Knowledge Graphs for Building Design Decisions

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The planning process involves multiple phases, from initial design considerations to final approval and construction. Architects begin with conceptual ideas, represented in sketches or 3D models. Designs are refined to include structural, electrical, plumbing, and HVAC elements, often coordinated with engineers.

While Building Information Modeling (BIM) offers advantages for increasing the efficiency of those tasks, revisions, coordination and the approval process, it is not universally adopted in architectural offices [1], leaving conventional constructions error-prone. However, different aesthetic preferences of those involved can also lead to conflicts and delays impacting costs. Designing and evaluating multiple design aspects and alternatives delays the planning process. [2] To enable this, the use of knowledge graphs is suggested, enabling architectural designs to be compared with each other, adopting existing building design concepts and allowing buildings to be adaptive and quickly customizable.

Representing digital building data is complex. The standard for BIM-based data exchange is Industry Foundation Classes (IFC), facilitating hierarchical data representation. Converting this hierarchy into knowledge graphs, which is increasingly applied in the AEC industry [3], represents building components as nodes and their relationships as edges. This provides a structured representation of the building components and information. Knowledge graphs in the AEC industry enhance data storage, simplifying querying and analysis. Transfer methods include Resource Description Frameworks (RDF) and Labeled Property Graphs (LPG). [4]

A framework has been developed for decision support in building design, allowing to capture various project parameters of an emerging building and comparing them with existing buildings or building components stored in a database. [5] The aim is to utilize the design-decision framework to identify analogous sub-models from established buildings, integrate them into the new project, and facilitate modifications as needed. To facilitate modifications, three building variants have been defined that allow the classification of building components and their exchange according to defined rules. [5]
As the use of BIM and IFC proved to be too extensive in terms of data storage and information retrieval, knowledge graphs are employed to find design inspirations for buildings. LPGs are used to transform building models into knowledge graphs. This choice is based on better performance for complex and detailed queries in larger data

volumes compared to RDFs. Moreover, the labels are used to classify variant types to avoid major changes to the building statics when modifying the graph. These labels enable possible alternatives to the variants to be subsequently stored as option nodes.

Identifying object properties requires pattern matching and similarity assessments. Both are crucial in data analysis and machine learning. Graph pattern matching is applied to match the entire structures of buildings, while subgraph pattern matching identifies building parts and variants.

Similarity values between nodes and edges are calculated in the graphs to compare them with predefined requirements or other models. Distance-based and similarity between to data sets are applied to compare entities, properties, and relationships. In the end, the architect can be inspired by the most similar design proposal for the new project.

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