Automatic Code Checking Applied to Fire Fighting and Panic Projects in a BIM environment - BIMSCIP

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ABSTRACT

This work presents a computational implementation of an automatic conformity verification of building projects using a 3D modeling platform for BIM. This program was developed in C# language and based itself on the 9th Technical Instruction from Military Fire Brigade of the State of Minas Gerais which covers regulations of fire load in buildings and hazardous areas.

Keywords: Code Checking, BIM, Fire Load, Revit.

1. INTRODUCTION

Every building under a jurisdiction must pass, at its project phase, through a legal verification and standard analysis processes which is based on a compilation of codes and technical standards, assuming, in general, a method that can be transcribed numerically. The parameter checking process is usually made manually and, due to this, is often time-consuming and doomed to interpretation failures even if it has supporting IT tools. Oriented object programs and parameters modulation offers a way to automates verifications since it is possible to associate rules and characteristics to virtual model's components allowing manual verification to be done by an automatic computer program [1].

At first, PROSCIP, a code-checking system, was developed for AutoCAD platform as a request of the Military Fire Brigade of the State of Minas Gerais which main purpose is to verify building condition based in safety standards and technical instructions of Firefighting and panic.

Subsequently, the research evolution adopted BIM technology for its development, whose concepts of 3D information modelling allowed the creation of code-checking applications to be more efficient and interoperable. Development advances forced the creation of BIMSCIP system, for Autodesk® Revit®.

3D modeling parameters are ideal for the use in technical applications whose information in modeling may not be as well visualized in 2D [2]. Therefore, the construction of an information modelling system in fire security field requests the use of 3D platforms what is crucial to obtain realistic results [3][4]. Autodesk® Revit® software has been chosen for offering an application development environment (plug-ins) integrated to its native entities, ensuring, among other things, the correlation between design tools and conceptual modelling. The choice for Autodesk® Revit® platform justifies itself by allowing the adoption of BIM concepts and 3D modelling that permits the application of integrated information methods at application development.

Background Research of BIM

The utilization and development of BIM concepts represents a new paradigm for conception, construction and maintenance of buildings. This new technology was defined as a group of policies, processes and technologies that interact among themselves creating a methodology which assists essential parts management of design and construction project by using digital information, supervising all life cycle of the construction at issue [5][6]. With the technology evolution, civil construction projects are becoming more complexes, and generally cut across many disciplines, integrating knowledge from different sources. In this way, the administration of those conditions has become an essential issue that can be facilitated by information modelling if it is used BIM technology. Applying BIM concepts transcends construction project phase to become an important tool at building operation and installation management phase, as

well as being a support to its several uses at regulation application.
BIM models are the basis for information management and building installations [7]. Therefore, by implementing BIM in Architectural, Engineering, Construction and Operation Industry (AECO), and also in management field, it is changing how safety issues are being discussed [3][8]. In that context, the main purpose of this work is to develop a BIM system to automate project verification related to standards of safety and firefighting system requirements. 3D parametric modelling together with BIM concepts transforms the application into a tool capable of simulating results of a personal inspection from SCIP verification..

The BIM system developed was named BIMSCIP, which was structured to make an automated code-checking to verify the fulfillment of the standards of safety and firefighting from Military Fire Brigade of the State of Minas Gerais. The particular object of this present work is to implement and presents the operation of automated application from the 9th Technical Instruction – Fire Load at Buildings and Hazardous Areas.

Correlated Work

Previous works show contributions of automated code-checking field, applied to the verification of standards and regulation of safety and firefighting requirements by using a BIM platform. Those initiatives have been used at engineering with the purpose to avoid manual failures and slowness in procedures. According to Ethymios (1995) [9], the process to code verification requires deep knowledge of the regulations, awareness of continuous changes at current law, good comprehension of design process and capable programming people. Due to its complexity, the use of code-checking in engineering projects is a challenging area and a real opportunity to apply artificial intelligence techniques [10].

Ethymios (1995) [9] presented a prototype program to analyze Standard Fire Safety Requirements for hospitals, that does not introduce resources to explore graphic models, what impedes that the system can have any interface communication with CAD platforms.

At Wang's (2014) [11] work the use of BIM software allowed the creation of a virtual environment that can be used for tests and previous analysis of buildings and interface communication. This study, despite of not using code checking concepts, reached the simulation of several models to be analyzed at Fire Safety Regulations using a BIM platform. Likeness, Cheng (2014)[12] adopts the same approach, yet to analyze energy consumption and sustainability level in edifications.

The innovation presented in this article, thus, pretends to associate the code-checking adoption to BIM concepts, through an application environment (plug-in) that allow management and automated analysis of all phases of life cycle of buildings. However this present work is specific to SCIP, a methodology of application development, it shows a general use from concepts and BIM platform to model information, permitting its administration to simulate virtually as construction and operation phases of a building. This standard shape of data and information generated through BIM technology ensure a secure integration of construction processes since the conception phase passing by projects, construction, operation and facilities management.

2. METHODOLOGY

The Military Fire Brigade Code there is composed by 38 Technicals Instructions regarding Safety and Firefighting Requirements. Those instructions are broadly extensive to a range of possible fire outbreaks situations and some standards are even quite specific for unusual instances. At BIMSCIP system, result of this work, it has been implemented 14 specific Technical Instructions of the mentioned regulation to automatize the verification of the code fullfillment. The implemented Instructions are: 1st TI, 3th TI, 4th TI, 5th TI, 6th TI, 7th TI, 8th TI, 9th TI, 13th TI, 14th TI, 15th TI, 16th TI, 17th TI and 18th TI..

This study purpose is limited by the development of the implementation in BIMSCIP of the 9th Technical Instruction – Building's and Hazardous Areas's Fire Load, which establishes characteristics values of Fire Load in buildings and hazardous areas, regarding specific use and occupation. The code of BIM application was programmed at C# language using Microsoft Visual Studio Ultimate© framework and it was implemented as a plug-in for Revit®.

The BIMSCIP system explores the potential of parametric 3D modelling and BIM concepts of Autodesk® Revit® platform, seizing natives entities or extending its functionalities, creating new entities and interface through API (Application Programming Interface) in which the application (plug-in) works fully integrated as part of its own platform.

3. RESEARCH AND DEVELOPMENT

For developing a robust BIM system it is necessary to first have a solid knowledge of BIM platform and its tools. It is equally important, in code-checking situation, to have a deep awareness of current law and codes as well as its changes over time, design process beyond qualification on software development, according to Ethymios (1995)[9]. This requirements permits standard terms to be translated into data representation that can be understood by computational systems [13]. At the specific case of 9th TI it was needed that the code could be able to transform, through modelling information, the area delimitation and principal uses bounds into the ideal Fire Load1 defined at 9th TI, and after be capable to calculate Specific Fire Load2.

Autodesk Revit® BIM platform was employed to develop BIMSCIP application allowing 3D parametric modelling of buildings through which the system can be adjusted to make identification and delimitation of areas as well as define the

1 Fire Load is defined by 9th Technical Instruction[14] as the sum of calorific energy possible to be liberated in complete combustion by inflammable materials at a particular area, including floor, wall, ceiling and partition coatings.
2 Specific Fire Load or Fire Load Density is defined by 9th Technical Instruction[14] as being the value of the result of a division between Fire Load and the complete area of the delimited sector, expressed in MegaJoule (MJ) per square meter (m²) or at equivalent dry wood kilograms.

main occupation of them. Therefore, it is permitted to the user to correlate those priority uses with standards and regulations of Safety and Firefighting requirements. To this presented case, the definition of Fire Load (9th TI), the system offers the interface shown in Fig. 1, through which the user can define building and Fire Load classification in accordance with fragmented areas type occupation. After, the calculation of Fire Load and Specific Fire Load is automatically done.

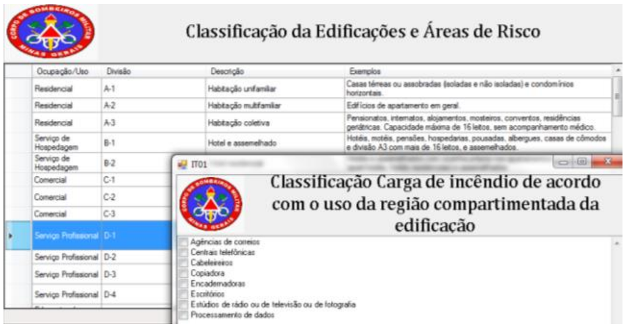

Figure. 1 – List with use/occupation types to be selected by user

Assuming that Fire Load calculation is essential to the verification of other implemented Technical Instructions in BIMSCIP, it was decided to considerate those definitions as one of the initial configuration. For this reason, this phase of verification was implemented as a part of 1st TI, which covers the configuration processes of automated verification of Standards and regulations of Safety and Firefighting Requirements, considering the importance of having both variables of Fire Load already calculated for subsequently stages of code-checking.

Fire load calculation

A building Fire Load can be determined in two manners. Through an indirect method, if the type of building occupation was specified at Appendix A of 9th IT [14] and the technical responsible of the fire and safety project understands as uniform the spatial distribution of the environment. In this case, the Fire Load density characteristic of the building will be the predetermined value by standards and regulations for this type of use and occupation.

The second way is a direct method based in the specific use of the fragmented area or section. This method is usually used if it is a dedicated facility to deposits, exhibition centers and non-listed occupations by Appendix A, but it's determinate by Appendix B from 9th TI [14] or when the technical responsible of the fire and safety project evaluates its convenience. To calculate Fire Load by this second method it is used this follow equation:

$$q_{inc} = \frac{\sum M_i H_i}{A_f} \quad (1)$$

Qinc is the value from Specific Fire Load expressed in MegaJoule per square meter of floor area (MJ/m²); Mi is the total mass of each i component of flammable material in kilograms (kg); Hi is the specific calorific potential of each i component of flammable material in MegaJoule per kilogram (MJ/kg); and Af is the total area from the section in square meter (m²).

User interface and operation tests

The initial interface (Fig. 2) from BIMSCIP consists in a definition of data configuration of the project to further verification and fulfillment of Technical Instructions requirements. This configuration interface of fragmented areas, to type occupation definition, appears highlighted to the user (Fig 2) as it is crucial for the desired verification (code-checking). The interface fos Fire Load determination is opened by pressing the button indicated by the yellow arrow in Fig. 2.

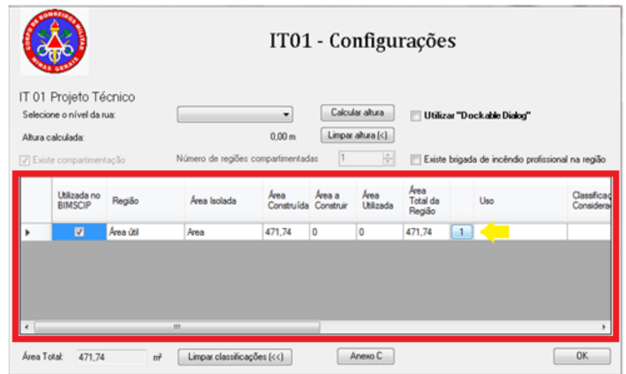

Figure. 2 – Initial interface of area configuration

Depending on type occupation of the given area, the program identifies which Fire Load method determination should be used. Fig. 3 shows the interface to type occupation areas, which presents a spatial uniform distribution, as it was established at initial interface in Fig. 1.

Figure. 3 – Selection and classificaton interface of Fire Load (1st Method)

Occupation areas from specific type requires a more detailed data survey providing, for example, sub-regions data and their stored products information. In Fig. 4 it is shown the interface to define those needed information for Fire Load determination by specific type occupation.

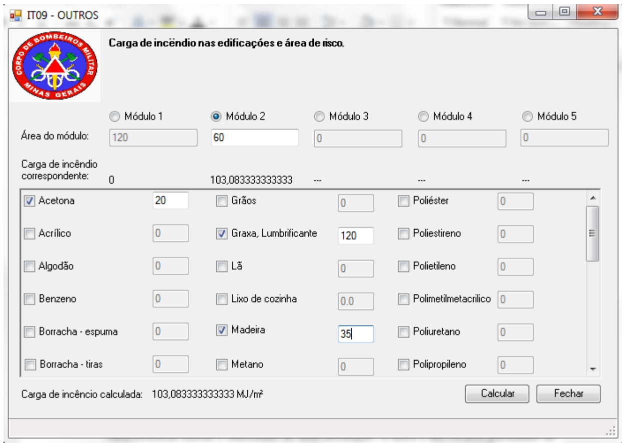

Figure. 4 – Selection of specific use type and classification Interface of Fire Load (2nd Method)

BIMSCIP system passes by continuous consistent tests to preserve and ensure its correct operation. The determination of Fire Load, for example, has to be validated by 9th TI determination, or by its Appendix A or Appendix B [14]. 3D projects that are modelled in BIM, of academic nature or existing projects, as an example of BIM modelling of 1st Block of Engineering School of Federal University of Minas Gerais (UFMG), served to test corroborated BIMSCIP consistence.

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With the purpose to validate the automatic results obtained by BIMSCIP system, it was made comparative tests of these results with the Fire Load values obtained by manual calculation from configured areas of BIM modelling and associated to several occupation types. This comparative result shown consistent Fire Load values among them and the requirements of 9th TI.

4. RESULTS

The general objectives of BIMSCIP system is to automate the verification of standards and regulations of Safety and Firefighting Requirements from the Military Fire Brigade of Minas Gerais, which consists of 38 Technical Instructions. To this present work will be shown the results of the implementation of 9th Technical Instruction referred at the Regulation, whose definitions, criterial and requests were transformed in an algorithm to allow its automated verification.

Verification tests and results consistence obtained validated the system to calculate Fire Load basing on the 9th TI, allowing those results to be used in further stages of standard automated verification, as an example from 6th TI (Structural Security of Buildings) implementation. For the determination from the Required Time of Fire Resistance (RTFR), one of the most important parameters at a fire outbreak situation, in accordance with criterias stipulated by 6th TI, it is necessary to have already determined the precise Fire Load value.

Similarly, the values determined for Fire Load to each fragmented area of the building, specified in accordance to the example in Fig. 5, will have a fundamental importance to the validation of Technical Instructions. Each area outlined by the user will have a unique inside treatment predicted in their use and occupation, what makes the result of the Fire Load calculation an essential parameter.

The variety of area types in a building is an intrinsic factor to construction projects and type occupation, given the diversity of buildings types and their purposes, what implies in different Fire Load values for each environment. In this way, the concepts of BIM technology permitted the partitioning of areas in a building as a simple project tool, also facilitating the modelling information in an intuitive and easy way for further manipulation and management as well as the operation of applications (plug-in) as BIMSCIP..

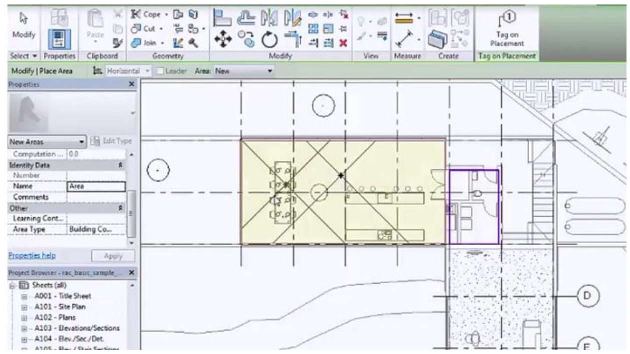

Figure. 5 – Area configuation for BIMSCIP analysis

5. CONCLUSIONS

BIM, or Building Information Modeling, it is a digital representation of physical and functional characteristics of a building.

BIM (Building Information Modelling) is a new paradigm in AECO industry, what allows a digital representation, in a unique 3D parametric model, from physical and functional characteristics of a building, a facility or an object modelling. The modeled information covers all AECO industry processes since conception through building life cycle (project, construction, administration, operation, maintenance, etc.). The complexity of buildings nowadays prevent compartmentalized actions and force optimization of interoperability in construction information modelling technologies into a tangled networks of involved projects. In regard to other industries (automobile, aerospace, petro chemistry , etc.), new technologies are being used [2] in civil construction, according to circumstances of unviability of manual checking processes[15]. BIM technology reunite the evolution of information technologies, with the techniques of construction processes automation and with the resources to information management in construction. In addition, BIM fulfill the requirements to enable integration among professionals to promote a collaborative work. This new paradigm allows reusing building information and conserves knowledge in ruling constructive processes through information management of a building life cycle.

3D parametric models resultants of BIM modelling generate project elements with determined properties, such as function, structure, uses and general information. Those characteristics establish those modeled information as highly appropriated functionalities for use in code-checking [4][15] and with great

potential to explore and use in automated verification of firefighting regulation [16].
This BIM potentiality is shown by 9th TI in which BIMSCIP access project area definition alongside to submitted data offered by the user to establish parameters (Fire Load and Specific Fire Load) essential to verification continuity. Drawing upon the utilization of tools and properties pre-existent at BIM software and extending its functionalities it was possible to ensure cleanly and relatively fast implementation of code-checking.

Although the usual obstacles that could have been encountered in programming, with OOP approach codes, once considered as complex and extensive, were enabled to be implemented. The methodology applied to 9th TI was able to accomplish a simple way to be succeeded at its verification and, as well, sharing information with the other Technical Instructions, suggesting the use of creation in BIM environment programs based on automated code-checking concepts.

6. REFERENCES

[1] MARTINS, João Poças; MONTEIRO, André. LicA: A BIM based automated code-checking application for water distribution systems. Automation in Construction: Elsevier. 29: 12-23 p. 2013.

[2] GORDON, V. R.; HOLNESS, P. E. Building information modeling: Future direction of the design and construction industry ASHRAE Journal: SCOPUS (Elsevier B.V). 48: 38-46 p. 2006.

[3] ZHANG, Sijie. et al. Building Information Modeling (BIM) and Safety: Automatic Safety Checking of Construction Models and Schedules. Journal Automation in Construction: Elsevier. 29: 183-195 p. 2013.

[4] WANG, Shih-Hsu. et al. Applying building information modeling to support fire safety management. Automation in Constrution: Elsevier. 59: 158-167 p. 2015.

[5] BRYDE, David; BROQUETAS, Martí; VOLM, Jürgen Marc. The project benefits of Building Information Modelling (BIM). Broquetas, M. International journal of project management. 31: 971-980 p. 2013.

[6] KRALING, Rebecca Krull; DUNBAR, Matthew. BIM and educational projects. Engineered Systems: GALE Cengage Learning. 28: 30-36 p. 2011.

[7] RÜPPEL, Uwe; SCHATZ, Kristian. Designing a BIM-based serious game for fire safety evacuation simulations. Advanced Engineering Informatics: Elsevier. 25: 600-611 p. 2011.

[8] ZHANG, Sijie; . et al. BIM-based fall hazard identification and prevention in construction safety planning. Safety Science: Elsevier. 72: 31-45 p. 2015.

[9] ETHYMIOS, A. Delis; DELIS, Alex. Automatic Fire-Code Checking Using Expert-System Technology. Journal of Computing in Civil Engineering. 9(2): 141-156 p. 1995.

[10] MARTINS, J.P. Poças; ABRANTES, V. Automated code-checking as a driver of BIM adoption. Journal for Housing Science. Vol. 34, No 4 pp 287-295. 2010.

[11] WANG, Bin. et al. BIM based virtual environment for fire emergency evacuation. The Scientific World Journal. vol 2014, Article ID 589016, 22 pages, 2014.

[12] CHENG, Jack C.P.; DAS, Moumita. A BIM-based web service framework for green building energy simulation and code checking. Journal of Information Technology in Construction (ITcon). 19: 150-168 p. 2014

[13] LUO, Hanbin; GONG, Peisong. A BIM-based Code Compliance Checking Process of Deep Foundation Construction Plans. Journal Intell Robot System: Springer Science + Business Media Dordrecht. 75. 549-576 p. 2015

[14] MINAS GERAIS (Estado). Instrução Técnica do Corpo de Bombeiros Militar de Minas Gerais - CBMMG. IT - 09 Cargas de Incêndio nas edificações e área de risco. Belo Horizonte [20--].

[15] CHOI, Jungsik; CHOI, Junho; KIM, Inhan. Development of BIM-based evacuation regulation checking system for high-rise and complex buildings. Automation in Construction: Web of Science. 46: 38-49 p. 2014.

[16] SHINO, Gregory K. BIM and fire protection engineering: by including all life safety systems in the BIM rendering, engineers improve the building's model as a whole. Consulting Specifying Engineer 50.3: 24-41 p. 2013