spiritual dances, which express praying for auspices and blessing by the gods, heaven, Buddha.

We identify regional features and messages transmitted in a dance, based on many aspects such as dance posture and movement, clothing, dance props, music. In the first phase, we concentrate only on representing and analyzing movement aspects of folk dances. We only focus on the representation and analysis of aspects of the folk dance movement type Mõ, which belongs to the Red river delta region. Mõ is classified as a self-sounding wine, popular in Vietnam. Actually they are used in different environments and have different functions. In the pagoda, Mõ is used as the role of rhythm when chanting recitation [2].

Historically, in the rural life of the ancient Vietnamese, there was a man called Mõ. On the village's occasion or events, Mõ would beat Mõ instrument and inform the information to the villagers. People put Mõ on the buffalo neck. When the buffaloes move, walk, two pieces of wood are steadily knocking on the inner wall and emitting interesting sound. So, Mõ Dance simulates how people beat Mõ instrument to make rhythm and interesting sound [3].

3. ONTOLOGY FOR VIETNAMESE DANCE

Formally, a dance is typical of human movement; it is knowledge when we can use an ontology to model it. We propose to use ontology technologies to represent and reason on dance choreographies by building a dance ontology using OWL. This logical dance description allows us to express complex relationships and rules of inference for the realm of human movement. However, the reasoning capabilities facilitate the extraction of new knowledge from existing knowledge.

An initial ontology for Vietnamese folk dances is built up as proposed in Figure 1. For dance annotation, the Labanotation [5] seems useful for conceptualisation, which has symbols related to travelling and travelling time of dancers, the relationship between dancers, between dancer and stage. It is composed of several parts. These parts record the general idea behind movements and allow an improvement of basic movements. Other parts descript specifically and precisely movement elements such as body parts, time, direction and dynamics.

[1]http://www.euh2020aniage.org

[2]https://www.youtube.com/watch?v=3sO-WkNxjZc

[3]https://www.youtube.com/watch?v=3IlX4Yavvmo

We apply body parts based on Labanotation division in the dance analysis. Based on a hierarchy structure of dance movements and expertise knowledge of the folk-dance domain, OWL will be used to describe classes and properties. Next, dance and its domain descriptions are represented formally in Description Logic, in which the reasoner supports answering different queries on Vietnamese folk-dance.

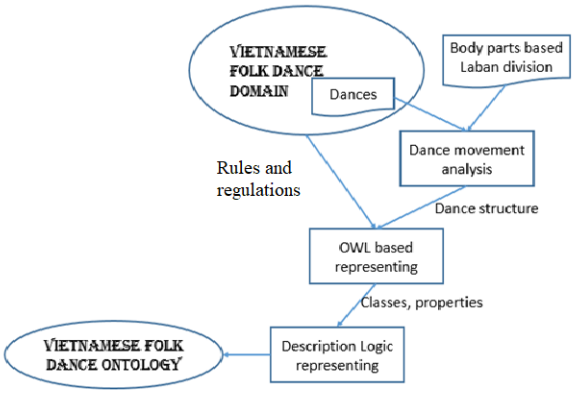


Figure 1: Proposal of an ontology for Vietnamese folk dance.

The ontology development process identified by [11] is based on the following steps: definition of the purpose of ontology, conceptualization, and formalization [12]:

- *Objective of ontology.* Ontology may appear as useful way to structure descriptions of video content semantics. They can support semantic descriptors for images, sounds, or other objects. We use the ontological solution to effectively annotate video content.
- *Conceptualization.* We start by defining the video components. In this work, we segmented the video input into sequences. The visual characteristics will be used to associate a description with each sequence, which consists of several particular poses.
- *Formalization.* Our ontology has been formalized using OWL and Protege 5.2 [4] [17]. It can be easily reused and shared. To formalize in OWL the composition of the movements, we use the method defined by [22]

Our goal is to explore how the different stages of traditional Vietnamese dances in a video can be categorized and described to extract knowledge from the video. The dance ontology is mainly developed by the description of its terminological box (TBox), where concepts and roles (abstract roles and concrete roles) are defined, we call this the "AniAge" ontology. For classification of dance elements, a set of rules is described using the language SWRL (Semantic Web Rule Language), which is added as part of the OWL ontology "AniAge".

A video sequence can be segmented to many dance poses using video processing techniques. These poses are the elementary units to be used for recognizing the dance classes.

[4]https://protege.stanford.edu/products.php

Each pose is described by positions of body parts. This dataset is described as an assertional box (ABox) ontology, which imports the ontology "AniAge" with its set of SWRL rules. From this explicit knowledge, an implicit knowledge can be entailed to classify the dance movements by answering SQWRL (Semantic Query Web-enhanced Language) queries.

3.1 The AniAge Ontology

A dance is realized by a dancer described by the concept $DancerBody$ or group ($Group$) of dancers, where a dancer can be a member ($memberOf$) of a group. In a dance, a group of dancers can have a shape declared as concept $GroupShape$, creating a circle relation ($CircleRelation$) or line relation ($LineRelation$).

For example, the concept $CircleRelation$ can be one of the objects, left side to the centre ($LeftSideToTheCentre$), back to the centre ($BackToTheCentre$), facing the centre ($FacingTheCentre$) or right side to the centre, which is represented by $RightSideToTheCentre$. All these relation kinds are declared as individuals (objects) ot the concept $CircleRelation$.

An Asiatic dance is composed of Vietnamese and Malysian dances, logically it is formulated by

$$VitenameseDance \sqcup MalysianDance \sqsubseteq AsianDance$$
$$AsianDance \sqsubseteq Dance$$

A Vietnamese dance belongs to a Vietnamese region of the concept $Region$. There are seven regions declared as individuals (abstract objects) of type $Region$, which are $SouthEast$, $SouthWest$, $RedRiverDelta$, $NorthCentral$, $HighLands$, $CoastalSouthCentral$ and $HighLandMiddleLandRegion$.

A Vietnamese dance can express ($hasMessage$) a message ($Message$), which is one of the classes, $DailyLifeActivities$, $FestivalActivities$ or $HumanSpirituality$.

$$DailyLifeActivities \sqcup$$
$$FestivalActivities \sqcup$$
$$HumanSpirituality \sqsubseteq Message$$

The $DailyLifeActivities$ class is composed of objects, which are $SailingDance$ (mùa chéo thuyên) and $WeavingDance$ (mùa dệt cùi). The class $FestivalActivities$ is one of the sub-classes $Ceremonial$ and $LocalFestival$ (which has the instances $DrumDance$ and $SpreadingDance$). The class $HumanSpirituality$ is composed of the objects $ChauDance$ and $HauDongDance$.

We identify regional features and messages transmitted in a dance, based on many aspects as clothing ($Clothes$). We specify a dance D belonging to a region, for example, $RedRiverDelta$ by $(D, RedRiverDelta) : regionOf$ and the Mõ dance belongs to the red river delta dance, which is a Vietnamese dance by,

$$MõDance : VitenameseDance,$$
$$(MõDance, RedRiverDelta) : regionOf$$

We start building a dance ontology by defining dance components. As mentioned above, we segment a dance into basic units ($PhraseMovement$) using techniques for analyzing movements [18]. Each basic unit is defined as the smallest movement with a complete meaning.

$$Dance \equiv \forall hasPhrase.MovementPhrase$$

A dance can contain many basic movements ($MoInviting$, $GameCompetition$, $TraditionalGameTUG$, $MoExchange$, $MoRotationJumping$, $MoToeTouching$, $AskingADoctor$, $MoFootDragging$, etc.), which are declared as individuals of $MovementPhrase$ type. Most visual and meaningful features will be used to associate a description to basic movements.

Movement phrase contains several movement primitives. A primitive has at least two basic poses (beginig and end action) with a duration, changing from the first pose to the last one.

$$MovementPhrase \equiv \forall hasPrimitive.MovementPrimitive$$
$$MovementPrimitive \equiv \geq 2 hasPose.MovementPose$$

There are two main types of movements, corresponding to basic actions: actions of the whole body $BodyMovement$ and actions of some body parts $BodyPartMovement$ as in Labanotation [5], which has symbols related to travelling and travelling time of dancers, the relationship between dancers, between dancer and stage.

Body movement makes the position of the whole body of dancer changed in space; dancers move on stage. On the other hand, dancers change their positions on a plane. The Vietnamese traditional folk dance is different from modern dances in body movement. There are no body movements, which lift dancers on the air. So, body movements in the Vietnamese folk dance are not too complicate.

Each movement phrase is a simple body movement (basic movement), which has a trajectory in the form of a line, an arc, a dot on a plane as a straight pathway, a curved pathway and stillness as in the Labanotation [5].

Body movements are composed of phrases, which means the dancer body is related to movement phrase by the abstract role $hasPhrase$. As said above, movement phrases include moving spot (a dot), translation (a line), and rotation (an arc). A translation can be done in one of eight orientations. There are two types of rotation: clockwise and counter clockwise. Moving spot phrase can be also in the turn (with different degrees) or no turn.

$$Spot \sqcup Translation \sqcup Rotation \sqsubseteq MovementPhrase$$
$$\exists hasPhrase.Thing \sqsubseteq DancerBody$$
$$\top \sqsubseteq \forall hasPhrase.MovementPhrase$$

Body part movements make the position of different parts of dancer's body changed. Along with the implementation of the body phrases, dancers perform body part movements, called as movement primitives represented by the concept $MovementPrimitive$. Movement primitives are quick movements, which change the position of body parts. On the other hand, a movement primitive is a movement between main dance poses. Movement primitives include hand movements, upper/lower arm movements, feet movements, upper/lower leg movements, head movements, and combined arm-leg movements.

$$\exists hasPrimitive.Thing \sqsubseteq DancerBody \sqcup MovementPhrase$$
$$\top \sqsubseteq \forall hasPrimitive.MovementPrimitive$$
$$\exists hasPose.Thing \sqsubseteq DancerBody \sqcup MovementPrimitive$$
$$\top \sqsubseteq \forall hasPose.MovementPose$$

A movement phrase can be described as parallel composition of many movement primitives. A dance pose represented by the concept $MovementPose$, is a particular position of dancer body part. There are basic head poses, basic hand poses, basic arm poses, basic leg poses and basic combined arm-leg poses. We use dance orientations, angles between arms/legs with the torso and angles between limbs inside arms/legs to describe basic body part poses.

Many dancer body parts are declared as individuals (objects) of the concept $DancerBodyPart$. We can find the individuals $Head$, $Hands$, $RightHand$, $LeftHand$, $Arms$, $RightArm$, $LeftArm$, $Legs$, $RightLeg$, $LeftLeg$, $Heels$, $RightHeel$, $LeftHeel$, $Knees$, $RightKnee$, $LeftKnee$, etc.

In Vietnam folk dances, there are eight orientations, denoted by Orientation 1, Orientation 2, Orientation 3, Orientation 4, Orientation 5, Orientation 6, Orientation 7, and Orientation 8 corresponding to forward, right front diagonal, right side, right back diagonal, backward, left back diagonal, left side and left front diagonal, respectively (Figure 2).

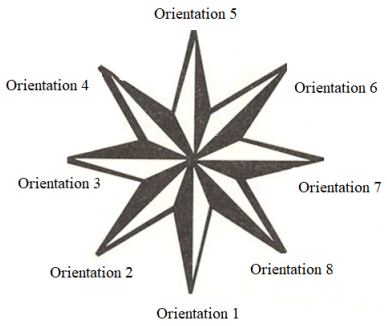


Figure 2: The orientations of the body parts.

For each orientation pose, there is an object property $orientation_iPose$, where $i = 1, \cdots, 8$. These object properties relate a dancer body part to an orientation pose as its property. Their DL description is

$$\exists orientation_iPose.Thing \sqsubseteq$$
$$MovementPose \sqcup MovementPhrase$$
$$\top \sqsubseteq \forall orientation_iPose.(DancerBody \sqcup DancerBodyPart)$$

As mentioned above, there are two types of movements related to body and body parts. Hence, it is necessary to discriminate orientation of body or body parts. For the first type (for example, the description below), the dancer moves straight in orientation 1, which means he moves straight forward (performs a phrase movement).

$$A : DancerBody, P : MovementPhrase,$$
$$(P, A) : orientation1Pose$$

The second type of orientation (also included 8 values) is associated with body parts (considered as a local coordinate). In this type, Orientation 1 coincides with the forward of the dancer. For instance, we described a leg position as follows: both legs are straight, left foot is in Orientation 8 and right foot is in Orientation 2.

$$A : DancerBody, P : MovementPose, (A, P) : hasPose,$$
$$(P, Legs) : straightPose(P, LeftFoot) : orientation8Pose,$$
$$(P, RightFoot) : orientation2Pose$$

It is clair that the second description is a detail of the first description, which means that a movement phrase can be described by poses of body parts.

In addition to these eight orientation poses, we need to add pose adjectives to describe other positions, like the adjectives $beforePose$, $middlePose$ and $frontRightSidePose$ to say that a body part is positioned before, in the middle or in front right side of another body part, respectively. The properties (adjectives) $raisedPose$, $raisedHexagonalPose$, $bentPose$, $straightPose$, $openPose$, $bentPose$ are to say that a body part is raised, raised hexagonal, bent, straight, open or orthogonal, respectively. If the property "namePose" corresponds to one of these pose properties, its DL description is as follows.

$$\exists namePose.Thing \sqsubseteq MovementPose$$
$$\top \sqsubseteq \forall namePose.DancerBodyPart$$

A set of datatype properties are defined for sequencing the movement poses, primitives and phrases. Each movement pose or phrase has a data type property $timeOf$:

$$\exists timeOf.Thing \sqsubseteq MovementPose \sqcup MovementPhrase$$
$$\top \sqsubseteq \forall timeOf.Time$$

The data properties $beginTime$ and $endTime$ are associated with each movement primitive and with movement phrases, which are described as parallel combination of primitives.

$$\exists beginTime.Thing \sqsubseteq$$
$$MovementPrimitive \sqcup MovementPhrase$$
$$\top \sqsubseteq \forall beginTime.Time$$
$$\exists endTime.Thing \sqsubseteq$$
$$MovementPrimitive \sqcup MovementPhrase$$
$$\top \sqsubseteq \forall endTime.Time$$

Where, the data type $Time$ is defined by the expression $Time \sqsubseteq xsd{:}noNagtiveInteger$

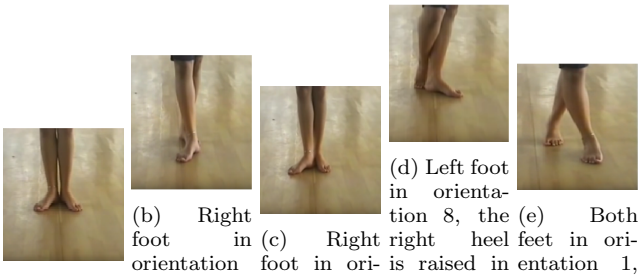
3.2 Example

In the Vietnamese dance Mõ, we can describe the basic movement *MõFootDragging*, which is a parallel combination of legs poses (Figure 3) and arms poses (Figure 4). The images 3a, 3b, 3c, 3d and 3e illustrate the different poses in this basic movement of the feet from the initial pose to the final pose (end of basic movement).

To give complete formal description, we assume that the basic movememnt is realized by an individual A of type $DancerBody$ ($A : DancerBody$). Thus, there are five legs poses LP_1, LP_2, LP_3, LP_4 and LP_5, where each pose corresponds to an image of Figure 3, 3a, 3b, 3c, 3d and 3e, respectively. Their DL descriptions are as follows.

$$3a \equiv \left\{ \begin{array}{l} (A, LP_1) : hasPose, (LP_1, 0) : timeOf, \\ (LP_1, Legs) : straightPose, \\ (LP_1, LeftFoot) : orientation8Pose, \\ (LP_1, RightFoot) : orientation2Pose \end{array} \right\}$$

$$3b \equiv \left\{ \begin{array}{l} (A, LP_2) : hasPose, (LP_2, 1) : timeOf, \\ (LP_2, RightHeelLeftToe) : beforePose, \\ (LP_2, LeftFoot) : orientation8Pose, \\ (LP_2, RightFoot) : orientation2Pose \end{array} \right\}$$



(a) Right foot in orientation 2 and left foot in orientation 8.

(b) Right foot in orientation 2 and left foot in orientation 8 with right heel before the right toes

(c) Right foot in orientation 2, left foot in orientation 8, right heel is in the middle of the left foot

(d) Left foot in orientation 8, the right heel is raised in orientation 1, the right toes are at the left of the heel, the right knee is bent

(e) Both feet in orientation 1, the left foot in front the right side of the right foot the right heel is raised

Figure 3: Different positions of the action *MO foot-dragging*

$$3c \equiv \left\{ \begin{array}{l} (A, LP_3) : hasPose, (LP_3, 2) : timeOf, \\ (LP_3, RightHeelLeftFoot) : middlePose, \\ (LP_3, LeftFoot) : orientation8Pose, \\ (LP_3, RightFoot) : orientation2Pose \end{array} \right\}$$

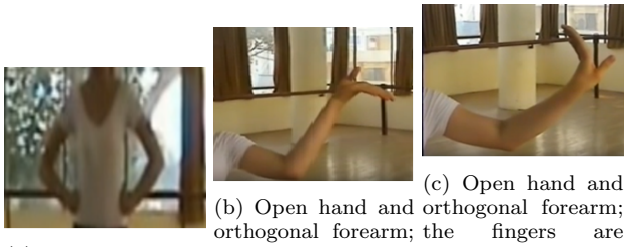
$$3d \equiv \left\{ \begin{array}{l} (A, LP_4) : hasPose, (LP_4, 3) : timeOf, \\ (P_4, RightKnee) : bentPose \\ (LP_4, LeftFoot) : orientation8Pose, \\ (LP_4, RightHeel) : orientation1Pose, \\ (LP_4, RightHeel) : raisedPose, \\ (LP_4, LeftHeelRightToe) : beforePose \end{array} \right\}$$

$$3e \equiv \left\{ \begin{array}{l} (A, LP_5) : hasPose, (LP_5, 4) : timeOf, \\ (LP_5, RightHeel) : raisedPose, \\ (LP_5, LeftFoot) : orientation1Pose, \\ (LP_5, RightFoot) : orientation1Pose, \\ (LP_5, LeftFootRightFoot) : frontRightSidePose \end{array} \right\}$$

Now, we represent the sequences of the positions of the arms and hands for the dance movement *MO foot-dragging* of the Mõ dance. All the descriptions given in the images 4a, 4b and 4c on the movement of the left hand apply to the right hand. These arms poses are represented by the individuals (objects) ot type $MovementPose$, AP_1, AP_2 and AP_3, respectively and their DL descriptions are as follows.

$$4a \equiv \left\{ \begin{array}{l} (A, AP_1) : hasPose, (AP_1, 0) : timeOf, \\ (AP_1, Arms) : raisedHexagonal, \\ (AP_1, LeftArm) : orientation8Pose, \\ (AP_1, RightArm) : orientation2Pose \end{array} \right\}$$

$$4b \equiv \left\{ \begin{array}{l} (A, AP_2) : hasPose, (AP_2, 1) : timeOf, \\ (AP_2, Hands) : openPose, \\ (AP_2, ForeArms) : orthogonalPose, \\ (AP_2, Fingers) : straightPose, \\ (AP_2, BigFingers) : orthogonalPose \end{array} \right\}$$



(a) Left arm in orientation 8, right arm in orientation 2, the arms are raised in hexagonal form

(b) Open hand and orthogonal forearm; the fingers of the index to the little finger are straight; big finger orthogonal to other fingers

(c) Open hand and orthogonal forearm; the fingers are straight; the large finger orthogonal to the other fingers that are oriented towards the head

Figure 4: Sequences of the positions of the hands for the dance movement *MO foot-dragging* Mõ

$$4c \equiv \left\{ \begin{array}{l} (A, AP_3) : hasPose, (AP_3, 2) : timeOf, \\ (AP_3, Hands) : openPose, \\ (AP_3, ForeArms) : orthogonalPose, \\ (AP_3, Fingers) : straightPose, \\ (AP_3, BigFingers) : orthogonalPose, \\ (AP_3, FingersHead) : towardPose \end{array} \right\}$$

The parallel combination between the actions of the feet with the actions of the hands/arms is a complete corporal movement. Note that some actions execute in a repetitive way that is what we apply in the annotation of the movements.

This dataset (assertional box) is an ontology representing descriptions of dance poses (video sequences) by referencing imported concepts and properties from the dance terminology defined in the ontology "AniAge".

A reasoning task will be applied on this dataset ontology to entail implicit knowledge from the explicit knowledge to answer queries on dance movements. The reasoning procedure is based on classification rules, which are developed using training datasets.

4. CLASSIFICATION OF DANCE MOVEMENTS

The movement classes are declared as individuals (abstract objects) at different levels. Thus, there are classes for the concepts $MovementPose$, $MovementPrimitive$ and $MovementPhrase$ in the ontology "AniAge". These declarations are results of training tests, for example, the movement poses can be classified to the classes $LegsPose1$, $LegsPose2$, $LegsPose3$, $LegsPose4$ and $LegsPose5$, for legs poses in the typical dance movement *MO foot-dragging*. By the same way, there are three pose classes for arms poses, $ArmsPose1$, $ArmsPose2$ and $ArmsPose3$.

In addition to these pose classes, two primitive classes (individuals) can be declared, one primitive class for legs poses "*LegsPrimitive*" and the other primitive class for arms poses "*ArmsPrimitive*". The parallel combination of these two primitive is identified by the phrase class "*LegsArmsPhrase*".

To classify the movement poses ($MovementPose$), the movement primitives ($MovementPrimitive$), the movement phrases ($MovementPhrase$) and dance movements, a set of rules is written using declared abstract roles (*poseClass*, *primitiveClass*, *phraseClass*) to associate a class with each movement pose, primitive or phrase, respectively.

The Semantic Web Rule Language (SWRL) [14] is a language for the Semantic Web that can be used to express rules as well as logic, combining OWL DL or OWL Lite with a subset of the Rule Markup Language. Rules are of the form of an implication between an antecedent (body) and consequent (head). The intended meaning can be read as: whenever the conditions specified in the antecedent hold, then the conditions specified in the consequent must also hold.

Both the antecedent (body) and consequent (head) consist of zero or more atoms. Atoms in these rules can be of the form $C(x)$, $P(x, y)$, $sameAs(x, y)$ or $differentFrom(x, y)$, where C is an OWL concept (class), P is an OWL property, and x,y are either variables, OWL individuals or OWL data values. There are many built-in atoms. The set of SWRL rules to classify the poses are described below.

- $DancerBody(?d) \wedge hasPose(?d, ?p) \wedge orientation8Pose(?p, LeftFoot) \wedge orientation2Pose(?p, RightFoot) \wedge straightPose(?p, Legs) \Rightarrow poseClass(?p, LegsPose1)$
- $DancerBody(?d) \wedge hasPose(?d, ?p) \wedge orientation8Pose(?p, LeftFoot) \wedge orientation2Pose(?p, RightFoot) \wedge beforePose(?p, RightHeelLeftToe) \Rightarrow poseClass(?p, LegsPose2)$
- $DancerBody(?d) \wedge hasPose(?d, ?p) \wedge orientation8Pose(?p, LeftFoot) \wedge orientation2Pose(?p, RightFoot) \wedge middlePose(?p, RightHeelLeftFoot) \Rightarrow poseClass(?p, LegsPose3)$
- $DancerBody(?d) \wedge hasPose(?d, ?p) \wedge orientation8Pose(?p, LeftFoot) \wedge orientation2Pose(?p, RightFoot) \wedge raisedPose(?p, RightHeel) \wedge beforePose(?p, LeftHeelRightToe) \wedge bentPose(?p, RightKnee) \Rightarrow poseClass(?p, LegsPose4)$
- $DancerBody(?d) \wedge hasPose(?d, ?p) \wedge orientation1Pose(?p, Feet) \wedge frontRightSidePose(?p, LeftFootRightFoot) \wedge raisedPose(?p, RightHeel) \Rightarrow poseClass(?p, LegsPose5)$

If a dancer body specified by the variable d has a movement pose p and this movement pose satisfies the description specified by the atoms in the rest of rule body then it is classified by the class specified by the second argument of the atom *poseClass*. The same thing applies for classification of arms poses.

- $DancerBody(?d) \wedge hasPose(?d, ?p) \wedge orientation8Pose(?p, LeftArm) \wedge orientation2Pose(?p, RightArm) \wedge raisedHexagonal(?p, Arms) \Rightarrow poseClass(?p, ArmsPose1)$
- $DancerBody(?d) \wedge hasPose(?d, ?p) \wedge openPose(?p, Hands) \wedge orthogonalPose(?p, ForeArms) \wedge orthogonalPose(?p, BigFingers) \wedge straightPose(?p, Fingers) \Rightarrow poseClass(?p, ArmssPose2)$
- $DancerBody(?d) \wedge hasPose(?d, ?p) \wedge openPose(?p, Hands) \wedge orthogonalPose(?p, ForeArms) \wedge orthogonalPose(?p, BigFingers) \wedge towardPose(?p, FingersHead) \wedge straightPose(?p, Fingers) \Rightarrow poseClass(?p, ArmsPose3)$

A sequence of movement poses can create a predefined movement primitive. The consecutive legs poses will create for example, a primitive of legs movements, which is of class *LegsPrimitive*. By the same way the consecutive arms poses will create a primitive of arms movement

$ArmsPrimitive$. The SWRL rules to create these two primitives are below.

- $DancerBody(?d) \wedge$
  $hasPose(?d, ?p1) \wedge poseClass(?p1, LegsPose1) \wedge$
  $hasPose(?d, ?p2) \wedge poseClass(?p2, LegsPose2) \wedge$
  $hasPose(?d, ?p3) \wedge poseClass(?p3, LegsPose3) \wedge$
  $hasPose(?d, ?p4) \wedge poseClass(?p4, LegsPose4) \wedge$
  $hasPose(?d, ?p5) \wedge poseClass(?p5, LegsPose5) \wedge$
  $timeOf(?p1, ?t1) \wedge timeOf(?p2, ?t2) \wedge$
  $timeOf(?p3, ?t3) \wedge timeOf(?p4, ?t4) \wedge$
  $timeOf(?p5, ?t5) \wedge add(?t2, ?t1, 1) \wedge$
  $add(?t3, ?t2, 1) \wedge add(?t4, ?t3, 1) \wedge$
  $add(?t5, ?t4, 1) \wedge makeOWLThing(?pr, ?d) \Rightarrow$
  $MovementPrimitive(?pr) \wedge$
  $primitiveClass(?pr, LegsPrimitive) \wedge$
  $hasPrimitive(?d, ?pr) \wedge hasPose(?pr, ?p1) \wedge$
  $hasPose(?pr, ?p2) \wedge hasPose(?pr, ?p3) \wedge$
  $hasPose(?pr, ?p4) \wedge hasPose(?pr, ?p5) \wedge$
  $beginTime(?pr, ?t1) \wedge endTime(?pr, ?t5)$

- $DancerBody(?d) \wedge$
  $hasPose(?d, ?p1) \wedge poseClass(?p1, ArmsPose1) \wedge$
  $hasPose(?d, ?p2) \wedge poseClass(?p2, ArmsPose2) \wedge$
  $hasPose(?d, ?p3) \wedge poseClass(?p3, ArmsPose3) \wedge$
  $timeOf(?p1, ?t1) \wedge timeOf(?p2, ?t2) \wedge$
  $timeOf(?p3, ?t3) \wedge add(?t2, ?t1, 1) \wedge$
  $add(?t3, ?t2, 1) \wedge makeOWLThing(?pr, ?d) \Rightarrow$
  $MovementPrimitive(?pr) \wedge$
  $primitiveClass(?pr, ArmsPrimitive) \wedge$
  $hasPrimitive(?d, ?pr) \wedge hasPose(?pr, ?p1) \wedge$
  $hasPose(?pr, ?p2) \wedge hasPose(?pr, ?p3) \wedge$
  $beginTime(?pr, ?t1) \wedge endTime(?pr, ?t3)$

These two rules use two built-in atoms. The first built-in atom $add(?x, ?y, ?z)$ is from the library $swrlb$ ant it is true if $?x = ?y + ?z$ else it is false. The second built-in atom $makeOWLThing(?x, ?y)$ creates a new OWL Thing individual, which is assigned to the variable $?x$ based on the value of the variable $?d$.

A parallel combination of legs primitive with arms primitive will create a movement phrase of class $LegsArmsPhrase$. This phrase is a basic movement of the class $MoDraggingFoot$ of the dance Mõ.

- $DancerBody(?d) \wedge hasPrimitive(?d, ?pr1) \wedge$
  $primitiveClass(?pr1, LegsPrimitive) \wedge$
  $beginTime(?pr1, ?bt1) \wedge endTime(?pr1, ?et1) \wedge$
  $hasPrimitive(?d, ?pr2) \wedge$
  $primitiveClass(?pr2, ArmsPrimitive) \wedge$
  $beginTime(?pr2, ?bt2) \wedge endTime(?pr2, ?et2) \wedge$
  $greaterThan(?et1, ?bt2) \wedge greaterThan(?et2, ?bt1) \wedge$
  $makeOWLThing(?phr, ?d) \Rightarrow$
  $MovementPhrase(?phr) \wedge$
  $phraseClass(?phr, MoDraggingFoot) \wedge$
  $hasPhrase(?d, ?phr) \wedge hasPrimitive(?phr, ?pr1) \wedge$
  $hasPrimitive(?phr, ?pr2)$

The execution of the reasoning procedure on the dataset ontology importing "AniAge" with its set of SWRL rules will generate the implicit knowledge, which represents classification of movement poses, primitives and phrase. The entailed knowledge can be added to the dataset ontology.

4.1 Querying the dance ontology

There are different languages to specify queries on ontologies. Since OWL can be serialised as RDF, SPARQL [20] can be used to query it. However, SPARQL has no knowledge of the language OWL constructs that those serialisations represent. Then, it can not directly query entailments made using those constructs. To use SPARQL for querying the dance dataset ontology, the former should be entailed by a reasoner to have complete knowledge about dancing and then it can be queried to retrive required information.

Queries on dance dataset ontologies are specified with the language SQWRL (Semantic Query Web-enhanced Rule Language) [19], which is based on the SWRL rule language and uses SWRL's strong semantic. In the contrary of SPARQL, answering SQWRL query uses inference on the dataset ontology, which imports the "AniAge" ontology and its classification SWRL rules. SQWRL takes a standard SWRL rule antecedent and treats it as a pattern specification for a query. It replaces the rule consequent with a retrieval specification. For example, the query

$$Query(pose, time, image) \leftarrow phraseClass(phrase, MoFootDragging) \wedge hasPrimitive(phrase, primitive) \wedge hasPose(primitive, pose) \wedge timeOf(pose, time) \wedge video(pose, image)$$

retrieves the poses, their times and their video sequences (images) of the basic movement Mõ foot-dragging of the Vietnamese dance Mõ and it can be specified using the query language SQWRL as

$$Query: phraseClass(?phrase, MoFootDragging) \wedge hasPrimitive(?phrase, ?primitive) \wedge hasPose(?primitive, ?pose) \wedge timeOf(?pose, ?time) \wedge video(?pose, ?image) \rightarrow sqwrl:select(?pose, ?time, ?image) \wedge sqwrl:orderBy(?time)$$

Where $video$ is OWL datatype relating a movement pose to a string representing a file. The core SQWRL operator $sqwrl:select(?pose, ?time, ?image)$ builds a table using its arguments as columns of the table. This query returns tuples of poses, times and video sequences with one row for each tuple. The results are ordered by time ($sqwrl:orderBy(?time)$). The left hand side of a SQWRL query operates like a standard SWRL rule antecedent with its associated semantics. The atoms in the SQWRL will not match only all direct OWL individuals in the ontology, but will match also individuals that are entailed by the ontology to be OWL individuals. The query answers can now be used by a matching animation process of the AniAge project.

5. CONCLUSIONS AND PERSPECTIVES

A dance ontology is a very complicated task. On the one hand, it requires additional work on image processing for video segmentation. On the other hand, a cultural interpretation must be presented. In this article, we have built a Vietnamese folk dance ontology by defining dance components, using the segmenting into basic units, which consists of one or more motion phrases.

This work consider only the beginning to create a specific vietnamese dance called Mõ. For future work, we can include some express complex relationships, concepts, and some rules about these concepts, adding more details of basic movement and their properties. Our future research is focused about generalization of this specific Vietnamese dance ontology to create a universal ontology of many kind of Vietnamese dances and we will classify them. Finally, we will apply the strategies proposed in [23] and [2] to select one base consistent when we have many sources of informations about the different dances.

6. REFERENCES

[1] R. Benesh and J. Benesh. *Reading dance: the birth of choreology*. McGraw-Hill Book Company Ltd, 1983.

[2] S. Benferhat, Z. Bouraoui, H. Chadhry, M. S. B. M. R. Fc, K. Tabia, and A. Telli. Characterizing non-defeated repairs in inconsistent lightweight ontologies. In *Signal-Image Technology & Internet-Based Systems (SITIS), 2016 12th International Conference on*, pages 282–287. IEEE, 2016.

[3] S. Benferhat, Z. Bouraoui, and K. Tabia. How to select one preferred assertional-based repair from inconsistent and prioritized dl-lite knowledge bases? In *IJCAI*, pages 1450–1456, 2015.

[4] H. Blades. Creative computing and the re-configuration of dance ontology. In *EVA*, 2012.

[5] A. K. Brown and M. Parker. *Dance notation for beginners*. Princeton Book Co Pub, 1984.

[6] A. Clarance. A proposal for the creation of a dance ontology. In A. L. Brooks, E. Ayiter, and O. Yazicigil, editors, *Arts and Technology*, pages 86–99, Cham, 2015. Springer International Publishing.

[7] D. De Beul, S. Mahmoudi, P. Manneback, et al. An ontology for video human movement representation based on benesh notation. In *Multimedia Computing and Systems (ICMCS), 2012 International Conference on*, pages 77–82. IEEE, 2012.

[8] K. El Raheb and Y. Ioannidis. A labanotation based ontology for representing dance movement. In E. Efthimiou, G. Kouroupetroglou, and S.-E. Fotinea, editors, *Gesture and Sign Language in Human-Computer Interaction and Embodied Communication*, pages 106–117, Berlin, Heidelberg, 2012. Springer Berlin Heidelberg.

[9] K. El Raheb and Y. Ioannidis. From dance notation to conceptual models: A multilayer approach. In *Proceedings of the 2014 International Workshop on Movement and Computing*, MOCO '14, pages 25:25–25:30, New York, NY, USA, 2014. ACM.

[10] K. El Raheb, N. Papapetrou, V. Katifori, and Y. Ioannidis. Balonse: Ballet ontology for annotating and searching video performances. In *Proceedings of the 3rd International Symposium on Movement and Computing*, MOCO '16, pages 5:1–5:8, New York, NY, USA, 2016. ACM.

[11] M. Fernández-López, A. Gómez-Pérez, and N. Juristo. Methontology: from ontological art towards ontological engineering. In *American Asociation for Artificial Intelligence*. MIT Press, 1997.

[12] A. Gangemi, G. Steve, and F. Giacomelli. Onions: An ontological methodology for taxonomic knowledge integration. In *ECAI-96 Workshop on Ontological Engineering, Budapest*, 1996.

[13] P. Hitzler, M. KrÃűtzsch, B. Parsia, P. F. Patel-Schneider, and S. Rudolph. OWL 2 Web Ontology Language Primer. W3C Recommendation, World Wide Web Consortium, October 2009.

[14] I. Horrocks, P. F. Patel-Schneider, H. Boley, S. Tabet, B. Grosofand, and M. Dean. SWRL: A semantic web rule language combining OWL and RuleML. W3C Member Submission, May 2004. Last access on Dez 2008 at: http://www.w3.org/Submission/SWRL/.

[15] L. Loke, A. T. Larssen, and T. Robertson. Labanotation for design of movement-based interaction. In *Proceedings of the Second Australasian Conference on Interactive Entertainment*, IE '05, pages 113–120, Sydney, Australia, Australia, 2005. Creativity & Cognition Studios Press.

[16] P. Q. M. *Folk dance Origin of professional dance*. Master thesis, Hanoi Academy of Theatre and Cinema, 2010.

[17] M. A. Musen. The protégé project: a look back and a look forward. *AI Matters*, 1(4):4–12, 2015.

[18] K. Nguyen Tam and N. Nguyen Thu. *Classical dance curriculum Vietnam*. Ethnic Culture, 2014.

[19] M. O'Connor and A. Das. Sqwrl: A query language for owl. In *Proceedings of the 6th International Conference on OWL: Experiences and Directions - Volume 529*, OWLED'09, pages 208–215, Aachen, Germany, Germany, 2009. CEUR-WS.org.

[20] E. Prud'hommeaux and A. Seaborne. SPARQL Query Language for RDF. W3C Recommendation, January 2008. http://www.w3.org/TR/rdf-sparql-query/.

[21] J. Rett, J. Dias, and J. M. Ahuactzin. Bayesian reasoning for laban movement analysis used in human-machine interaction. *IJRIS*, 2(1):13–35, 2010.

[22] S. Staab and R. Studer. *Handbook on ontologies*. Springer Science & Business Media, 2010.

[23] A. Telli, S. Benferhat, M. Bourahla, Z. Bouraoui, and K. Tabia. Polynomial algorithms for computing a single preferred assertional-based repair. *KI-Künstliche Intelligenz*, 31(1):15–30, 2017.

[24] N. D. Thinh. *Regional Culture and culture zoning in Vietnam*. Young Publisher, Vietnam, 2012.

[25] R. von Laban and R. Lange. *ChorÃl'graphie, ou L'art de dÃl'crire la dance*. Scott - York University Libraries, 1700.

[26] R. von Laban and R. Lange. *Laban's principles of dance and movement notation*. Macdonald & Evans, 1975.