Non-Geometric Information Visualization in BIM: An Approach to Improve Project Team Communication

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Abstract: *Building design and construction processes use geometrical models as well as other documentation for communicating information during all phases of a project. Currently, an important amount of information included into the documentation is not linked to the 3D model, such as emails or decision-making updates. A huge challenge is an accurate and effective management of this non-geometrical information to improve team communication. This paper proposes the uses of Information Visualization techniques for managing these data visually, enhancing human understanding and interpretation. This research area is situated in the intersection of three areas of computing: Design Computing, Information Visualization (InfoVis), and Human Computer Interaction (HCI).*

Palabras clave: Building Information Modeling (BIM); non-geometrical information; information visualization; team project communication.

Introduction

Building design, development, and construction is a very complex process due to the number of multidisciplinary professional teams involved (owners, architects, engineers, consultants, and contractors), and the multiple phases of the projects. An enormous amount of information is managed during the building life cycle. Building Information Modeling (BIM) is the paradigm of generating and managing data during the building life cycle (Lee, Sacks, and Eastman, 2006). It works based on Building Product Models (BPM), and it includes geometrical information, spatial relationships, and object properties. Most of the information that was traditionally paper-based nowadays is adapting the new technologies and shifting to electronic files (Mao et al., 2007).

The computing environment has a huge impact on the creation and managing of information. However, many systems, such e-mails, replicate some of paper-based models, therefore, a significant amount of time is needed to extract and handle the crucial information from these files. This may cause inadequate decision-making due to misinterpretation or lack of analysis of the information (Mao et al., 2007). Communicating the information among project team members becomes essential to improve building processes.

Efficient collaboration is affected by the use of heterogeneous systems for data integration. Advances in Information Technology during the last 15 years have improved the data communication issue working with Internet- and web-based technologies. However, the major problems on interoperability systems include: access to precise data, information, and knowledge on the right time and in every phase of the building process; and the existence of several standards competing for metadata. "A common methodology for managing a project's information assets does not exist" (http://www.fiatech.org).

BPM Product and Non-product information

Building Product Models (BPM) is defined as models of objects that describe a building. It includes more than just geometrical information (Amor R. & Anumba C., 1997), specifying the information type and the way it is structured in a database (Eastman, 1999). That information is classified as product information (e.g. geometry) and non-product information (e.g. construction schedule), separating geometrical data (model) from data derived from the model. Product information is commonly visualized on the screen as geometry (lines, surfaces and solids) with parameters and other aspects of the model linked to it. Non-product information could be derived directly from the model (areas), and stored in a database, or it could be extracted from an external database (from suppliers), and be stored in a dataset that is dependent to the geometry (materials for cost estimation), or independent to the geometry (e-mails). Generally, important information is exchanged using geometrical models in a structured format, or documents in an unstructured format (Caldas et al., 2005).

BPM capabilities. BPM

Should support individual interaction, management, perpetuation of design intent, visualization, an open architecture for specific requirements, standards for representation, interchange and interoperability within heterogeneous tools (Eastman, 2010); not supporting the direct manipulation of parameters (or other aspects of the model) from an exclusive hierarchical tree that is independent to the geometrical objects. Although the manipulation of parameters exists, they are always linked to the geometry and distributed in the model. The lack of visual organization of parameters does not allow a clear understanding of the model parameters' structure.

Linking information

Product information is linked to the geometry, generally, as objects that could be imported into the geometry, such as set of windows. Non-product and structured information is not linked but derived from the geometry, such as volume calculation. Non-product and unstructured information is neither liked nor derived to/from the geometry, but affects directly the product model. This is the case of an e-mail that describes a modification of the building structure, for example. Currently, we can find huge amount of unstructured information that is not linked to the 3D model. In several unstructured documentation, explicit references exist related to objects, processes or information management, and "such references are constant among the instances of the same type of documents, which forms some type of 'structure' (Mao, Zhu, and Ahmad, 2007).

Existing Work

The efforts of information linking and management are not new in Architecture, Engineering and Construction (AEC). One approach is a study that developed a Text Information Integration Methodology (TIIM) (Caldas, Soibelman, and Gasser, 2005). It is based on text mining to improve management of text documentation, and its integration into the model. Another approach is the application of metadata to create connections between components contained in documents to facilitate its process (Lee, Sacks, and Eastman, 2006). Other applications are Solibri and New forma. The first one is used for BIM model checking, and allows design collaboration while the second one, for project information management. It uses several platform structures to manage different types of data.

Solibri - Open Design Collaboration

Solibri allows exchange of building design information, and model checking to analyze BIM for integrity, quality and physical security. It helps to reveal potential flows and weaknesses in the design. It analyzes rule applications into the model, such as accessibility and escapes routes; coordinate spaces; check incompatible components; check model with building codes; and compare the design product among disciplines incrementing collaboration and design coordination.

Newforma - Project Information Management

Newforma is a text-based application. It works on top of outlook for the management of e-mail content and attachment. It has comprehensive search feature, indexed file names, documents extensions, and into every instance of the searched text in the model. Text information is indexed under Action items, Submittals, Request for Information (RFI), Transmittals, Record copies, and Mark-ups. Newforma allows Internal and External communication using internet-based automated and secure methods. It also allows notifications and reminders for important actions, project calendar, changes communication and mark-ups sessions or PDFs. All these features work based on text (http://www.newforma.com).

Visualization of Non-geometric Information

The main goal of this research is to state the framework for synchronized information visualization for information types that currently are not included in a BIM geometrical model, allowing an intuitive data management, information coordination, and collaboration among project members. To accomplish this goal it is necessary to construct an N-dimensional BIM model that includes the geometrical information plus the links to other types of project information (such documents, schedules, and e-mails). To visualize and facilitate the data management and interpretation, it is necessary to design an interface that allows a graphic visualization and direct interaction with the information in different styles, such as text analysis, values comparison, relationships among data points

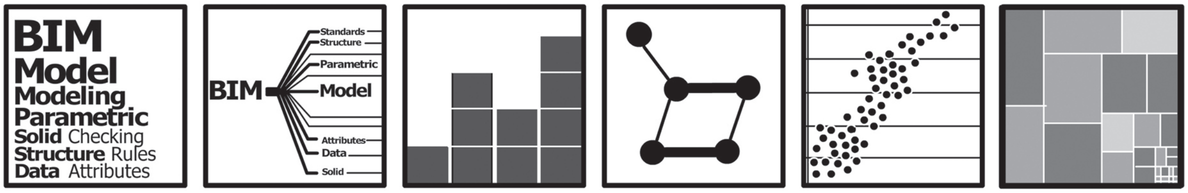

Figure 01: Data visualization of: a) Phrase Net, b) Word Tree, c) Block Histogram, d) Network Diagram, e) Scatter plot, f) Tree Map Comparisons, and g) Stack Graph for Categories. Adapted from ManyEyes: http://www-958.ibm.com/

Data structure organization

Depending on the data type, unstructured data could be structured in a database under some structure alternatives: Phrase Net, Word Tree, Block Histogram, Network Diagram, Scatter plot, and Tree Map Comparisons (Figure 01). Phrase Net displays networks of related words and ideas. Word Tree shows a branching view of how many times a word or phrase is used in the text. It is possible to navigate it by zooming and dragging, selecting the words and obtaining works connection to other words. Block Histogram allows a quick sense of how a single set of data is distributed; each item in the data is an individually identifiable block. Network Diagram shows the connections lay out as a network. Scatter plot-point one variable across the x-axis, the other up the y-axis. The size of a dot could represent a third variable; The classic scatter plot gives you a bird's eye view of how your factors relate to each other; Tree Map Comparisons allows you directly compare two different items from a set items arranged into a set of categories and subcategories by Stack Graph structures (Viegas et al., 2006).

Usability principles in BIM towards data interpretation

Since the 80's, Human Computer Interaction (HCI) has developed a list of Usability Principles for interfaces (Dix et al., 2005). Basically, these principles are good practices and shared knowledge structured in a list of "golden rules." One of its objectives is to enhance human cognition toward data interpretation and understanding through Information Visualization. Its success can be measured under two aspects: the impact on the community (influential ideas), and people's personal tasks performance. The main reason to use InfoVis in BIM is to help project members in a specific task for data interpretation, intuitive management, coordination, and collaboration. The complexity of a building design and construction demands the conventional usability principles of HCI to be specific and BIM-oriented, which are not task-specific to the BIM domain (Lee et al., 2010). Although in BIM the amount of information could be considerable less in number than in other areas, the variety of this information makes the application of HCI in BIM unique, opening a new research area.

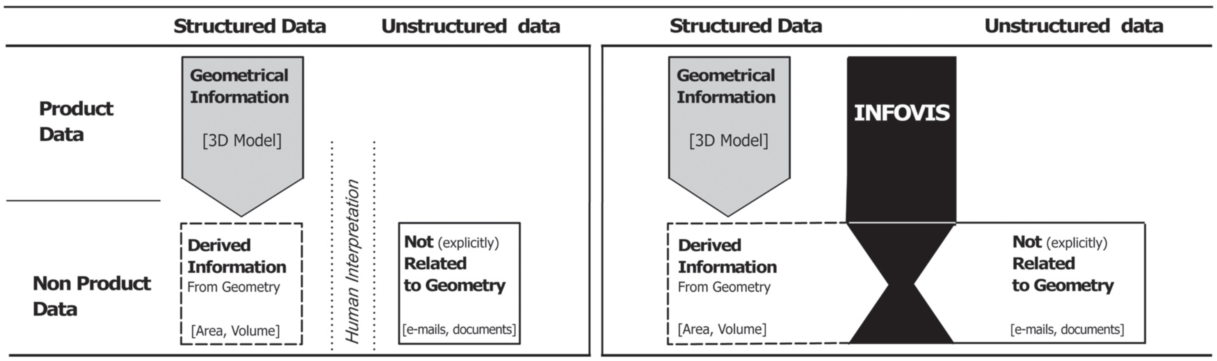

Figure 02: The current stage of structured and unstructured data representation, and the proposed inclusion of information visualization to reduce human interpretation of unstructured data.

Intuitive data management

In one hand, non-product data type allows users to access to the information by recalling particular attributes, which users must remember. In order to find a file, for example, the user should type it into a searching data system. In the other hand, product data type is discrete and the foundation for product models. It defines the relationship between different aspects of the model, most of them provided by different teams that have different approaches to the project.

Current software that manage building project data, are based on textual inputs, and built on top of existing platforms for checking, tracking, and storing. All these applications enhance the coordination of documents related to the project, however, the relation is made analogically –it is not automatic updated and the link to the model is not automatically established (Figure 02).

Some models provide inputs for other aspects of the project, constructing interdependencies. However, the access to the data is discrete. An easy and intuitive data management refers to: Having multi-access to the data, in which the user can access directly to one file, or to other files related to the initial file; Visualizing the parameters that control the specific data; Having a navigation system that allows users to search for a specific file, track a specific change on the project, or search for explicit relationships between the non-product data and the 3D model; Having multiple views that present the data simultaneously and consistently help users to search for correlations of diverse types of attributes. "Information visualization takes advantage of the human eye's broad bandwidth pathway into the mind to allow users to see, explore, and understand large amounts of information at once, focusing on the creation of approaches for conveying abstract information in intuitive ways." (James et al., 2005).

Conclusions

According to the industrial survey on the Canadian construction IT industry (Shen et al., 2008), "The most frequently identified issue is related to collaboration, including communications, document management, and interoperability." From the same survey, "the trends in information technology that will be important for the construction industry over the next 10 years will be web-based collaboration and project management systems" (67%) followed by the "integration of software tools across the project lifecycle" (43%). Another related challenge is the communication with other projects team members who are not proficient in BIM tools (http://www.solibri.com/), because the biggest barrier for technology development is related to the people acceptance of these new technologies.

Changes of the project during all its phases are very frequent. They are made by different sources, various reasons, and at any stage of the project; they may have negative impacts depending on how professionals manage its communication. Two main types of changes are re-doing and re-order a process that was not implemented correctly (Shen et al., 2008). This type of change is commonly caused by poor design and negligence, involving waste of time and money; however, an effective data communication and management could reduce these wastes.

Currently, project changes or adjustments exist at all stages of building design, development, and construction. An EPSRC (Engineering and Physical Sciences Research Council, U.K.) report states that "the clients' dissatisfaction is due to the fact that over 50% of construction projects suffer from delays and over-spending, while more than 30% of the completed projects have quality defects. Furthermore, some 30% of construction is rework." (M. Sun, et al., 2004).

The application of Information Visualization techniques into BIM will improve the users' cognitive capacity up to three times to the capacity used to read unstructured data (http://www.fiatech.org/), and will offer them an easy to use interface that do not require such a proficiency in BIM tools. Visualization and interaction, the two main branches of Information Visualization science, will help to interpret the data to support easier and faster decision making. This research implies working at the database level to reorganize and 'structure' the unstructured document data under some aspects, and the later construction of visualization.

Acknowledgements

The author thanks Chuck Eastman, who established the context of this research, as well as the Fulbright-CONICYT program from Chile, which supports her doctoral studies in Design Computing since 2008.

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