Traditions based on context

HOW CONTEXT ONTOLOGIES CAN HELP ARCHAEOLOGICAL SITES

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ABSTRACT:
Nowadays ICT tools are part of the cultural tradition of designers and over time have replaced pencil and paper in design development. The application programs for design are many and for different purposes, but the role and importance of Context often are underestimated. For new tradition, it needs "Context Knowledge Model" based on ontologies for the management of buildings and preservation and enhancement of cultural heritage with technological innovation. Context modeling gives the opportunity to address the management of pre-existing building in a conscious way. The interoperability of data and knowledge of Context is important to analyze the quality of building process. This is based on standard concepts of the project for the recovery and restoration of the buildings starting from knowledge of context. The goal of this research is to exploit information technology to advance and define knowledge of context monitoring, management and maintenance of historic buildings. The representation of context is important to understand physical, social, economic and normative Context in which the building was placed. The process used to analyze Context entities were Ontologies. This theoretical model will be applied to underground archaeological Roman sites, to implement semantic levels in IFC and BIM for building design.

KEYWORDS:
Archaeological sites, Collaborative design, Context, Ontology, Design Process

1. Introduction

Traditions in Architectural Design may be related to different fields: constructions, methodologies, forms, practices and techniques. Moreover, tradition means when a new technology or a methodology that successfully passes threshold of use for several years becomes a "new tradition". Each designer uses technology even if, apparently, refuses or wants to avoid it; digital technology is pervasive and in Architecture is now necessary.

The difficulty is to join these fields, that can be seen like different kinds to shape the world, to different actors involved in Design Process, etc.

These differences can improve design by means of Collaboration among actors, giving opportunities, suggestions and evidencing constraints.

One of the researchers' challenges is the developing of computational methods to help designers to design aware solutions, not based only on "Traditional" Knowledge, but also based on specialist knowledge not yet supported by tradition. Just for instance, innovative physical-mathematical reasoning models, which are connected to different disciplines from biology to philosophy in order to have a design that may have performances required by users.

In this regard, turn into "new tradition" an innovative Context modeling fits well in the theme of the conference "Future Traditions."Architecture has always had relations with Context, which influences building and changes users' needs and aims.

The objective of this research is to model with new tools and methodologies that in the past depended mainly on designer's experience who analyzed environmental, economic, cultural and legislative "Context" in which they worked. In fact, Design was defined as a "situated" activity (Gero, 1998), dependent on the "site" and external factors, changing in times.

Design needs and requirements change in relation with Context, and for this reason it is complex to formally and accurate define Context entities and computable with computer.

Building Information Modelling is one of the most promising developments in Architecture, Engineering and Construction (AEC) industries because it helps building owners, managers and designers throughout a structure's life cycle by providing visual context related with data and other projects, but it lacks Context entities.

The huge diversity between archeological buildings and new ones, actually makes BIM methodology and tools not able to assist 'in a correct way' actors, because unfortunately BIM tools still miss most concepts needed for historical heritage analysis. Therefore, Archaeological Context Knowledge plays an important role to support these concepts.

Archaeological Context Knowledge is a multidisciplinary domain that makes possible:

- A more agile collaboration among actors involved;
- A better interoperability among different tools that are used to study building sites and their management;
- knowledge sharing to find better solutions to monitor, maintain and manage archaeological buildings and ruins.

Context Knowledge must be managed in a holistic way though the seamless interaction of Information Technology tools that are used in the different stages of work (exploration, problem definition solution). Thus, this research wants to help to manage architectural sites in a more aware way.

The utilization of "intelligent" concepts is what makes more efficient the management of archeological sites. Archaeological Context Knowledge can be successively put together with the other knowledge "Realms" of design process: Product, *Procedure and Actor* (Fioravanti et al. 2011).

2. Background

There are two approaches to use Context in digital design: *bottom-up* or *top-down*.

The first tackles the problem analyzing the management of Context Knowledge from the bottom, using single program at a time that use Context to reach the Design Solution, then put together these partial solutions to optimize it.

The second starts from an integrated, formal and global design Context Knowledge to reach Design Solution. The first method is "more direct" because allows designers to design from the beginning, but it is less useful in the later stages when conflicts arise between project idea and its realization as difficult to manage. The second one requires a greatest articulation in start phase, but allows, having pursued a synthesis from the outset, to achieve goals in a most "smooth" Design Solution reducing conflicts. Goal of the research is an holistic approach with the formalization of Archaeological Context Knowledge.

At present, several application software are available on the market, conceived to enhance domain specific design capabilities and to resolve even very complex tasks in well-defined disciplinary boundaries, but none of these analyzes in detail "Context". Although application programs can well work within the domain they have been built for, they actually don't sufficiently consider Context, nor embedded in 'collaborative design'.

To achieve better "interoperability" such as Collaborative Design between disciplines and software applications for industry and professions, it has been developed the Industry Foundation Classes (IFC), proposed by IAI - "International Alliance for Interoperability" and registered by ISO as ISO/PAS 16739. It consists in an open standard, as specification of a data model non-proprietary that is slowly emerging among industries, due to its interesting bottom-up approach (Yan, Liu 2007). These existing models of collaborative design software allow 'data exchange' and 'interoperability formats', but not 'concept interoperability'. Several research groups have dealt with these limitations defining different objectives and methodologies (Brusasco et al. 2000; Kalay 2001) and focusing their efforts to the definition of more suitable semantic structures.

Successively new tools for representation of concepts in limited fields have been applied: the 'ontology editors'. These application programs are designed to support the creation and modification of the structures of entities - concepts representing a portion of reality - characterized by distinct languages and functions. Among them, the most popular are Altova Semantic Works® e Protégé.

The potential of these new tools for ontologies representation have been usefully and successfully applied in disciplinary areas different and far from design. Therefore, their development demands further research work, both 'conceptual' and 'instrumental', for a future application to Architectural Design and Restoration especially in archaeological sites.

2.1. Specific archaeological entities

The complexity that characterizes the hypogeum architecture requires of an interdisciplinary participation and strict coordination between the different skills involved (architect, archaeologist, chemist, physicist, biologist, structural engineer, geotechnical). However this kind of participation is often disregarded in current practice.

This multidisciplinary approach is, moreover, not yet codified by specific operational guidelines which may deal with the topic in a broader way than in the usual management of a building site.

The purpose of the first part of the research is the general understanding and synoptic evaluation of the different archeological underground Roman sites. This will be carried on by reading and comparison of morphological, typological, constructive and, more generally, architectural characters, unique to each site, in order to grasp its similarities and outline a system of, endogenous and exogenous, factors able to influence the site conservation. The reading will make possible the development of a conservative strategy in order to control environmental conditions, degradation factors and management of the monument.

Within the classifications proposed (probably related, at first, to morphological types of dug areas, usually intentionally hypogeum, filled in and partially filled in, largely involved by the various phases of stratification of the city), the relationship between architectural spaces, uses (even considering the dependence or independence from the outside), lighting conditions, internal ventilation and constructive aspects (materials, construction techniques, finishes, decoration pattern etc.) will be analyzed.

Detailed analysis will involve the realization of ad hoc surveys and the carrying on of analytical studies of the architectural plant, its constructive and figurative aspects, the relationship with the above ground level etc.. A particular focus will be addressed to diagnostic study, with specific attention to the microclimate monitoring. It will focus on a careful analysis of the degradation and, using different assays, deep the issues highlighted during the first phase of the research.

The set of measurement campaigns will be designed in order to develop a shared model about the method of recording the knowledge gained and the management of the wider perspective of collaborative design.

The attention to interior surfaces of the hypogeum sites was by its own declined in its specific historical and artistic value, looking at the nature and meaning of the paintings, mosaics and, more rarely, floor coverings, or the material decay phenomena, and nevertheless the causes related to them.

On the latter topic, in particular, the studies of physicists, biologists (Bartolini 2010), chemists (Santarelli, Torraca, Giavarini 2004) have focused their interest, respectively, to characterization of the site internal microclimate, to the specificity of organic formations related to light and microclimate conditions favoring them, to the aspects of material alteration associated with the major pathologic causes usually identified. The studies spotlighting structural problems of underground sites, except from few researches concerning the relationship between structure and microclimate, are very specific and related to the particular architectural and constructive site configuration.

Among the rare situations showing a real analysis convergence by all specialists involved there is "Domus Aurea" site that has been for decades a focus of measurement campaigns, monitoring and restoration aiming at the identification of the most appropriate conservation strategies. Alcuni contributi danno conto della ricerca in corso e sono stati redatti tenendo conto della natura diversificata degli apporti (Domus aurea 1986; Nugari, Giuliani, Cacace, 1991).

3. Purpose of research

The research has two tasks: the first deals detailed definition of the topics related to the architecture of the sites and the second tackles the theme of modeling and management knowledge. Initially we organized the basic structure of the research and deepening the aspects considered essential for a correct formulation of the joint study, in a second phase the activity has converged through the elaboration of the results obtained in a common strategy of organization and knowledge management.

The work will continue with the development of two research channels conceived as parallel paths but communicating with each other. One will be addressed to the examination of hypogeum case studies at a scale close to the ongoing definition of a model based on knowledge that will gather the required multidisciplinary contributions. The study will develop taking into account the work done by other national research groups whom methods and approach will be applied to the specific analysis of hypogeum archeological sites.

The work, specifically, aims are the formalization and conceptual implementation of a theoretical Context Knowledge Modeling (CxtKM) already developed and a prototypical BIM based software platform in development, checking its congruence and validating it by means of a case study with an effective collaborative design approach (Figure 1).

Figure 1 – Case Study "Domus Aurea" site in Rome-, Archaeological Context Ontologies and BIM relationships.

The Research Group is implementing the theoretical model through:
a) construction of an 'experimental prototype of Context Knowledge Structure' for the formalization of context knowledge, confined to limited, but representative, entities, attributes and rules;
b) construction in the above mentioned domain of an 'experimental model of knowledge management' structured in KS (Knowledge Structure), namely a 'Shared KS' and several 'Specialist KS' and a 'Filtering system', formalized by means of Ontologies linked to BIM references.

The 'experimental prototype of Context Knowledge Structure' will be compared with the work done by other research groups for the development of BIM applied to Cultural Heritage.

4. Methodology

The Research Group will implement the theoretical model through:
a) construction of an 'experimental prototype of the Knowledge Structure' for the formalization of technical knowledge, confined to limited, but representative, entities, attributes and rules in new complex building discipline and in Cultural heritage architecture, in particular on archeological Roman sites; b) construction in the above mentioned domain of an 'experimental model of knowledge management' structured in KS (Knowledge Structure), namely a 'Shared KS' and several 'Specialist KS' and a 'Filtering system', formalized by means of Ontologies linked to BIM references.

The development will be guided by the following research guidelines:
1) representation of information at the different semantic levels implied by the various documents, drawings, prints, etc. produced during the analysis and design process; 2) subdivision of logical entities: architectural entities (eg components, their geometry, dimensions, hierarchy, topology, etc.),

actors (i.e. stakeholders and decision-making processes), context (location, culture, regulations, etc..); 3) definition of specific institutions for specific building techniques: environmental unit, architectural units, construction components, functional components, functional elements, material components, pathologies, vulnerability elements, etc.; 4) definition of an innovative protocol structured on web-based languages for the ontologies, to implement semantic levels actually hidden in IFC standard and in actual BIM tools for building design; 5) analysis of a case study to examine in-depth a narrow but significant field, with the aim of evaluating the generalization of the model.

These levels aims at:
1) modeling and structuring information and knowledge from different specialists and necessary to efficiently represent the considered domain for the effective sharing and collaboration among the actors involved in the design process; 2) semantic interoperability, as the 'mapping' and the integration among different knowledge models, as well as the translation of specialist meanings at a higher semantic level than what allowed by BIM.

Activities were aimed to a depth examination of design methodologies, by applying physical and energetic aspects of ancient buildings to archeological underground environments, to improve their conservation, at the same time ensuring their use.

The current investigation involved a multidisciplinary approach analysis (architectural, chemical, biological, structural and management above all) and modeling of different kind of Archeological Underground Roman Sites. These Sites were selected because they represent a significant mixed demonstrator for construction period, typology, size, technology, material, system, condition and use. A holistic approach was adopted to define them for their management.

The archeological Roman sites investigated in this research are located in different sites. Each one needs of a specific project solution, but there are some invariant that we have always to consider.

4.1 System definitions, data sources, standards and model

The first step was setting up the BIM standards in order to allow the possibility of collaborative work: the model was divided into separate files (architectural, structural, mechanical,…etc.) based on certain rules, so that multiple persons can work on one single BIM model at the same.

The second step – related to pre-site inspection – was quickly modeling existing structure at urban scale, usable for each typology of archeological sites. This BIM model captured building location, typology, size, volume and construction period can be exported into an XML code or IFC (Industrial Foundation Classes).

The third step was the implementation of some Context Rules for Archaeological Roman Sites by means of an ontology language of previously defined BIM entities.

The fourth step was to import again these entities into BIM software and start the collaboration showing advices of proposed design modifications to actors involved.

The starting point was a series of old drawings on essay. At first, these drawings were imported in CAD (based on traditional 2D drawings), then it was needed BIM software to define archaeological objects and providing various levels of information associated with these objects) extract and export drawings as independent objects and to define standard for 3D oriented-object. It was defined a common model applicable to different kind of typologies of hypogeum building sites (from the catacombs to the crypts) and objects (walls, roofs, bricks etc.) with a series of element used in different ways.

The fifth step – related to post- site inspection – will be to use this methodology on sites to update data in order to increase the knowledge of building sites so their conservation can be improved in relation

with the Context in which they are placed.

Each building, for its own specific nature and prototype peculiarity (each building is unique as it is one, in a specific place, in a specific time) represents the chosen design solution developed by its designers for a specific place and time, and for the specific needs of the Client and the final users.

The above-mentioned assumption infers that each Building (even archeological ones) is always affected by several external factors, which contribute to model it introducing constraints, limitations, suggestions and aspects to be taken into right account.
All these aspects are included in the Context Knowledge Model, because they are not strictly part of design. Context has been modeled in the following entities (Fig.2):

- Normative, investigates on the evolution of the law, the relationship between archeological sites and new building and how to manage them;
- Social, to study the relations among culture, people that lived in that places and their customs, and now how people perceive them;
- Environmental, divided into subclasses: geographic location, existing constructions; accessibility, climate data. They, in turn, may have other subclasses in which assign relations and constraints;
- Economic, contains the need related to economic conditions to preserve this places, the variation of money cost, the purchasing costs of products for restoration , etc.

All these factors are dynamic because all previous entities change in times.
The research has implemented some entities, rules and functions among ones previous defined.
Entities were formalized by an Ontology Web Language and rules have been implementing define characteristics and logical inferences.

The research analyzed the critical issues related to Context Knowledge constraints and how these ones can be related to different actors involved in Archeological Site definitions.
The Protégé Ontology Editor allows associating any formalized concept a Documentation box.
The prototype includes:

- Textual definitions;
- External links;
- Example images/applications/ 3D models .

Figure 2: Context Model Ontology

5. Results

The extended use of BIM together with ontologies for Archeological Roman Sites is a challenge for the characteristics of sites, but at the same time, it is an opportunity to show how the use of both could improve interoperability among tools and collaboration among actors involved making knowledge explicit and computable.

Due to the early stage of the project, a significant set of results is not yet available. The following paragraphs summarize the state of art of the ongoing work.

Several tests have been carried out in a significant number of elements in order to discuss and test the various type of uses for the finished product. The main results – work in progress - are shown below.

The *first test* was on the basic model identifying location, typology, size volume, and construction period. In a few hours the models were built for one of the archeology site defined.

The *second test* concerned the 3D building analysis of the principal aspects of the building's performances, with a particular emphasis on maintenance and management. Using Environmental Context entities is possible to study how Climate influences the internal microclimate to reduce degradation of internal surface.

Actually, these tests are essential because they represented the starting point of BIM process in optimizing the communication process. To know exactly what kind of data and among which software they can be exchanged has needed interesting consideration about the standards that must be used during the preliminary modeling phase in order to optimize the design activities during the management phase.

The Archaeological Context Knowledge Modeling is enriching by incorporating rules about heating, cooling, humidity, etc. that could change monumental elements like frescos, columns, statues, painted architecture, stuccoes or others in hypogeum Roman Sites analyzed.

In short, the Context Knowledge model is defined; now it has been implementing rules for the general archeological building performances and in the future, it will be possible to add rules more specific for each analyzed typology.

Acknowledgments

The research was partially funded by Education, University and Research Ministry; Scientific Research Programs of Relevant National Interest: "Built Heritage Information Modeling/Management – BHIMM".

References

Brusasco P.L., Caneparo L., Carrara G., Fioravanti A., Novembri G., Zorgno A.M., 2000: Computer Supported Design Studio, in Automation in Construction, 9, 4, 393-408.
Bartolini M., 2010: The underground rooms of the Roman domus in Celio: biological investigations for the control and prevention of bio-deterioration: the journal of the restoration, 23 (77), 45-54.
Fioravanti A, Loffreda G, Trento A, 2011: An innovative comprehensive knowledge model of Architectural Design Process, in International Journal of Design Sciences & Technology, 18(1), 1-18.
Fiorani, D. 2004: *Architectural Restoration and digital tools: guide to design representation*. Naples: Liquori Press.
Gero, J.S. 1998: Conceptual designing as a sequence of situated acts, in I. Smith (Ed.), Artificial Intelligence in Structural Engineering (pp. 165-177), Springer, Berlin.
Kalay Y.E., 2001: Enhancing multi-disciplinary collaboration through semantically rich representation, in Porter W.L., Goldschmidt G., Special Issue: Design Representation, in Automation in Construction, 10, 6, 741-755.
Macii, E., Osello, A., 2011: Smart Energy Efficiency Control in Existing Buildings by a BIM Interoperable Process, in Europia 13 Conference, Rome, 217-229.
Nugari M.P., Giuliani M. R., Cacace C., 1991: Domus Aurea: preservation proposal for control of micro flora growth of frescoes in hypogean environments, in International Conference on Biodeterioration of Cultural Property, National Research Laboratory for Conservation of Cultural Property, Lucknow, New Delhi(India), Macmillan India Ltd, 359-371.
Pavia C., 1998: *Underground Rome Guide*, Roma: Gangemi Press.
Santarelli M. L., Torraca G., Giavarini C., 2004, Environmental studies for the conservation of underground rooms in the Domus Aurea, in Materials and structures: problems of conservation, II (3-4), 30-47.
Yan W., Liu G., 2007: BIMGame: Integrating Building Information Modelling and Games to Enhance Sustainable Design and Education, in Kieferle J.B., Ehlers K. , Predicting the Future, Kanne Graphischer Betrieb GmbH Ginsheim-Gustavsburg, Francoforte, 211-218.