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Design and Use of CALM : an Ubiquitous Environment for Mobile Learning During Museum Visit

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Abstract—The development of mobile devices, such as smartphones and tablets, has led to a new kind of learning environments: ubiquitous learning environments. These environments are particularly interesting in the framework of school learning in museum, as they permit to provide learning content to students, adapted to their positions and interests. The students are free to move in the museum and the ubiquitous learning environment provides authentic learning situations. These environments are thus an alternative to classics guided tours which limit drastically the freedom of visit (for instance, during a guided tour, it is not possible to contemplate an artwork as long as you want).

We present in this paper the design of an ubiquitous learning environment named CALM (ContextuAlized Learning in Mobility), for school learning during museum visits. In CALM as well as in other ubiquitous environment, the main challenge is to reconcile the freedom of movement and action, that characterizes authentic situations, with pedagogical control by the teacher, necessarily limiting this freedom. Our system aims to provide learners with situated interactions, while giving teachers the opportunity to integrate learning objectives that will influence the proposed interactions. We use semantic proximities over a semantic model of the domain (cultural heritage) and context (e.g. position in the museum, activity) to automatically generate contextualized learning activities: artworks suggestion and comparison, serious games based on what the learner has seen. We present the use of semantic rules to enable a loosely-based control of these activities by the teacher (thematic control) together with a fine direct control of proposed activities (contextual control).

I. INTRODUCTION

The development of mobile devices, such as smartphones and tablets, has led to the emergence of a new kind of learning environments: ubiquitous learning environments. Using the mobility of devices and their ability to detect elements of context (e.g. position, activity), these environments enable situated learning [1]. For instance, [2] provides vocabulary information to foreign college students depending on their position on the campus (e.g. information about how ordering food near the cafeteria). The pedagogical advantage of ubiquitous learning is to place the learner in an authentic situation and to provide information at the right time, at the right place. Ubiquitous learning then favors the contextualization of knowledge which should lead to a better understanding and a more sustainable learning.

These learning environments are particularly interesting in the context of school learning in museum. School visits in

museum are proven to be an effective way to contextualize classroom lessons [3]. A conflict then appears in the design of ubiquitous learning environments for museum visit. Indeed, one of the major interests of these environments is to preserve the authentic nature of museum visits, by giving the student the same freedom of moving and acting than an informal visitor, thus showing to the learner that a museum visit is interesting *per se* and encouraging her to visit museum out of the school context. However, particularly within the framework of primary and secondary school learning, there is a need to provide the teacher with some degree of control on learning situations. The problem is to determine how to offer this pedagogical control while preserving for the learners some degree of freedom.

We present in this article the design and use of the CALM (ContextuAlized Learning in Museum) environment which gives elements of response to this problem. CALM is an ubiquitous learning system based on a semantic model of the learning domain (Cultural Heritage) and a semantic model of the learning context (e.g. position in the museum, learners activity). We show how contextualized learning activities (games, suggestions and comparison of artworks) can be generated by using semantic proximities over the semantic representation of artworks. We detail how to provide learning activities that best fit the students need using the semantic representation of context and how the system can be controlled by a teacher using semantic rules over these semantic models.

II. STATE OF THE ART

Learning in museum and learning from museum has been a field widely studied over the last decade. Some major consideration have emerged from these research [4]. At first it is essential to take into account the motivations of the museum visitor: why is he in the museum for, what are his interests? Then in a constructivist learning perspective it is fundamental to take into account the variety of people's personal history to provide them the right content [5]. Finally the social role of exchanging with the peers during the visit is fundamental [6] to construct a shared understanding of the exhibit. In our work, we are trying to take into account the first two points by taking into account interests and history of visits while providing the teacher with learning guidance capabilities.

Various works have been proposed to instrument museum

visits either in a school visit perspective or in an informal visit perspective. These works can be classified in two categories. The first category is task-based systems, these systems are generally designed for school visits. In these systems, the learner is supposed to accomplish various tasks in the museum with the support of a mobile device. The second category of systems is more designed for informal visits. In these systems, the visitor can browse among museum knowledge using the mobile device.

A. Task-based systems

Museum Detective Guide [7] illustrates well task-oriented approaches. The system is intended for students who interact with a device which reproduces existing paper form learning exercises. Students are grouped in pairs and the course is imposed. In front of each work, a series of multiple choice questions should encourage students to consider properly the work in question (e.g. What material is it made of?). Correct answers provide additional information while incorrect answers provide clues to determine the correct answer. In addition to traditional MCQ, learners may take part in more sophisticated games, such as drawing exercises works on tablet. More open questions such as "What do you think the statue would say if it could talk?" aims at initiating discussion among learners about the exhibits.

Several other task-based systems have been designed for mobile learning (not limited to the museum visit) CAESARUS [8], LORAMS [9], IPerG¹ (2008) ... Different kind of scenarios can be considered: role plays, simulations, puzzles ... We can find a review of such systems in [10]. Despite surface differences, these systems share various similarities. They share a constructivist perspective of learning, allowing the learner to construct representations through situated interactions. They all have a playful aspect and they promote social interaction between learners.

These approaches are interesting because they help to maintain interest throughout the learning session, which is sometimes difficult for the younger student. However, they leave very little place to the teacher to define learning objectives. They generally offer a specific solution, well suited to a given place. But this specific solution is limiting involvement of the teacher and does not allow him to use his pedagogical knowledge to modify the learning activities. Moreover, in these approaches, the scenario and activities are often highly constrained, leaving little effective freedom to learners. On the computer science perspective, these approaches are also limited. They are not generic and therefore not easily transferable to other locations or areas of learning.

B. Navigation based systems

Navigation-based systems differ from task-based system by only offering opportunities for browsing among documents related to work, without offering more sophisticated interactions (e.g. games, annotations). These approaches are rather intended to instrument informal visits to museum. Many navigation-based systems use knowledge representation formalisms for easy navigation through information resources (audio, video, etc.).

The HIPPIE project [11] was one of the first systems using automated reasoning in the context of museum visits. HIPPIE uses a characterization of works based on the ICONCLASS² taxonomy, an exhaustive classification of the different themes of western art. Users are characterized by scores of interest for the different themes of the taxonomy. When an user moves into the museum, the system detects her position using a radio location technique. Therefore, HIPPIE is able to inform the user on the works around her that are relevant according to her interests.

The CHIP project [12] is a recommendation system of artworks based on the users' interests. The artwork model includes information from ICONCLASS and three artistic taxonomies published by the Getty Vocabularies Program³: ULAN (Union List of Artist Names), TGN (Thesaurus of Geographic Names) and AAT (Art and Architecture Thesaurus). When a user is interested by an artwork, she may give a score of interest related to different characteristics of the work (style, subject, author ...). The system can then recommend her artworks that are also likely to be of interest for her (e.g. a visitor loving Magritte will be suggested surrealist painters).

These systems are interesting from the computer science perspective, as they are applicable to different museums and cultural venues. They are based on a semantic representation of works which gives them a certain genericity. In addition, they allow the user a large freedom during the visit and automatically adapt to his interests. However, they are poorly suited to support a visit by a class. They offer no educational activity and do not allow the teacher to exercise guidance over the course of the visit.

Our proposal is at the intersection of the two approaches that we have described. It is based on a semantic modelling of the field, that is to say, the cultural heritage. We propose the use of semantic proximities to provide opportunities for navigation among art knowledge. These proximities also allow us to suggest other types of activities such as games of self-assessment and open questions on the works according to their characteristics (e.g. "What sense expresses the character?" for a question about a portrait). In addition, we propose a semantic model of the visiting context seamlessly supplied according to the movements of the learner and his interaction with the application (e.g. consultation of information about an artwork, games ...) . This double modelling, semantic and contextual, allows to provide the teacher with means of controlling learning activities.

III. SEMANTIC PROXIMITIES FOR CONTEXTUALIZED ACTIVITIES

We propose to use semantic proximities between ontological elements to provide opportunities for browsing museum documents. These proximities also allow to offer different kinds of activities such as self-assessment games and open questions about the artworks depending on their characteristics (e.g., "What sentiment expresses the character?" for a question about a portrait).

Furthermore, we propose a semantic model of visiting context updated according to the displacements of the learner

¹<http://iperg.sics.se>

²<http://www.iconclass.nl>

³<http://www.getty.edu/research/tools/vocabularies>

and the interactions with the application (e.g. consultation of the information about a work, games...). These semantic and contextual models allow to provide the teachers with some control over the course of the visit. This is detailed in Section 3.

We have described in [13] the semantic models of domain and context that we propose, and the use of semantic proximities for the generation of contextualized activities. We summarize this proposal before examining how to offer to the teacher pedagogical control on the system.

A. Semantic Model of Artworks

In order to represent the cultural aspects of works, we use three sources of knowledge: CIDOC-CRM¹, Getty-AAT and ICONCLASS. CIDOC-CRM is the reference ontology for describing cultural heritage. Among others it defines the concepts of *work*, *person*, *historical event* and *place*. CIDOC-CRM permits to semantically different aspects of artworks precisely. For instance one can express that *Mona Lisa* was painted by *Leonardo da Vinci*, who was born in *Vinci*, was the master of *Salai* and also produced *The Vitruvian Man*.

However, CIDOC-CRM is a generic ontology. It does not include concepts for a fine description of works of art, such as the style or the theme. We then extended this model by including the ICONCLASS taxonomy, an extended classification of art themes and the Getty-AAT thesaurus (Art and Architecture Thesaurus) about art and architecture techniques and materials. The main reason to include these taxonomy is to be able to compare artworks based on their styles and themes, for instance, to be able to find that an artwork representing *Jesus* is semantically close to an artwork representing the *Virgin Mary*. Indeed, their theme are both *New Testament* which is a semantic category of ICONCLASS.

To include these hierarchies in CIDOC-CRM, we have expressed them as SKOS vocabularies. SKOS is an ontology that allow to express "weak" semantic relations, (e.g list relations, taxonomy, thesaurus). We used *skos:broader* and *skos:narrower* relationships for expressing hierarchical relations for Getty-AAT and ICONCLASS vocabularies. We then created properties to enable the integration of these SKOS vocabularies into CIDOC-CRM. An excerpt of the resulting semantic model of artworks is presented in figure 1.

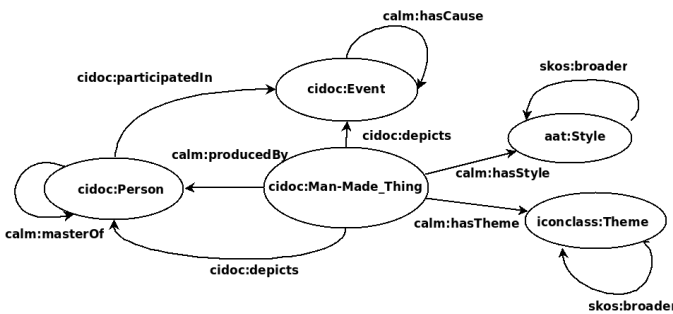


Fig. 1. Semantic model of artworks

B. Semantic Proximity Between Instances

In order to offer relevant situated interactions to learners, we rely on a calculation of semantic proximities. It is based on the proximity by properties approach proposed by [14]. The proximity between two objects (instances of CIDOC-CRM) is based on the proximity between their features. From an ontological point of view, the features of objects correspond to the properties of instances representing these objects. This kind of proximity makes sense in an human point of view because humans tends to compare object and concept based on their features.

In order to determine the set of properties of interest for the comparison we defined a set of concepts of interest. A concept of interest is a concept of the ontology whose instances will appear in the proposed interactions (e.g. suggestions, MCQ). We selected a set of six concepts of interest in the CIDOC-CRM ontology: person, style, work, historical event, place and theme.

We summarize the choice of concepts of interest by an array of properties of interest (Table I). It is an array T , where $\{T[0, k] = T[k, 0], k > 0\}$ are the concepts of interest and $T[i, j]_{i, j > 0}$ is the set of relationships of interest whose domain is $T[i, 0]$ and range is $T[0, j]$.

TABLE I. EXCERPT OF THE ARRAY OF PROPERTIES OF INTERESTS

	cidoc:Person	getty:Style	cidoc:Artwork
cidoc:Person	hasParent hasMaster hasStudent	hasStyle	creates owns
getty:Style	\emptyset	broader narrower	\emptyset
cidoc:Artwork	depicts	hasStyle	partOf

For example, line 2 of table I show the possible comparisons between two instances of *Person*, according to their parents, teachers or students, their styles or the works they have created or owned. We construct a vector of proximity quantifying, for each property of interest, the vicinity of two instances. Two methods of calculation are necessary according to the range of the property: if the range belongs to ICONCLASS or Getty-AAT hierarchies (case 1), we use a hierarchy proximity based on [15], otherwise, we compute the number of common values of the property (case 2). For two instances a and b , $P(a)$ and $P(b)$ being the set of values of a and b for the property P , the value of the proximity this property is :

$$Prox(a, b)_P = \frac{2 * depth(lca(a, b))}{depth(a) + depth(b)} \text{ if case 1}$$

$$Prox(a, b)_P = \frac{|P(a) \cap P(b)|}{|P(a) \cup P(b)|} \text{ if case 2}$$

Where lca is the least common ancestor of a and b using the skos *skos:broader* relation. These calculations lead to a vector of proximity whose dimensions are the properties. To obtain a proximity value for a couple of instances, we assume that all properties have the same importance and take the average of this vector coordinates as the value of proximity. We note in the following $Prox_{Sem}(a, b)$ the proximity value between a and b .

¹<http://www.cidoc-crm.org/>

C. Semantic Model of Context

The context model enables to link purely contextual knowledge (e.g. position of the learner) and museum specific knowledge (e.g. semantic description of works close to the learner). To that end, we represented contextual information through contextual spaces, a contextual space is structured by a domain ontology that defines the kind of interaction between the student and the museum specific knowledge. A contextual space is therefore a knowledge base representing how learners interact, implicitly (e.g. by moving in the museum) or explicitly (e.g. by accessing information) with museum knowledge.

The contextual spaces are populated automatically during the visit. This process occurs as follows: the learner triggers an implicit (e.g. to stop in front of an work) or explicit (e.g. to consult information on the work) interaction with a work. This interaction will activate rules of population of contextual spaces. These rules of population use the domain ontology that defines the relationship between the visitor and the museum knowledge associated to the artwork and add or remove assertions in the contextual space. For instance, when the learner moves in front of a new artwork, assertion describing the artwork in question are added to his location context.

We selected three categories of information for the representation of the visiting context: information about the location, information on the history of visit and information about the interests of the learner.

The location context is constituted of the set of instances representing artworks accessible to learners' perception. In order to obtain these information, we built a semantic model of physical space in museum, using the spatial ontology proposed by the DAIsy¹ laboratory. Our space model is a meshing of the different places in the museum; the unit cells are instances of *daisy:Location*, and correspond to a ten square meters physical area. Each cell is associated to adjacent cells using the *daisy:adjacentTo* relation. The link between a cell and an artwork is provided by the *daisy:contains* relation, which combines one or more artworks to an instance of *daisy:Location*.

The historical context of the user aims to capture the temporality of the visit. This context is modeled using the SEM (Simple Event Model) ontology [16]. This ontology is well suited to our problem. It indeed describes the basic concepts (*sem:Event*, *sem:Place*, *sem:Actor*) to represent visiting activities as well as their temporal aspects.

We defined several types of events as subclasses of *sem:Event*. An event is added to the history context of the user during an interaction with a work *via* the mobile device (e.g. consultation of documents, games). The following example presents the event "consultation of information about an artwork".

```
b rdf:type calm:ConsultEvent.
b sem:hasDate <DATE>.
b sem:hasActor <VISITOR>.
b sem:hasLocation <LOCATION>.
b calm:involvesEntity <ARTWORK>.
```

LOCATION, VISITOR and ARTWORK are the URIs of instances representing the location, visitor and the artwork respectively and <DATE> is the current date.

The interest context of the user aims at representing his interests. This context is very similar to the historical context except that the date and location, which are not relevant for the interests are not represented and that the relation *calm:involvesEntity* is replaced by the relation *calm:interestedBy* which range is the set of concepts of interest. Indeed the learner may be interested by a style or an artist as he can be interested by an artwork.

Figure 2 represents the automatic population of the contextual spaces from the begin of visit. At first, only location context contains statements, then, when the learner request information about specific artworks or characters, the history of visit and

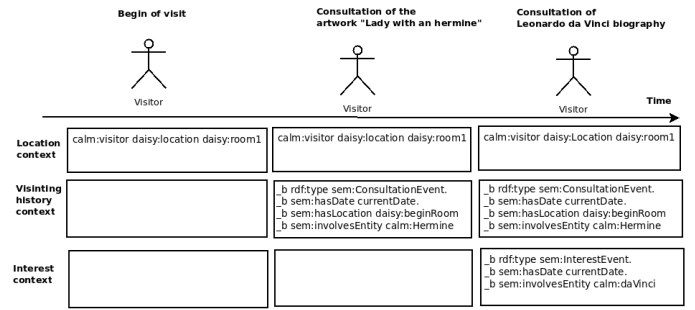


Fig. 2. Population of contextual spaces through time

D. Activities in Museum

The use of semantic proximity allows to offer three types of activities: browsing museum documents, playing self-assessment games and answering open questions about artworks.

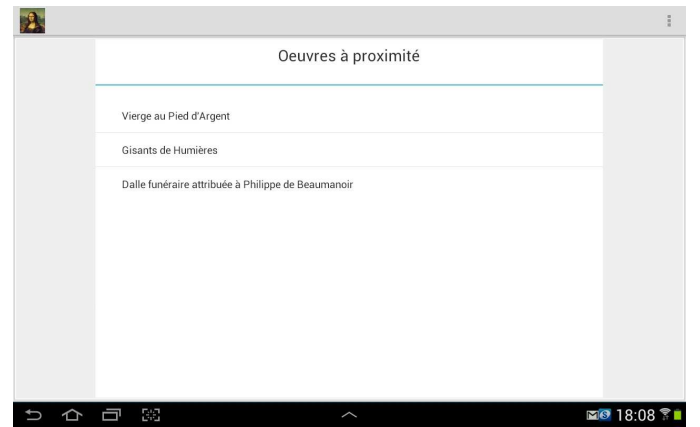


Fig. 3. Selection of visually accessible artwork

When the learners are in a room, they can choose an artwork around them from a list, this list contains only artworks that are visually accessible from their position, (figure 3). When an artwork is selected in the list, learners can browse museum documents about the artwork, the style... (figure 4).

¹<http://daisy.cti.gr/svn/ontologies/AtracoProject/AtracoSpatialOntology/Spatial.owl>

In addition, for each category of elements (e.g. artist, work, style), the learners are provided with suggestions of elements of the same type, semantically close to the element they consider, and belonging to their location or history context. For instance, in figure 4 the learner is considering the statue *La Vierge au Pied d'Argent* (Virgin Mary of the Silver Foot), a XIII^e siècle statue representing Madonna and the child. She is therefore suggested to consider two related artworks in the museum: another representation of Madonna and the child and the *Retable de la vie de la Vierge* (Life of Virgin Mary rededos).



Fig. 4. Suggestion of artworks

These suggestions are associated to justifications, generated automatically from the assertions of the knowledge base that describes artworks. From the previous example the justification for suggesting the Rededos is "These are two representation of the Virgin Mary. On the first part of the Rededos, Virgin Mary is also represented enthroned with the Child" (figure 5). The aim of these justification is to help learners to mentally represent the relationships between the artworks, but also the relationships between characters, styles and themes.

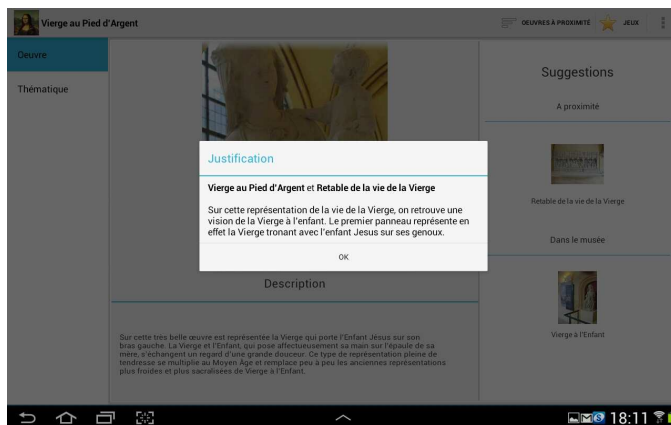


Fig. 5. Justification of a suggestion

The second type of activities we propose are self-assessment games (figure 6). Three types of games are offered: MCQ, true-false questions and classification games (e.g. classification of works by date, style).

These games are dynamically generated from the assertions of the knowledge base. For example, from the assertion: (*calm:RecumbantEffigyOfHumieres cidoc:hasStyle aat:Renaissance*) one question can be : What is the style of the Recumbant Effigy of Humieres? Incorrect answers, also called distractors, are selected among the instances of the knowledge base which are semantically close to the correct answer (Renaissance).

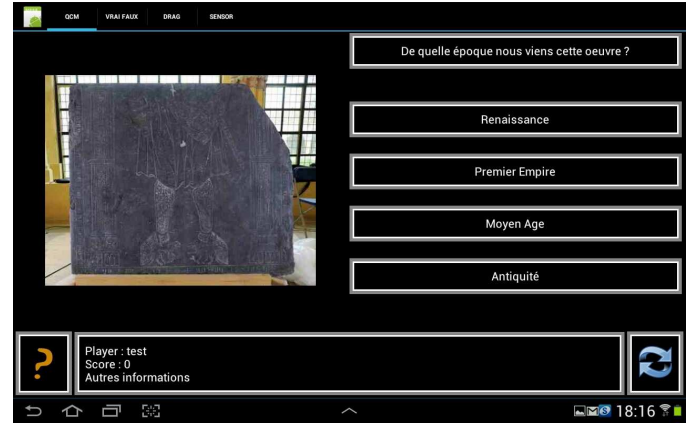


Fig. 6. Example of MCQ game

The last type of activity are open questions about the works. These questions are chosen by the teacher and are of the type "What feeling expresses the character?". The learner responds to these open questions *via* the mobile device. These questions are designed to allow learners to develop an argument using the knowledge acquired in the museum context.

IV. PEDAGOGICAL CONTROL BY THE TEACHER

We present in this section the possibilities of pedagogical control by the teacher over the proposed activities, preserving the sense of freedom that is part of the interest of a museum visit. Our hypothesis is that the museum has a topic related to the curriculum (e.g. Middle Ages for primary school pupils in France). This topic explicitly defines the axes along which the visit should be organized.

Moreover, we assume that even if the teacher does not have in-depth knowledge in museology, she has pedagogical knowledge on how to organize and structure the proposed activities (e.g. to suggest a QCM about historical figures at the end of visit). We present two modes of pedagogical control: thematic control and contextual control. The first control mode aims to place all visit activities in the same theme (e.g. a theme specified by the curriculum). The second control mode is more specific and aims to propose certain types of activities according to a state of the context. For example, the learner is proposed to answer an open question near the end of the visit if the work she considers is a portrait.

We first present how to select activities that are relevant in the learner context and then present how to influence the actual activities that will perform the learner depending on pedagogical objective of the teacher.

A. Contextual Adequacy of Activities

In order to provide interactions that are contextually relevant, we propose to calculate the contextual adequacy of each possible activity. The main idea is that a suggestion or a game will be more understandable and more interesting if it involves elements that are physically close to the learner (i.e. in his location context) or elements that belong to her historical or interest context.

To compute the contextual adequacy of activities, we propose to compare the set of instances involved in an activity with the set of instances included in the learner contexts. If G is a self-assessment game, let $I(G)$ be the set of instances involved in this game. For example if G is a MCQ game, $I(G)$ will contain the instances corresponding to the correct answers, the distractors and the instances involved in the question.

The computation of contextual adequacy for G is therefore given by :

$$Adequacy(G, C_L, C_H, C_I) = \frac{|I(G) \cap I(C_L)|}{|I(C_L)|} + \frac{|I(G) \cap I(C_H)|}{|I(C_H)|} + \frac{|I(G) \cap C_I|}{|C_I|}$$

where C_L , C_H and C_I are the set of instances respectively in the location context, in the history context and in the interest context.

B. Thematic Control

The first type of control covers the entire visit and aims to ensure thematic consistency throughout the course. It helps attract learners' attention on relevant artworks or information according to the theme chosen by the teacher.

To this end, we propose to the teacher to choose a number of resources in the museum knowledge base. For example, if the theme focuses on "The French First Empire", she will have to select the characters, places, events, styles and works related to this theme (e.g. Napoleon, Waterloo, Marie-Louise). This set of instances defines the theme of the visit and is noted T thereafter.

The choice of the set T changes the behaviour of the system concerning the presentation of information. When learners consult the list of works nearby, the works that are semantically the closest to the set T will be highlighted in order to encourage learners to consider these works. Similarly, when viewing information about a work, the elements (e.g. styles, characters) belonging to or close to the set T will be highlighted to facilitate their consultation by the learner.

In addition, the calculation of contextualized suggestions is adjusted to fit the choice of T . The idea is to suggest elements semantically close to the set T , while remaining consistent with the item consulted by the learner. This modification takes the form of a new ordering of suggestions to promote those close to T . Initially suggestions are simply ordered according to their semantic proximity with the current entity: if the learner consults information about an entity e (i.e. an instance of the knowledge base representing a work, an artist...), the score of a suggestion s is given by $Prox_{Sem}(e, s)$. Taking

<p>Rule 1 :</p> <p>Time interval : from 100 min to 120</p> <p>Precondition : none</p> <p>Activity : MCQ</p> <p>Subject : SELECT ?artwork WHERE</p> <p>{</p> <p>?event rdf:type calm:consultEvent.</p> <p>?event sem:hasTime DATETIME.</p> <p>?event sem:hasActor VISITOR.</p> <p>?event sem:hasObject ?artwork.</p> <p>setDateTime(DATETIME, 0, 30)</p> <p>}</p>	<p>Rule 2 :</p> <p>Time interval : None</p> <p>Precondition :</p> <p>(?activity rdf:type calm:ConsultEvent.)</p> <p>(?activity sem:hasActor VISITOR.)</p> <p>(?activity calm:involvesEntity ?artwork.)</p> <p>(?artwork calm:hasTheme iconclass:Portrait.)</p> <p>Activity : Open question</p> <p>: What feelings expresses the character?</p>
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Fig. 7. Example of contextual rules

into account the theme of the visit, the score of a suggestion s with respect to the entity e becomes:

$$Score(e, s) = \alpha * Prox_{Sem}(e, s) + \beta * Prox_{Sem}(s, T)$$

with $Prox_{Sem}(x, T)$ being the mean of proximities between x and every instance of T , and α and β such as $\alpha + \beta = 1$.

Finally, the mode of self-assessment games generation is also modified to take into account the theme of visit. Initially, questions and distractors are selected from the history and location context. The relevance score of a game according to the context is calculated as follows:

$$Score(G, C_L, C_H) = \frac{1}{2} \left(\frac{|I(G) \cap I(C_L)|}{|I(C_L)|} + \frac{|I(G) \cap I(C_H)|}{|I(C_H)|} \right)$$

with $I(G)$ the set of instances involved in the game (e.g. for a MCQ, the instance representing the subject of the question and the instances representing correct answer and distractors), $I(C_L)$ the set of instances in the location context and $I(C_H)$ the set of instances in the history context. By taking into account the theme choice, the computation is now:

$$Score(G, C_L, C_H) = \frac{1}{3} \left(\frac{|I(G) \cap I(C_L)|}{|I(C_L)|} + \frac{|I(G) \cap I(C_H)|}{|I(C_H)|} + \frac{|I(G) \cap T|}{|T|} \right)$$

C. Contextual Control

The contextual control aims at providing the teacher with the ability to propose specific activities depending on context. For example, the teacher may wish to propose, at the end of the visit a quiz about the works that have been seen at the beginning of the visit, or may wish to propose an open question on a work according to certain criteria (e.g. if the work is a portrait from the Italian Renaissance). Contextual control rules are defined by three parameters: the time interval during which the rule applies, the context of the rule application (preconditions) and finally information constraints on the proposed activity when the rule is triggered.

In figure 7, the first rule specifies to propose an MCQ to the learner at the end of the visit (after 100 min, supposing the visit lasts two hours). The second rule specifies to ask an open question if the subject of the considered artwork is a portrait.

V. VALIDATION

We have evaluated two aspects of our proposal: the relevance of the generated questions and recommendations and the usability of the system in a situation of museum visit. We then present the validation plan that we have planned.

A. Relevance of generated questions and recommendations

To assess the relevance of the questions and recommendations generated by the system, we have built a knowledge base containing fifty works and ten artists from the Middle Ages to modern times. That knowledge base was generated from semantic descriptions available in DBpedia. We generated for each work and artist the four closest recommendations. We also generated a set of MCQ about artists and artworks. We then asked a domain expert to assign a score from 0 to 10 for each set of recommendations and a score from 0 to 10 for each question. The results are summarized in the following table.

Suggestion				
Subject of suggestion	Min score	Max score	Mean	
Artist	2	9	6,8	
Artwork	1	10	7,2	

MCQ				
Subject of MCQ	Min score	Max score	Mean	
Artist	3	8	7,1	
Artwork	4	9	7,7	

Fig. 8. Evaluation of recommendations and MCQ

The average score is relatively good for recommendations and questions. The low minimum can be explained by the mode of construction of the knowledge base. Artists and works with low scores in terms of recommendation or questions are artists or works whose semantic description is extremely brief in DBpedia. These scores may be improved if the descriptions are completed.

B. Usability experiment

We conducted an usability experiment during an actual museum visit. The experiment took place in the Great Hall of the Imperial Palace of Compiègne (France) and involved 37 visitors. For this experiment, since we were testing only usability we used a previous version of the system where suggestions were hard-coded. We used a classical approach to validation interfaces inspired by the System Usability Scale method [17]. The visitors were asked to perform a set of tasks using the application: consultation of information about artworks, consultation of suggestion, annotation and consultation of annotations on the artworks. The visitors then filled a questionnaire to assess the usability and usefulness of each task. The table II summarizes the scores of usability and usefulness of different tasks on a scale from 0 to 100.

TABLE II. USABILITY AND UTILITY

Task	Usability	Utility
Consult artwork description	83	97
Consult suggestion	78	86
Consult annotation	73	60
Submit an annotation	63	52

We see that the consultation and suggestions activities achieve good scores in terms of usability and usefulness. The tasks getting the worst scores are annotation and consultation of annotations. Following this experiment, we decided to replace the free annotation with open questions, which, if they leave less freedom, make it easier to comment artworks.

C. Experimental validation

After testing usability and relevance of our proposition, we designed an experimental validation of our system. This validation plan consists in two phases. On the first phase we are going to compare the behaviour of students of two schools groups in a museum visit. On the second phase we are going to conduct interviews of students to have a more subjective vision of their experiences.

During the first phase, the control group will visit the museum with the teacher and a guide while the experimental group will use the CALM application to visit the same museum. We have established three measurable criteria of comparison between the students behaviours. The first criterion is the time spent looking at the artworks which is a good indicator of students' interest [18]. The second criterion is the time spent listening to the guide or reading information for the control group versus the time spent consulting information or using learning game in the other group, this should give us an indicator on how each group is focused on actual knowledge acquisition. The third criteria is the time spent by students exchanging with others about the artworks, indeed peer exchanges is a major criteria of appreciation of the museum experience and help students to construct their knowledge by exchanging their views of artworks [19].

During the second phase we will interview students of the experimental and control group. We will try to determine the impact of the system on the recall of information about artworks. We will also seek to determine whether students who used the system will be more likely than others to go to further visits or to inquire about artworks that are exhibited in the museum.

The last phase of evaluation would involve evaluating the acquisition of meta-knowledge about the museum visit, such as: how to compare artworks? How to apprehend a museum visits? What and where information can be found before and after the visit? This evaluation would be very interesting but we are not planning it for now since it would require a long work with teacher and education professional.

VI. CONCLUSION

We presented in this paper an ubiquitous learning system designed to assist a school group museum visit. Using a semantic representation of the context and cultural heritage we proposed various contextualized activities to help learners to navigate through the museum knowledge and to use the acquired knowledge through self-assessment activities and open questions. The originality of our proposal is based on the dual modelling, semantic and contextual, which allows us to provide the teacher with a certain control over the tour while allowing students a certain degree of freedom.

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