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BUILDING CODE COMPLIANCE CHECKING USING BIM TECHNOLOGY

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ABSTRACT

Building code compliance checking is a challenging task in building design, which needs to be monitored and maintained throughout the design and construction process. Existing BIM software tools are unable to explicitly rationalize how a building component or system selected by a designer affects the overall project with respect to building codes and regulations. This makes it difficult for the designer to determine when and how to adjust the design object in the case of design changes so that the overall project complies with the building codes. This paper outlines a framework for a collaborative building design environment where all project participants, during the design process, are able to keep track of the status of code compliance of their designs using BIM technology. The tool will assist designers in ensuring the code compliance in their designs and in exploring alternative building code-based designs during the design process.

1 INTRODUCTION

Building code compliance checking is a challenging task in building design, which needs to be monitored and maintained throughout the design and construction process. As with traditional building design methods, building code compliance checking based on the graphic representations of conventional CAD (Computer-Aided Design) requires a great deal of human intervention and interpretation, which makes the checking process costly and/or time-consuming. In the last 20 years, information technology has revolutionized the building design and the adoption of advanced CAD modeling in building design has made the final products more efficient and less costly since it provides the data needed for building performance analysis and evaluation (e.g. building code compliance checking) as design on the project proceeds. This approach to building design is so different from that using conventional CAD software which has been named as BIM (Building Information Modeling). While current BIM applications are helpful in quickly retrieving data that may be useful for code compliance checking, they are insufficient in supporting the collaboration between building code checkers (or inspectors) and other project participants (i.e. architects, engineers, and project managers) in regard to maintaining the code compliance as the design evolves and changes throughout the course of the project. Furthermore, existing BIM software tools are unable to explicitly rationalize how a building component or system selected by a designer affects the overall project with respect to building codes and regulations. This makes it difficult for the designer to determine when and how to adjust the design object in the case of design changes so that the overall project complies with the building codes. This paper is aimed at developing a framework for a BIM-based building design environment where all project participants, during the design process, are able to keep track of the status of code compliance of their designs. Such a computerized tool would be helpful in not only assisting designers in ensuring the code compliance in their designs, but also allowing them to explore alternative building code-based designs during the design process.

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2 THE INTERNATIONAL CODE COUNCIL

The International Code Council (ICC) was founded in 1994 by the Building Officials and Code Administrators International, Inc. (BOCA), International Conference of Building Officials (ICBO), and Southern Building Code Congress International, Inc. (SBCCI). The ICC publishes building codes that promote safety and fire prevention. The result is a uniform building code used throughout the U.S. to construct residential and commercial buildings, including homes and schools (ICC 2011). The first step taken in the current research is to extract the necessary knowledge contained in a building code document for implementation of the proposed computer-based building design system. The building code document selected for this implementation is the International Building Code (IBC), from which the knowledge contained in several sections is extracted and used as essential information for developing the proposed building design system. Below are typical building code requirements *(Section 706-Fire Walls)* extracted from *Chapter 7 – Fire and Smoke Protection Features* in the IBC document that will be implemented in the proposed system as demonstrative examples. *Openings in Firewalls*: Each opening through a fire wall shall be protected in accordance with Section 715.4 and shall not exceed 156 square feet (15 m2). The aggregate width of openings at any floor level shall not exceed 25 percent of the length of the wall (IBC 2009). *Fire Resistance Ratings*: In Type II or V construction, walls shall be permitted to have a 2-hour fire-resistance rating (IBC 2009). *Horizontal Continuity*: Fire walls shall be continuous from exterior wall to exterior wall and shall extend at least 18 inches (457 mm) beyond the exterior surface of exterior walls (IBC 2009).

3 BUILDING CODE COMPLIANCE CHECKING

Traditionally, building code compliance of a building at a particular design phase is not evaluated until all design works for the building have been completed. Further, the evaluation task is usually conducted in a manual fashion through numerous physical meetings (Goedert and Meadati 2008). This in turn makes the evaluation process time-consuming, potentially expensive, and prone to error, since the meeting participants or evaluators often become overwhelmed with a huge volume of project information and design criteria. In the case that the building design does not comply with the current building codes, the designer need to meet with other project participants, whose designs may have affects on the code violations, to determine how to appropriately modify the design so that the code violations can be avoided. At present, with computer supports the performance evaluations can be handled with relative ease. Therefore, design objectives concerning various performance aspects (e.g. energy efficiency, budget limit, constructability, code compliance, etc.) of a building project should be implemented in building design systems and must be evaluated as the design proceeds to avoid any changes that are usually costly due to rework. Presently, many CAD technologies (e.g. Building Information Modeling) have offered feasible solutions for the representation of 3D geometric information of design objects as well as allowing the addition of semantic attributes to support various design evaluations (e.g. code compliance checking) (Eastman et al. 2002).

4 THE PROPOSED BUILDING DESIGN FRAMEWORK

The proposed building design framework is developed using the formality of a standard process and information model, i.e. IDEF0 (Integrated Definition for Function Modeling) (IDEF0 2011). The IDEF0 model indicates major activities and the input, control, output, and mechanisms associated with each major activity. In the context of building code compliance checking of a building design project, inputs are the typical building components analyzed and evaluated by a process. Outputs are the status of code compliance resulted from the transformations/checking of the inputs by the process. Controls are the standards, criteria, guidelines, etc., that guide the assessment process (e.g. building codes/regulations). Mechanisms are the code checking tools/methods or techniques, i.e. algorithms to deduce complex building information and functions to verify for code compliance, which accomplish the actions delineated within the process. Figure 1 is an abstract view of IDEF0 notation for the building design framework. The next step taken in the current research is to develop the algorithms for building code compliance checking.

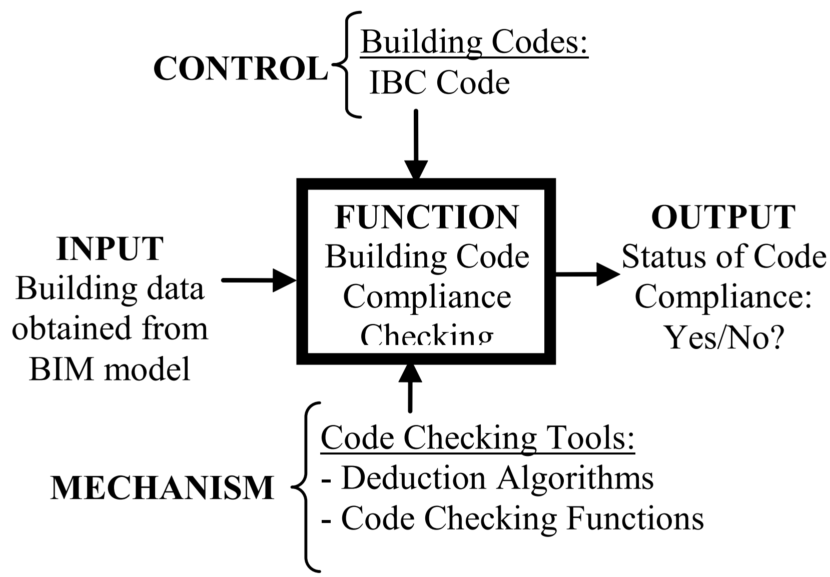

Figure 1: The Proposed Building Design Framework

5 ALGORITHMS FOR BUILDING CODE COMPLIANCE CHECKING

The algorithms for checking the compliance of the building code requirements concerning *Openings in Firewalls, Fire Resistance Ratings, and Horizontal Continuity* presented above were developed and implemented into the code compliance checking engine of the proposed building design framework. Below are the brief explanations of how the information needed for building code checking is extracted from the BIM model and the building component is verified for its code compliance.

(i) To check for the code compliance of an opening in firewall, its geometric data available in CAD database first is retrieved to verify if the opening is contained-in a firewall. This can be done by means of the function to deduce containment relations, as described in Nguyen and Oloufa (2001). Then, the geometric information about the wall's dimensions in the CAD database is extracted for computing the area and the length of the wall. Finally, the system checks if the wall area is less than 120 square feet and the opening width is not more than 25 percent of the wall's length.

(ii) To check for code compliance of a fire resistance rating, the function to deduce adjacency relations is used to identify the fire areas that are adjacent - to each other as well as the common boundary wall (i.e. the fire separation assembly) between the fire areas, whose information about thermal properties provides its fire resistance rating. Refer to Nguyen and Oloufa (2002) for details. A code checking function then verifies whether the fire resistance rating of the wall is at least 2 hours.

(iii) To check for code compliance of horizontal continuity of a building, the adjacent exterior walls of the building must be first identified. This can be automatically done by the function to deduce adjacency relations which were developed and incorporated into the proposed system. Then, a code checking function verifies if the exterior walls are continuous from exterior wall to exterior wall and whether they extend more than 18 inches (457 mm) beyond the exterior surface of exterior walls.

6 IMPLEMENTATION

The proposed building design framework was implemented into Autodesk Revit Architecture 2011, a BIM software commonly used in the Architecture, Engineering, and Construction industry. Autodesk Revit Architecture was built using parametric building modeling technology, in which buildings are represented as an integrated database containing both graphical and non-graphical information (Dzambazova et al. 2008). In effect, beyond graphically depicting the design, BIM models in Autodesk Revit Architecture contains parameters that can be used to represent building code knowledge and can be automatically captured during the design process for supporting code compliance checking. In Revit, each building or design component is associated with predefined parameters which are grouped into two categories: type parameters and instance parameters. The type parameters control all elements of the same type whereas the instance parameters control selected or created instances. The type and instance parameters are further categorized into different groups. Each parameter can be stored in different formats such as: text, integer, number, length, area, volume, angle, URL, material, and yes/no. In addition, new parameters representing the knowledge in building codes can be created and stored as project parameters which can be used to determine the code compliance of a building component. For instance, in Revit Architecture 2010, new parameters such as *area of opening in firewall, width of opening in firewall*, etc. can be created as project parameters or shared parameters, in which only the shared parameters can be exported to databases. These are shared by other families and projects, whereas project parameters are not exported to the databases. The newly created parameters on this project focused on information needed for the building code checking. Figure 2 shows examples of code compliance indicators (IBC requirements for Firewalls) that are created as new project parameters under the project property 'IBC Code' in Revit.

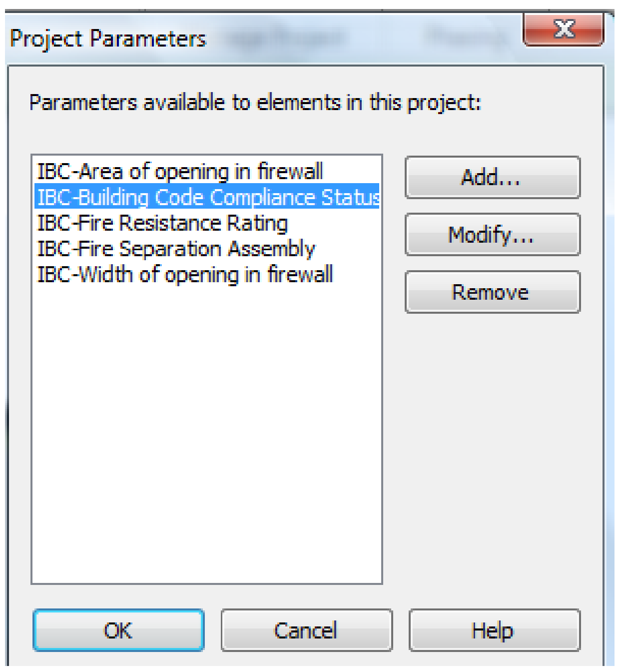

Figure 2: IBC Code for Firewalls Created as New Parameters in Revit Software

Also, the architectural design of a typical residential building project was used as a case study to verify the applicability of the proposed framework. In order to use the Revit BIM as a building code compliance checking tool, it is necessary to program some additional features into the software (Dzambazova et al. 2008). The additional features are needed to display a static graphical model showing the building components together with their own properties including both graphical and non-graphical information. The static BIM model used VB.Net to create the conditional query. Executing conditional query is not readily available in Revit but it is feasible through Revit API (Application Programming Interface) (Dzambazova et al. 2008). This feature was customized by developing an interface between Revit, and MS Access through Revit APIs using Visual Basic V. 6.0. This query facilitates the retrieval of information necessary for building code checking; e.g. area and width of an opening in firewalls. Figure 3 shows a typical interface screen for executing a building code compliance checking query and providing the final report on the code compliance status of a building element.

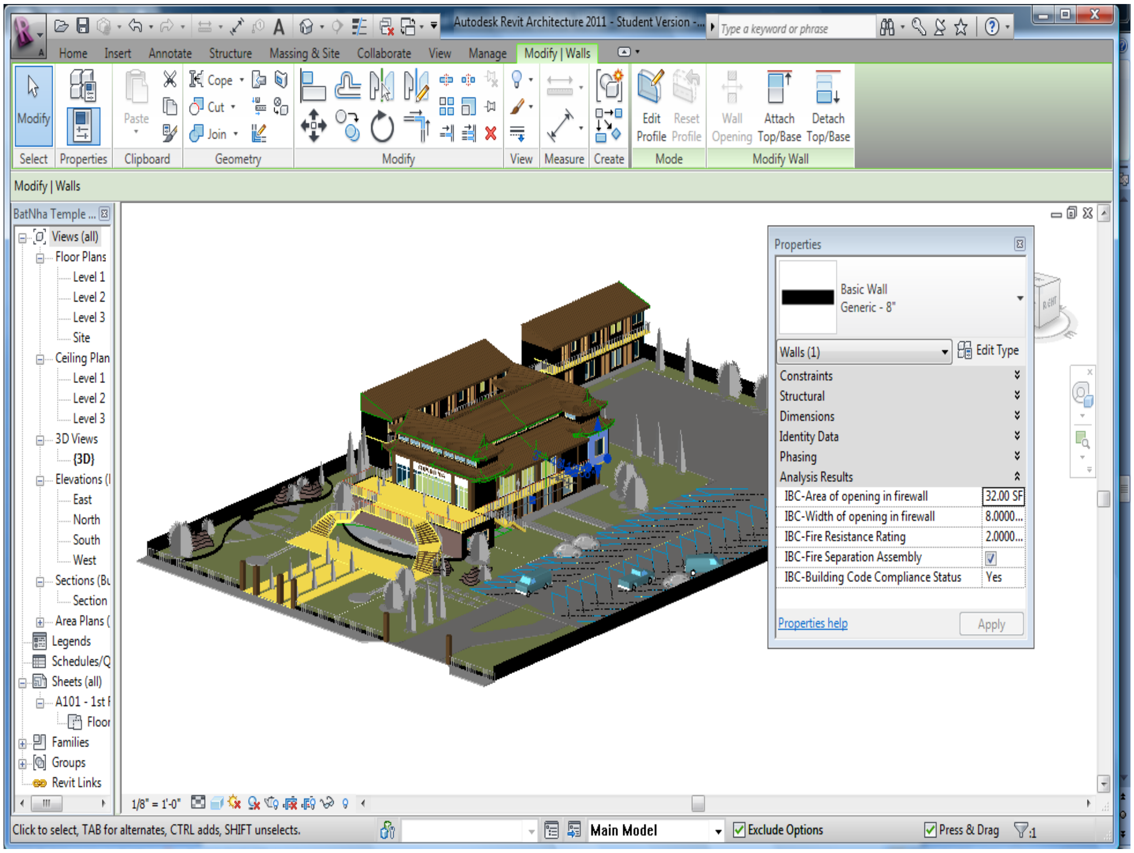

Figure 3: Results of Building Code Compliance Checking

7 ALGORITHMS FOR BUILDING CODE COMPLIANCE CHECKING

Design objectives concerning various building performance aspects (e.g. building code compliance, energy efficiency, budget limit, constructability, etc.) of a building project must be evaluated during the design phase so as to avoid or eliminate design changes causing costly rework. BIM software, e.g. Autodesk Revit Architecture, have been found to be a suitable CAD platform for developing an automated building design system because they provide both geometric and non-geometric information that can be quickly extracted for evaluating the building code compliance as well as other building performance aspects. The proposed building design system makes use of BIM techniques to represent building components including the knowledge contained in building codes (e.g. fire resistant rate of a firewall), enabling the automatic generation of the information needed for building code compliance. The proposed approach is aimed at demonstrating the feasibility of using BIM technology to develop a computerized building design system that supports automation in various design activities including code compliance checking.

REFERENCES

ICC, “The International Code Council,” Available at http://www.iccsafe.org/, Accessed on April 2, 2011.

IBC, "The 2009 International Building Code," Available at http://publicecodes.citation.com/icod/ibc/2009/index.htm, Accessed on April 2, 2011.
Goedert, J. D., and P. Meadati. 2008. "Integrating Construction Process Documentation into Building Information Modeling," *Journal of Construction Engineering Management*, 134 (7), 509-516.
Eastman, C., Sacks, R., and G. Lee. 2002. "Strategies for Realizing the Benefits of 3D Integrated Modeling of Buildings for the AEC Industry," *Proceedings of the 19th International Symposium on Automation and Robotics in Construction*, Washington D.C., 23-25 September, 2002, USA.
IDEF0, "Integrated DEFinition Methods," Available at http://www.idef.com/idef0.html, Accessed on April 2, 2011.
Dzambazova, T., G. Demchak and E. Krygiel. 2008. *Mastering Revit Architecture 2008*, Wiley Publishing, Inc., Indianapolis, Indiana.
Nguyen, T.H. and A.A. Oloufa. 2001. "Computer-Generated Building Data: Topological Information," *ASCE Journal of Computing in Civil Engineering*, 15(4).
Nguyen, T.H. and A.A. Oloufa. 2002. "Spatial Information: Classification and Applications in Building Design," *Journal of Computer-Aided Civil and Infrastructure Engineering*, 17(4).

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