Ontological domain coding for cultural heritage mediation

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Ontological Domain Coding for Cultural Heritage Mediation

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Abstract. An ontology-based representation of information about a domain is flexible enough to support different strategies in presenting the information. In this paper, we present two applications for creating interactive presentations in a cultural heritage domain, that share the same database of informative units and the same representation of the domain, encoded in a light-weight ontology.

An application for drama-based guided tours assembles the informative units in a location-aware fashion, by exploiting the structure of the ontology to enforce the notion of discourse focusing in the generated presentation. A browsing-based application for accessing the informative units supports semantic search, consulting the ontology to suggest modifications of the user's search to circumscribe or enlarge the result sets.

Introduction

Today, the ample support to interactivity provided by the multiplicity of available network infrastructures and user devices (desktop computers, mobile devices, phones) has propelled the development of personalized and adaptive applications for the access to information. In particular, in the domain of cultural heritage, the annotation of archives with semantic tags is the key to personalized access to information, as exemplified by the applications described by [1] and [11].

In this paper, we present two applications for creating interactive presentations in a cultural heritage domain. These applications are based on the same ontological representation of the domain, but realize two different strategies for mediating between the user and the domain. The informative items which constitute the knowledge base of the applications are encoded as self-contained audiovisual clips in which an artificial character, the anthropomorphized spider Carletto, presents specific information about a historical site (see Figure 1). The domain of the presentation consists of a historical location situated in Turin, Palazzo Chiablese, a 16th Century baroque palace that hosts the former royal apartments of the Savoy family. The royal apartments include five rooms:

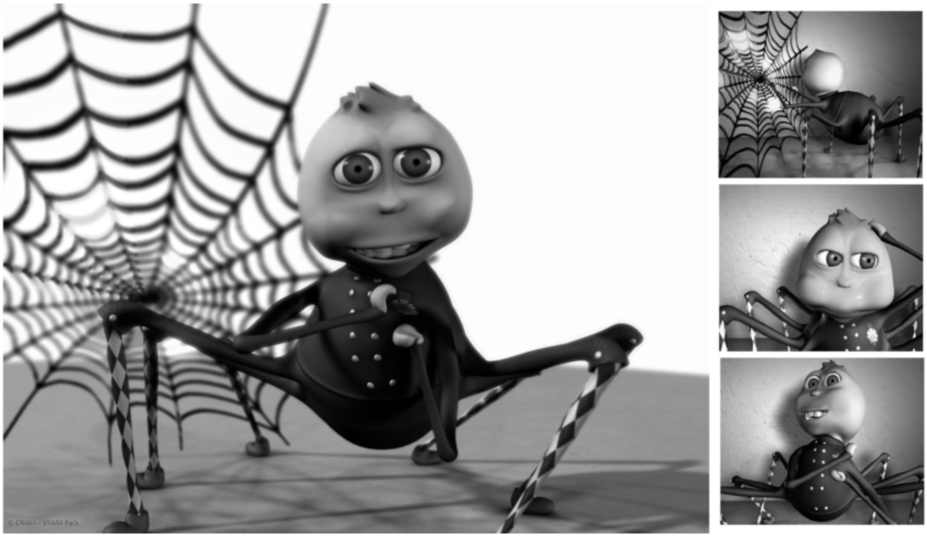

Figure 1. "Carletto the spider".

the Guardroom, the Room of the Valets, the Reception Room, the Dining Room, and the Room of the Tapestries. A domain expert (an historian of the art) has provided the information to be conveyed to the users. The input from the domain expert has been encoded in a set of micro-scripts by a drama expert, from which the audiovisual clips containing the presentation delivered by the artificial character have been produced (*presentation units*), with the help of a multimedia production team. The description of the domain has been encoded in an ontology with the assistance of an ontology engineer, providing the basis for the semantic tagging of the units. The production process is described in detail in [9].

The first application, 'Carletto the virtual guide', was designed to create guided tours in the palace for a public opening in April 2006. The presentation, delivered on a mobile device, is generated by selecting and sequencing the clips in a way that accounts for the position of the user in the historical site. The semantic coherence of the presentation is guaranteed by the fact that the system follows the relations encoded in the ontology to generate the presentation. The peculiarity of this application is that the presentation strategy is inspired to the principles of drama, with the goal of adding an emotional quality to the user experience (see [3] for the drama-based presentation paradigm).

In parallel with the guided visit, we designed a web-based application for direct access to the audiovisual clips, 'Carletto the search engine', by relying on the fact that the encoding of domain information in a ontological form provides a highly-structured semantic representation that supports personalized ways of accessing the same conceptual domain [4,2]. In this application, the user inserts a set of keywords, and a set of clips are retrieved based on the semantic match between the keywords and the concepts represented in the ontology. The structure of the ontology is also exploited to suggest modifications to the user's search, by circumscribing or enlarging the result sets.

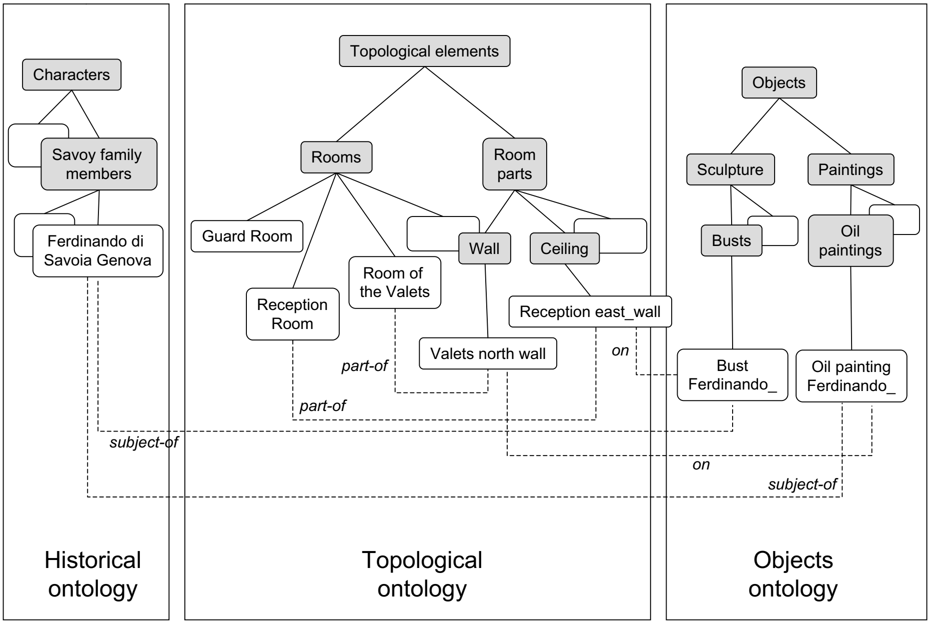

Figure 2. A fragment of the domain ontology concerning Palazzo Chiablese, including portions of three specific ontologies (historical, topological and object ontologies). Grey boxes represent classes, white boxes represent instances. Subclass and instance relations are represented by solid lines, non-taxonomic relations are represented by dashed lines.

1. Ontology-based representation of domain

The two applications described in this paper share the same repository of informative items (audiovisual presentation units). Units are self-contained, so a single unit can be delivered to the user without the risk of introducing unwanted references to other units.

Units have been tagged by their author with a description of their content through semantic metadata. Semantic metadata refer to a set of light-weight domain ontologies that encode the concepts needed to describe the domain (Palazzo Chiablese). Basically, the application for guided tours uses these metadata to sequence the units in a location-aware fashion and to manage the presentation focus in a coherent way given the current location. The search application, given the keywords provided by the user, exploits them to select a set of semantically relevant units based on a predefined mapping from keywords to concepts, and lets the user select among the proposed units.

Since the location of Palazzo Chiablese is a complex domain, that can be described according to several semantic dimensions (like history, art or topology), the representation of the domain is subdivided into five specialized ontologies (see Figure 2), and the topic of the presentation units is described as a tuple of references to these ontologies. This representation accounts for the fact that the same unit possibly concerns more than one topics, each described by a different ontology. A unit is constrained to refer to only one class or instance in each ontology, but may not refer at all to a certain ontology (provided that at least one ontology is referenced).

- The *topological ontology* describes the topology of location, centered on notions like rooms and room parts, according to the practice normally followed by human guides. Since both applications are intended to support the visit of the location in some way, topology provides a dimension of primary importance to organize the domain information.
- The *historical ontology* describes the historical facts related to the location. This ontology includes two main branches, describing respectively the historical characters who lived in the palace and those who worked in it (further subdivided into painters, architects and craftsmen).
- The *ontology of objects* systematizes the variety of pieces of furniture and other items located in the apartments, most of which are awkwardly termed and unknown to standard visitors.
- The *chronological ontology* is an ontology of time intervals that serves the purpose of providing a temporal framework for locating the historical events.
- The *symbolic ontology* describes the concepts (reigns, battles, marriages) that are celebrated by the art objects, located in the palace (paintings, statues, ect.).

In these ontologies, concepts are connected by subsumption relations in which each concept has only one ancestor, so all the ontologies are taxonomies. In order to simplify the description, the same concept cannot appear in more than one taxonomy.

In order to represent the non-taxonomic relations among concepts, orthogonal relations (different than subsumption) have been added to the domain description to connect concepts within the same ontology or across different ontologies. For example, the topological ontology contains a taxonomy of topological concepts (like rooms and room types) and the *part-of* relations according to which these entities are related, specifying, for instance, that a room contains a set of walls, a ceiling and a floor. As an example of relations spanning across different ontologies, consider the *subject of* a painting (object ontology), *located in* a room (topological ontology) and *painted by* an artist (historical ontology) to *celebrate* an event (symbolic ontology). The domain ontologies have been developed with the Protégé ontology editor; orthogonal relations have been implemented as Protégé slots [5].

2. Drama-based presentation

The core of the dramatization process consists in setting up, for the display to the user, some internal conflicts of the character, concerning its emotional values [8,10]. Conflict here is intended as a tool to help the user/visitor to build an emotional bond with the character. The visitor is part of the process of dramatic achievement, since during the presentation she/he provides feedbacks that are used to let the character's conflicts emerge. For example, if the visitor remains in the same room for a certain time, the virtual character switches from the role of a professional guide to the role of a 'storyteller', reflecting his personal involvement in the history of location.

The system architecture for the application "Carletto the virtual guide" is represented in Figure 3. It includes three cascading modules for managing, respectively, the interaction with the visitor (Interaction Manager), the presentation strategy (Presentation Manager), and the delivery of the audiovisual units (Delivery Manager).

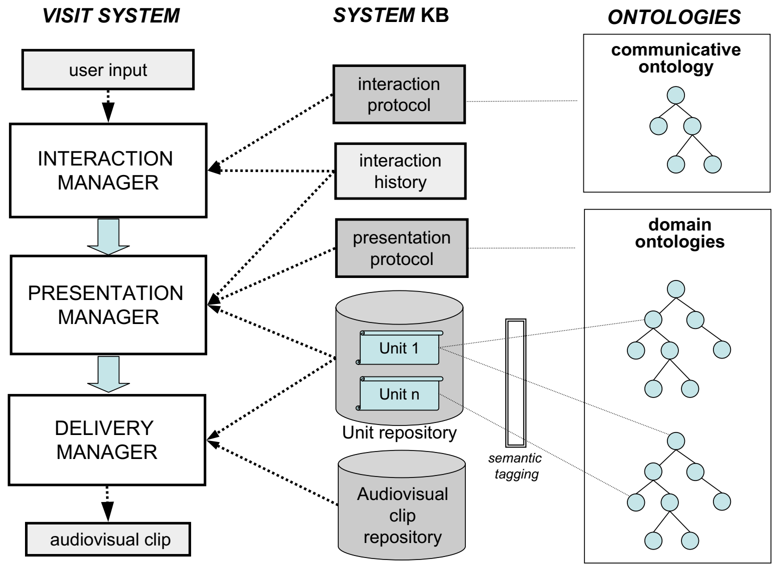

Figure 3. The architecture of the application “Carletto the virtual guide". Solid lines represent control flow, dashed lines represent data flow.

The strategy followed by the Interaction Manager to structure the interaction with the visitor and the adaptation to location is encoded in the *interaction protocol*, that specifies the communicative behavior of the character in terms of *communicative functions* [7] (encoded in a separate ontology). The activation of a function depends on the communicative context, given by the user input, the interaction history and the current location of the user.

In short, the interaction strategy of the application is the following. The visitor’s actions of switching the PDA on or off have the highest priority and activate the functions that correspond to the opening and closing of the interaction. The termination of the visit (defined by the general visit requirements posed by the management of the historical site) has the immediately following priority, and results in the same effect of activating the closing function. If the location of the visitor is unknown, the character signals to the visitor that the location cannot be obtained, and invites the visitor to move in order to regain visibility (directive function). Finally, if the system detects that the visitor has remained in the current room for too long, it enters a waiting loop in which the character invites the visitor to a different room (directive function), and starts waiting for a reaction by alternating the character’s idle state (phatic function) with new requests to move (e.g., Carletto polishes his medals and says impatiently “what about changing room?"). The notion of remaining in a room for too long is implemented as a threshold on the set of available presentation units for the room in the system knowledge base - a set that is decreased every time the visitor returns to the room.

If none of the previous cases occurs, the control passes to the Presentation Manager, that follows the location-adaptive *presentation protocol* represented in Figure 4. First of

```
1  PROCEDURE presentation_protocol (room, interaction history)
2     IF room has changed THEN
3        set current ontology to topological
4        set focus to room
5        select unit
6     ELSEIF focus set to room THEN
8        set focus to first room part
9        select unit
10    ELSEIF related unit on history exists THEN
11       set current ontology to historical
12       select unit
13       set current ontology to topological
14    ELSEIF delivery ratio of current room part is reached THEN
15       move focus to next room part
16    ELSE
17       select unit
18    ENDIF
19  ENDPROCEDURE
```

Figure 4. The presentation strategy of the application “Carletto the virtual guide".

all, the system checks if the visitor has moved to a new room (line 2). If so, it sets the ontology to the topological one (line 3) and sets the focus to the current room (the node of the ontology that corresponds to the room, line 4), so that a generic presentation unit about the room is selected (line 5, see below the selection criteria).

On the contrary, if the visitor is in the same room as the previous selection cycle, the system either starts or continues the description of the content of the room. By doing so, it is driven by a topological principle, i.e., by the order according to which items are positioned with respect to the four walls of the room and the ceiling (i.e., the room parts). If the focus was previously set at the room level (line 6), the system moves the focus to some room part (line 8).

At this point (line 11), the protocol realizes an alternation between the topological ontology and the historical ontology. This alternation aims at realizing the character’s inner conflict between the roles of a guide and of a storyteller. When switching to the historical ontology, the selection of the subsequent presentation unit is driven by the attempt to minimize the transition from the topological ontology. So, the presentation units whose topic metadata include a reference to the historical ontology are searched for those that share the same topic as the current one for the topological (or historical) ontologies (“related unit on history", line 10). If no such unit is available, the systems searches for the units whose topic is a more general topic than the current one, and so on, until the top of the ontology is reached. If no such unit is available, the system skips the ‘historical’ detour.

After the ontology alternation has been dealt with, the algorithm checks whether there is any non-delivered information left to say about the current room part (line 14); otherwise it moves the focus to the next room part (the next sibling of the wall node on the ontology, line 15). Notice that the described strategy complies with the focussing rules stated by Grosz and Sidner [6] for task-oriented dialogue. According to Grosz and Sidner’s rules, maintaining the focus on the current task has the priority over moving the

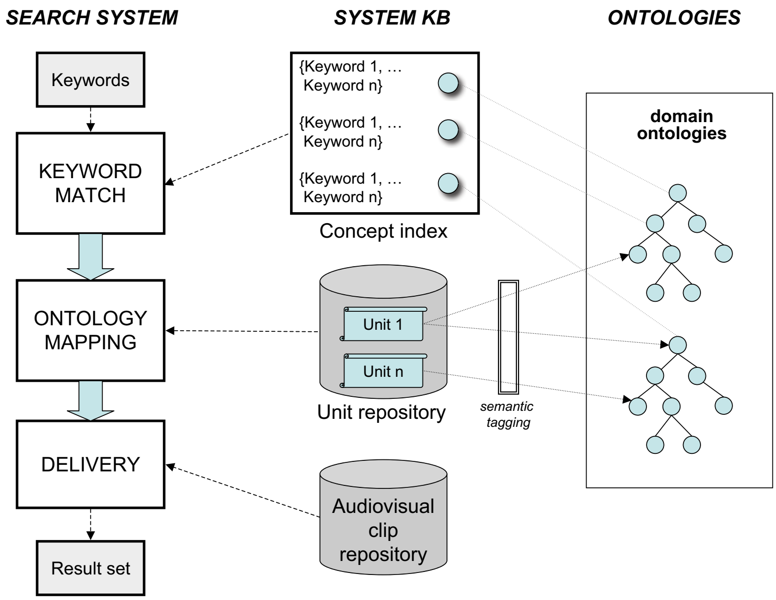

Figure 5. The architecture of the application “Carletto the search engine"; the architecture shares most of the system kb and domain ontologies with the application “Carletto the virtual guide" (Figure 3).

focus to a subtask of the current task, that has the priority over moving the focus from the current subtask to a different subtask of the same task. [1]

The visit server and client are implemented in Java (http://java.sun.com), while the clip repository is implemented as a mySql data base (http://www.mysql.com). The client software is executed by a virtual machine on a PDA (ASUS A636 PocketPC series).

3. Keyword-based search

Beside the system for creating character-based, dramatized guided tours, we designed an application in which the same repository of audiovisual units can be accessed through a simple semantic search engine. In this application, the user enters a set of keywords to perform a search on the repository, possibly retrieving a non empty set of units. The user can ask the system for suggestions to improve the search through narrowing or widening. The architecture of this application, “Carletto the search engine", is sketched in Figure 5.

In the search application, the repository does not include the units devoted to the management of the interaction with the user (for example, the units in which the virtual character greets the visitor – without providing any domain information), since the interaction with the user is limited to the insertion of a set of keywords in the search interface.

[1]The actual implementation supports the focussing procedure on a taxonomy of any depth. However, here we report the algorithm only for the levels of the room and the room parts, since only these two were developed in the final version of the system.

```
FUNCTION search (keywords list)
   FOREACH keyword IN keyword list
      IF keyword matches ontology node THEN
         add node to matching node set
         FOREACH node IN matching node set
                IF related units exist THEN
                   add units to result set
                ENDIF
         ENDFOREACH
      ENDIF
   ENFOREACH
   return result set
 ENDFUNCTION
```

Figure 6. The search strategy of the application “Carletto the search engine".

Given keywords entered by the user, the system consults an index in which the nodes of the domain ontologies are mapped to a set of keywords, selected by an interaction designer. If one or more matches are found, the system queries the repository of audiovisual units for the units that are related with the matching nodes through their semantic metadata.[2] The process is illustrated in Figure 6.

The selected units are proposed to the user as a list of links to the clips, that the user can access in different modalities (text or multimedia) and formats. A priority is given to the matches with the topological ontology, given the relevance of this dimension. When the user selects a unit from the list, the system also displays links to the other concepts to which that unit is related, extracted from the metadata of the unit itself. If the user clicks on one of these links, the system searches the repository with the selected concept as new matching node; through this modality, the user can browse the repository as a hypertext.

If the user wishes to broaden or restrict the search, the system can make suggestions following the hierarchical relations in the ontologies (Figure 7). To broaden the search, the system repeats the query on the unit repository by replacing the matching nodes in the node list with their direct ancestors (if the nodes are instances, the instances are replaced by the class to which they belong). On the contrary, to narrow the search, the system replaces each node with the set of its children. If explicitly requested by the user, the system can also query the unit repository for all the units that are related with the node list via subsumption, bypassing in one step the iteration of the narrowing process until the leaves of the taxonomies.

This application is currently being prototyped in Java by exploiting on the tools made available by Protégé for the access and manipulation of the ontology.

4. Examples

In order to exemplify the role of the ontologies in the two applications, we resort to an example based on the portion of ontology shown in Figure 2. The figure shows some fragments of the historical, object and topological ontologies; as it can be noticed by observing the figure, the node representing the historical character of the Duke Ferdi-

[2]Units that are not *directly* connected with the matching nodes are not considered, following the assumption that the level of abstraction selected by the user must be preserved.

```
FUNCTION broaden-search (node set)
   FOREACH node IN node set
      replace node with ancestor
      FOREACH node IN node set
              IF related units exist THEN
                 add units to result set
              ENDIF
      ENDFOREACH
  ENDFOREACH
  return result set
ENDFUNCTION
```

```
FUNCTION narrow-search (node set)
   FOREACH node IN node set
      replace node with descendants
      FOREACH node IN node set
              IF related units exist THEN
                 add units to result set
              ENDIF
      ENDFOREACH
  ENDFOREACH
  return result set
ENDFUNCTION
```

Figure 7. The algorithms for broadening and narrowing the scope of the search in the semantic search application.

nando di Savoia Genova (one of the owners of the Palace, instance of the class "Savoy family members") is connected to some instances of the object ontology by a relation of the type “subject_of". In fact, two of the busts contained, respectively, in the apartments (Reception room) and in the entrance hall of the Palace, represent the character of the Duke Ferdinando. The Duke Ferdinando is also depicted in an oil painting contained in the Room of the Valets.

In “Carletto the virtual guide", Carletto is likely to talk about the Duke Ferdinando at different points in the presentation (due to location adaptation and to random aspects in the presentation, presentations vary from a visitor to another, and from a session to another with the same visitor). When the system follows a topological order of presentation, the Duke Ferdinando may be mentioned when Carletto is talking about the locations in which the painting and the busts are located. The Duke Ferdinando may subsequently become the subject of a historical digression centered on the Savoy family.

So, the presentation flow may be constituted by the following sequence of presentation units (taken from one of system logs):

4 $\texttt{PU\_33} < \texttt{Topology} : \texttt{Room\_of\_the\_Valets}, \texttt{History} : \texttt{Carlo\_Felice} >$

...

7 $\texttt{PU\_35} < \texttt{Topology} : \texttt{Room\_of\_the\_Valets\_north\_wall},$
$\texttt{Objects} : \texttt{oil\_painting\_Ferdinando}, \texttt{History} : \texttt{Ferdinando\_di\_Savoia} >$

8 $\texttt{PU\_107} < \texttt{Topology} : \texttt{Palace}, \texttt{History} : \texttt{Ferdinando\_di\_Savoia},$
$\texttt{Chronology} : \texttt{1850}, \texttt{Symbols} : \texttt{Marriage} >$

With PU_33, the system starts introducing the room of the Valets by giving general information about its function and the character who gave it its current shape (Carlo_Felice), then illustrates the room walls one by one (for brevity, we omitted the two units about the south and east walls, represented by the dots). After presenting the oil painting on the north wall of the room (PU_35), the system switches to the historical digression. So, Carletto starts talking about the Duke Ferdinando (PU_107), with a unit that talks about his marriage with an Austrian princess, that led some main renovations in the Palace. Remember the system tries to minimize the transition between the ontologies by looking for a unit that shares the most of the values in the semantic metadata with the last selected one: in this case, the closest match for the unit PU_35 is the unit PU_107, that has the same value for the historical ontology (see the item `History` : `Ferdinando_di_Savoia`).

Alternatively, the system may introduce the Duke Ferdinando when presenting the Reception room, which contains a bust that represents him. Or, he may be mentioned in a historical digression after Carletto talked about the Duke's marriage, since this event is explicitly mentioned in one of the units concerning the Reception Room.

In the application, "Carletto the search engine", if the user inserts the keyword "Ferdinando di Savoia Genova", the system finds a set of presentation units that refer to the Duke Ferdinando in their semantic metadata. As shown above, some talk about him as a historical character (PU_106, PU_107), who played a role in the history of the Palace, some mention him as the subject of artworks (PU_58, PU_35). In order to broaden the search, the system would propose the user to use the keywords "Savoy" or "Savoy family", that are associated with the class representing the Savoy family, of which the Duke Ferdinando is a member; in this case, a larger set of results would be proposed (25 units). The search can be further broadened by pointing to the node that refers to the historical characters in general (yielding 34 units).

If the user cliks on the link associated with the word 'bust' in the text of the PU_58, the system shows all the units concerning the busts contained in the palace (PU_58, PU_31, PU_27, PU_48). Or, if the user cliks on the link associated with the Reception Room, the system retrieves all the units in which Carletto talks about that room (7 units).

5. Discussion

The two applications described in this paper rely on the semantic annotation of a repository of informative items (presentation units), which take the form of scripted audiovisual units. In both applications, items are retrieved and delivered to the user based on their semantic annotation in a context-dependent way, although the role of the context varies from the location-awareness of the virtual guide (Section 2) to the keyword-driven search in the search application (Section 3). A common feature underlying the two approaches is that the processes of writing the units that compose the presentation and the process of semantically annotating them are integrated in one process of "writing & tagging", accomplished by the author who writes the units. In both cases, the semantic metadata that the system relies on to retrieve the units are predefined with respect to the process of writing the presentation contents and constitute a framework by which the author is constrained and driven in the writing process, as described in [9]. This approach, although it poses important limitations to the author, is motivated mainly by practical considerations: by giving a rich semantic characterization of the presentation units (the units are annotated according to a set of light-weight domain ontologies, as illustrated in Section 1), the system is not required to perform complex ontological reasoning, but navigates the domain ontologies by relying on the author's annotations.

A major drawback of this approach is that the effectiveness of the systems depends on the author's expertise and competence in tagging. For example, consider a presentation unit about a painting: the semantic metadata of that unit point to a certain instance of 'painting' in the object ontology, but if the the unit also mentions the author of the painting (modeled by the *painted by* relation between the painting instance in the object ontology and an author instance in the historical ontology), the unit metadata concerning the historical ontology should point to that specific painter instance. This style of representation makes some basic forms of ontological reasoning unnecessary for the system that accesses the presentation units; going back to the example before, it makes it superfluous for the system to query the ontology in search for a filler of the *painted by* relation between paintings and painters for a specific painting, as this information is likely to emerge from the manual encoding of the semantic metadata. The consistency of the manually-coded semantic metadata with the relations between the ontological representation of the domain is not guaranteed, since it is not governed by formal rules; rather, it is left to the initiative and the skills of the author who writes and tags the units: if the unit in the example marginally mentions a different painter than the painting author, it is not advisable – though not forbidden – to encode the reference to this other painter in the tuple.

The two systems presented here permit the data and their annotation to be modified to a limited degree. In particular, in the virtual guide application, the presentation script that drives the location-aware delivery of the information relies on the topological ontology and on the historical ontology to create a dramatic conflict in the virtual guide. In addition, the presentation script assumes some predetermined levels of detail in the description of the location (palace, room, room parts and objects), matching the structure of the topological ontology, and dictated by the design goal of mimicking the 'situatedness' that characterizes the visit with real guides. So, while adding new rooms or objects to the visit would not affect the system, designed and implemented to be scalable, transporting the system to a domain in which the topology is structured in a different way would require the presentation script to be modified. On the contrary, the search application is not influenced by the content of the domain ontologies, since it mainly relies on the navigation of taxonomic ontologies.

Concerning the evaluation of the domain coding adopted for the two applications, an evaluation study, conducted during the opening to the public of the virtual guide system, has revealed that the visitors appreciated the applications and were satisfied with the quantity and quality of the information provided (respectively, with a score of 3.80 and 3.72 on a scale from 0 to 5), and that they were able to find the items addressed by the virtual guide (83% of the visitors). Although the evaluation did not specifically address the appropriateness of the ontologies employed by the application, the overall appreciation for the system seems to confirm that they were suitable to represent the domain for the application purposes, and that the focusing mechanism that they supported was adequate to establish an effective reference system for the user.

6. Conclusions

In this paper, we have presented two applications for creating presentations that mediate between users and domain information in the field of cultural heritage. Although inspired by different design goals – the dramatized presentation system aims at improving the user's reception of the information by generating an engaging guided tour, while the web-based application is a simple search interface – the two applications share the same ontological representation of the domain. This representation, necessary for accounting for the complexity of the presentation domain (a historical location), lends itself to developing different paradigms to access the information, allowing at the same time the process of reusing data among different applications.

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