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INTEGRATING VISUAL PRESENTATIONS OF CONSTRUCTION MULTI-MODELS: VISUALIZATION DESIGN SPACE EXPLORATION

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1. PROBLEM AND RELATED WORK

The core of a building information model (BIM) is the description of the future building in terms of its physical properties, mainly geometry and material. Several other models containing additional non-spatial information about the construction process, e.g. costs and schedules, are mutually interlinked with the core building model. Thus, the BIM is extended to contain data from different domains. To allow for gaining insights for the user, the visual representation of this data is essential. While for each of these models traditional visual representations exist, their combination allows for and requires visualization techniques which reflect the integration of the information aggregated in the extended BIM.

Traditionally, the planned building is visually represented as architectural drawing. During the last decades the digital drawing has evolved into a full featured BIM. Due to the extension of the geometric information to the third dimension and the inclusion of further semantics, e.g. material, schedule and cost information, the generated visual representations where extended to photorealistic 3D images, time-based visualizations (Haque and Rahman 2009) and visualizations with elaborated colour-schemes (Chang et. al. 2009). However, construction informatics lacks a generic approach with regard to the visualization of n-dimensional construction data.

On the other hand, in the research area of information visualization many classifications and graphical vocabularies evolved. Studies on the formal description of visualizations (Wilkinson 2005) continually developed to matured visualization languages (Jeffrey and Bostock 2010). Further, exploratory visualization focuses on the interactive connection of multiple visualizations and the coordination of several single views to foster the knowledge internalization process (Adrienko and Adrienko 2007). Unfortunately, information visualization stays rather neglectful towards 3D information, which is an essential part of BIMs. An approach to integrate domain specific knowledge for multi model visualization (MMV) is required in addition.

2. MULTI MODEL VISUALIZATION APPROACH

In this paper, we define a concept for multi model visualizations, a set of relevant multi model configurations and three disjoint visualization integration methods. The spanned visualization design space is illustrated with prototypical implementations and exemplary data sets

Multi models consist of interlinked elementary models, which are defined as instances of a data model with a delimited domain (Fuchs et. al. 2011). Based on a set of known visualization techniques of an elementary model representing the visualization knowledge of a specific profession and for specific tasks, we study the combination of these visualization techniques in order to obtain integrated MMV techniques.

Three properties of the BIM are crucial for visualization purposes: the *domain*, the *level of detail*, and the *status*. Therefore, we analysed pairs of elementary models which could be distinguished due to one of these characteristics. Based on the elementary building and cost models we designed three multi model scenarios: different *domains*, different *level of detail* of the building model and different *status* of the cost model.

To represent multi model data using existing visualization techniques, we identified three disjoint integration methods to build a combined visualization technique. First, it is possible to represent each elementary model in one independent “view”. To facilitate the explorational user experience, the views are interlinked (*integration by interaction*). A second more integrative approach is to employ independent master and slave visualizations where the latter is (partly) integrated in the master (*integration by embedding*). The most integrative approach is to blend two elementary models into one which are then mapped to a single visualization model (*integration by blending*).

For each of the described visualization integration methods we analysed related work and developed a prototypical implementation. In addition, for each of the elementary models a visualization technique was implemented to evaluate the three integration methods in the context of the multi model scenarios.

3. RESULTS

Each sample of the spanned MMV design space was reviewed and discussed based on the above mentioned evaluation. Conclusions were drawn per integration method and per multi model scenario. Comparing the implementation effort for each integration method, we could state that the effort rises if the approach is more integrative.

The different integration methods stress different kinds of human computer interaction (HCI) resources. We define them as both the resources of the user who reads the visualization and the requirements for the medium or system which produces the visualization. While *integration by interaction* requires more time to interact with the visualization, *integration by embedding* requires more display space. *Integration by blending* on the other hand stresses the user’s cognition and ability to read the image. The mainly utilized HCI resource corresponds to the means by which each integration method represents complexity. We found that the closer an integration method represents the correlations between the elementary models, the less it communicates details of the single elementary model.

Performance of the integration methods in terms of the effective usage of HCI resources depends on the amount and structure of data to be visualized. By analysing which kind and amount of data conveys well-balanced HCI resource utilization for each integration method, we can predict for which multi model configuration the respective integration method might be appropriate.

To sum up the per scenario conclusions, for the domain scenario the integration by interaction method will fit best, while integration by embedding or blending performs only under the condition that one of the elementary models can by reduced to a subset. For the LoD scenario the integration by embedding method is appropriate without modifications, while the integration by interaction and blending methods need adaption to perform effectively. For the comparison scenario every integration method can be applied depending on the extent to which the data to be compared varies.

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