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Code compliance with building information modelling

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Abstract

Compliance Checking involves comparison of known and derived information about a design with a set of constraints obtained from a building regulation. Because of the variety of hierarchical subdivisions and cross references, misinterpreting and overlooking the building code information is possible which may cause serious problems with respect to building safety due to code violations. The manual checking of building designs for compliance against National Codes is complex task and prone to human error with significant cost implications. Thus there is need of computer based tool which can facilitate the building code compliance checking process. In the case of AEC (Architecture, Engineering and Construction) design processes, building product models, also known as Building Information Models (BIM), form a suitable representation. This paper examines the role of BIM for automating the checking of compliance with building codes, thus improving the efficiency of building design and execution. It also presents BIM challenges and issues in developing countries, with India as a case study.

Keywords – Building Information Modelling, BIM, CAD, Building Codes

1. Introduction

Building code compliance is considered an integral part of Engineering, Design and Construction process. Dictionary defines a building code as: "a collection of regulations adopted by a city to govern the construction of buildings". The purpose of having building codes "is to establish the minimum requirements to safeguard the public health, safety and general welfare through structural strength, means of egress facilities, stability, sanitation, adequate light and ventilation, energy conservation, and safety to life and property from fire and other hazards attributed to the built environment and to provide safety to fire fighters and emergency responders during emergency operations" [1].

Regulations are generally written in natural text and have logical structure, typically in a hierarchical fashion from general to most specific. Building officials and designers can have different views concerning code interpretation of various clauses based on their functional responsibilities. Because of the various hierarchical subdivisions and cross references, misjudging and overlooking the building code information is possible which may lead to serious problems with respect to building safety due to code violations.

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In the past 10 years, design tools in the Architecture, Engineering and Construction (AEC) industry has been improved from 2D Modelling to 3D Modelling i.e. from Computer Aided Design(CAD) to Building Information Modelling (BIM). BIM as a powerful set of design management's tool has recently become a topical research area. Technical developments in Building Information Modelling (BIM) offer the potential for a new generation of software tools that can automate the checking of compliance with building codes. The automated compliance checking would not only prove beneficial to designers but to also building certifiers, consultants, building code authorities, specification writers and builders [2].

2. Building Information Modelling (BIM)

Building Information Model involves integration of CAD (Computer-Aided Design)drawings, geo-spatial data and other graphical and non-graphical data. It represents the view of a building from any practitioner perspective: architect, specification drafter, and engineer, fabricator, leasing agent, lender and general contractor. As such, it serves as a shared source of information on a building, forming a reliable basis for decision making during its life cycle.

A building information model is a digital representation of the building process. It facilitates the exchange of information in digital format which makes possible accurate cost estimates, simulations, scheduling, and energy analysis. BIM also aids coordination with engineering, fabricating and construction partners.

2.1.Advantages of switching from 2D CAD to BIM

- BIM use the common language of building elements (wall, door, floor etc.) as used by designers;
- Document coordination is improved and simplified;
- BIM software allows 3 D visualistions where an output can be simple grey scale 3D representations, cut-away 3D sections or photorealistic renderings from a single building information model;
- the interoperable platform of BIM software simplifies collaboration with other architects, designers and consultants;
- BIM models can be exported to common drawing formats (such as .dwg or .dxf), and to spreadsheets to create schedules that can be used for costing, material take-offs, etc.)

3. Technological Development

Approaches to developing automated building code-checking have been reported in the literature for the last two decades [3]. Continuous research efforts have been made to improve automated compliance checking. Industry Foundation Classes (IFCs) provide a common standard for data interoperability and have been used as a common model in AEC domains. These support interoperability across the individual, discipline-specific applications that are used to design, construct, and operate buildings by capturing information about all aspects of a building throughout its life cycle.

Major CAD vendors have provided interfaces to IFCs, thus making it easier to integrate CAD systems with external analysis tools[4]. Eastman et al.[3] in their paper reviewed five IFC based efforts to automate rule checking in buildings. These are Singapore CORENET project, the HITOS project by Norwegian Statsbygg, the effort by the Australian Building Codes Board, the International Council in the US and the General Services Administration effort.

Gowri et al.[5] has used an expert system for checking health and safety code using integrated hypertext as case studies database. A hybrid prescriptive-performance-based approach for automated checking on disabled access provisions of America was proposed by Han et al. [6]. Based on this approach, a framework for on-line code checking has been developed to support disabled access analysis.

Nguyen and Asa [7] in their paper implemented a computerized framework underlying an automated building code compliance checking system in a 3D solid modeling system, where building components are represented by both geometric (e.g. dimensions, locations) and non-geometric data (e.g. fire resistant rate of a firewall). An automated online code-checking process has been implemented by Yang and Xu [8]. It examines the OO code knowledge model and the IFC-compliant information model as more effective representations for building rules and design data in distributed code-checking systems. Greenwood et al. [9] reviews previous research into automated code complianceand identifies the key issues for future development and examines the causes of information paucity for compliance checking in the current generation of BIM tools. Pauwels et al. [10] discusses the improvements generated by deploying semantic web languages which can overcome limitations imposed by IFC, thus enabling a range of significant improvements and possibilities for automation in building design and construction.

4. Software for Building Code Checking

For automated code-checking, there is a need for a standard model that provides more information than a collection of drawing primitives like CAD provides [3]. As Building Information Modelling (BIM) becomes more commonly used by building design teams, usage of the model for code analysis is becoming more important. Much software exists today that does automatic rule checking applied to a standardised BIM.

4.1. BP-Expert

BP-Expert[11] was the initial approach to automated code checking in the CORENET (COnstruction and Real Estate NETwork) project in Singapore which used Artificial Intelligence (AI) and Feature-based CAD technologies for building plan checking. This system checks architectural plans, 2D representation of building designs, for compliance to building codes of the relevant authorities in Singapore. However, this project failed because of varied reasons such as the focus on 2D drawings rather than 3D, the proprietary nature of the application, its inability to handle inconsistent/bad data, its limited coverage of code clauses, and overall performance. The BP-Expert can only supply AutoCAD drawing. Other CAD software's drawing cannot be used by BP-Expert as their formats are not the same as AutoCAD's [2].

4.2.Solibri Model Checker

The Solibri Model Checker (SMC) is a software application from company Solibri Inc. that analyses Building Information Models (BIM) using the open IFC

format [13]. It checks that the model complies with building codes, business best practices and program requirements, international and national standards etc. One of the differences between SMC and BP-Expert is that SMC reads IFC R1.5.1 and IFC R2.0 product including AutoCAD, ArchiCAD, etc, while BP-Expert can only work with AutoCAD [2]. However, due to built-in checking rules of SMC, its very hard to change current rules and add in new rules.

4.3.SMARTcodes

SMARTcodes is a joint project with the International Code Council (ICC), AEC3 and Digital Alchemy [14], introduced to automate code compliance checking in the U.S., November 1, 2006 in Washington, D.C.SMARTcodes is the most process oriented approach to rule checking among the various rule checking offers. With simple selections, SMARTcodes automatically check the building for compliance with envelope and lighting provisions of the 2006 International Energy Conservation Code, highlighting areas of non-compliance and provide a three-dimensional view and written description of the code violations.

4.4. EDM Model Server

The Express Data Manager (EDM) model server provides comprehensive validation of any data set based on the EXPRESS data Modelling language (ISO 10303-Part 11) [15].EDM has been built specifically to manage the extremely complex data structures found in military and industrial applications that deal with product data models. This could for example be 3D models of buildings, ships, or airplanes or related BIM applications. It verifies that the data is consistent with the rules and constraints of an EXPRESS schema. In addition, it conducts detailed diagnostics at the instance and attributes levels. It is a generic tool which makes it possible to validate any data according to any schema defined in EXPRESS. EDM Model Server is a very powerful platform for building rules [15]. With EDM, the user can build computable rules on an open standards format and can execute them. The platform is flexible, but also complex, and requires highly skilled professionals to run.

4.5.e-PlanCheck

e-PlanCheck is a project started in 2000 for code checking in Singapore. e-PlanCheck checks codes for specific aspects of Architecture and Building services like building control regulations, barrier free access, adherence to fire code, and so on [16]. FORNAX essentially provides the development and deployment platform for e-PlanCheck. The building codes are interpreted and built using FORNAX. FORNAX is a C++ object library that derives new data and generates extended views of IFC data [3]. FORNAX objects carry rules for assessing themselves, providing good object-based modularity.

4.6.DesignCheck

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) initiated and led the DesignCheck project [4]. It was funded by Australia's Cooperative Research Centre for Construction Innovation.DesignCheck [17] assesses building designs against complex building codes. The DesignCheck system provide an automated code checking process, flexibility by allowing a design to be checked by selected clauses or object types and support for checking various stages of design during the design process, such as at the early stage of design, detailed stage of design and specification stage of design. The DesignCheck system is for use by building professionals such as certifiers, architects and designers.

5. BIM in Developing Countries

In developing countries, most architects still use CAD software for construction purpose and most of the construction drawings are still paper-based [18]. Some initiatives have started from which most promising is the InForm architects firm in India.

5.1.InForm Architects: BIM implementation in India

Use of BIM in India has just started.Its full adoption has a long way to go. InFORM Architects, Bangalore, is a 40-person architectural firm in India established in 1997 which started using Building Information Modelling software Revit in 2006 [18].

InFORM Architects has worked on over 250 projects of varied building types, such as housing towers, institutional campuses, office buildings, housing, industrial buildings, museums, hospitals, etc. in India. This company has won several National Design Competitions, 51 Awards at the National Level, nominated twice for ARCASIA awards at the International Level and is extensively published in the National and International Media [19]. The firm's work gets critically acclaimed for various projects.The main reason why this firm has shifted from CAD to BIM was that firm's projects were complicated to describe in basic drawings. The company provided training to all the staff on Revit.It instituted its own "BIM awards" to encourage more use of BIM. The benefits firm has achieved by deploying BIM are: easily visualization through multiple 3D views, improved efficiency, more accuracy, less time in repetitive tasks and thus in project delivery.

6. Challenges for BIM adoption in developing countries

The major challenges for deployment of BIM are:

1. Lack of time to update skills of staff while working on projects in companies.
2. Lack of formal training and effective online support. BIM software is more complex than CAD. To exploit it correctly requires formal professional training.
3. Cost of the application i.e. annual subscription of BIM software is quite high.
4. Cost required in learning and training on the new software [20].

7. Need of Building code checking software

Analysing advantages of BIM such as complex projects developed in less time, with more accuracy and more understandable drawings, it is time to use it for code checking as well. The primary goal of government agencies is to ensure public safety by ensuring compliance of structural safety codes, and BIM has the potential to fulfill this requirement. Many developed countries like USA, Australia, Singapore has developed Automatic building code checking software using BIM such as Designcheck, e-PlanCheck, Solibri model Checker etc. and using it for their projects for checking code violations. Developing countries should also start using BIM for building projects and codes conformance.

Conclusion

Checking building designs for compliance against various building codes is a complex task and one with a high cost of failure. Automation will not only reduce time and resources but will also minimise errors. And Building Information Modelling (BIM) offers the potential for the same. Many efforts have been made to address the above issues for the representation and execution of building codes of practice and standards. In a developing country like India, adoption of BIM has just started, but is bound to increase due to potential of BIM in increasing profit. Use of BIM for Code Checking is just a future scope. Further research is still needed to develop the object-based, more efficient, sharable and standardised and open source representations for both code provisions and building designs.

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