DESIGN PROCESS VISUALIZATION SYSTEM INTERGRATING BIM DATA AND PERFORMANCE-ORIENTED DESIGN INFORMATION

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ABSTRACT: The essential role of design process visualization is to capture and represent design information as well as the change of design objects to keep track of reasons behind decision-making activities. The most prominent benefit of BIM, among its wide-spectrum potentials, would be that it made possible to consider simulated building performances such as energy efficiency for critical decision-making criteria even during the early stages of design project. Advanced design process visualization centered around BIM calls for reflecting performance-oriented design information generated from the various simulation tools from the early stages of building project. This will certainly demand a different approach in terms of process modeling and representation strategies.

This paper introduces a visualization tool addressing these issues. It is on the top of an Open BIM Server to manage evolving IFC data model in a systematic way, integrating quantitative design data generated from performance evaluation tools. A data model was developed to represent the design process composed of evolving versions and alternatives interwoven with decision-making factors. The system, with its timeline-based interactive user interface, will give a better insight into the design process and easy access to the reasons behind decision-makings in an intuitive way.

Keywords: *Design Process Visualization, BIM Data, Design Versions, Building Performance Evaluation, Social Data*

1. INTRODUCTION

One of the most essential functions of building process visualization is to capture and represent reasons behind decision-making activities as well as their results to give a better insight into the evolution of design information during the project. Research efforts on design process visualization tools so far have mainly focused on the externalization of designer's cognitive actions [1-3]. On the other hand, object-based 4D-CAD systems have mainly focused on the visualization of construction process after the completion of design [4]. There are few project visualization systems bridging the early and fully developed design stages in which information about decision-making factors persist throughout the building lifecycle along with evolving model data.

Decision-making factors tend to be more related with subjective issues such as aesthetic concerns or normative rules like building codes at the early stages of the design process while performance-wise quantitative data is available only after the design is fully developed. This information divide can be overcome by the utilization of BIM data at least in theory.

Advances in BIM technology enable the streamlined design information management. For example, the BIM-based models can be used to improve the energy performance of buildings during their whole life cycle by supporting comparisons between building designs and building performance during building operation [5].

However, especially during the conceptual stages of the design process, numerous design versions rapidly proliferate, and so is the number of decision-making activities whether in explicit or implicit forms. As the BIM-based process facilitates performance simulation even before the completion of fully modeled data, simulation-related data will become as significant as subjective design information. All these information need to be better organized and represented throughout the whole building lifecycle because it is tremendously difficult to trace back to early stage design information that might have caused the current problem found in construction stage or even during the operation of building.

The objective of this research is to propose a building design and construction project information visualization system, focusing on the management of decision-making criteria along with evolving BIM data. The system is on the top of an Open BIM Server to manage evolving IFC data model in a systematic way, integrating quantitative design data generated from performance evaluation tools interacting with the model. The proposed visualization system, with its timeline-based interactive user interface, will give a better insight into the design process and easy access to the reasons behind decision-making moments in the context of integration of co-evolving BIM data and performance evaluation data.

2. CONCEPT

The major concepts used in this research include

- BIM in the early design stage;
- representation of design versions as a main skeleton of the process visualization;
- integration of performance-oriented design information; and
- integration of social data as a potential enhancement to the process visualization.

They will be discussed in the following sections

2.1 BIM in the early design stage

Traditionally in an AEC domain, drawings have been at the center of all information exchange needed for design collaboration among stakeholders of the project. The drawing is giving place to the BIM recently, to ensure the more effective sharing and reusability of the information. BIM enhanced the precision of information delivery up to the level of product engineering as it can deliver the three dimensional component information which was not possible using the traditional 2D drawings. Hence, the simulation of building performance can be conducted without complicated data conversion and remodeling. In conclusion, Benefit of BIM, among its wide-spectrum potentials, allows possibilities to include more performance evaluation data such as energy and thermal analysis by dynamic simulations from the early stages of design process [6].

2.2 Representing Design Versions

Traditionally, in software engineering, the typical way of dealing with evolving object is the versioning: the management of source code, documents, graphics and related files in a large software project. Version-control software provides a database that is used to keep track of the revisions made to a program by all the programmers and developers involved in it. Design version is, in general, defined as a snapshot of evolving design object [3]. Version graph is the typical graphic representation of versioning.

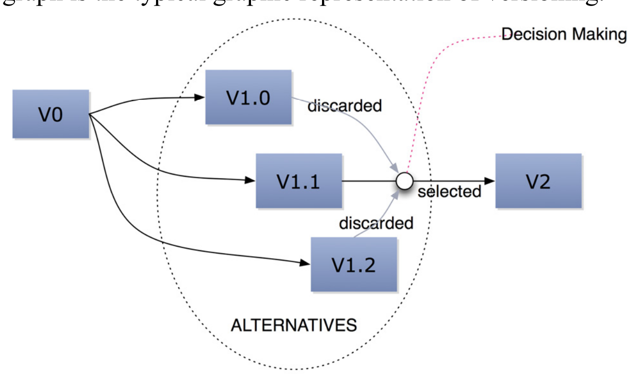

Fig. 1 Design versions and alternatives

Fig. 1 illustrates a typical design versioning scheme. There can be multiple child versions each of which is a modification of the previous version in the design process. They are considered as alternative design versions (V1.0, V1.1, V1.2 in Fig. 1). This situation naturally requires selection process, and a decision-making activity follows.

2.3 Integration of Performance-Oriented Data

From the perspective of design information management, possibility of flexible performance simulation based on BIM data leads to the explosive increase of design information from the early stage of design process, such as simulation results, alternative designs, and decision-making process in addition to the constantly modified BIM data. Advanced design process visualization centered around BIM data calls for the better integration of performance-oriented design information from the early stages of building project, generated from the interaction with various 'generate-and-evaluate' tools or processes. This will certainly demand a different approach in terms of process modeling and representation strategies.

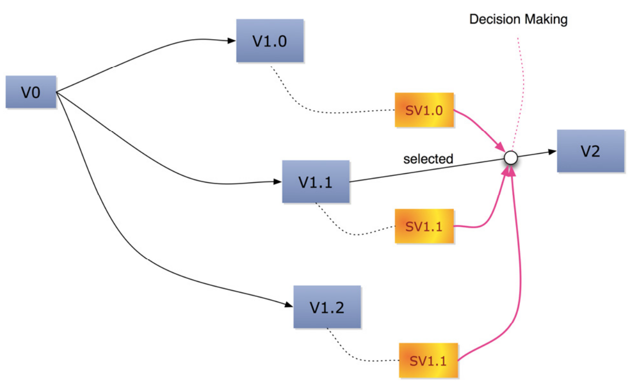

Fig. 2 Integration of simulation data into the version graph representation

Hence, version graph can be more elaborated as illustrated in Fig. 2. Each alternative version, in the selection process, might need the modification of its containing BIM data to be used as a source for simulation. The SV objects in the figure thus represent this type of versions. The decision-making activity will be based on the simulation result of these versions. Decision makers are to compare the results and select the best-performed model (V1.1 in the figure) as a candidate for the further development.

The version object for simulation data may consist of optimized (converted or extracted) model data and the simulation result. Decision-making activity is about collating and comparing of the simulation data.

Naturally, the decision result also needs to be stored. In thi scenario we introduce three kinds of data-stores: BIM, SIM (Simulation Information Model), and Design History data stores. (Figs. 3&7). The Design history is a database for storing decision-making activities and its relations with BIM data versions SIM data versions in the process.

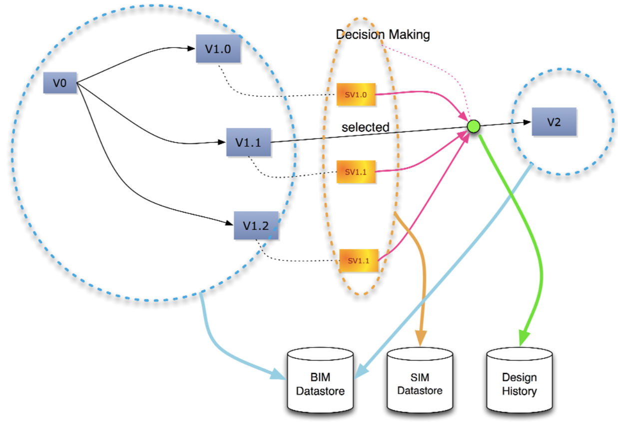

Fig. 3 Data-stores for the version management

2.4 Potential of Social Data Integration

The idea of integrating social data is still experimental, yet has significant potential especially for education purpose. In addition, social communication via shared BIM data is gaining more significance. Social networking is huge phenomena and not the exception in a design domain [7]. During the planning stage, anonymous participants may contribute to the direction of the project by social media. During the design stage, it can facilitate the design communication and reflect various opinions from both the design group and outside participants.

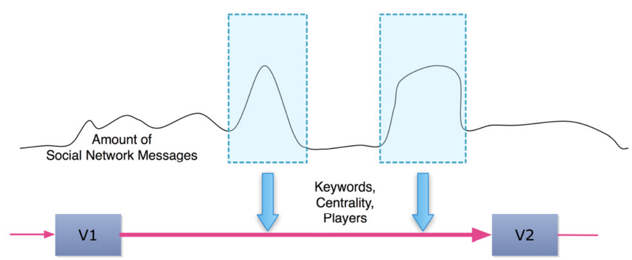

Fig. 4 Integration of social data into the design process

As in Fig. 4, correlations can be analyzed between the social data and the design quality once the data feed is established. In the long run, our system will include any kinds of sensor data in this way, correlations between sensor data and BIM model through the whole lifecycle of the building.

3. VISUALIZATION SYSTEM DESIGN

The visualization environment of the visualization system (BIMScape) consists of four visual components. The main component is a graphical browser showing the history of BIM data modifications as an evolving version graph along the timeline. It is an interactive viewer responding to the mouse interaction to freely navigate the version graph and change the zoom scale (Fig. 5).

The basic skeleton of the version graph is based on a version tree whose root object is located at the most left end of the viewer. In other words, the tree structure is rotated 90 degrees counter-clockwise from its typical representation. The tree structure is sufficient to represent the evolution of modified versions of BIM data in most cases. The representation of parent-offspring correlation (previous-next version) is straightforward, and the sibling correlation between versions can be easily identified in this representation. That is, two or more children nodes having one parent node in common are siblings to each other.

The sibling is especially the correlation of importance in the BIMScape system as it represents the design alternatives modified from a common previous version. Theoretically, they can be generated at the same time, but the creation time varies within a certain time span in reality. In an actual building design project, some alternatives will be chosen for further development or examination, and other will be just discarded or kept without any specific reason. When an alternative is chosen for further development and continue to evolve, there should be a reason for such a decision-making whether it is explicit (simulation data) or implicit.

The second visual component of the system, the node properties viewer, is used to present such design information explaining the reasons behind decision-making. The reasons can be a list of informal explanations about the design criteria used for the choice, or a checklist even in the most structured cases.

As the BIM-based performance simulation becomes universal and affordable, it is makes sense to expand the system functionality of above two components. Each version node of the tree structure can be associated with linkages to simulation data using the BIM data of the version. For example, there can be multiple performance simulations on a specific version of BIM data, and each simulation requires data modifications, creating different sub-versions of the data. This type of version does not constitute major part in terms of overall version development. However, they need to be managed with much more importance when it comes to the management of design information crucial to the directions of project development.

Hence the version browser is required to support a version graph representation more complicated than just a mere tree structure. In this sense, the each version node can be expanded to have its own version graph composed of simulation cases and their successive versions. It will make the version graph almost undecipherable in real world situations where successive simulations are usually conducted within a short time span. Accordingly, the system adopted a logical LOD (level of detail) strategy so that this type of sub-version graph expands visually only by user's request.

The node property viewer works as an information viewer on any selected node object. This requirement necessitates a flexible data representation mechanism so that the viewer can handle various kinds of simulation data as well as the basic version information of the selected version object. It turned out that viewer itself is better off to be a HTML viewer and the node properties are generated as a HTML page on the fly.

The third component of the system is the sensor data channel viewer. The meaning of sensor here is broad enough to cover not only the devices embedded into the building but also the concept of social network data. Suppose a design studio where the system is monitoring the conceptual design stage and participants are communicating through the social networking tools, which has recently become common. It is possible to correlate the content and activity patterns of the networking massages with the quality of design result. For example, it is easy to imagine that there is a strong probability of design breakthrough with the sudden increase of interactions through this kind of communication environment. Application of typical sensor data will be more meaningful when the system is used to monitor the actual building through the interaction with corresponding virtual model (BIM data). Types and numbers of the sensors can be multiplied in this way and expanded to the urban level in the long run, where multiple building projects are examined or monitored by massive users of the city.

The last component is the map. A Google map based geospatial viewer is embedded at the left side of the version browser. It shows the location of the building project in association with the version browser when a corresponding version is selected. It is useful when this version browser hosts multiple design projects at different locations evolving in parallel. Furthermore, this map can be used for showing the location and activities of sensors at a certain time.

Fig. 5 A Prototype Interface of Design Process Visualization System

These four components are highly interdependent to construct a systematic view on the design process. In fact both version browser and sensor channel viewer are synchronized along the timeline, providing a diachronic view about the building design project. On the other hand, the properties view and map viewer show a snapshot of a specific time, giving a synchronic view of the process.
An interactive slider bar has been added to maximize this notion of diachronic/synchronic views so that the user moves it along the timeline to get a synchronic view through the map viewer and the properties viewer in a dynamic manner.

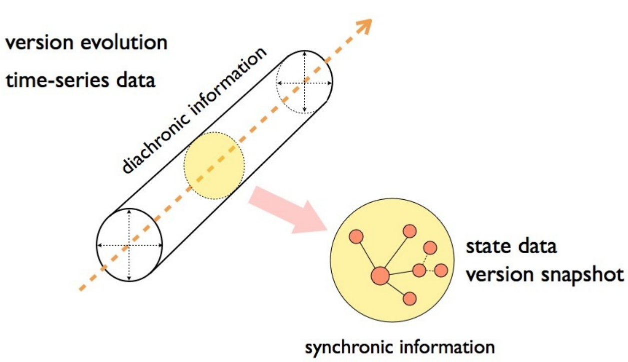

Fig. 6 Concept of Diachronic/Synchronic views

4. SYSTEM ARCHITECTURE

The open-BIM Server will function as a base platform of BIM-based design collaboration. The BIMScape system works on the BIM Server to utilize the basic BIM data querying functions as well as its version management tools. The current implementation has a limited set of functions mainly aimed to interrogate the BIM data to construct the version graph and minimum information for other viewers.
The system communicates with the BIM Server to interact with the BIM datastore, and also interacts with Sensor Datastore as well as Simulation datastore. The Process manager aggregates and processes the data for the BIMScape system (Fig. 7).

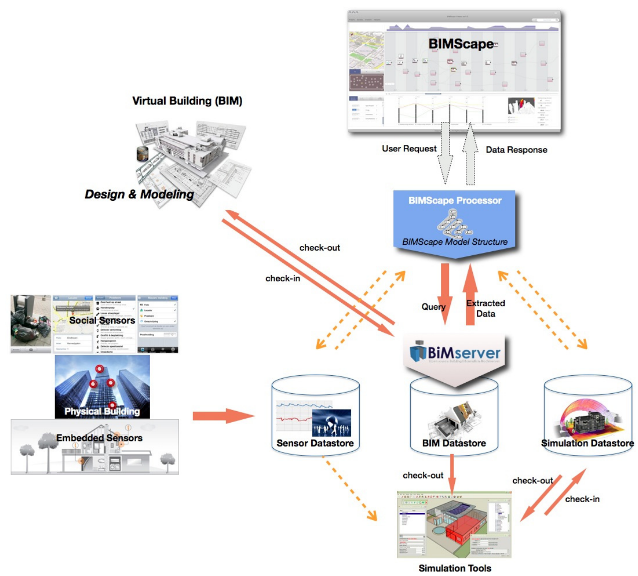

Fig. 7 System architecture of the BIMScape system

5. CONCLUSION

This research proposed a prototype project management system based on the design process visualization centered around evolving versions of BIM data. The system especially focused on the management of various simulation data in terms of design decision-makings. This type of system provides an insightful view to the whole building design project process compared with the management systems merely relying on the version management mechanisms of the BIM Server technology, enhancing its usability to the maximum level.
The notion of diachronic/synchronic views has been introduced as a powerful tool to understand the design

process. More development will follow in terms of dynamic user interaction in order to maximize its usability.

The most prominent feature that provides a potential to be a new type of design collaboration tool is the social sensor data integration. When used for a studio level design exercise, this function can provide a effective collaboration and analysis tool. It will be further useful as a monitoring tool for completed and operating buildings. Monitoring of sensor data and evaluation can directly going back to the design phase data and decision-making moments with ease using this type of system. By up-scaling to the multi-project site in a urban context, the system can integrate both social sensor data and embedded sensor data to monitor and analyze the lifecycle performance of the project, and trace back to the design data of certain time.

In terms of human-computer interaction perspective, the system brings a new dimension to the BIM data management, in conclusion. Further development will be followed to apply to the real-world project problems and enhance its usability. Multi-touch gesture interaction functionality will be added to the user interface in order to enhance the flexibility of navigation. Also, smartphone or tablet-pc-based apps are under development to feed the social sensor data to the system from various sources. Experiments are also under way to test the system from a small-scale design problems step by step.

ACKNOWLEDGEMENT

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2010-0023194). This work is partially supported by Korea Minister of Ministry of Land, Transport and Maritime Affairs (MLTM) as U-City Master and Doctor Course Grant Program.

REFERENCES

[1] Conklin, J. and M. Begeman, M. "gIBIS: A Hypertext Tool for Exploratory Policy Discussion", ACM Transactions on Office Information Systems 6(4). 1998.

[2] Goodwin, R. and Chung, P. W. H., “An Integrated Framework for Representing Design History”, Applied Intelligence, Vol. 7, No. 2, pp. 167-181, 1997

[3] Kim, S., Version Management in Computer-Aided Architectural Design, Doctoral Dissertation, Harvard University, 1997

[4] Akinci B., Tantisevi, K., and Ergen, E., Assessment of the Capabilities of a Commercial 4D CAD System to Visualize Equipment Space Requirements on Construction Sites, Proc. of Construction Research Congress 2003

[5] Crosbie, T., Dawood, Nashwan, and Dawood, S., Improving the energy performance of the built environment: The potential of virtual collaborative life cycle tools, Automation in Construction 20, pp205~216, 2010

[6] Laine, T, Hänninen, R., and Karola, A. Benefits of BIM In The Thermal Performance Management, Proc. Building Simulation 2007, p1445-1461, 2007

[7] Smith, TNO, Seminar on The Potential of Sensor Networks, http://www.tno.nl, 2010

[8] Singh, V., Gu, N., and Wang, X., A theoretical framework of BIM-based multi-disciplinaty collaboration platform, Automation in Construction 20, pp134-144, 2010