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Towards a client-oriented integration of construction processes and building GIS systems

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ABSTRACT

BIM (Building Information Modelling) methodology allows sharing the information about the same construction between the involved stakeholders. The same building will be affected by different AEC (Architectural, Engineering and Construction) processes. Some n-dimensional extensions have been recently proposed in the literature. The fourth dimension of BIM represents the planning of the building phases. This dimension can be used to simulate the building state at a fixed point in time, as a snapshot. This paper shows the development of a Web3D visualizer, which integrates 3D documentation with building planning following the BIM methodology using just Open Source software. Our main contribution is the merging of project planning and 3D documentation into a single model, which can be visualized in a modern web browser without plugins. Different construction phases are visualized in a unique and shared global model, which is updated along execution time according to a well-specified visual planning. Our application allows identifying bottlenecks or delays in processes with a status indicator, which is updated along time. Filtering processes allows select the most meaningful aspects for each stakeholder to improve management and satisfaction for final client. The use of Open Source software and standard protocols and technologies allows a wide spread and rapid adoption of the solution, which can be easily extended to support future use cases.

1. Introduction

This work aims to establish a feedback between the common practices of technicians in AEC and its computer implementation in terms of KMS (Knowledge Management Systems). To achieve this goal, we have developed a *methodology* which combines structural and functional aspects. The former ones are described in terms of objects and relations, whereas the latest one are described in terms of generalized functions which act on structural aspects or a symbolic representation given by graphs.

In this section, we provide an adaptive representation of a flowchart in terms of basic units (cells) which are grouped in cubic complexes by means of simple operators (join and intersection, e.g.). The representation for large elements is given in terms of nodes, edges and "faces", which are compatible with usual methods for structural computations in terms of finite elements. Beyond the formalism, our methodology provides a modular support to update information, insert and evaluate modifications (usually forbidden in constructive processes).

Visualization tools are focused towards a better understanding of reality and, consequently, they involve to cognitive science and its improvement through interaction with smart interfaces. Knowledge improvement is supported by the representation of physical objects, but they must be accompanied by a semantic which gives sense to the objects. Semantics involve to the meaning which must be described in terms of context; beyond structural aspects (involving objects and relations), it includes functionals to be evaluated on structural aspects.

The most common representations use geometric primitives and basic operations between them. Furthermore, our approach incorporates (1) a symbolic representation for constructive processes and (2) a support to perform computations linked to different kinds of functional defined on the structural model. Hence, our representation is compatible with a modular approach for design, implementation, execution and tracking objects and relations. It incorporates semi-automated procedures from the design phase till evaluation and tracking after ending the work. The proposed symbolic representation is given by an expandable dual

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graph of a 2D/3D representation which encodes the underlying semantics (interconnected spaces), and provides a guideline for representing different stages and building processes involving AEC environments.

Semantics can be described in terms of an ontology which is understood as a knowledge representation. Unfortunately, there is no a unique ontology, and it is necessary to develop methods and implement strategies for "connecting" different ontologies, with different strategies which can be labeled as fusion vs alignment. Fusion of ontologies is more expensive from the computational viewpoint; thus along last years, there is an increasing literature about aligning ontologies (see [1,2]).

3D GeoInformation is coded in terms of a three-dimensional representation which is compatible with any kind of geometric principles involving the design. Furthermore, it grows along the work execution, according to a generative grammar beyond simple shapes (cuboids and their components) which are used for representing interconnected spaces. Indeed, the composition principles for basic geometric primitives can be replaced by any other topologically equivalent primitives if one replaces linear by more general continuous maps for matching together primitives.

nD GeoInformation is constructed as special case of nD Information Systems, i.e. in terms of a collection of layers involving different attributes and/or properties related with installations and interaction with a changing environment. Supplementary dimensions can involve to time, temperature, costs or any scalar or vector functional. Color maps allow to visualize changes involving these functionals which are superimposed to the original volumetry. In particular, the proposed representation provides support for nD GeoInformation which is stored in terms of different layers which are superimposed according to AEC needs.

In this work, we have developed some visualization tools for GeoInformation involving AEC environments arising from the Web3D. They are focused towards the design and modeling of evolving 3D contents inside the browser which allows their integration with other HTML elements. More specifically, we have developed an HTML5 web based application called 3DSIMOS to visualize different construction stages according to a well specified planning. Our application is able of rendering complex models in the browser without additional plug-ins such as Flash thanks to the use of the WebGL technology to render 3D graphics inside the browser. Additionally, it support advanced visualization methods applied to Building Information Modeling (BIM) processes to perform computations involving the elements included in the represented scene [3].

The rest of the paper is organized as follows. Section 2 summarizes the background of the paper and the state of the art regarding GeoInformation and visualization. This section also proposes several natural extensions concerning to 3D Georeferencing. A sketch of our approach to *nD* GeoInformation systems is introduced at the end of this section too. Section 3 states the problem and provides a simplified explanation (mathematical details have been minimized) to the mathematical framework which supports data management and visualization. Section 4 includes details about design and implementation of our software application to evaluate our approach. This section shows a general overview of the application linked to the client more meaningful requirements and features from a point of view of software engineering. The end of this section shows the results which have been evaluated over our own Fallingwater showcase which has been specially developed for this demonstration. Finally, the last section highlights some thought-provoking conclusions and challenges to be solved in the next future.

2. GeoInformation and visualization in AEC

The main purpose of GeoInformation Systems in AEC environments is to provide a support for the management of built spaces and multiutility networks. They include visible infrastructures and non-visible underground installations. Their integration requires enough flexible Visualization tools to display planning, interventions and tracking of their performance. For their representation, we adopt a methodology inspired in CityGML framework [4].

The use of semi-destructive techniques (for building refurbishment, e.g.) and destructive techniques (for underground excavations, e.g.) requires a simulation able of integrating effects of human interventions and natural catastrophes (linked to floodings, earthquakes, fire effects, etc). The simulation is performed on 3D GeoInformation Systems which support added layers to represent effects involving the terrain (geological aspects, e.g.), infrastructures (underground installations, e.g.) and structural aspects (built spaces, e.g.). In view of the different customers for the application, their integration is displayed at semantic level, even if the support is given by a geometric and/or topological underlying support.

There are several approaches to integrate semantic information for AEC information management within 3D models. For instance, in [5] the authors have proposed a framework which harmonizes mappings to make compatible the semantics of the IFC (Industry Foundation Classes) and CityGML for utility networks. Their approach reinforces connectivity issues between components for a distributed spatial representation of elements by means of specification of taxonomies. We have followed a similar approach, but including temporal representation of flowcharts with functions to manage structural aspects, materials and interior utilities. The focus is on the development of Web Services around the temporal evolution of the workflow to ease the interaction between office and workplace.

Usual approaches are based on static views which display structural aspects, materials and interior utilities; axonometric views are very common because they provide isometric representations which can support different layers. All geometric connected representations use a support which can be reinforced in terms of structural constraints for the model. Structural approaches are characterized by objects and relations between objects; a typical example is given by cubical complexes which are stored in relational databases such it appears in [6]. In our case, geometric aspects can be navigated and visualized in an interactive way; their management is performed by using the underlying topological constraints.

Some relevant novelties concern to add functional involving structural aspects and the temporal evolution of morphological and functional representations which allow to compare previous planning with the performed execution. Interaction includes typical functionalities (updating, tracking and corrections) to ease such tasks for responsible at workplace and to provide a global representation to potential final clients which are not expert in semantic approaches. In our approach, issues related to the environment characteristics are secondary in our approach, but they can be incorporated and rendered in an independent way as an additional layer. This choice is motivated by large development of models and software tools for aligning ontologies involving CityGML- and BIM-based models, and the relatively scarce amount of friendly software tools for an intuitive information management. Recent work about software tools for automatic alignment of ontologies involving BIM and CityGML can be read in [7].

2.1. Georeferencing

The goal of Georeferencing is to provide a representation of geospatial information w.r.t. some type of projection linked to terrestrial geographic data. Most common is given by UTM (Universal Terrestrial Mercator) coordinates. Cadastral data in urban environments provides additional functionals (height, age, installations) which can be incorporated on a planar representation and eases a quick overview at quarter level.