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Ontology-based visualisation of cultural heritage

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***Abstract*—In recent years, a number of projects have been undertaken for the access to cultural heritage that rely on metadata derived from an ontology. Ontologies also open to visualization techniques that leverage the structure of the semantic relations to bridge the gap between the complexity of data and the need for immediate, simplified access.**

In this paper, we address the representation and access to the intangible cultural heritage, that has received much attention recently and typically lacks a physical counterpart. In order to illustrate this approach, we describe two case studies in ontologies and visualization for cultural heritage. In the first case study, the user is immersed in a 3D labyrinth where turning points and paths represent, respectively, a set of cultural artifacts and the semantic relations holding among them; the second case study relies on an ontology of contemporary art and a cartographic visualization of the public art in a city.

I. Introduction

In the last decade, the access to cultural heritage and the distribution of media objects have moved toward a digital convergence [1]. In cultural heritage, this process has taken the form of digital platforms, such as online museums, cultural websites, etc., aimed at encouraging the access to the cultural heritage by the general public (consider, for example, the Europeana web portal).[1] In the paradigm of cultural convergence, where new and old media interact, content producers and consumers are given equal rights and cooperate to share content and generate alternative contents, threatening the traditional paths of cultural markets and education.

In parallel, the advent of new media has pushed forward re-mediation practices [2]: according to the paradigm of re-mediation, the contents of one medium are re-focused onto another medium (like for example, the transposition of a novel into a film or the reuse of movie contents in videogame design). However, the convergent culture has not been effective yet in creating user instruments for generic organization and access in the field of cultural heritage. Searching media objects, in fact, is still largely based on keywords and/or tags, by which users can filter contents to find what they need.

As reviewed by [3] and [4], computational ontologies are especially suitable to encode conceptual models for the access to digital archives, since they are open to the integration among different models, and contain an explicit description of the concepts that are employed to structure the interaction between the archive and the users. However, to a certain degree, the representations provided by formal ontologies exacerbate the lack of the immediacy of access, since the conceptual models encoded in ontologies are typically of abstract nature and difficultly communicated.

In this paper, we propose the use of visual metaphors, embedded in virtual environments, as tool to convey the conceptualization of cultural heritage items and the relations holding between them, stored in an ontology. To this aim, we introduce a framework for ontology based visualization of data in the domain of cultural heritage and describe two case studies. The first, Labyrinth, relies on an ontology of cultural archetypes to create a 3D "labyrinth" of semantic relations between artworks; the second, Invisibilia, relies on an ontology of the "intangible" knowledge about contemporary artworks (such as installations, performances, etc.). The ontologies employed to describe cultural heritage items are briefly described in Section II; the ontology based visualization is described in Section III. Conclusions and future work end the paper.

II. Ontologies for Intangible Heritage

In cultural heritage, media objects require rich metadata about their creation and content, in order to support the access by different audience types. The range of available perspectives span across a number of different disciplinary fields, including history, archaeology, aesthetics, narratology, etc. [5]. Semantic annotation enables an explicit representation of the relations underlying metadata: for example, the relation between a location and the artistic streams to which it relates, the relation between the subject of a painting and the character of a story, etc. . In the following, we describe the ontologies employed in our two case studies, the ontology of cultural archetypes Archetype Ontology for the Labyrinth project and the Intangible Component of Contemporary Art Ontology for the Invisibilia project.

A. Archetype Ontology

In cultural heritage, many artworks have, by and large, some type of narrative content. In visual arts, for example, story episodes are often displayed in paintings and characters are depicted in statues; even abstract artworks, notwithstanding their non–representational nature, often refer to narrative elements. Stories are narrated by tales and novels, but also – though in nonverbal terms – by different kinds of musical works, from operas to symphonic poems. More recently, traditional and new media, then, such as film or advertisement campaigns, have a more or less recognizable narrative

[1] www.europeana.org

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content. However, differently form literary narrative works, the narratives found in artworks are normally fragmented into single narrative elements, such as episodes or actions. Also, the manifestations of the same story often contain significant variations, like the omission or addition of parts.

The Archetype Ontology provides a core model of narrative, aimed at representing fragmented narrative contents in the field of cultural heritage. Inspired by the research in iconology and narratology ([6], [7]), the Archetype Ontology encodes the notion of cultural archetype, described as set of related stories, characters, locations and objects which share some symbolic meaning. Common examples are the archetypes of the "labyrinth", the "journey", the "hero", etc. . Automatic reasoning tools allow tracking the connections that a set of artworks hold with the archetypes represented in the ontology, thus letting the shared narrative elements emerge among the artworks. The resulting framework lends itself to the creation of personalized navigation paths in cultural object repositories, represented in digital form, for the sake of exploration and study.

The top level classes of AO are the represented in Figure 1. The **Archetypes** class contains the archetypes to which a story can be referred; the **Artifact** class contains the media objects, organized according to the FRBR model [12]; the **Dynamics** class represents actions, processes and state of affairs involving the narrative entities; **Entity** contains the characters and objects represented in an artifact or involved in a story; **Story** represents a collection of stories; **Description Templates** contains the role schema (**SituationSchema**) that can be filled by narrative entities (characters and objects) in a dynamics (i.e., a process or state), inspired by the "Situation Description" ontology pattern [8]; the **Format** class encodes the format and type of media resources; **Geographical Place** and **Temporal Collocation**, finally, represent the classes where it is possible to encode, respectively, the spatial and temporal information related to artifacts, stories and archetypes. The reference to the FRBR model [12] is useful to address the distinction (more or less apparent in all domains of cultural heritage) between the idea underlying an artwork (the primitive *Work*), its encoding in some artistic language, called *Expression*, and its *Manifestation* in an artwork, which may be replicated in a number of different *Items*.

Consider, for example, the painting "Minotauromachia" by Pablo Picasso: the *hasResourceType* property describes the type (image) of the associated media resource; the *hasCreator* property connects the painting with its author, "Pablo Picasso". As for the archetypal meaning of the subject, the property *evokes* connects the painting with the "Labyrinth" archetype; *displays* connects the painting with the entities which appear in it, i.e., Theseus and the Minotaur; *describesAction* describes the action type it depicts ("killing"). Finally, the painting is related with the story it is about, i.e., **Minotaur Story** and **AriadneAndTheThread**.

B. Intangible Component of Contemporary Art Ontology

The ontology developed for the Invisibilia project extends the CIDOC-CRM ontology [9] to the world of the intangible component of contemporary art. Contemporary art is characterized by the commixture of installations (often impermanent), performances and interactive elements. In particular, specific inadequacies of CIDOC-CRM emerged regarding the modelling needs of interactive installations and live performances. The top level of CIDOC-CRM includes five classes: **TimeSpan**, **Place**, **Dimension**, **PersistentItem** and **TemporalEntity**. **ManMadeThing** (subclass of **PersistentItem**) encompasses the classes for representing **PhysicalObjects** and **ConceptualObjects**, further subdivided into the **PropositionalObject** and **SymbolicObject** classes.

Previous extensions of the CIDOC-CRM models can be found in the literature. For example, [10] propose an extension aimed at modeling the notion of reliability and provenance in the transfers of possession of cultural heritage items. A relevant extension of CIDOC-CRM, for the Invisibilia project, is given by [11] where the notion of performance is proposed for the integration into CIDOC-CRM. Our proposal relies on the introduction of new properties to describe the "invisible" component of contemporary artworks and to put them in relation.

The Intangible Component of Contemporary Art Ontology adopts the approach proposed by the FRBRoo working group [12] for the mapping of the FRBR model onto the CIDOC-CRM. According to this proposal, the notion of **Work** corresponds to the **ConceptualObject** class in CIDOC-CRM, and different versions of the same work are represented as instances of the **Manifestations** class, which corresponds to the **SymbolicObject** class in CIDOC-CRM.

Although CIDOC-CRM is mainly devoted to the representation of physical artworks and of the processes involved in its dissemination, preservation, etc., the use of CIDOC-CRM enables the representation of the processes involved in the artistic creation, Through the **Event** class enables, for example, the representation of the Creation activities (typically including video making, sketching and interaction design), conducted by different agents with roles such as director, illustrator, multimedia designer, and sometimes formalized in collective creative sessions, or workshops. The class **Event** is also employed to represent the performative aspects of the artworks, such as the artists' performances, the interaction of audience with the artwork, etc. .

Another extension concerns the representation of the relations between a work (or performance, or manifestation) and its documentation (e.g. pictures taken during the design activity, or videos shot during a performance) and the manifestation and the maintenance instructions (where present) for the manifestations. Documenting all the phases of the artistic creation and providing explicit instructions for maintenance, in fact, are highly relevant issues for the intangible component that characterizes contemporary art.

For example, the idea of the artwork "Fontana" by the artist Mario Merz. The Fountain of Mario Merz is a public artwork in Turin, released in 2002, that has the shape of igloo with the surface consisting of a puzzle of plates of slate, emerging from a rectangular water tab, with water jets, located in a road widening; four red neon lights, that light up at

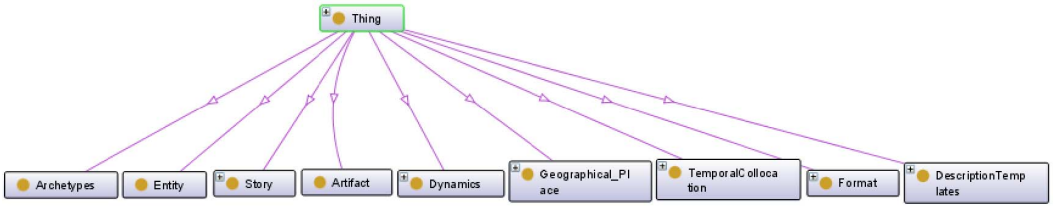

Fig. 1. The top level of the Archetype ontology.

evening, mark the cardinal points [2]. The artwork is an instance of **PropositionalObject/Work** class, and is described by a **ProceduralPrescription** (executive specifications) to which it is connected via the property *isRealizedIn*. The manifestation (instance of the **SymbolicObject/Manifestation** class) of the idea is given by an installation made of plates of slate and neon tubes, whose size, layout, etc. are also described in the ontology. The physical artwork, then, is related to its maintenance activity (instance of **MantainanceActivity**), documented by some specific document (instance of the **MaintenanceDocumentation** class), and distinct (for time, location, actors) from the **CreationActivity** that originated the monument, which has a different Time and Location.

Finally, the class **Score** was added as a subclass of **Design** and **Procedure** classes with the goal of representing scripted, complex artistic performances. In the case of Merz's Fountain, it is simply used to describe the enlightening of neon lights at evening.

III. Visualization of Semantic Metadata

Notwithstanding the obvious advantages it brings about, the structural complexity of this representation exacerbates in some sense the need for immediacy of access. The Visualization architecture we propose aims at overcoming this difficulty by translating the information about the cultural heritage items into a more intuitive, executable visual representation.

A. Visualization Framework

The visualization of cultural heritage data is the result of the interplay of three elements, namely the data repository, the ontology server, and the visualization interface, which communicate with each other through specific APIs. The information stored in the ontology server about the items in the repository is dynamically extracted from the ontology and made available to the visualization interface, which reacts to the user input with the appropriate view on the item(s). As a result of this interplay, the user interface dynamically orchestrates a set of visual elements which embed the cultural heritage items, staging and setting them based on their properties, as represented in the ontology server.

The visualization framework consists of elements of different nature: visual components, control, communication protocol.

[2]"The igloo structure has been frequently revisited by Merz, since 1968, with essential forms, providing an idea of living a place, a balanced architecture, with an internal/external space, that enlarges according to life necessities." (from the records of the Municipality of Turin)

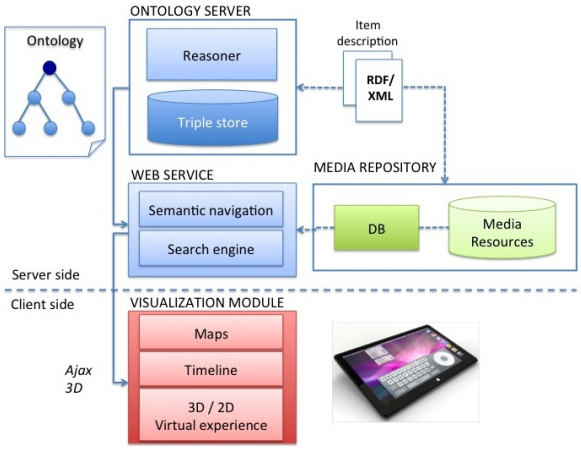

Fig. 2. The ontology-based visualization architecture.

The visual components are the elements whose appearance depends upon the narrative metaphor which drives the visual experience (here, the "labyrinth" for the Labyrinth project and the "city map" for Invisibilia). Visual components include:

- an environment, that provides the narrative context of the visualization, where the iconic objects (i.e., the narrative elements) below are located and experience their behavior;
- a set of iconic objects, possibly with behaviors triggered by the user interaction;
- a scene layout, i.e., where objects are located in the environment.

The control components consist of the mapping between the cultural heritage items and the visual elements, actually the mapping of the item properties onto the visual features of the icons (colour, size, shape, etc.), of their relations into spatial relations and the interaction design specifications, which are inspired by the notion of guidance (vs exploration), in order to facilitate the user access to the environment and the meaning conveyed through it.

Finally, a communication protocol between the visualization component and the ontology server queries the ontology and feeds the results into the visualization.

B. Visualization Architecture

The system encompasses four main modules (see Fig. 2):

- the Ontology Server maintains the ontology – where the cultural heritage items are described – and provides the reasoning services. Also, it provides the SPARQL endpoint for querying the ontology;
- the Media Repository contains the media objects related to the cultural heritage items and is indexed by a relational database (typically, a mySql database);
- a Web Service, written in Java, implements the API that client side applications exploit to query the Ontology Server. Depending on the project, the RDF triples extracted from the ontology are serialized as Json or XML data;
- the core Visualization Module supports the interaction with the user through 2D/3D navigation (or, else, standard hypertext including maps, timelines, etc.), as standalone application or embedded in a browser.

The API embedded in the Web Server is a core component of the architecture described above. Basically, the methods in this API include a command for starting a session, a command for setting the user parameters along the session (preferences, defaults, etc.), one or more specific commands for querying the ontology and a command for ending the session and/or copying its data into a log.

C. Case studies

1) Labyrinth: The Labyrinth system[3] allows the user to explore a repository of media resources through the conceptual mediation of an "archetype" of narrative nature. The user can see how the resources, which represent artworks, relate with the various element which compose the archetype model (places, stories, characters, objects, etc., see Section II-A), and how they are connected to each other through the archetype (for example, resources displaying the same character or symbol, related to a certain archetype). The system integrates a top-down, hyper textual exploration of the repository with a 3D navigation environment, aimed at encouraging the exploration of the repository. The visualization maps the elements of the conceptualization to be conveyed onto the elements that characterize the environment of the labyrinth: artworks are mapped onto the labyrinth nodes, where their representation are posited, and the semantic relations among them are mapped onto the paths which interconnect the nodes. The interaction metaphor is "finding one's way": here, however, the user does not gain the exit (always accessible from a control panel overlaid on the 3D), but the creation of a personal path in artworks' hidden meaning.

For example, consider the artwork Minotauromachia, a painting by Pablo Picasso (see Section II-A). When the user is posited in the node where this painting is displayed, the information about the artwork (creator, location, and so on) is provided. From this location, the user can explore the repository by searching for similar artworks, i.e., artworks that are semantically connected with the current one in the ontology. Each type of similarity is mapped onto a different path starting from the current artwork: same story, same characters, same type of event, same location, etc. For example, by following the path marked as "same characters", the user will find a set of artworks depicting "Theseus" or the "Minotaur" (or both), possibly with other characters. Or, by following the "same story" path, the user may find other representations of events belonging to the same story, such as "Ariadne and Theseus", "Dedalus and Icarus", etc. In case only one item is contained in the media repository for a given path, the user will find the artwork in a node posited at the end of the path. Otherwise, the path will end in an empty node, where different (unlabelled) paths will lead to the available artworks.

[3] http://app.labyrinth-project.it:8080/LabyrinthTest/

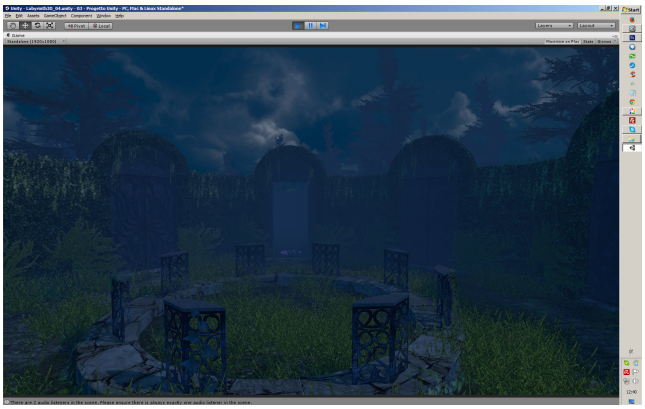

Fig. 3. A screenshot of the 3D labyrinth.

The user is free to explore the labyrinth, going back to previous locations and clicking on artwork representations to receive information and experience them via the appropriate plugins. As the path unfolds, small lights appear where the user walked, as to form a sort of "red thread", marking the path made by the user so far.

2) Invisibilia: The visualization of project Invisibilia shares the same approach and architecture described for the Labyrinth project but is at a design stage. With respect to the Labyrinth project, artworks of Invisibilia arrive with a marked visual stance, that makes a visualization of intangible knowledge more challenging. Given our considerations above, we can sum up the following premises about the visualization:

- it cannot be a replacement for the original artwork;
- it has to balance between the goals of the visualization and peculiarities of the artwork;
- it must adhere to the model (of the features) of the artwork;
- the authorial intervention should be limited to the "invisible".

For the visualization of project Invisibilia, the project management decided to focus on a specific class of the contemporary artworks, namely contemporary public art. Public art has been a very dynamic area, contrasting with modernism tendency to host art in museums, involving both public and private subjects and originating a novel professional artist category[13]. Public art has the peculiarity of being planned and staged in some public place and space[14], usually open air or in publicly accessible buildings and it is accessible to all people.

Mapping Public art to the Contemporary ontology terms introduced above, and referring to the tripartite FRBR model (Work, Expression, Manifestation), we address the following features that will be addressed in the visualization:

- Work: concept (the values the artwork conveys, expressed in terms of abstract icons, related documents, and visual interviews with the artist);
- Expression: what materials are employed, visual elements used in the artwork, the dynamics of the artwork;
- Manifestation: placement of the artworks in the physical site, with a characterization of the surroundings, audience access to the artwork, realization of the artwork.

The values conveyed by an artwork are usually expressed by the artist through statements that are in the documentation owned by the commissioner or the curator; they can be texts as well as recordings of the artist expressing the role of the artwork in the context of the physical site. The materials are classified according to some taxonomy and their functions in the artwork; the visual elements, with their positioning in the artwork, are retrieved from the sketches of the artist, where possible, or reconstructed from photos; finally, the dynamics of the artwork is retrieved from the documentation or documented from the real functioning. The placement of the artwork takes into account what is the typology of the surroundings (park, buildings, and what kind of buildings, squares, ...), what are the methods and the ways for accessing and experiencing the artwork, photos and video of the realization of the concrete artwork. Public art also has boundaries connected to the administrative boundaries of an institution. So, the visualization can reveal the relationship of an artwork with respect to other public artworks in the same city. We decided to take into account both the features of an individual artwork as well as the relationship with other artworks in the city.

The ontology–based visualization task displays the artwork features represented in the ontology. The visual components that represent the feature values are derived from the existing documentation and are augmented with iconic elements appropriately designed by the visualization artist. These elements are in overt contrast with the original elements, though creating an environment that can visually host the original elements. While the visualization of archetypes, being based on a visually abstract conceptual knowledge, could work freely in the devise of the visualization, Invisibilia requires the acquisition of existing components and to integrate them in a single visual framework.

Given the considerations above, we provide two visualization levels:

- a synoptic view on a number of artworks that are connected through a number of features;
- the exploration of an individual artwork.

The synoptic view provides a top-view cartographic representation on a city map of the public artworks, with their relative positions; the public artworks are represented by visual items that propose the shape of the artwork; these items can

Fig. 4. The design for the public art visualization for Invisibilia.

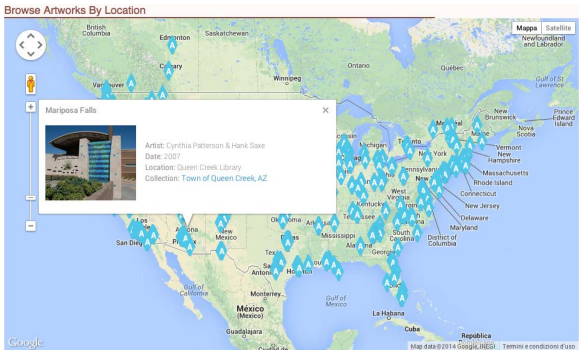

Fig. 5. The visualization of the ”public art archive” at world level (http://www.publicartarchive.org).

be original (if they exist in the documentation) or introduced The inspiration for this solution originates in the tourist city maps, that combine topological and topographical elements: in our case, we insert topographic elements, such as the rivers and major access and inner roads to provide orientation cues, and topological elements, one per public artwork with a glow that provides a sense of presence against a dark background. In our case, we decided to sightseeing touristic maps, which have a longstanding tradition in cartography and are effective in guiding tourists in picking the preferred sites in a city.

The idea of applying the sightseeing map metaphor, exploiting the visual contents of the public art, is new; usually (see e.g. the visualization of Figure 4), the visualizations are mere positionings of the same icon on the map.

We can go from the synoptic to the individual artwork view by clicking on the visual item that represents some work. The individual artwork view is a perspective view that is reached through a 3D-simulated camera motion: this view remains in the graphic style described above (monument in glow with a detail of the map), with superimposed active icons for accessing the visualization of the ontology features, namely concept, production, access plan.

In Figure 6 we can see the visualization of Merz Fountain. It is surrounded by roads and high buildings: the icons of buildings, cars and pedestrians are in purple edges and black

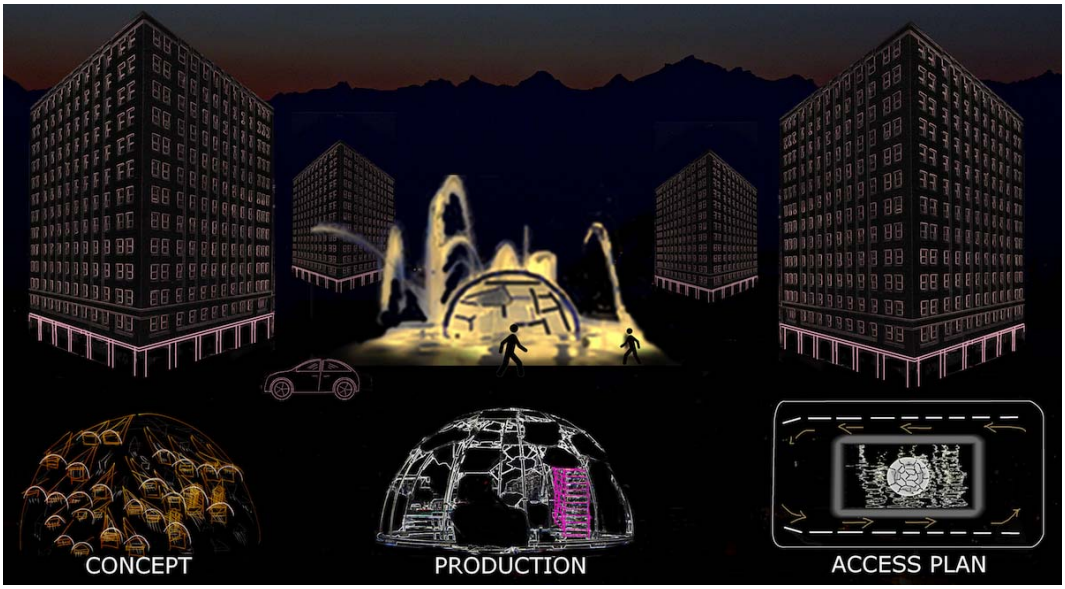

Fig. 6. The design for the visualization of Merz fountain.

surfaces; icons provide perspective views that are integrated with the original visual material in gold. In the lower part, we can access the details of the documentation, related to concept, that illustrate the ideas of the artist, the production stages, that illustrate the various phases of the realization of the artwork, and the access plan, that, combined with the positioning provided by the synoptic view, provides visitors with an idea of how to access the artwork (by foot, by car, etc.). Again, we have a combination of icons (access plan and production scaffolding) and original materials (concept and production layout structure).

This design will be implemented on website and mobile apps, though we are at a design stage with what concerns the implementation platform. In particular, the debate concern whether addressing a pure 3D approach (in Unity3D, as in the case of Labyrinth) or a 3D-simulated in a 2D environment.

IV. Conclusion

In this paper, we described an approach to the visualization, via 2D and 3D graphic interfaces, of conceptual models employed to describe and access repositories of media items in the domain of cultural heritage. In particular, after introducing a general framework for the ontology based visualization, we described two case studies in which this framework was applied. The two projects are in the implementation stage (Labyrinth) and design stage (Invisibilia), respectively. We are going to carry on an evaluation phase for the first and the implementation phase for the second. The validation of this framework through experiments with real users are aimed at assessing the effectiveness of this approach and comparing it with more traditional interfaces, such as standard hypertexts.

Acknowledgment

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