Semantic topologies for complex medieval buildings and their annotation

Approaches for the description of historic architecture in the Semantic Web

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Semantic Web and semantic topologies – present approaches

In recent years, there has been an increase in the number of initiatives to develop ontologies as generalised authority data that describe the phenomenology of historic architecture and can be used for Linked Data.[1] In contrast, the semantic modelling of concrete historic buildings received less attention. Initial approaches to modelling historic architecture as an ontology focused on the events associated with the architecture and achieved quite impressive possibilities for modelling stratigraphic relationships and building-historical knowledge (Ronzino et al., 2016; Ronzino, 2019). However, a structural description of concrete buildings in the form of ontologies was not carried out in detail. If one realises that a structural breakdown of buildings is the outline structure for the analogue documentation procedures in heritage conservation, it becomes clear that the breakdown of architectural monuments in the form of ontologies as object-related authority data would open up a digital turning point for the recording and preservation of cultural heritage. Ultimately, such ontologies can be seen as semantic infrastructures for topologically referencing the multimodal diversity of information in the recording of cultural heritage and make the objects accessible for Linked Data.

As part of the research project "The Great Churches of Nuremberg", computer scientists from the University of Passau and building archaeologists, art historians and restoration scientists from the University of Bamberg developed an ontology using the example of St. Lorenz in Nuremberg. As a semantic topology, this ontology maps the relationships between the individual architectural elements and is the central element of the MonArch system, a software developed by the University of Passau and further developed during this research project. In this software, the semantic topology of the building is linked to a graphical representation in 2D or 3D, it can be annotated by terms from

[1] Initiatives in Germany include the Gemeinsame Normdatei (GND) developed from the library system, the idai.vocab of the German Archaeological Institute (available at: https://archwort.dainst.org/de/vocab/, accessed 27 July 2021) or the Wortnetz Kultur of the Landschaftsverband Rheinland (LVR) (available at: http://lvr.vocnet.org/wnk, accessed 27 July 2021).

authority data vocabularies, and various information and documents can be referenced to it in topological detail (Fig. 1) (Stenzer et al., 2019). This triad of building ontology, referenced authority data and graphic representation offers the basis for indexing historic buildings for Building Information Modeling (BIM) (Kuroczyński et al., 2019; Stenzer et al., 2019, pp. 387-390). An insight into the ontology of St. Lorenz will illustrate how a semantic topology of a building should be structured to enable interoperability of different disciplines from object-related science and heritage conservation.

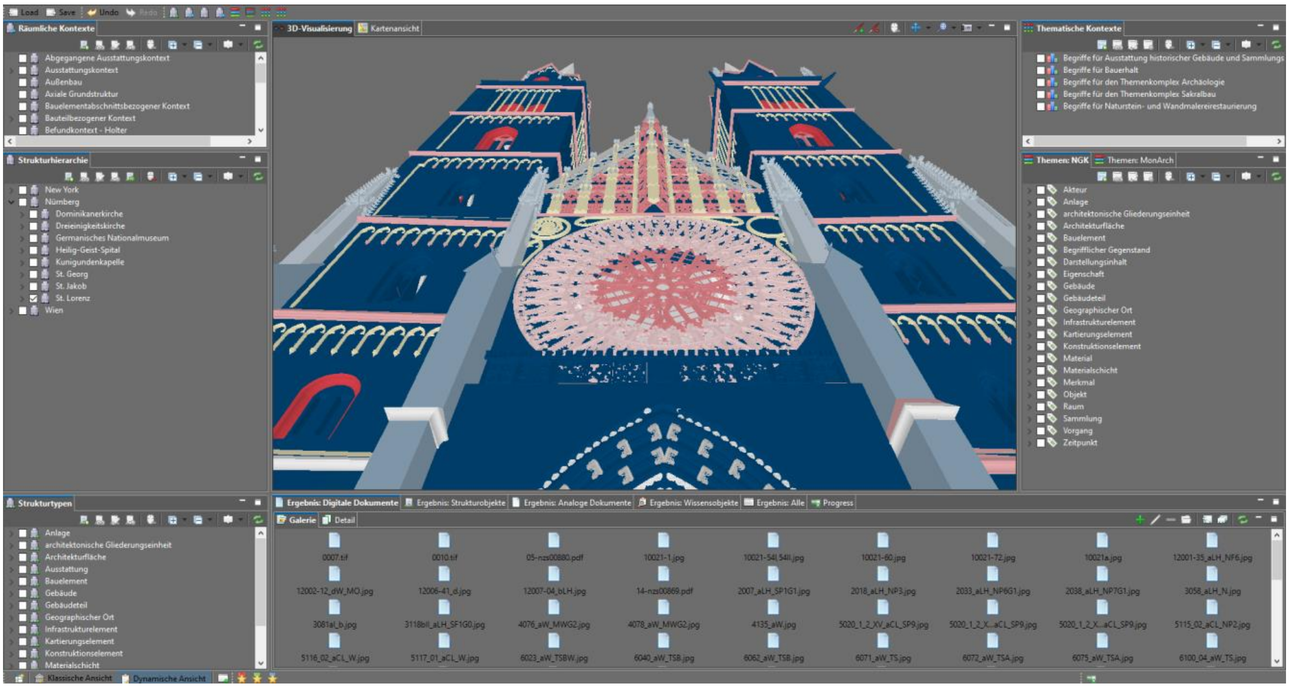

Fig. 1. The MonArch system: The semantic topology (left column) is linked to the graphical representation in the middle and to terms from authority data vocabularies (right and bottom left column). (© Alexander Stenzer).

Technical foundations of the ontology

The semantic topology of St. Lorenz was modelled as an OWL-ontology which complements CRMba and is composed of *spatial symbolic entities*. For their hierarchisation, a distinction is made between two directed relationships: While the *part of*-relationship formulates an existential dependency and can therefore only be used once, a *belongs to*-relationship expresses a weaker relationship and can be used for multiple assignments. In addition to these hierarchising relationships, mutual *connects*-relationships can be used to formulate adjacencies of two spatial symbolic entities. The spatial symbolic entities receive their content designation by matches to authority data vocabularies based on SKOS (Simple Knowledge Organisation System). The *type*-relationship expresses what kind of object the respective spatial symbolic entity is, and the *topical reference*-relationship can be used to assign several properties for a further description of this spatial symbolic entity.

The semantic topology as a description of the spatial relationships of a building

If one starts from the structure of the "Raumbuch" as a documentation system in heritage conservation[2] and transfers this surface-related breakdown into an ontology (Fig. 2, left), the building can first be divided into interior and exterior. In the next step, the interior is divided into its individual building

[2] The "Raumbuch" ("room book") as a documentation system of monuments is subdivided into rooms and then into wall surfaces (Petzet and Mader, 1995, pp. 178–179).

parts (interior choir, interior nave) and then into its individual room sections (bays, roof spaces). The respective wall surfaces – in this example the northern wall surface section nX facing the central nave bay nX and the corresponding wall surface section nX facing the roof space – are assigned to these room sections.

The two wall surfaces initially stand at two different places in the strictly hierarchical structural graph, without an essential structural connection between these two surfaces having been formulated in the ontology, namely that they are part of the same wall section. To establish this connection in the ontology, a further subdivision into building elements, like the wall, the vault or the pillar, must be made (Fig. 2, left). Now the building parts would be separated into their building elements (walls, pillars, vaults, etc.), which can be divided into individual sections according to the given spatial units. The two wall surfaces can now be subordinated under the northern wall section nX, whereby their structural connection is modelled.

Ultimately, a general modelling scheme can be seen in this single example (Fig. 2, right): A building is composed of rooms and building elements, which is expressed with a part of-relationship. Depending on the size, the building can first be broken down into building parts, before the subdivision into building elements and rooms follows.[3] Building elements and rooms can also be subdivided into sections, which is usually expressed for building elements with a part of-, for rooms with a belongs to-relationship. On the lowest level are the architectural surfaces, which have an existential dependency (part of-relationship) on the building element and are assigned to the room by a belongs to-relationship. In contrast, there are no belongs to-relationships between rooms and adjacent building elements, as this would cause transitively incorrect spatial subordinations of the surfaces.

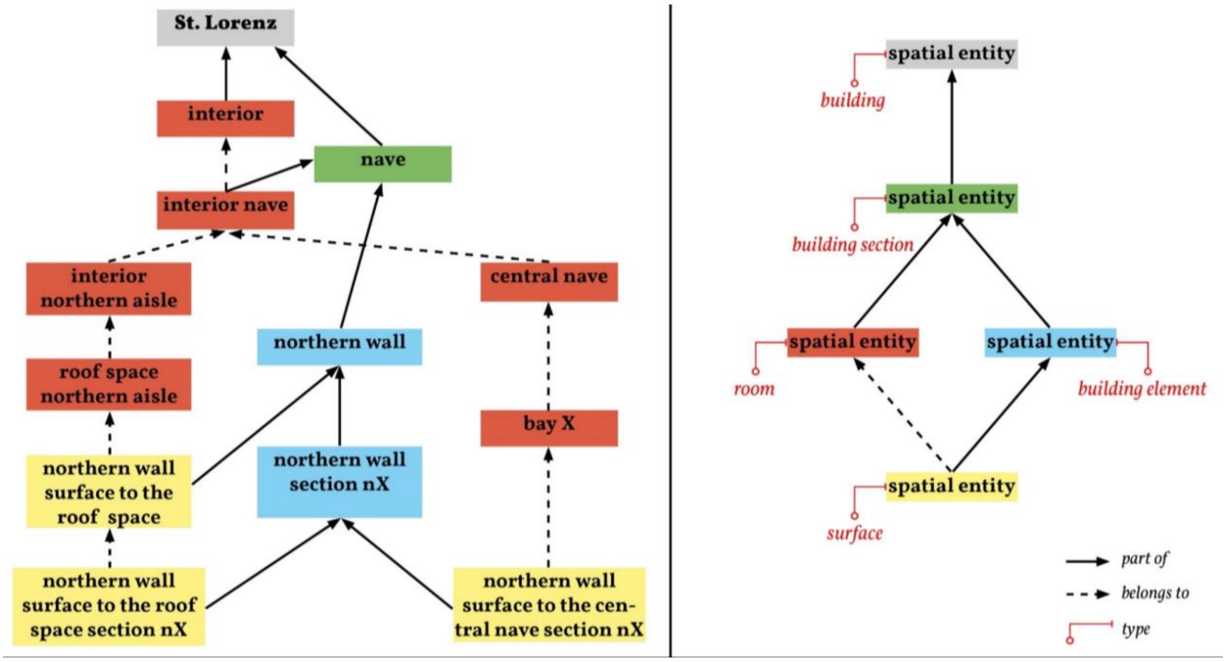

Fig. 2. Left: An example from the semantic topology of St. Lorenz. Right: Basic scheme for a consistent semantic topology representing the relationships between the individual architectural elements. The spatial symbolic entities are defined with architectural terms from an authority data vocabulary developed during the research project. The individual terms are subordinated to the top concepts shown in the scheme. (© Tobias Arera-Rütenik, Leonhard Salzer).

[3] The spatial symbolic entites describing building elements or rooms are similar to the classes B3 Filled Morphological Building Section and B4 Empty Morphological Building Section in CRMba, the CIDOC CRM extension for building archaeology (Ronzino et al., 2016, p. 73).

Semantic topologies as research data infrastructures

The topological building ontology of St. Lorenz interweaves two different systems of access to architecture and thus creates an interface for different disciplines that approach the existing building differently in their daily work practice: the consideration of rooms and spatial units is fundamental for planning questions of the architect, but also for room climate monitoring or the research of historic functional structures. The structural consideration of the individual building elements with regard to their statics is in turn the approach of the civil engineer. The focus on architectural surfaces is one of the restorers and building archaeologists. Thus, the use of semantic topologies – as developed for the MonArch system – ultimately enables reference systems and an infrastructure to store, retrieve and update the multimodal wealth of information of heritage conservation in an object-related manner. Furthermore, the semantic topologies open up the possibility of describing the concrete objects in the Semantic Web by annotating authority data vocabularies and at the same time referencing generalised authority data vocabularies by concrete objects. They thus enable digital networked monument management and at the same time provide the data basis for new research questions in architectural history.

Author Contributions

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