Ontological Presentation of Bulgarian Revival Residential Architecture

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Abstract. This article presents a symbiosis between science and art, future and past, building and preserving the old. The ontological approach used for this purpose presents a world from the past for the future - namely the old Bulgarian Revival architecture in and around the Revival Period.

Keywords: Ontology, Semantic Modeling, Protégé, Bulgarian Revival Architecture, Cultural Heritage.

1 Introduction

Developing a future for the past, we are moving towards a fuller present. The presentation of the many paper sources and the few electronic ones in a complete model, subject to machine processing and visualization, is possible with innovative and flexible methods – ontologies.

Preserving the memory of the magnificent Bulgarian Revival architecture for future generations would be useful from a historical perspective. But not only that – the theme is specific to architecture and would arouse interest in professional circles. The project could help future architects and civil engineers as an appropriate guide for their study of the history of architecture as a discipline, as there is no comprehensive model of houses with their similarities and differences in view of their regional nature.

In order to be completely reliable in the data we use, the ontologies are structurally and architecturally aligned with leading architects and specialists in the preservation of Bulgarian architectural heritage.

As a subset of the cultural and historical heritage of Bulgaria, the objects are representatives of NIICH (the National Institute of Immovable Cultural Heritage) (National Institute for Immovable Cultural Heritage, 2021) and thanks to such initiatives, tourism can be developed.

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Last but not least, they would contribute to providing access to the e-model of houses for people who are not able to visit them physically for health reasons or because of their remoteness.

In Bulgaria – and correspondingly on the Balkans, for all we know, no such ontologies have been created.

The ontologies are part of the CHH-OntoNet (Cultural and Historical Heritage – Ontology Network) module of the ViPS architecture for digitization of the Bulgarian cultural and historical heritage towards development of an Intelligent Tourist Guide Assistant (Stoyanov, Stoyanova-Doycheva, Glushkova, & Doychev, 2018) (Glushkova, Stoyanova-Doycheva, Ivanova, Stoyanov, & Radeva, 2020).

All the ontologies are designed according to the international standard for cataloguing cultural objects – the CCO standard (Baca, M., Harpring, P., Lanzi E., McRae, L., Whiteside, A., 2006), in order to achieve sharing among different societies and systems.

2 Ontologies in Informatics: A State-of-the-art Review

Ontological engineering is a subdomain of artificial intelligence related to the development of data storage in the form of ontologies. The output data is intelligent, distributed, connected, and consistent in terms of semantic modelling.

In recent years, ontology-based systems engineering has grown significantly. Ontologies act as an enabler of good knowledge management as they focus on establishing well-defined domain concepts in terms of terminologies, definitions, and relationships. In addition, the use of formal semantics is essential for explicit, sharable, and reusable knowledge representation. (Yanga, Cormican, & Yu, 2019)

For purposes of illustration, some example ontologies are: educational ontologies, ontologies for cultural heritage data, ontologies for mythology like the Greek one (Syamili & Rekha, 2017), agriculture ontologies, cybersecurity ontologies, biomedical ontologies such as the ontology on genetic disease (Iqtidar, Muzaffar, Qamar, & Rehman, 2017), ontology for diseases of the spine (Lee, Lee, Seo, Yoo, & Kim, 2015); as well as diagnostic ontologies such as ontologies for predictions – like COVID-19 cases, or ontologies for managing the COVID-19 crisis (Sayeb, Jebri, & Ghezala, 2021), and so on.

3 Domain Modeling

A lot of analytical tools have been developed over the years, but they have one thing in common: helping people understand the world by forming an abstract description that hides certain details while highlighting others. These abstractions are called models (Allemang & Hendler, 2011).

3.1 Semantic Modeling of Assembled Knowledge

The semantic models:

- help people communicate. A model describes the situation in a particular way that other people can understand.
- explain and make predictions. A model relates primitive phenomena to one another and to more complex phenomena, providing explanations and predictions about the world.
- mediate among multiple viewpoints. No two people agree completely on what they want to know about a phenomenon; models represents their commonalities while allowing them to explore their differences (Allemang & Hendler, 2011).

The efficiency of such a model is measured by the degree of success whether the developer's intention is interpreted correctly, and respectively whether the knowledge is consistent, coherent, and expresses the real concepts and relations between them.

3.2 Semantic Modeling According to the CCO Standard

Due to the internationally accepted standard CCO for documenting works of art and architecture – cultural artifacts and their images in general, sharing between different societies and systems is achieved.

Providing rules for the description of works standard defines a framework that facilitates their further use in museums, libraries, and so on. The attributes that an object needs to have are clearly defined and there are mandatory and recommended (additional) ones. Dictionaries of terms are also maintained, which allows synchronizing the stored descriptions in the systems (Baca, M., Harpring, P., Lanzi E., McRae, L., Whiteside, A., 2006). Sharedness is extremely important, but it can be achieved through distributed data.

Currently, seven ontologies have been created:

- **An objects ontology** – it presents the domain house and the characteristics of a standard house.
- **A locations ontology** – it stores information about the location of the instances according to three indicators – the physical geographical region, the administrative one, and the location according to the urban planning.
- **A subjects ontology** – it provides information about the years and periods in relation to the houses such as the period of construction of the houses considering the time in history, for example the Bulgarian Revival period, the year of a house's restoration or registration as a cultural property, etc.
- **A materials ontology** – it contains the materials, techniques, and building structures needed to build the houses.
- **An agents ontology** – it expresses the connections of a house with a person – the builder, its owner or restorer; as well as a collective body.
- **A functionalities ontology** – it is an additional ontology, auxiliary and optional according to the CCO standard requirements. With it we aim to achieve detail in the architectural domain by describing the rooms with their function and specific names, and also make a comparison with the rooms we know today.
- **An oldhouses ontology** – a collective image of the Revival house with its detailed architectural characteristics. The class hierarchy is exhaustive,

representing a complete structure of characteristic elements needed to describe a concrete house or a set of houses.

The distribution of ontologies in sets is not imposed only by the standard itself, but it is an approach caused by the amount of information they will cover. Recommended authorities and corresponding ontologies according to the CCO standard are illustrated in Figure 1.

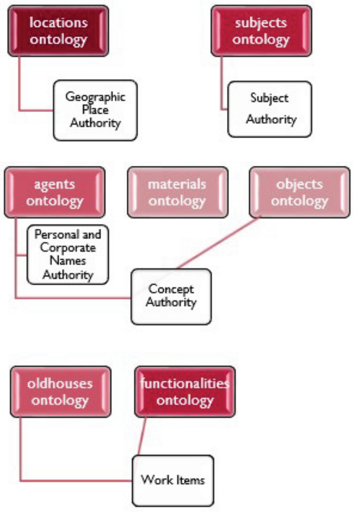

Fig. 1. The CCO standard – authorities and ontologies

4 Ontology Engineering - Steps in a Nutshell

4.1 Protégé

As with any assignment, the implementation of the assigned sub-goals to achieve the main one is supported by a development environment. Protégé is a free, open-source ontology editor and framework for building intelligent systems. Stanford University created this environment with open source. It uses the OWL-DL sub-language and provides an opportunity to present concepts and the relationships between them, as well as to reach indirectly defined conclusions based on defined axioms. The current version and the one used to build the ontologies is 5.5.0. (Musen, 2015)

4.2 OWL 2

Protégé fully supports the latest OWL 2 Web Ontology Language and RDF specifications from the World Wide Web Consortium. (Musen, 2015) The main components of an OWL-ontology are individuals, properties, and classes. The language is based on the well-known RDF object-predicate-subject model for distributing data in the form of triplets but with significantly more possibilities for the user in terms of semantic formalism.

4.3 The Ontologies of Bulgarian Revival houses

The main elements of an OWL-ontology are classes (collections of similar objects); individuals (concrete instances), and properties (characterizing classes). Namely, these are the units used to describe the Revival houses on the territory of Bulgaria.

The concepts in the ontologies are described by a hierarchy of classes that are linked to each other by properties (data property or object property). Thereby, axioms are formed that represent assertions. In this way, information is stored not only symbolically but also semantically so that it can be used not merely as a text for processing and visualization. There are concepts that are meaningfully related, which allows to draw conclusions about the truth of the claims made in the field. (Stoyanova-Doycheva, Doychev, Spassova, & Ivanova, 2020)

A strict hierarchy of classes has been created in accordance with the architectural principles in the ontologies describing the houses. The properties can also be organized in hierarchies, if necessary. In Protégé, all classes are subclasses of the class "owl:Thing", the "object properties" are sub-properties of the "topObjectProperty", similarly the "data properties" are sub-properties of the "topDataProperty".

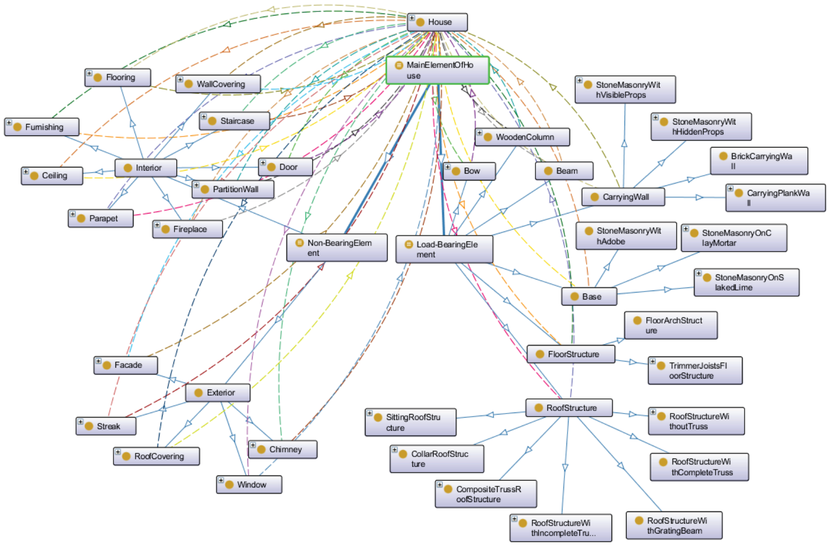

Fig. 2. An OntoGraf view of some classes and the relationships between them in the oldhouses ontology

Figure 2 shows a brief OntoGraf view of some of the classes and some of the relationships (through properties and "subClassOf" axioms) between them in the largest ontology – oldhouses.owl. The "Non-BearingElement" and "Load-BearingElement" classes are subclasses of the "MainElementOfHouse" class. They also have subclasses; by way of illustration, the “Interior” and “Exterior” classes are subclasses of “Non-BearingElement”. All their varieties, peculiar to the Revival architecture, are included in the ontologies. Merely to provide an overview, the subclass of the “Interior” class, namely the “Ceiling” class, has the following subclasses: “CeilingWithApplicationsAndGeometricCompositions”, “CeilingWithBoardAndBatten”, “CeilingWithCeilingRose”, “CeilingWithCentralMotif”, “CeilingWithPlasteredHolkel”, “CeilingWithTholobate”, “CeilingWithVisibleBeams”, “CeilingWithWoodCarving”, “PlasteredCeiling”, and “TiledCeiling”.

Some of the data properties in the oldhouses.owl are technical and economic indicators of spatial planning – “hasBuilt-UpArea”, “hasTotalBuilt-UpArea”, “hasTotalNumberOfFloors”, “hasTotalNumberOfRooms”; some of the object properties in the same ontology are “hasFireplace”, “hasFacade”, “hasBow”, “hasRoofCovering”, “hasChimney”, “hasCeiling”, “hasDoor”, “hasWindow”, “hasComposition”, “hasFloorStructure”, “isBuiltBy”, “isRestoredBy”, “isOwnedBy”, “isRelatedWith”, “isLocatedIn”, “isMadeOf”. Some of the properties are described with characteristics such as functional, inverse functional, and others; also domain and range. For instance, the data property “hasBuilt-UpArea” is functional with the domain class “House” and the range datatype “xsd:string”.

Restrictions define named classes and form unnamed ones. There are four types of restrictions – “existential”, “universal”, “cardinal”, and “has value” and we have used each one of them in the ontologies. Classes are semantically defined and their subclasses inherit all of their restrictions. Protégé forms axioms (assertions about the domain that are true) while we define the elements of an ontology – classes, properties, and others. For example, the “DisjointClasses” axiom – classes that are incompatible, or the “SubClassesOf” axiom – a “parent class-subclass” relationship between classes that form a class hierarchy.

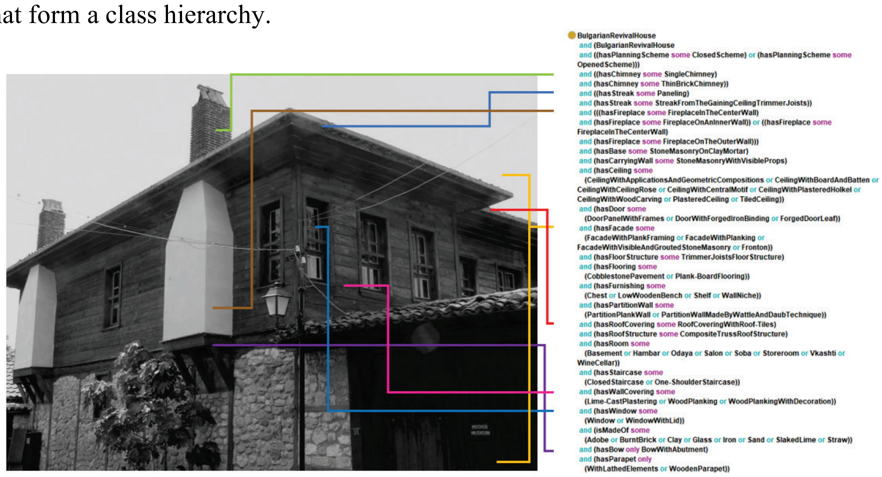

Fig. 3. An equivalent class description of a Black Sea House – the Moskoyani house individual.

The ontologies describing the domain include primitive and defined classes. Figure 3 shows the “necessary and sufficient conditions” of the equivalent class “BlackSeaHouse” in the oldhouses ontology. These are the conditions that require an individual, such as the Moskoyani house (Museum Ancient Nessebar, n.d.), to comply with all the restrictions of the class to which it belongs. The individual houses differ from each other, but they also have similarities that unite them in a given class. To illustrate, the Black Sea houses have a facade with wood planking; they also have a bow with abutment, and much more.

Based on the created hierarchies and defined axioms, differences and similarities have been modelled that are necessary for the description of the typological groups and houses classes – "ArbanassiTypologicalGroup", "ZheravnaTypologicalGroup", "LovechHouse", "RhodopeHouse", "PlovdivHouse", "BanskoHouse", "Kovachevska-House", "KoprivshtitsaTypologicalGroup", "MelnikHouse", "StaroreshkaTypologicalGroup", "Tryavna-ElenaTypologicalGroup", "StrandzhaTypologicalGroup", "BlackSeaHouse", and "YablanovoTypologicalGroup" (Stamov, 2007). Reasoners (in the built-in Protégé) can consider classes as subclasses of the equivalent ones. The typological groups and houses are implicitly reduced as subclasses of the "Pre-Revival-House", "EarlyRevivalHouse", and "HouseOfTheRevivalPeriodProper" (Stamov S. , 1989), depending on the available representatives preserved in time and, of course, the necessary and sufficient conditions specified in the equivalent classes in the OWL ontologies defining them unambiguously. The individuals have all the characteristics of the class, but also additional ones, which define them as private cases of the class. The types of houses and groups are defined and described in the oldhouses.owl. To present an idea, some of the individual houses are the "KonstantsalievaHouse" (from the "ArbanassiTypologicalGroup" class), "KordopulovaHouse" (from the "MelnikHouse" class), "TheHouseOfAnaTrendafilova" (from the "BlackSeaHouse" class), "Kuyumdzhiogluhouse" (from the "PlovdivHouse" class), "TheHouseOfVasilGenov-Cheshneto" (from the "LovechHouse" class), "PangalovaHouse" (from the "RhodopeHouse" class), and many others.

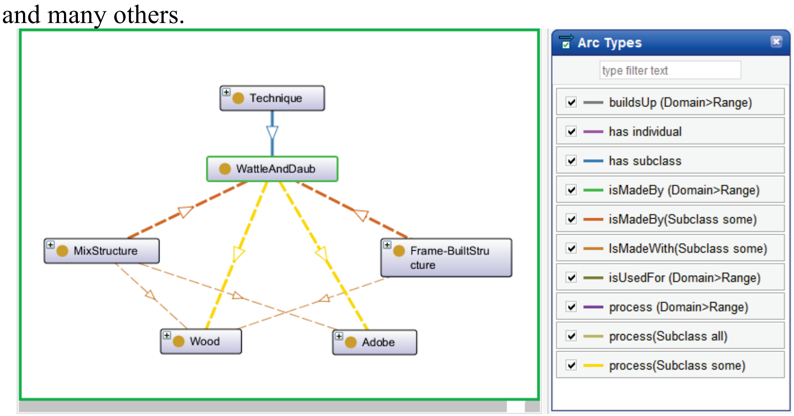

Fig. 4. An OntoGraf view in the materials.owl of the "WattleAndDaub" class

Details about the materials, techniques, and constructions can be found in materials.owl. Particularly, the "wattle and daub" technique is distinctive for old builders. It is created as a class in the "materials ontology" with a definition in its description to be a subclass of the "Technique" class and to be connected via the "process" property with two of the subclasses of the “BuildingMaterial” class – “Adobe” and “Wood”, as seen in Figure 4.

The “subjects” ontology includes periods, important to the houses, like the defined classes “BulgarianPre-RevivalPeriod”, “BulgarianRevivalPeriodProper”, and “EarlyBulgarianRevivalPeriod”. The data property “hasYearOfConstruction” connects the above classes restricted to “some values from restriction” with the xsd:integer datatype and values from the specific range.

The “agents” ontology includes individuals and organizations associated with the described architectural objects. Some classes in the class hierarchy are “Person”, “MainRole”, “LifeRole”, “Nationality”, “CorpodateBody” with subclasses “EducationCorporateBody”, “NonprofitOrganization”, “Institution”, and “Institute” (with “NIICH” as an individual). A variety of properties have been created, including object properties for interpersonal and family relationships like “hasAssociativeRelationshipWith” with its sub-properties “hasFather”, “isMotherOf”, “isChildOf”, “hasKinship”, “isSiblingOf”; or data properties like “hasBirthDateValue” and “hasDateOfEstablishmentValue”.

In the “functionalities” ontology the rooms are described in greater detail. For example, the following classes have been created: “Boaria”, “Brashnenik”, “Canopy”, “Chardak”, “Cowshed”, “DarkRoom”, “Dukyan”, “Estrada”, “Fudaya”, “Hambar”, “Hammam”, “Hashevo”, “Hayet”, “HomePrison”, “Horizma”, “Kioshk”, “Klet”, “Odaya”, “Podnik”, “Prust”, “Poton”, “Soba”, “Stobor”, “Varunluk”, “Vestibule”, “Vkashti”, and “WineCellar”. They are connected in the different ontologies via the same Internationalized Resource Identifier (IRI). This is an approach based on properties, classes, and individuals used to link the ontologies.

The “locations” ontology has been modelled for detailed localization of the elements that have a location. For instance, classes “PhysicalGeographicalRegion”; “AdministrativeGeographicalRegion” with subclasses “City”, “Country”, “HistoricalGeographicalRegion”, “Municipality”, “Province”, “Quarter”, “Street” and “Village”; “UrbanPlanning” with subclasses “CadastralIdentification” and “RegulatoryPlanning”. In particular, additional conclusions are drawn based on logic and transitivity of the object properties “isLocatedIn” and “includePlace”. Another interesting example is the “CoordinatePlace” class which has connections with the “hasLatitude” and “hasLongitude” data properties, both with the datatype xsd:decimal “ranges”.

The knowledge about the knowledge – meta-data in Protégé-OWL, is represented by different types of annotation properties. Comments (rdfs:comment with a tag –[language: bg]; [language: en]), labels (rdfs:label with a tag – [language: bg]; [language: en]), and images have been added for the elements of the ontologies – classes, individuals, properties, and the ontologies themselves. An annotation also presents the various synonyms under which the corresponding class or individual may be encountered. Thereby, we can further describe knowledge in several languages – in our case Bulgarian and English; especially for the individuals, with photographs of the houses and their elements – a façade view, decoration, bow, windows, rooms, furnishing, as well as people – the owners, builders, restorers, and so forth.

All this together is needed to achieve a detailed model of the Revival houses as a final result.

5 Conclusions

Researching the available information about the Bulgarian Revival architecture and the consultations with professionals in the field are a voluminous task and the very structuring of the ontologies and the creation of an e-model of the Revival house is even more labor-intensive. The objects from the house type include many elements. Their representation with English equivalent expressions is difficult due to the nature of the topic and obsolete words, but also the professional field poses challenges because it involves a whole construction dictionary. The data and metadata on the topic have a non-unified structure; nevertheless, despite the complex task, a unified ontological model of a Revival house was achieved.

We are getting as close as possible to the real "equivalents" of the model. At the time of writing the article, the ontologies describing Revival houses include a total of over 600 classes, over 1,000 individuals, and over 7,700 axioms. We have explored more than thirty houses-representatives from the register of NIICH (also from other sources) and they are in the process of being added in the ontologies.

The article is a brief overview of the whole description of the project construction process. It is a part of ViPS with a sub-area of cultural and historical heritage of interest for the development of an intelligent tourist guide.

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