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SIGABIM: a framework for BIM application

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Abstract

Building Information Modeling tools are slowly but steadily becoming a recurring tool for architectural and engineering design. As contractors realize that BIM also provides benefits when adopted for the construction phase, the need for dynamic ways of exchanging information between different models, of different specialties, during different phases of the project, becomes increasingly important. The IFC format is usually pointed as the best solution for interoperability issues, however, it is not a one hundred per cent reliable platform for exchanging data between BIM models; it must me complimented with a dynamic, standardized, framework for BIM application that addresses interoperability and defines protocols for adequate information management within a BIM flow.

This article elaborates on the problematic of BIM frameworks, while also presenting key aspects and findings of the research project SIGABIM.

1 Introduction

Increasing productivity and efficiency in the Architecture, Engineering and Construction (AEC) sector is becoming a primary goal, and information management is one of the best ways to achieve that. One of the major reasons for the deficient information management seen in the AEC industry, when compared to other industries, is the lack of information technologies' (IT) adoption [1]. IT is currently present in the AEC life cycle but that does not mean it has been properly used. In fact, most IT usage is partial and isolated, with lack of dynamics between different systems.

Building Information Modeling (BIM) is a comprehensive system that has been slowly entering many practices in the AEC industry. BIM relies on a virtual 3D model of the building to manage much of the AEC life cycle information [2]. The primary application for BIM is both Architectural and Engineering design. Unlike traditional Computer Aided Design (CAD) tools, where the design is not more than a drawing of the building's schematics, BIM's object oriented parametric modeling consists of an assembly of the building elements, with each having its unique properties [3]. The BIM model is a dynamic platform, i.e. information is added dynamically to the model; the model automatically adapts to the inputs, and automatically generates information based on the building model's specifications. This is a very important evolution over traditional CAD tools' based methods that required the user to manually generate new documentation by drawing new schematics, assemble new lists of building elements or perform new calculations. Plus, BIM has also been reported to increase the overall quality of the design, improve visualization, communication, and optimize project coordination and project management.

Currently, the AEC sector is still dominated by CAD tools. BIM is either used as a stand-alone tool, or it is just not present in practitioners' frameworks [4]. Many authors point that in order to benefit from BIM's true potential it should be applied to the whole building life cycle, used as a continuously updated platform shared by the different specialties [3]. Such dynamic can only be possible if there is a way to adequately share information between each one's unique system. The Industry Foundation Classes (IFC) is an exchange format for building model data [5]. IFC provides a comprehensive data structure with definitions for the different AEC domains. It lacks definitions for some specific elements and properties, which can nonetheless be added in the form of property sets. The biggest issue is the lack of compatibility with proprietary format's exclusive features.

BIM awareness has been increasing and government agencies throughout the world are not indifferent to this trend. As such, they have been releasing methods and guidelines for BIM application in the hopes of stimulating its adoption and standardizing its usage. The importance of BIM standards will be developed further in this article.

In Portugal there is a lack of both BIM adoption and awareness. SIGABIM is a research project that results of an initiative between University of Oporto, Mota-Engil Engenharia and Arquifam, to answer these issues; in this research project, BIM tools are tested in a controlled environments and a framework for BIM application is developed in the form of BIM standards, application methods and best practice guidelines. Some of the results of the research are already available and are shared in this article.

2 Interoperability: a fundamental prerequisite

2.1 Overview

Before anything else BIM is a design tool; one that provides instant benefits to the user, which is something positive, however, it is also leading to a few misguided applications that may or may not result in additional work and unwanted and unnecessary conflicts in both the design and planning process. This happens, mostly, due to the lack of interoperability between different systems. Interoperability being the capability of exchanging information between systems, in a BIM context, can be seen as file format interoperability, semantic interoperability and feature interoperability. File format interoperability is becoming less of a problem as developers are including IFC specifications in their software more frequently. Currently, most BIM tools already include the IFC format and advertise it as being perfectly compatible with their proprietary specifications; semantic interoperability refers to the proper mapping of the IFC format by two different proprietary formats, i.e. the process of having an IFC entity be referenced by different entities with the same semantic meaning in the different formats exchanging information. This type of interoperability presents a bigger concern over the first one, however, a few BIM tools already include translator features that allow the user to manually map the IFC structure of their model to fit the desired organization. Feature interoperability, on the other hand, is the biggest concern. Since software developers want to get the upper hand, they tend to focus on proprietary features that can give them the edge over their competition. Proprietary features are impossible to exchange, even if they can be mapped using the IFC, as the receiving application will not be able to interpret that feature since it is not defined in its database.

Overall interoperability should be a major concern in every BIM framework as studies show that inadequate interoperability may lead to severe expenses [6].

2.2 Research findings

An extensive interoperability test has been made in the ambit of SIGABIM. The goal of the study was to analyze the dynamics of an IFC flow and test the influence of different parameters in the exchange process. The first major conclusion was the need to differentiate format interoperability and feature interoperability. The first was found to be a satisfying process as most BIM tools already include IFC specifications. The second on the other hand requires some work by software developers. Improvement is expected on this field once IFC becomes a fully, official, universal, ISO-approved standard for AEC data representation.

IFC was found to cover most representation needs, as most generic type classes are defined in the model. However, the model loses data with each export-import cycle. Even if the user is working with an IFC file, since any modification added to the model is made according to the proprietary specifications of the BIM tool, there will be loss of data when the file is saved back to IFC.

In general, the model was found to keep its geometry with each IFC exchange. This is because even when IFC does not recognize a specific element, it keeps its geometry and visual properties and saves the element in form of an IFC proxy. As mentioned before, the biggest concern is proprietary features. These include layer and ID, colors, axis location, connections between elements, etc., all properties whose semantic meaning is directly associated to the BIM tool of origin. These are the kind of features that are typically used in the definition of a BIM framework, which means, IFC cannot be successfully used at its fullest in a framework based on this kind of information management.

3 The importance of standards for BIM application

3.1 Level of detail

BIM has many possible applications. It can be used to generate layouts with building views, for quantity takeoff, to extract information for construction forecast and planning, to asses building performance, to simulate possible building solutions, to perform clash detection, etc. Each application requires different

specifications, whether in the amount of information added to the model, or in how the information is added to the model. Because some applications require less data input than others, it must be perfectly clear what and how the data can be extracted from the model for the specific use.
Developed by Vico Software, the Model Progression Specification [7] framework separates BIM applications and data input by five different Level of Detail (LOD). Going from 100 to 500, the LODs macro application vary between pre-design, schematic design, construction documentation, fabrication and assembly, and as-built.

Table 1: LOD specification [8].

LOD (Level of Detail)	Life-Cycle Step	Features
100	Planning	Conceptual design, volume analysis, spatial configuration, simple estimates.
200	Design	Schematic design, generic elements, approximate geometries.
300	Tendering	Traditional construction and shop drawings; accurate dimensions, capacities and connections between elements.
400	Fabrication and Assembly	Clash detection; assist construction managers.
500	Facilities Management	As-built specifications; as-built architecture, engineering and building service schematics.

3.2 BIM framework

A BIM framework is a set of proceedings based on a strategy to ensure that the BIM process runs smoothly, which means, controlling all aspects related to the BIM-based information flow. The aim is to develop an open and shared standard for BIM process, to define BIM modeling and analysis requirements, to facilitate a collaborative project environment between all parties, to use BIM as an information and communication tool, to execute coordinated project documents through parametric modeling and to enable the long term viability and usage of the BIM database through facilities management software [9].
The BIM framework should be done prior to beginning of the project and developed specifically for each one. The framework must take in account the building function, the ones involved in the project and construction development, and the tools at disposal. However, the framework's structure should be standard as it establishes the parameters that must be defined for each project. These include defining the LOD, the BIM coordinator, the software that should be used, IFC-translator specifications, milestones

and deliverables, the Model Component Author by phase, clash detection parameters, data exchange protocols, modeling tools, classification system, modeling tools, etc.

3.3 Notable standards

Government entities all around the world are beginning to realize the potential of BIM and the benefits that can be expected when BIM is used. The need for a framework for BIM application has also been identified as a fundamental prerequisite to guarantee optimal usage. Several documents with defined strategies for BIM application have been released by governmental entities in different countries.
In the USA, the USA - National BIM Standards [10] has been developed to "establish standard definitions for building information exchanges to support critical business contexts using standard semantics and ontologies". In Australia, the aim of the NATSPEC National BIM Guide [11] is "to assist clients, consultants and stakeholders to clarify their BIM requirements in a nationally consistent manner. This will reduce confusion and duplication of effort". In the UK, the UK - BS 1192:2007 [12] was published to "provide a standard and best-practice method for the development, organization and management of production information for construction industry". Other standards and guidelines enforced by governmental entities are also worth mentioning: the Senate Properties BIM Requirements [13] in Finland, The Norwegian Directorate of Public Construction and Property – Statsbygg [14], Digital Construction [15] in Denmark, and the VA BIM Guide [16], GSA National 3D-4D-BIM Program [17] and the U.S. Army Corps of Engineers [18], all in the United States.

4 SIGABIM: methodologies and research findings

The aim of the SIGABIM research project is to develop guidelines and standards for BIM application in Portugal with both Lean Construction [19] and Integrated Project Delivery (IPD) [20] methods. Similar previous international efforts were studied, by analyzing existing documents and accounting in the knowledge and experience gathered and shared by several research and industry partners.

4.1 Methodologies

BIM was applied since the first stages of the research project in a few pilots, to quickly identify potential positive and negative impacts that should be expected. Visualization and conflict detection are examples of the benefits that were immediately experienced.
The BIMstandard is a series of documents and proceedings destined to facilitate and control both the modeling and the information management process. The BIM application methodology clearly defines the hierarchy structure, so that each single participant knows exactly what he can and cannot do. The whole process is managed and supervised by the BIM leader, which is the only figure to have complete access to the model, i.e. not only he is the one who defines what should be modeled and how, he is the only one that can change parts of the model that were not developed by him. The BIMstandard has two major scopes: modeling definitions and communication management.
The first document created for modeling definitions was the Workflow Chart, containing the mapping of all the activities, with the relations between modeling teams, external consultant teams and others. The second document, the Timeline, defines the estimated time needed for the modeling process, the model

checking and the data gathering processes. Productivity varies with the objectives for the model and the available resources. The third document, the LOD table, was an adaptation of existing documents to Mota-Engil's internal classification system and available resources, i.e. the LOD was also adjusted to take in account whether the time required to model the project is feasible or not.

For each project a Virtual Warehouse was created, which is a table that contains all the elements needed for the modeling process. The Virtual Warehouse is a library of objects with the desired properties, defined by the BIM leader, and arranged according to the classification system in effect. This greatly decreases the possibility of future information exchange errors in and speeds up the information extraction process. All of the Warehouse's objects are described in the Content Plan. The description includes layer codes, IDs, colors, type of modeling feature and modeling instructions.

The BIMstandard's modeling specifications are systematized in the form of Best-Practice Guidelines. These are arranged in a series of sheets that work as an instructions manual, designed for the following areas of development: project analysis, entry records, file management, attribute management, modeling, request for information, constructability and quality assurance. The Guidelines are systematically updated as more experience is gained with each project.

The BIMstandard also defines the communication management process. The Internal Request for Information (RFI) is done in a formal and organized way and be-comes available to all the modelers, to avoid repeating the same questions and mistakes. The Quality Assurance Report (QA) identifies corrections to be performed or situations that must optimized and is continuously updated to keep a track record of all the changes made to the model. Whenever an error, omission or clash is detected in the design model, it is identified directly in the model by placing a Constructability Issue Object (CIO) next to the conflict. The CIOs were developed to represent different degrees of severity according to the conflict's impact in the construction process, and are assembled in the Constructability Report, which is then delivered to the de-signers.

4.2 Research findings

Research findings confirm BIM's potential benefits, in terms of visualization, coordination and clash detection. One of the greatest improvements is also in communication, as it becomes considerably easier to exchange information with the worksite and update the design model. Quantity takeoff using BIM has been found to be reliable, as the differences in results obtained through traditional, manual process were considered very small. Construction planning has also been the subject of study in the project, and the LOB's potential benefits in production control and risk assessment, con-firmed as well.

Research performed during this project shows that formwork is BIM's weakest link regarding automated quantity takeoff. It was not possible to use the model to extract complete quantities. To do so, the formwork must be added to the building model manually, which duplicates the time required to model, which is not feasible in most cases.

The IFC is also a concern when it comes to BIM workflows. A comprehensive interoperability test has been made, and results show that, while the IFC contains object definitions for most elements, it does not support continuous workflows, as a portion of the information is lost with each exchange.

Overall, results have been considered pleasing by the organizations involved in the research project. As BIM continues to be used in a more comprehensive way, in pro-jects with a larger scope, these organizations expect to experience more benefits. SIGABIM's outputs, in terms of methods that have been developed and knowledge that has been gathered, are being shared with the Portuguese AEC community with an aim to establish a set of common practices and rules that should prove to be beneficial to all parties.

5 Conclusions

A framework for BIM application is an essential requirement for adequate BIM application as it is absolutely vital to ensure a proper and interoperable mechanism to exchange and manage information within a BIM-based environment. Governmental entities play a decisive role on this subject by releasing BIM standards that fit local specifications; developing these standards should be a joint effort between all the interested practitioners, and application for public contracts made mandatory.

Following these trends, the SIGABIM research project is a pioneer initiative regarding BIM application in Portugal. Research findings and methodologies are gradually being released to the Portuguese AEC community as they are tested. The foundations for a continuous and collaborative effort among AEC practitioners are being created, so that BIM-process development effort in Portugal continues after the conclusion of the research project.

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