Public summary of PhD-thesis of Thomas Krijnen
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Advances towards efficient, long-term and multi-disciplinary access to information about our built environment

From its early conception, the construction industry has communicated by means of exchanging line drawings, initially on paper and drawn by hand, later as digital drawing formats and print-outs. The meaning and intent behind such drawings are not machine-interpretable and these drawings cannot encode detailed information besides a symbolic appearance and annotations. This can lead to errors due to manual reinterpretation and inconsistencies between the diverse fragmented and heterogeneous information carriers.

With the transition to Building Information Modeling (BIM), industry stakeholders exchange detailed building engineering information in semantic and computer-readable data bases. The Industry Foundation Classes (IFC) are the main open standard according to which this information is structured. This dissertation addresses issues that arise when extending and generalizing the use of IFC data to other related disciplines, such as cultural heritage documentation, digital long-term preservation, land registration and cadastral management, geospatial analysis, building asset management and civil engineering. These issues originate from the use of unrelated ontologies, mismatching levels of detail, different geometric modeling paradigms, inefficient storage of information, lack of full featured query languages and no means for mutation management.

To provide more efficient storage mechanisms for IFC instance models, a binary storage format is introduced, based on the open HDF5 standard for scientific computing. Binary data is data that computers can readily apprehend, rather than textual data, which is intended more for human interaction. Storage space is reduced to as little as 11.2 \% of original encoding for large models, but the most profound reduction is in access times to descriptive meta-data, which can be derived in as little as 0.00665 \% to 3.54 \% of the time required on the currently prevalent formats. Furthermore, a query engine is implemented that operates directly on top of this format and compared to the state of the art storage engines from the Semantic Web ecosystem, a data modelling paradigm that also offers compelling methods to store and query building data.

Due to the complicated and implicit definitions of the geometric engineering constructs in BIM models, querying and reasoning on such geometric constructs is not directly feasible. In this dissertation an alternative description of IFC geometries is provided as Well-Known Text, a standard originating from the geospatial domain for human readable and explicit geometry definitions with well-defined semantics and relational predicates. Comparing to the original representation of IFC in the Semantic Web, for specific models, a reduction in definitions of up to 95.6 \% is achieved. For more general files from industry reductions of 44.1 \% and 51.9 \% are realized.

In BIM models, building elements are stored as individual geometries. This is too detailed for other disciplines that require higher level spatial relationships. Procedures are provided to translate the product-centric solid geometries of building elements into representations that cater to other modeling paradigms, such as thermal analysis, where thin-walled interfaces between thermal zones are required and geospatial analysis where a complete manifold building envelope is desired for topological and geometrical queries.
An approach is presented to detect modifications to a building over time by pairing the manually modeled IFC engineering geometries with point clouds directly obtained from acquisition devices. For this purpose a minimal schema extension is provided that enables to efficiently express, annotate and link point cloud segments to individual building elements. Due to the various independent layers of compression a 67.7 % compression ratio is obtained compared to the independent storage of point cloud and building model separately. The confluence of point cloud and building model also facilitates use cases such as structural health monitoring to assess the gradual deflections that elements incur over time and hybrid modeling approaches for detailed ornaments in digital cultural heritage documentation.

Title of PhD-thesis: Efficient storage and retrieval of detailed building models: Multi-disciplinary and long-term use of geometric and semantic construction information. Supervisors: Bauke de Vries, Eindhoven University of Technology; Jakob Beetz, RWTH Aachen University