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Enhancing augmented reality with cognitive and knowledge perspectives: a case study in museum exhibitions

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ABSTRACT
In this paper, we present our results related to the definition of a methodology that combines augmented reality (AR) with semantic techniques for the creation of digital stories associated with museum exhibitions. In contrast to traditional AR approaches, we augment real-world elements by supplementing contents of a museum exhibition with additional inputs that provide new and different meanings. In this way we augment a cultural resource with respect to both its presentation and meaning. The methodology is framed in the cultural re-mediation theory and is grounded on a set of ontologies aimed at modelling a cultural resource and correlating it with external multimedia objects and resources. To provide an easy tool for the creation of museum narratives, the methodology makes use of a set of recognised practices widely adopted by museum curators that have been formalised through inference rules. The defined methodology has been experimented in a scenario related to Flemish paintings to validate the augmentation of cultural objects with two different approaches, the first basing on similarities and the second on dissimilarities.

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1. Introduction

Augmented reality (AR) is widely adopted to enhance real-world elements with computer-generated sensory inputs such as sound, video, animations, etc. Recent research studies (Alelis, Bobrowicz, and Ang 2015) show that AR, at least in the form of 3D reconstruction of cultural objects, is enjoyable by older and younger adults, so AR is gaining importance in museum exhibitions. However, in quite all the applications of AR, 'augmentation' just impacts on object presentations with the aim of acting as stimulus and enhances the user's perception. It is questionable whether this can be really regarded as an enhancement and/or have an added value from an education perspective when it is not combined with methods aimed at providing a clear, better, or different meaning of real-world elements. In other words, we think that 'augmentation' should be afforded along two orthogonal perspectives: technological and cognitive.

Following this argument, we have defined and evaluated a new methodology to enhance cultural resources with digital contents that, on one hand, augments the user's sensory experience through the addition of multimedia objects and, on the other hand, improves the user's cognitive process by unveiling the different facets that lie behind cultural resources. The methodology, whose main purpose is to support museum curators in the definition of exhibitions, leverages on a knowledge model that correlates different ontologies, and on a set of inference rules that are based on practices adopted by museum curators to create exhibitions. Specifically, with the help of the set of rules, a curator can retrieve, from multimedia repositories such as *YouTube*, *IMDb*, etc., digital objects that fit well in a specific type of exhibitions. Then, comments, tags, and other textual sources of these objects are analysed in order to understand their content (e.g. they can be similar or dissimilar with respect to a cultural resource of the exhibition, more abstract or more specific, etc.) and, basing on that, the digital objects are linked to the exhibition.

The paper is organised as follows. Section 2 reports an overview of the research project that gave rise to the innovations here presented and provides the needed theoretical background about the re-mediation of cultural resources. Section 3 describes the defined methodology, while Section 4 illustrates some details about the knowledge model. In Section 5, such theoretical components are evaluated through a case study, while Section 6 reports a comparison of obtained results with related works. Finally, Section 7 draws conclusions and plans future works.

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2. The FIBAC project

Fruizione Innovativa dei Beni Artistici e Culturali - Innovative Fruition of Artistic and Cultural Assets (FIBAC)[1] is an Italian co-funded project on the valorisation of artistic and cultural resources in real and virtual museums. The theoretical ground of FIBAC is the cultural re-mediation theory developed on top of Bolter and Grusin (1999) as a means to establish a new way of mediation of the cultural heritage.

Bolter and Grusin define re-mediation as the representation of a media into another media, or the use of some features typical of a media within another media. Historically, re-mediation has been referred to be between analogical and digital media (e.g. a web page re-mediates a printed page). The re-mediation is based on two conflicting and antithetic logics: immediacy and hypermediacy. In the immediacy logic, the objective of the medium is to disappear: immediacy provides for a limitation or removal of the mediated nature of experience. For this purpose, immersive technologies are typically adopted. In the hypermediacy logic, instead, the medium and the mediated nature of the experiences are clearly visible. A clear example of this modality is the hypertext.

The two extreme sides of the re-mediation theory, that is, immediacy and hypermediacy, do not always provide an appropriate place for valorisation of cultural heritage. As mentioned above, in fact, immersive systems (not always available at least in the majority of the museums) are typically required for immediacy, while in the hypermediacy, the required interfaces may confuse the user.

It is recognised that at the core of the re-mediation theory there is the convergence between old and new media. The intuition of McLuhan (1964) 'the content of a media is always another media' evidences that re-mediation can be considered as a loan modality between media, based on the embedding or representation of another media.

FIBAC offers an additional perspective based on the convergence between different types of knowledge, that is, factual and user generated (social), and on the value of cross-fertilisation among domains, that is, cultural and not cultural. A cultural resource in FIBAC is re-mediated not only with respect to media and the ICT, but also mainly according to its meaning and associated knowledge.

3. The cultural re-mediation methodology

A FIBAC experience is composed of two different scenarios: the first (conceptual) is purposed to present, in a personalised and contextualised way during a visit to a (virtual or real) museum, the factual knowledge about a cultural resource, while the second (re-mediated) is aimed at adding new meaning to a cultural resource.

The *conceptual scenario* presents the cultural resource, that is, the knowledge about events, actors, time, and space related to a cultural resource. This scenario is built on the basis of (i) specific domain knowledge about the resource to be presented, (ii) personal preferences and knowledge background of the user, and (iii) environment (e.g. real or virtual museum) and technical contexts (e.g. kind of devices).

Starting from an assessment (cognitive and affective/emotional) in the previous scenario, the cultural resource is re-mediated in order to make more engaging and proficient the experience. The *re-mediated scenario* has the purpose of adding new meaning to the cultural resource, providing additional content on 'similar' or 'dissimilar' resources.

In the first case, additional meaning is derived by the provision of knowledge about, for instance, similar event, actors, etc. By using semantic technologies and inference rules, the discovery of new correlations between two cultural resources is possible in order to assign them new unspecified meanings.

In the second case, new meaning of a digital cultural resource is derived by the provision of contents about non-cultural data (e.g. relating a description of the *Virgin of the Rocks* painting with an entry in a blog commenting the *Da Vinci Code* book or a video extracted for the homonymous movie). Exploiting linked data, social networks posts, and/or blog (Celik, Abel, and Houben 2011), the knowledge on the cultural resources is correlated to that available on the web, filtered according to the 'non-cultural' interests of the visitors. The idea of connecting different contexts that are not immediately obvious is at the base of the so-called *lateral thinking* that FIBAC adopts to support the addition of new meaning.

Figure 1 gives an overview of the overall methodology adopted to create adaptive and contextualised knowledge paths, highlighting (in bracket in the figure) the processes and the methods that are involved, most of them validated also in the context of initiatives (Gaeta, Gaeta, Orciuoli, et al. 2012; Gaeta, Gaeta, Piciocchi, et al. 2012). In particular, the figure shows how, starting from a semantic layer, it is possible to create a personalised path to present factual knowledge about a cultural resource. The left side of the figure shows the semantic layer and the right side shows the conceptual scenario, relating several concepts about a cultural resource to present its factual knowledge. Each concept can have one or more associated digital objects.

The semantic layer follows an approach similar to the one proposed by Menzel (2003) and Borgo et al. (2002).

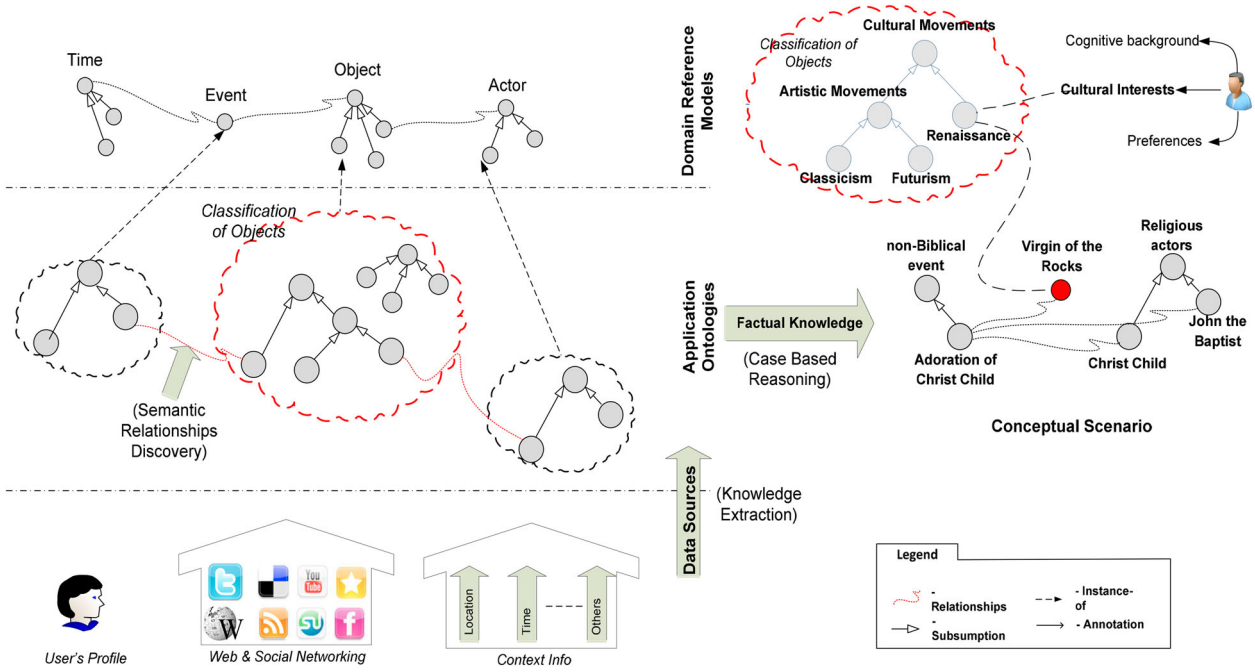

Figure 1. The semantic layer (left) and the conceptual scenario (right).

In the higher layer, there are the so-called *reference ontologies* that in our case are *domain reference models* (like the Comité International de Documentation Conceptual Reference Model (CIDOC/CRM)[2] scheme) providing a representation of the main concepts, properties and relationships of a domain, as well as a representation of users/visitors.

Top layer concepts can be classified leveraging on *application ontologies*, that is, lightweight ontologies that allow classifying concepts in *is-a* hierarchies. Application ontologies, in our case, are used also to correlate concepts belonging to different classification schemes (e.g. leveraging also on generic relationships such as the *SKOS:Related*) so that it is possible to discover/create relationships between actors, objects, events, time, etc. Lastly, the specific concepts of the application ontologies are associated with annotated digital contents stored in the internal or external repositories.

FIBAC acquires knowledge from several information sources, as highlighted at the bottom of the figure. Acquired information is conceptualised through *knowledge extraction processes*. On the other hand, *semantic relationships discovery* features allow extracting links among several and heterogeneous objects by analysing linked data, social network, blogs, and so on.

Leveraging on these semantic structures, an end-user can express her/his goal, in natural language, and let FIBAC retrieve a knowledge path and a set of corresponding resources able to support user goals, taking into account her/his preferences and cognitive background. This process results in the provision of the factual knowledge associated with a cultural resource.

The right side of Figure 1 provides an example of the factual knowledge that can be generated by a user's query about Leonardo's painting *Virgin of the Rocks*. FIBAC is able to create a path correlating the main subject of the cultural resource, that is, the *Adoration of the Christ Child by the infant John the Baptist*, to the object, that is, a picture of the *Virgin of the Rocks* painting, and to the actors, that is, *Christ Child* and *John the Baptist*. FIBAC can retrieve proper digital contents, taking into consideration preferences of the user and the technological context of the device. Associations between users' needs, profile, context, and paths followed by the users in FIBAC can be stored to be reused when similar conditions happen for other users.

The objective of the conceptual scenario is to provide the end-user with a set of digital contents composing the factual knowledge about a resource, and is only a part of a usual FIBAC experience. Figure 2 shows the second part: how from the conceptual scenario is it possible to produce the *re-mediated* one, aimed at providing a better engagement and new meaning to a cultural resource.

The right side of Figure 2 shows two possible re-mediated scenarios (Capuano et al. 2014) obtained from the same conceptual scenario. The idea is to provide an assessment of the user experience behind the conceptual scenario. Affective and emotional approaches are combined with traditional cognitive assessment in order to systematically evaluate the user engagement and cognitive growth after the provision of the factual knowledge.

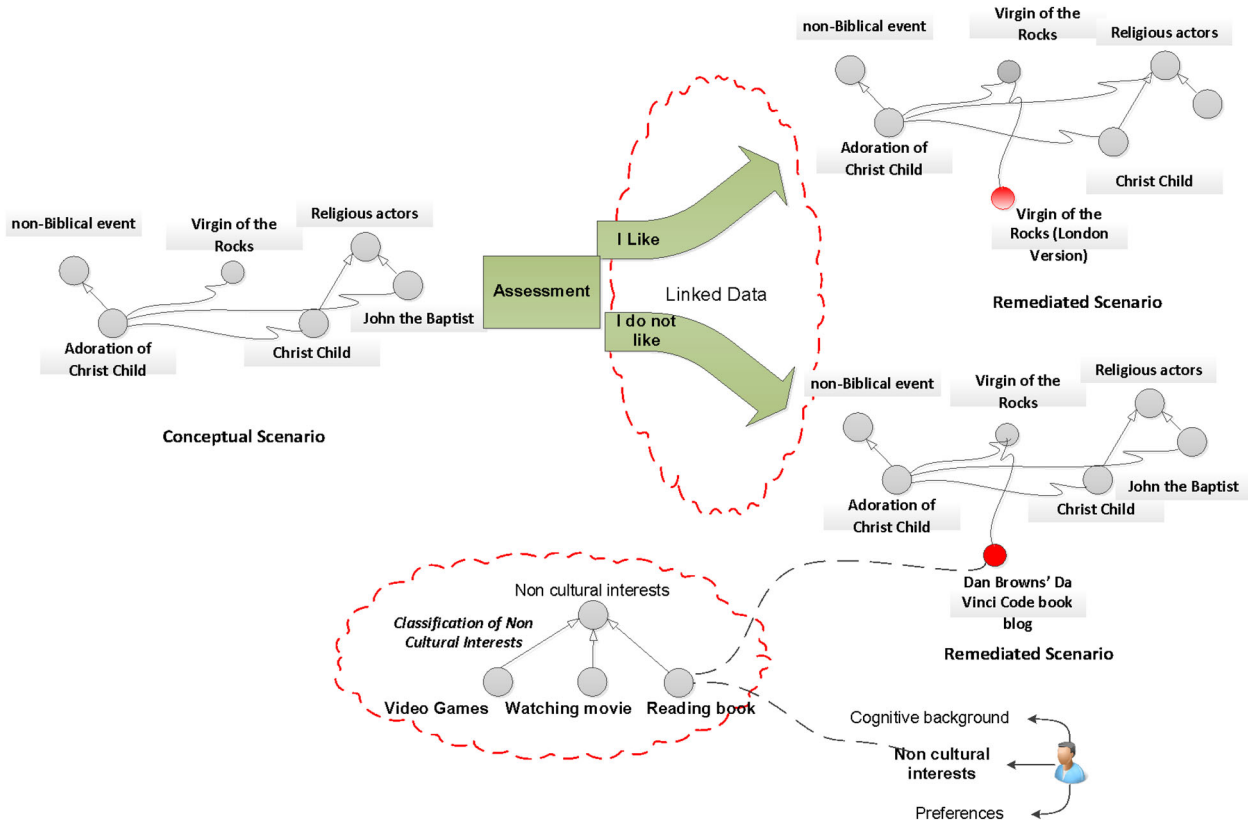

Figure 2. From the conceptual to the re-mediated scenario.

Basing on the assessment results, FIBAC decides on the appropriate strategy to adapt the experience via the re-mediated scenario. In general, in case of a positive assessment (the *I like* arrow in the figure), we exploit a strategy based on *similarity*. In this case, we maintain the same context, types, and semantic density of the digital contents of the conceptual scenario. We identify the appropriate external datasets via extraction of a set of features from the contents of the conceptual scenario (in the case of the example, we can extract a set of terms such as 'Museum', 'Leonardo', 'Virgin of the Rocks', 'Christ', etc.) and use the extracted feature terms to perform a search of the external dataset.

Once the appropriate external dataset is identified, the relevant classes inside the selected datasets are found, leveraging on ontology matching techniques. In case of positive assessment, in general, the objective of the re-mediated scenario is to provide additional meaning to a resource such as to improve the cognitive growth of the user.

In case of negative assessment (the *I do not like* arrow in the figure), the factual knowledge and the way it has been presented have not reached the objective of improving the cultural experience for the user. Thus, in this case, a *dissimilarity* strategy is exploited to shift the context and produce a re-mediated scenario able to correlate cultural resources with not cultural ones on the basis of not cultural interests of the user (books, music, films, sports, etc.). In this case, features extracted from the user profile about not cultural interests are used to identify the external datasets, while feature sets extracted from the cultural resource are used in the matching phase to identify, in the selected dataset, the appropriate instances.

In the case of the example, if the user is interested in books, the first step of such a strategy can result in the identification of datasets such as, for instance, *OpenLibrary*,[3] while the second can result in the identification of a review or a particular blog about the *Da Vinci's Code* book. In the case of negative assessment, in general, the objective of the re-mediated scenario is to *open the mind* of the user by correlating cultural and not cultural (but based on user's interested) contexts, so that a different meaning can be associated to the resource.

4. The knowledge model

The knowledge model is at the core of our methodology since it allows a formalisation of the cultural resources and of multimedia objects that are correlated and presented to the user. The approach designed to model the knowledge is based on a view separated into three

macro-areas (*Cultural Artefact Modelling*, *Knowledge Deduction Modelling*, and *Multimedia Modelling*) connected to each other, as shown in Figure 3.

In the *Cultural Artefact Modelling macro-area*, we represent and describe cultural objects by using an approach based on Reference and Domain Ontologies. Such ontologies are aimed at representing and structuring cultural entities according to CIDOC/CRM scheme and specific objectives. It is composed of CIDOC/CRM core entities (e.g. 'actor', 'place', 'object', 'time-span', and 'event'), which are indispensable information for representing the cultural heritage in museums, and relationships between the classes that represent them.

The goal of Domain Ontologies (referred as Museum Ontologies) is to represent and classify particular subject or domain areas. They represent the 'view' through which organisations and cultural communities describe the concepts in their domain, the relationships between these concepts, and instances or individuals who are the current subjects that populate the structure. The Domain Ontology allows to describe the concepts belonging to CIDOC/CRM core entities in a structured view and to classify them within the museum domain through the use of specific properties and relations.

In the *Knowledge Deduction Modelling macro-area*, on the basis of rules widely adopted by museum curators, it is possible to infer knowledge on some cultural resources related to the objective of the museum exhibition. In this way, authors of museum narratives are able to retrieve, from the internal or external repositories, resources and knowledge related to the objective of the exhibition. Table 1 reports a list of basic criteria that are usually considered by museum curators in order to prepare an exhibition. In addition, according to our experience in the FIBAC project, we have found the most used combinations of the basic criteria as shown in Table 2.

To ensure that the inference system can automatically generate museum paths by making inference reasoning on the available knowledge base respecting the criteria listed in the above tables, it is important that these criteria are encoded in appropriate inference rules. In our work, the inference rules are formulated in *SWRL*[4] syntax that combines *OWL*[5] with *RuleML*.[6]

The main components of a SWRL rule axiom are the antecedent (body) and the consequent (head). The antecedent is composed of all the prerequisite conditions to be verified, while the consequent describes the constraints to be applied to a concept or a relationship between instances. Both the antecedent and the

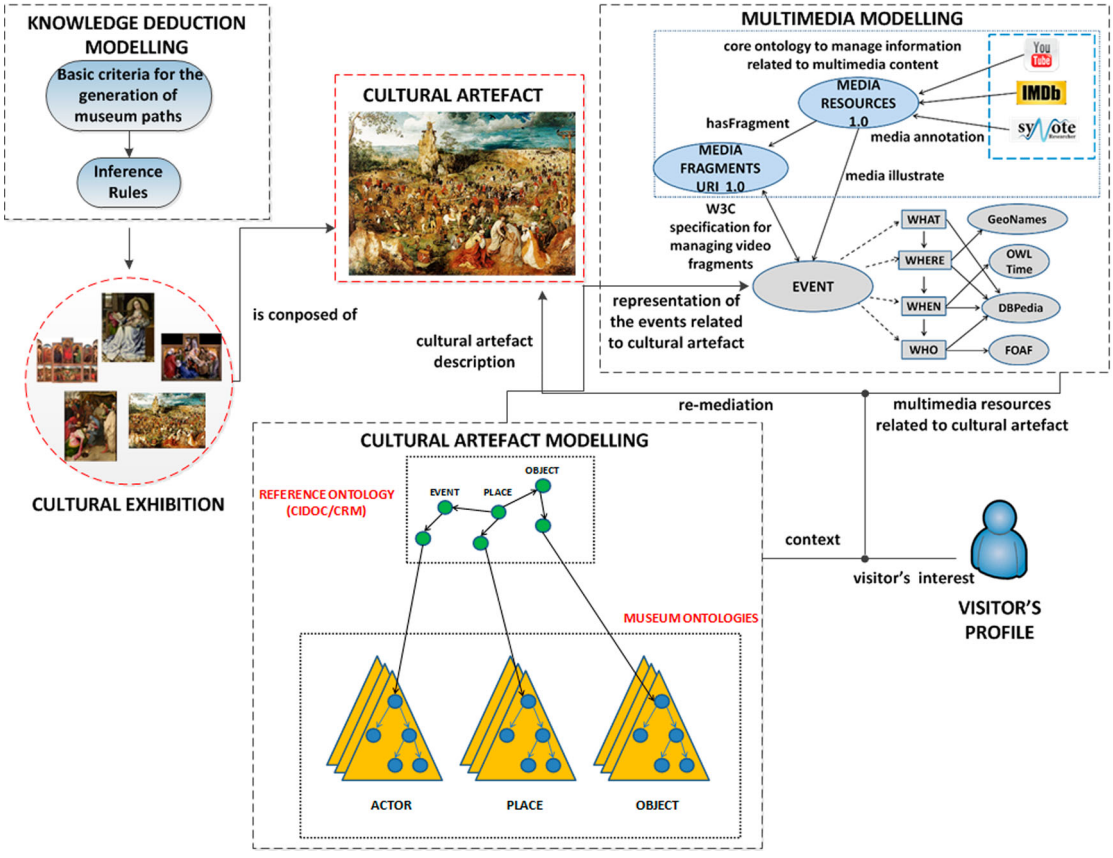

Figure 3. The knowledge model.

Table 1. Basic criteria for the generation of museum paths.

Criteria	Description
Age/Historical-cultural period	The criterion having as reference the chronological period is one by which, traditionally, are organised museum exhibitions, according to a timeline that presents the cultural objects in sequence. Examples: the thirteenth century, the late-Gothic, Mannerism, the nineteenth century, and so on.
General typology	It is a criterion that, in museums with different types of collections, is adopted to sort collections into homogeneous sections, which are then generally subordered according to criterion 1 (age/historical-cultural period); in this case, we can distinguish, for example, between the archaeological collection, sculpture, painting, applied arts, etc.
Specific typology	It is a sub-criterion of criterion 2, which tends to create links between similar works such as, for example, frescoes, statues, home furnishings, jewellery, etc.
Author	It is the criterion that creates connections between the cultural objects of the same author.
Geography	It is a criterion based on the geographical context where the cultural object or its author was born and developed; may have as a reference geographical areas as small as a country (the art in Urbino), a region (the art in Tuscany), a nation (Italian art), an archaeological site (ancient relic in Cuma), etc.
Material and technique	The connection, according to this criterion, is based on the materials and/or construction techniques of the cultural object; for example, inlaid woodwork, marble, gold, and oil paintings.
Subject	The criterion is applicable only to figurative works (e.g., Paintings) or with representations (e.g., Porcelain cup with hunting scene), and creates connections among the depicted analogue subjects such as, for example, portraits, scenes from the New Testament, and still life.
Represented elements	It is a sub-category of the previous criterion, and like this, it is applicable only to figurative works or representations; it creates connections between the elements depicted that do not necessarily constitute the main subject of the work; to exemplify, you can think about the dogs in art, about the elements of landscape or nature (storms, rocks, etc.), about the woman, about the gastronomy, etc.
Artistic movements	The artistic movements are in turn function of age and geography; connected under this category are those very specific artistic movements such as impressionism, functionalism, structuralism, art nouveau, and so on.

consequent are made of a list of atoms that can be of the form $C(x)$, $P(x, y)$, $sameAs(x, y)$, or $differentFrom(x, y)$, where C is an OWL description; P is an OWL property; and x, y are either variables, OWL individuals, or OWL data values (Lin, Hong, and Doerr 2008).

To understand SWRL rules syntax, we present a simple example of rule formulation proposed in Lin, Hong, and Doerr (2008) that illustrates the composition of a SWRL rule to derive the property of 'uncle'. The example shows that *X1*'s parent is *X2*, and *X2*'s brother is *X3*. If the above prerequisite conditions are both true, then new derived fact that *X3* is *X1*'s uncle can be obtained.

Antecedent (Body)
  hasParent (?X1, ?X2)
  hasBrother (?X2, ?X3)
Consequent (Head)
  hasUncle(?X1, ?X3)

Basing on the underlying concepts of SWRL, a CIDOC/CRM class is viewed as a $C(x)$ and a CIDOC/CRM property as a $P(x, y)$. An example of class is *E24 Physical Man-Made Thing* (*?X*), while an example of property is *P138B* (*?X, ?Y*), where *?X* and *?Y* represent variables indicating specific CIDOC/CRM instances. New knowledge is derived if all prerequisite conditions (atoms) are verified (Horroks et al. 2004). Table 3 shows the inference rules considering a knowledge base structured according to the CIDOC/CRM model, defined for the criteria listed in Table 2.

Table 2. Combined criteria to enrich a museum path.

Combined criteria	Example
General typology + Age/Historical-cultural period	Flemish painting in the fifteenth century
Represented elements + Material and technique + General typology	Representations of women in the marbles of the archaeological collection
Subject + Author	The Old Testament according to Raphael
Author + General typology	Sculptor Michelangelo
Material and technique + Age/Historical-cultural period + Geography	Gold and silver from the Sienese thirteenth century

In the *Multimedia Modelling macro-area*, it is shown how the knowledge model supports a re-mediation process through the semantic annotation of multimedia content related to cultural events associated with the artefact. The idea is to combine the representative structure of the events described with Reference Ontology entities with media description modelled by specific ontologies and languages, such as *Media Resources 1.0*[7] for the representation of the basic information of the multimedia content from different datasets (i.e. *Youtube*, *IMDb*, *Synote*, etc.) and *Media Fragments URI*[8] for the representation of media fragments. Realistic aspects associated with events are made possible by a description based on 'W questions', that is, questions like 'what' (what event happened), 'where' (the place where the event happened), 'when' (time period in which the event happened), and 'who' (people involved in the event). Entities that model the possible response to these questions can be also related to popular taxonomies, such as *Geonames*,[9] *OWL Time*,[10] *DBpedia*,[11] and *FOAF*.[12]

The designed combination is realised by using a 'bridging' technique, based on the creation of a specific connection property (i.e. 'Media illustrated'), resulting from the application of a mechanism for ontology alignment

Table 3. Defined inference rules based on CIDOC/CRM.

Rule 1 – General typology + Age/Historical-cultural period
E24 Physical Man-Made Thing (?X1) ^ physical_thingHasTypeConcept (?X1, ?X2) ^ Concept (?X2) ^ P108B was produced by (?X1, ?X3) ^ E12 Production (?X3) ^ P4 has time-span (?X3, ?X4) ^ E52 Time Span (?X4) ^ P78 is identified by (?X4, ?X5) ^ E49 Time Appellation (?X5) ^ E21 Person (?X6) ^ P14B performed (?X6, ?X7) ^ E12 Production Event (?X7) ^ P4 has time-span (?X7, ?X8) ^ E52 Time Span (?X8) ^ P78 is identified by (?X8, ?X5) ^ P108F has produced (?X7, ?X9) ^ E24 Physical Man-Made Thing (?X9) ^ physical_thingHasTypeConcept (?X9, ?X2) ^ P138B has representation (?X9, ?X10) ^ E38 Image (?X10) → hasSameGenre (?X1, ?X10)
Rule 2 – Represented elements + Material and technique + General typology
E24 Physical Man-Made Thing (?X1) ^ physical_thingHasElementRepresentedConcept (?X1, ?X2) ^ Concept (?X2) ^ E21-Person (?X3) ^ P14B-Performed (?X3, ?X4) ^ E12-Production Event (?X4) ^ P108F has produced (?X4, ?X5) ^ E24 Physical Man-Made Thing (?X5) ^ physical_thingHasElementRepresentedConcept (?X5, ?X2) know: physical_thingHasTypeConcept (?X5, ?X6) ^ Concept (?X6) ^ P45 consists of (?X5, ?X7) ^ E57 Material (?X7) ^ P138B has representation (?X5, ?X8) ^ E38 Image (?X8) → hasSameSubject (?X1, ?X8)
Rule 3 – Subject + Author
Concept (?X1) ^ E21-Person (?X2) ^ P14B-Performed (?X2, ?X3) ^ E12-Production Event (?X3) ^ P108F has produced (?X3, ?X4) ^ E24 Physical Man-Made Thing (?X4) ^ physical_thingHasElementRepresentedConcept (?X4, ?X1) ^ P138B has representation (?X4, ?X5) ^ E38 Image (?X5) → isNarratedIn (?X1, ?X5)
Rule 4 – Author + General typology
E21-Person (?X1) ^ Concept (?X2) ^ P14B-Performed (?X1, ?X3) ^ E12-Production Event (?X3) ^ P108F has produced (?X3, ?X4) ^ E24 Physical Man-Made Thing (?X4) ^ physical_thingHasTypeConcept (?X4, ?X2) ^ P138B has representation (?X4, ?X5) ^ E38 Image (?X5) → hasTypologyWork(?X1, ?X5)
Rule 5 – Material and technique + Age/Historical-cultural period + Geography
E24 Physical Man-Made Thing (?X1) ^ physical_thingHasTypeConcept (?X1, ?X2) ^ Concept (?X2) ^ E21 Person (?X3) ^ P14B performed (?X3, ?X4) ^ E12 Production Event (?X4) ^ P108F has produced (?X4, ?X5) ^ E24 Physical Man-Made Thing (?X5) ^ physical_thingHasTypeConcept (?X5, ?X2) ^ P45 consists of (?X5, ?X6) ^ E57 Material (?X6) ^ materialHasConcept (?X6, ?X7) ^ Concept (?X7) ^ P138B has representation (?X5, ?X8) ^ E38 Image (?X8) → hasSameGenre (?X1, ?X8)

using instance-based matching of types (or classes), that is (Duan et al. 2012), in order to link CIDOC/CRM and Media Resources 1.0 classes that model similar instances. Furthermore, information about the user's preferences stored in his profile is used to filter the media resource's typology to support user goals.

5. Experimental case study

To validate the methodology presented in previous sections, we have considered the following scenario: in the context of a museum exposition related to *Flemish paintings*, we adapt a visitor's experience via the re-mediated scenario in order to enhance the visit by providing additional or new meaning.

'Flemish paintings' exhibition is composed of cultural artefacts discovered by applying Rule 1 of Table 3 (general typology + age/historical-cultural period). The resulting set of objects (e.g. paintings) derives from filtering and categorisation processes according to a specific objective (e.g. *Flemish paintings in the fifteenth century*). For this purpose, value 'Flemish painting' and value 'Fifteenth century' are, respectively, assigned to *X2* and *X5* rule parameters.

Table 4 shows the cultural artefacts that have been retrieved from the internal knowledge base. Such events compose the standard exhibition on the chosen theme and each of them could be the conceptual scenario for the purpose of factual knowledge enhancement.

All information about cultural objects is described and modelled by the CIDOC/CRM core entities. We suppose that the user focuses 'The Procession to the Calvary' painting with his own mobile device (i.e. iPad or smartphone), so it becomes the main cultural object of the conceptual scenario on which the methodology, combining similarity and dissimilarity, is experimented to enhance the painting factual knowledge. Figure 4 shows the CIDOC/CRM description of 'The Procession to Calvary' painting.

The Factual Knowledge about the painting, as described in Figure 4, is presented to the user through digital content (e.g. YouTube video) that is retrieved from the knowledge base by applying the instance matching technique between Media Resource 1.0 classes that model the features of the digital content and CIDOC/CRM classes that model the subjects depicted in the painting.

After having obtained the results of the assessment for the user experience behind the conceptual scenario, a re-mediation process is applied. Figure 5 depicts a possible mixed strategy combining similarity and dissimilarity that enhances the factual knowledge about 'The Procession to Calvary' painting, by showing the linear links and the connections that could emerge from the painting.

In case of *positive assessment* (i.e. the visitor liked the presentation of the conceptual scenario), a re-mediation approach based on similarity is applied. By applying a feature extraction function, we have extracted the following set of features from YouTube video: 'Calvary', 'Gospel episode', 'Pieter Brueghel the Elder', 'Oil paint', 'Christ', and 'Cross'. By maintaining the same context, types, and semantic density of the digital content of the conceptual scenario, the extracted features have been used to perform a search in the external dataset *Dbpedia* in order to identify new objects providing additional meaning related to the painting. Resulting objects are reported in the first three rows of Table 5.

In case of *negative assessment* (i.e. the visitor did not like the presentation of the conceptual scenario), a re-mediation approach based on dissimilarity is followed in order to change the context (e.g. mixing the cultural context with 'non-cultural' ones) and producing a

Table 4. FIBAC Scenario, cultural artefacts, and events.

Artefact	Brief event description	Event properties
 The Procession to Calvary	The Procession to Calvary is an oil-on-panel by Flemish renaissance artist Pieter Bruegel the Elder of Christ carrying the Cross set in a large landscape, painted in 1564. It is in the Kunsthistorisches Museum in Vienna	Start time: 1564; End time: 1564; Location: Vienna; Agent: Pieter Bruegel the Elder; Activity: painting; Genre: Flemish painting; Material: oil painting; Subject: Calvary, Crucifixion, Gospel episode, Christ, Cross
 Virgin and Child	The painting realised by Robert Campin depicts the Virgin Mary when after laying a book she was reading, is preparing to breastfeed her little child Jesus	Start time: 1440; End time: 1440; Location: Städelsches Kunstinstitu in Frankfurt; Agent: Robert Campin; Activity: painting; Genre: Flemish painting; Material: oil painting; Subject: Virgin Mary and Jesus, Iconography of Jesus
 The Adoration of the Kings	In the chronological sequence of Bruegel's work, this painting of 1564 marks an important departure as the first to be composed almost exclusively of large figures. The group of people, taken from Italian mannerist painters like Parmigianino, permits Bruegel to concentrate on individual faces, giving each a quite distinct, and sometimes grotesque, expression	Start time: 1564; End time: 1564; Location: National Gallery, London; Agent: Pieter Bruegel the Elder; Activity: painting; Genre: Flemish painting; Material: Oil on panel; Subject: Mary and Baby Jesus, Joseph and a figure whispering, One of the Kings, Iconography of Jesus
 The Descent from the Cross	The painting realised by Rogier van der Weyden depicts the Descent from the Cross (or Deposition of Christ, or Descent of Christ from the Cross)	Start time: 1433; End time: 1438; Location: Museo Nacional del Prado, Madrid; Agent: Rogier van der Weyden; Activity: painting; Genre: Flemish painting; Material: oil painting; Subject: Jesus, Virgin Mary, Mary Magdalene, St. John, Joseph of Arimathea and Nicodemus, Iconography of Jesus

Pieter Bruegel the Elder
The Procession to Calvary

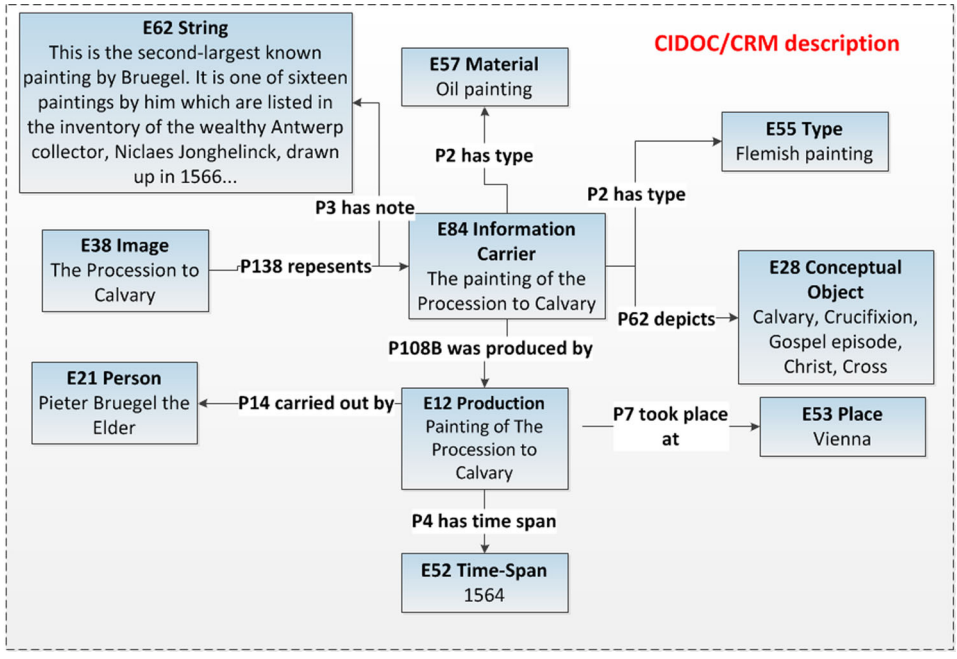

Figure 4. CIDOC/CRM description of 'The Procession to Calvary' painting.

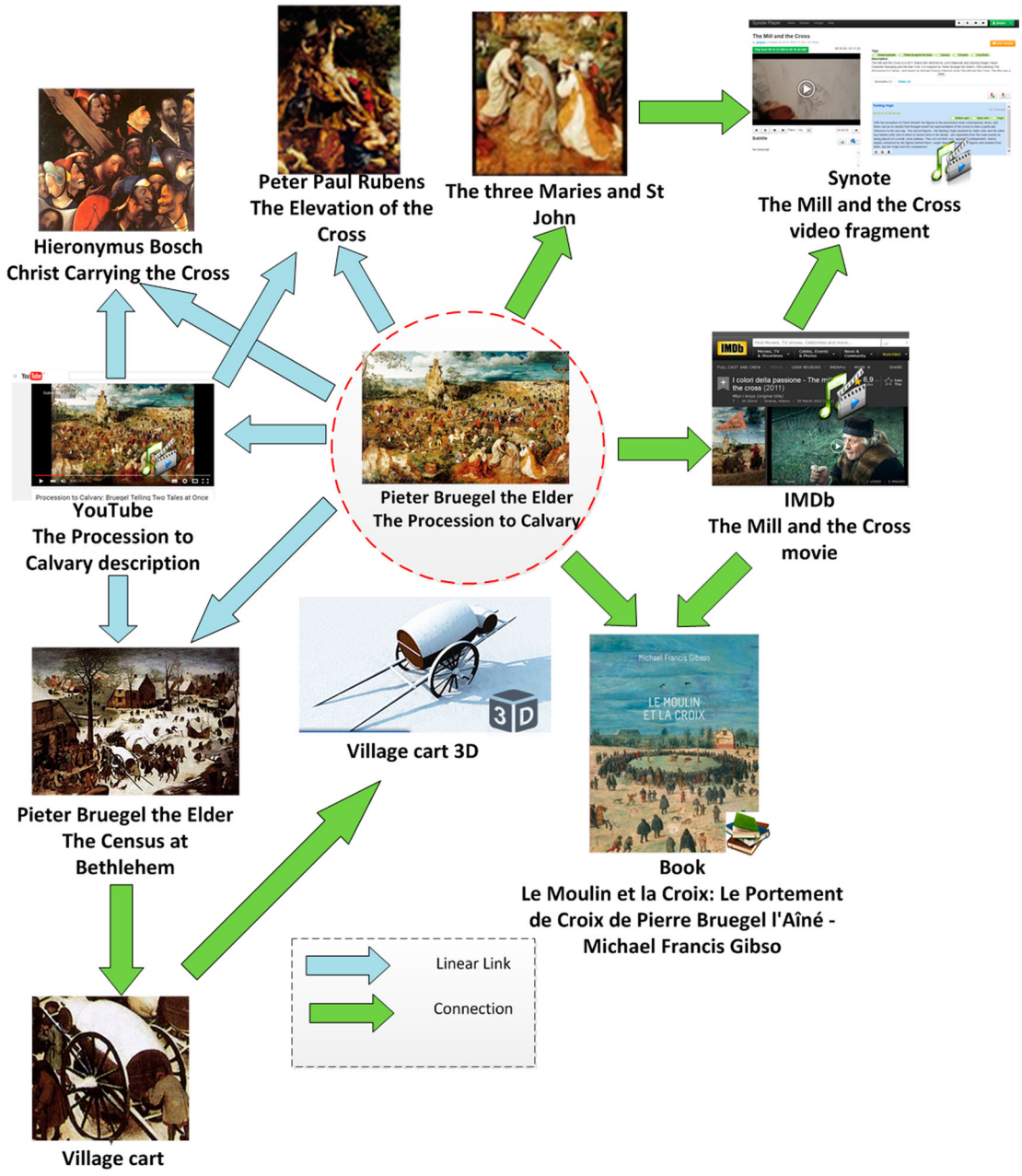

Figure 5. 'The Procession to Calvary' re-mediation.

re-mediated scenario that correlates digital cultural and non-cultural resources on the basis of non-cultural interests of the visitor (books, music, movies, sports, etc.).

Suppose that 'movies' is an interest of the visitor. This feature, extracted from the user's profile, is used to identify the feasible external datasets (i.e. IMDb[13] and Synote[14]). The media contents of such datasets are modelled by Media Resources 1.0 ontology, so the main information about the media, such as title, genre, actors, subjects, etc., is represented by specific classes and relations of the ontology.

To identify appropriated media resources related to 'The Procession to Calvary' painting, an instance matching approach is applied. It analyses instances of CIDOC/CRM classes that model a painting event (as shown in Figure 4) comparing them with instances of Media Resources 1.0 classes. In this way, we can obtain a similarity index, allowing us to relate media resources to cultural events and retrieve appropriate resources for the user's goal with respect to own interests. In detail, for the given example, the feature set extracted from CIDOC/CRM includes the following classes: 'Calvary', 'Crucifixion', Gospel episode', 'Pieter Brueghel the Elder', 'Oil paint', 'Christ', 'Cross', and 'Flemish painting'. Instead, the identified movie resource is 'The Mill and the Cross', as shown in the fourth row of Table 5.

Table 5. Re-mediated cultural objects.

Artefact	Event description
 The Elevation of the Cross	The Elevation of the Cross (also called The Raising of the Cross) is a triptych painting by Flemish artist Peter Paul Rubens, completed in 1610–1611. Rubens painted The Elevation of the Cross after returning to Flanders from Italy. The work shows the clear influence of Italian Renaissance and Baroque artists such as Caravaggio, Tintoretto, and Michelangelo. The Raising of the Cross is part of the Crucifixion of Jesus, and has been a distinct subject of Christian art. Notable depictions include The Elevation of the Cross by Peter Paul Rubens and The Raising of the Cross by Rembrandt. In John's gospel, Jesus predicted that he would be 'lifted up from the earth' in order to draw all men to himself. John notes that Jesus was referring to his death.
 Christ Carrying the Cross	The work depicts Jesus carrying the cross above a dark background, surrounded by numerous heads, most of which characterised with grotesque faces. There are a total of eighteen portraits, plus one on Veronica's veil. Jesus has a woeful expression, his closed eyes and the head reclined.
 The Census at Bethlehem	The Census at Bethlehem (also known as The Numbering at Bethlehem) is an oil-on-panel by Flemish renaissance artist Pieter Bruegel the Elder, painted in 1566. Acquired in 1902, it is currently held and exhibited at the Royal Museums of Fine Arts of Belgium in Brussels.
 The Mill and the Cross (2011)[a]	The Mill and the Cross (Polish: Młyn i krzyż) is a 2011 drama film directed by Lech Majewski and starring Rutger Hauer, Charlotte Rampling, and Michael York. It is inspired by Pieter Bruegel the Elder's 1564 painting 'The Procession to Calvary', and based on Michael Francis Gibson's book *The Mill and the Cross*. The film was a Polish-Swedish co-production. Filming on the project wrapped in August 2009. It premiered at the Sundance Film Festival in January 23, 2011.

[a]http://www.imdb.com/title/tt1324055/.

Furthermore, it is possible to increase the re-mediation of contents through AR. If the user brings along a mobile device during the visit, he can focus parts of 'The Procession to Calvary' painting and learn additional details due to overlapping levels of digital content to the real world filtered by considering his 'movie' preference.

For example, suppose that the user focuses the painting's part where the three Mary and St. John are depicted. By applying the instance matching approach between CIDOC/CRM classes that model this part of the painting and Multimedia Resource 1.0 classes modelling media resources, the 'The Mill and the Cross' movie fragment is retrieved and played to enrich the user's sensory perception of the detail. Figure 6 shows the depicted AR scenario.

6. Comparison with other works

There are numerous works on the application of AR, virtual reality, and mixed reality in museums. In general, the aspect that differentiates our results with respect to other works is the possibility of connecting different contexts, such as cultural and not cultural, linking museum objects with contents from other sectors and organisations (e.g. entertainment media). A FIBAC experience is thus tailored with respect to both cultural and not cultural preferences of a user.

Other works aim at tailoring AR experiences to user preferences, but considering quite exclusively the cultural preferences. Damala and Stojanovic (2012) propose the concept of adaptive augmented reality and evaluate

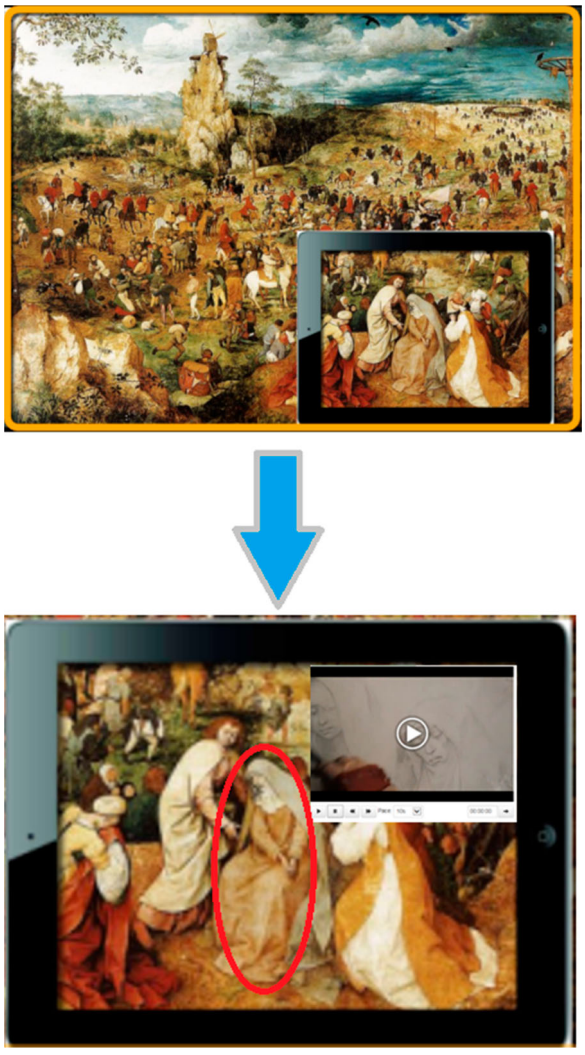

Figure 6. Possible augmentation of 'The Procession to Calvary' painting.

this concept within the context of the creation of an AR guide for the museum visit. The basic idea is to combine two sensory inputs (visual and acoustic) with affective monitoring. Adaptation, in this case, is done on the basis of engagement and interest measured with the affective monitoring. The adoption of engagement and interest gathered during the museum experience to adapt the museum paths is also present in our work. However, we mainly assume that engagement and interest can be stimulated not only with sensory inputs, but also with the provision of additional multimedia contents that are such to unveil the multifaceted nature of museum objects.

Keil (2013) propose the design of handheld AR experiences that are seamlessly incorporated into interactive museum narratives. In this work a form of mediation, similar to the one defined by the FIBAC re-mediation model, is employed. In the cited work, the mediation takes place in two different ways: the first is mainly explorative and experience driven (via interactions and mixed media), the second is more descriptive and explanatory. With respect to this last form of mediation, our approach makes use of inference rules derived from domain knowledge that can support authors of museum narratives.

The adoption of inference rules is employed also by Hatala et al. (2004), who use ontological models to retrieve and connect different cultural objects. Their work focuses on augmented audio reality and they are interested in sound objects. The retrieval mechanism is based on a user model and on conceptual descriptions of both the sound objects and the museum artefacts in the form of ontologies. The retrieval criteria are formalised as inference rules that represent knowledge from psychoacoustics, cognitive domain, and composition aspects of interaction. In our work, we have defined a set of inference rules based on CIDOC/CRM, but with a different objective. Our inference rules are devoted to the definition of museum paths for different narratives. Besides this, in our work the additional contents that we link to cultural artefacts can be considered as an additional piece of information provided to a visitor to stimulate his interest and on the basis of which one selectively pays attention to the message of artefacts.

We regard the connection between cultural and not cultural contents as a form of advertisement that can have a positive effect on the consumption of art (Enhuber 2015), supporting the connection between digital content from art organisations (e.g. museum) and contents arising from different organisations (film production, social media, etc.)

7. Conclusions and future work

In this work, we have presented an innovative way of remediating cultural objects that takes into account the possibility of correlating objects from cultural and not cultural contexts into an adaptive museum narrative. The methodology is based on the combination of semantic and syntactic/linguistic techniques, and has been validated in the context of the FIBAC project, where cultural experiences are delivered in the form of digital storytelling, with the aim of facilitating the authors of museum narratives in the creation of a virtual museum exhibition.

In defining and developing the FIBAC methodology to enhance museum experiences, we have been motivated by the recognition that current applications of AR to museums are mainly focused on technological enhancement of museum objects that are then included in museum narratives. Even if recent studies (Alelis, Bobrowicz, and Ang 2015) show that traditional technology-based AR may have a positive influence with regard to emotion and engagement, we consider useful also the addition of cognitive and knowledge perspectives in augmenting museum experience.

Future works will focus on the identification of additional inference rules and on the refinement of existing ones, on the application of more complex techniques of text analysis combining syntactic and semantic analysis, and on the implementation of the methodology directly inside an authoring system that will be able to recommend content starting from digital artefacts.

Notes

1. http://www.ponrec.it/en/open-data/projects/profile-project/?&ProgettoID=5236.
2. http://www.cidoc-crm.org.
3. http://openlibrary.org.
4. http://www.w3.org/Submission/SWRL/.
5. http://www.w3.org/TR/owl-features/.
6. http://wiki.ruleml.org/index.php/RuleML_Home.
7. https://www.w3.org/TR/mediaont-10/.
8. https://www.w3.org/TR/media-frags/.
9. http://www.geonames.org/ontology/documentation.html.
10. https://www.w3.org/TR/owl-time/.
11. http://wiki.dbpedia.org/about.
12. http://xmlns.com/foaf/spec/.
13. http://www.imdb.com/.
14. http://linkeddata.synote.org/.

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