Semantic Enrichment of the Geometric Elements of Historical Buildings in the Digital Model

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Abstract

Three-dimensional data acquisition technologies are successfully used in the three-dimensional representation of historical buildings of immeasurable value for a nation. In recent years, there is a tendency to extract as much information as possible on these heritage buildings. This article presents the virtual reconstruction of some geometric elements of historical buildings with the aim to use a semantic construction of the digital model. The virtual model will contain both the digital model of the historical building and its cognitive system. The digital model allows to represent building's architectural elements. It is important that semantic information be included in the 3D digital model, as conceptual and relational data are not highlighted, only pure geometric data playing an essential role in representations.

Thus, after the geometric modeling of the buildings, their semantic modeling will be achieved by semantic enrichment of geometric elements using ontologies.

In order to integrate information from a domain, it is necessary to have a unique representation of ontologies, since ontologies in the same domain can differ as syntax, structure, semantics. As is well known, web applications are receiving information and not raw data. The information will be stored as structured data, so each information has to be modeled at the semantic level, depending on what we want to express.

In conclusion, by using the semantic modeling of historical buildings we can add much more information about these buildings. Many of this information are lost in time. When several important buildings have been modeled using the same unitary structure, they can be represented in a semantic Web.

Keywords

Digital Model, Ontology, Modeling, Cultural Heritage, Semantic Web

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1. Introduction

Semantics is a "branch of linguistics that deals with the study of the meanings of words and the evolution of these meanings." [7] More specifically, semantics is the theory of significance (meaning behind words).

"Semantics (from Ancient Greek: semantikos, "significant" is the linguistic and philosophical study of meaning, in language, programming languages, formal logics, and semiotics. It is concerned with the relationship between signifiers – like words, phrases, signs, and symbols – and what they stand for, their denotation. "[17]

Also, "the Semantic Web refers to the extension of the World Wide Web via embedding added semantic metadata, using semantic data modeling techniques such as Resource Description Framework (RDF) and Web Ontology Language (OWL). On the Semantic Web, terms such as semantic network and semantic data model are used to describe particular types of data model characterized by the use of directed graphs in which the vertices denote concepts or entities in the world and their properties, and the arcs denote relationships between them. These can formally be described as description logic concepts and roles, which correspond to OWL classes and properties." [17]

In this article we will only deal with the semantic modeling of knowledge and not the cloud of points.

For a clear understanding of the notion we will begin with a classification of the features of annotation systems. The success of these systems consists in the simplicity of the underlying model as can be seen in Figure 1.

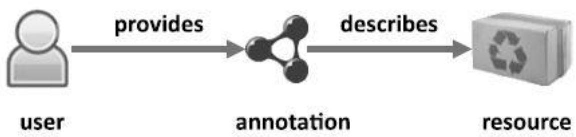

Figure 1: A generic Annotation Model [Andrews P. et al, 2012]

An example of this model is shown in Figure 2, where you can see the type of resource selected and the proposed annotation.

Figure 2: An example of a generic annotation model

A semantic modeling makes it possible to add, in addition to geometric data, as much information about architectural elements, their structure, historical, legality, and any other relevant information related to these constructions.

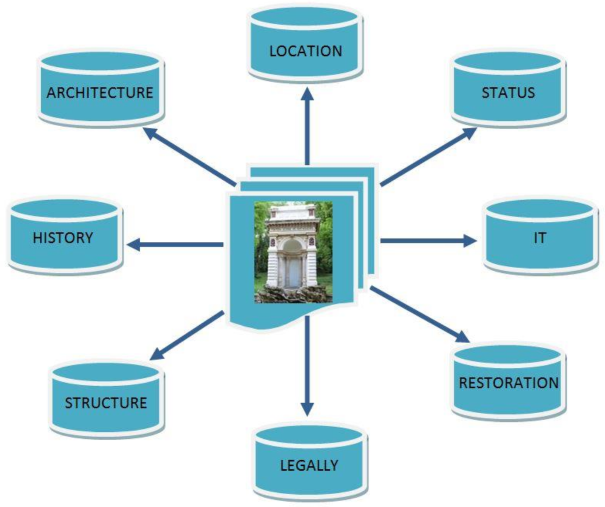

Figure 3: A lot of information about a historic building

2. Semantic annotation models

As it has been showed in [1], there are several types of annotations, such as tags, attributes, relations and ontologies. Tags are at the beginning of the spectrum and is the easiest form of annotation, while ontologies are at the end of the spectrum and represent the hardest form of annotation. [1]

a. Tags

A tag is a keyword assigned to a resource that describes a specific property of that resource (Figure 4).

As tags represent a minimal annotation, normally, a single word which describe resource properties, these tags may create ambiguities about the interpretation of these properties, as it can be seen on Figure 5.

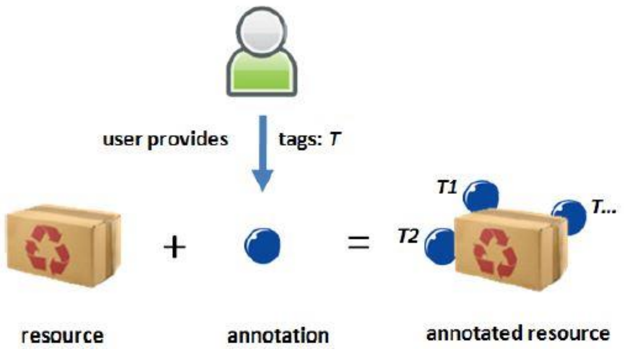

Figure 4: The Tag Annotation Model [Andrews P. et al, 2012]

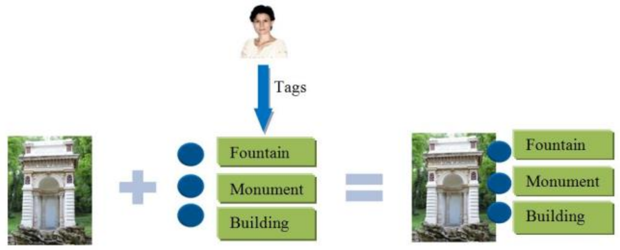

Figure 5: Resource annotation using the Tag Annotation Model

The word “fountain” describes a property of the resource on the picture: “A fountain (from the Latin "fons" (genitive "fontis"), a source or spring) is a piece of architecture which pours water into a basin or jets it into the air to supply drinking water and/or for a decorative or dramatic effect.” [19], but it also has another meaning, that of “a building made up of a cylindrical or prismatic pit with cobbled walls, with surrounding edges dug up to a layer of water that serves to water supply”[8]. Examples of such ambiguities can continue for the word *fountain*.

b. Attributes

An attribute is a pair of elements: the name of the attribute which defines the property of the annotated resource and the attribute value specifies the corresponding value[1].

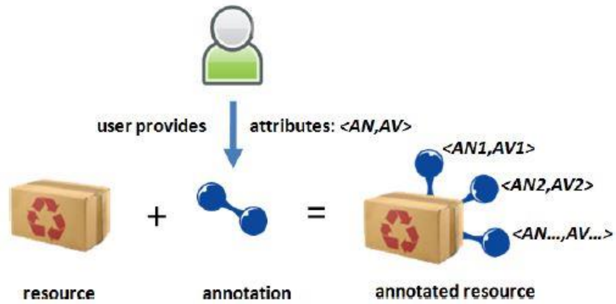

Figure 6: The Attribute Annotation Model [Andrews P. et al, 2012]

Unlike the tag annotation model, the attribute annotation model adds more properties to the resource, as can be seen in the example below.

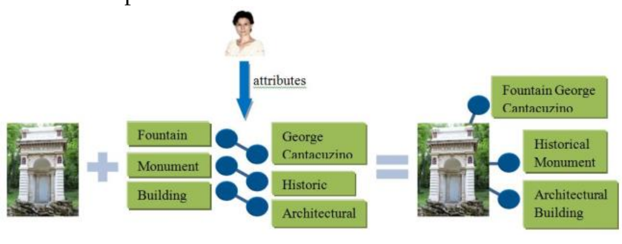

Figure 7: Resource annotation using the Attribute Annotation Model

Although the attribute-based annotation model allows to add more characteristics to the resource, it is still a limited annotation model because it refers to unique resources without creating interdependencies between resources.

c. Relations

A relation is made up of a pair of components: the name of the relation and the associated resource. “For instance, in a scientific paper a citation referencing another paper is an example of a relation annotation which defines a relation between these documents."[1]

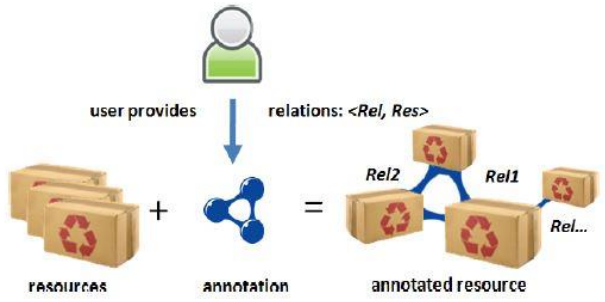

Figure 8: The Relation Annotation Model [Andrews P. et al, 2012]

The model is more complex than the previous one based on attributes because the user has to choose two resources and the relationship that links them.

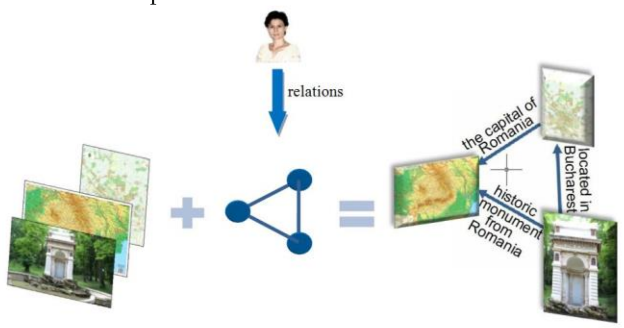

Figure 9: Resource annotation using the Relation Annotation Model

"The relation annotation model can also be used to define relations within a resource" [1].

If we consider the George Cantacuzino monument the resource, then we can distinguish several types of relationships within the resource as shown in figure 10.

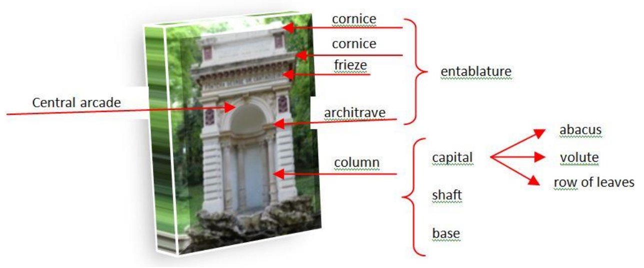

Figure 10: An example of Relation Annotation Model

In the example above we can easily see the created relationships: the resource *consists of* a central arcade, entablature, columns, etc. The entablature *consists of* cornice, frieze and architrave. The column *consists of* capital, shaft, base, which in turn are made up of other elements and so on, thus creating a complex structure.

d. Ontologies

"This model is based on the notion of semantic annotation" [1] and "it describes both the process and the resulting annotation or metadata consisting of aligning a resource or a part of it with a description of some of its properties and characteristics with respect to a formal conceptual model or ontology." [1]

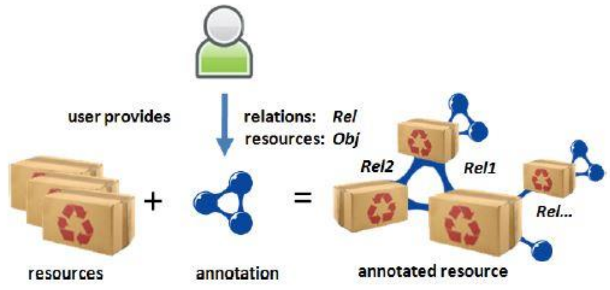

Figure 11: The Ontology Annotation Model [Andrews P. et al, 2012]

But what is an ontology? "In computer science and information science, an ontology encompasses a representation, formal naming, and definition of the categories, properties, and relations between the concepts, data, and entities that substantiate one, many, or all domains. Every field creates ontologies to limit complexity and organize information into data and knowledge."[20]

Semantic annotations are the most complicated. An example of such a model can be seen in the figure below.

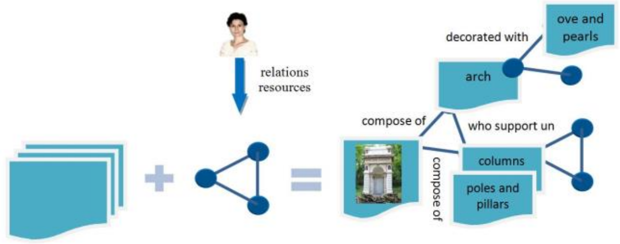

Figure 12: Resource annotation using the Ontology Annotation Model

Another example is shown in Figure 13.

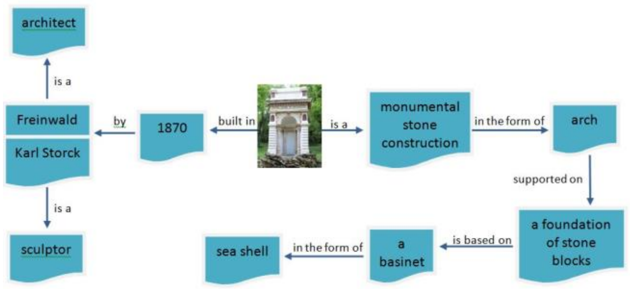

Figure 13: An example of Ontology Annotation Model

3. Architecture of ontology

Ontology organizes knowledge in a particular field for later access to this knowledge by end users through the semantic web.

We assume an ontological model, let's say O, which contains several sub-ontologies of the same resource, but from different domains, as shown in the relationship below:

$O = \{A, H, S, L, R, L\}$ (1)

where:

O - is the resource ontology, an ontology hierarchical type organized as a multi-branch tree;

A - an ontology of the resource but in the architectural field;

H - an ontology of the historical field;
S - an ontology of the resource related to the structure of the building;
L - an ontology of the legal resource;
R - an ontology of the resource that relates to restoration;
L - an ontology of the resource that refers to the location.
Let's start with architectural ontology.
An ontology is the representation of common concepts in a particular field.

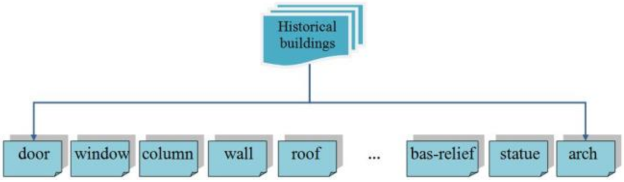

Figure 14: The basis of Architectural Ontology

As can be seen in the figure above, the domain description consists of classes that are concepts found in that area.

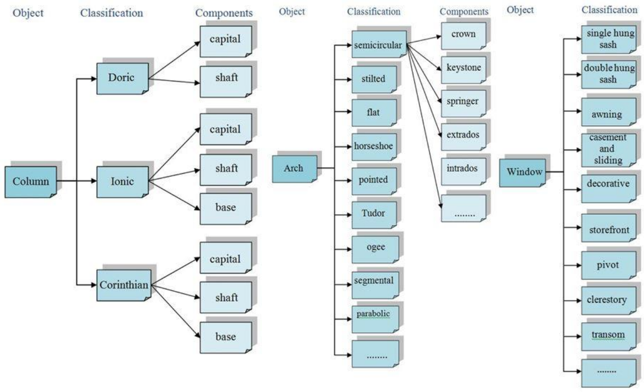

Figure 15: Examples of sub-classes

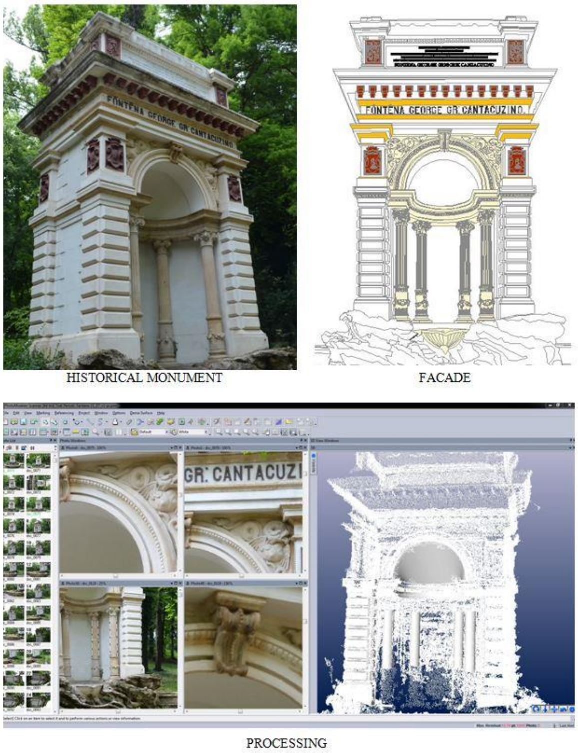

Figure 16: Examples of processing

Each class is organized as a structure with one or more sub-classes, which in turn are organized from other sub-classes and so on, forming a complex arborescent structure.
Each class in a field can be described (for example: Arch - describes a curved path between two support points, supports a wall above an opening, links two walls, two columns, or strengthens a vault).
There may be more structures for the same model and more ways of describing the same resource.
If we take one of these classes as an example, we can break it into more sub-classes. In the figure below are some examples.
In the figure below a wireframe modeling was created for a particular area of the historical monument that was used as a model and a semantic representation was made.

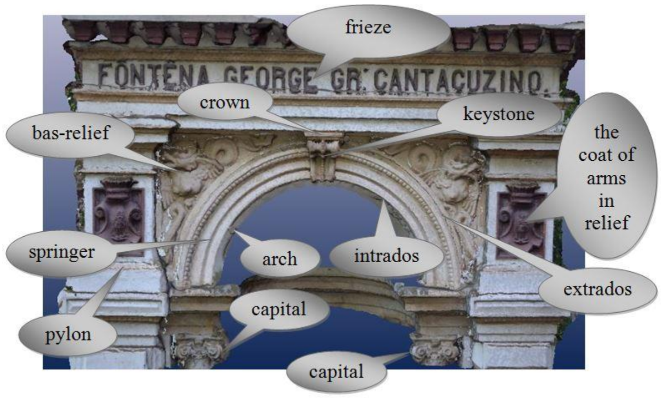

Figure 17: An example of semantic representation

Figure 18: More details

But the information about a building is only related to the architectural part? No way. When we talk about a historical monument, we bring more information about that building, such as information on the history of the place and the building, information about its structure, legal status, and so on.
It follows that for a building, several ontologies can be created for each area that describes the building, containing information about that building.
The built heritage has an exceptional value for a nation and should therefore be seen in its whole, with all the elements that define it. If the ontology of the building for architectural elements has so far been presented, it is further proposed to extend the information related to a historic building by creating several ontologies. In order for a historical building to be fully analyzed, it must include several ontologies in areas such as architecture, building structure, its history, legal status, localization, etc.
Semantic Annotation (SA) refers to the process of indexing

and retrieving useful information from documents [16].

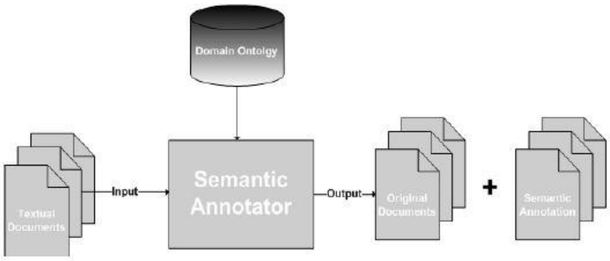

Figure 19: Semantic Annotation Process [Zeeshan Ahmed]

4. Semantic web

The idea of Semantic Web (SW) was introduced by Tim Berners-Lee, the Web's inventor (World Wide Web) as an extension of the existing Web.

“A semantic triple, or simply triple, is the atomic data entity in the Resource Description Framework (RDF) data model. As its name indicates, a triple is a set of three entities that codifies a statement about semantic data in the form of subject-predicate-object expressions.” [18]

As is well known, web applications are receiving information and not raw data. The information will be stored as structured data, so each information has to be modeled at the semantic level, depending on what we want to express.

Semantic Web technologies are used to provide automated ways of processing web data by integrating multiple databases available on the web. Integrating information into a domain includes the process of representing and uniting ontologies. In semantic web applications, ontologies are used as models of information representation. Since these ontologies are created by different people and contain different structures, automatic integration is quite difficult. Ontologies in the same domain may be different as syntax, structure, semantics. Information processing within a semantic web is only possible when all of them are semantically represented.

Describing data using semantic languages (RDF(S) or OWL), they can be exploited in a uniform manner, can be interconnected, and are available to all.

Semantic Web Standards:

- RDF - stores data as "triple" - subject, predicate, object
- OWL - defines conceptual systems called "ontologies"
- Sparql - interrogates data in RDF
- SWRL - defines the rules
- GRDDL - converts data to RDF

Ontologies are like an electronic dictionary that allows software to understand the meaning of words.

The semantic web refers to a technology that describes things in a way that computer applications can understand it. It does not mean links between webpages.

The elements of the Semantic Web are:

1. Web Ontology Language (OWL): is used by applications that process the content of the information.
2. Resource Description Framework (RDF): This refers to a language for describing information and resources on the web. The Semantic Web uses this language to define web resources.
3. RDF Scheme: It does not provide a list of application codes and properties, but instead provides the necessary features to describe classes and properties, and to indicate which of them can be used together.

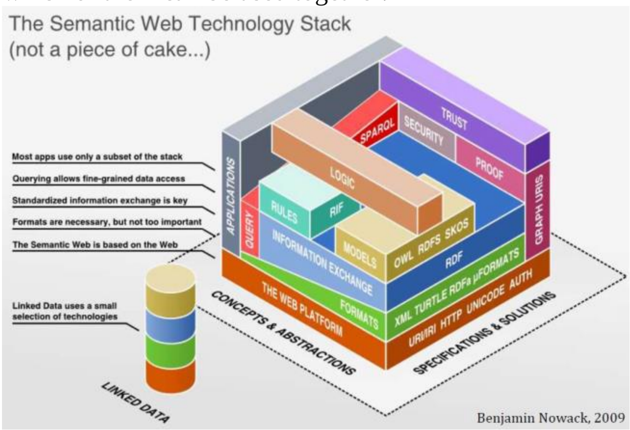

Figure 20: The semantic web technology

Based on the digital content obtained, processed and annotated, queries can be made and relevant information from a semantic point of view can be found.

The information query system allows users to identify architectural information and details by means of ontological guided natural language queries by which the user is provided with a set of suggestions relevant to the context of the query. These suggestions are formulated on the basis of a query grammar describing possible questioning structures for Romanian language and elements of domain ontology.

5. Conclusions

In this article, we describe a semantic annotation of a historical monument by extracting as much as possible existing information of that building and making it available to the end user.

Semantic annotation can be considered as a semantic enrichment of the geometric model.

Through the relationships that are created between the semantically modeled historical buildings, their knowledge and their promotion at the national and international level is sought.

Another purpose of modeling the built heritage is to preserve these buildings and restore them where it is needed.

Regarding the evolution of the protection of the built heritage, Professor Grigore Ionescu made a connection with the restoration of our day: Out of the rigorous guardianship of the "historical restoration" the intervention on the built heritage considers legitimate the adoption of creative initiatives capable of restoring the lacunar image of a historical monument [8].

The complexity of creating semantic modeling for the built heritage involves two major aspects:

- their special importance for a nation;
- the time allotted for a complete, precise, detail-oriented modeling (because they give the charm of buildings and transpose you temporarily during that time).

For the built heritage, automated and semiautomatic methods are not to be found at all costs to reduce the time needed for data collection and processing, but on the contrary, I think they deserve the full attention, time, creativity and imagination of man for gathering and processing all data, details and decorations that enchant these masterpieces. That's because they can be restored in case of damage or catastrophe as close to their original form. In conclusion, the semantic modeling of a historic building implies a complex interdisciplinary activity, where specialists from all fields need to join forces to create an open-source semantic application and a knowledge acquisition system.

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