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BIM OPEN SOURCE SOFTWARE (OSS) FOR THE DOCUMENTATION OF CULTURAL HERITAGE

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Abstract:

The Building Information Modelling (BIM) software enables the users to communicate and design, understand appearance, performance and cost in the spatial and urban design process. Another important use of the BIM technology is the documentation and 3D reconstruction of cultural heritage monuments. The appropriate BIM software equips the users with tools to easily capture and analyse concepts and maintain the coordination of design data through documentation and 3D modelling. Many developments come up in the BIM field and software industry for design, construction-reconstruction, restoration and management of the cultural heritage 3D models, using BIM tools; mainly commercial as well as free or open source. Nevertheless, recently the growing popularity of open source has altered the landscape in software industry, as they attract many users.

This paper presents a review of some recent research on the topic. We review the recent developments focusing on the Open Source Software (OSS) that can be used at various stages of BIM process in the digital documentation of cultural heritage. The results show that there is more preference in the commercial software due to the fact that the OSS is not yet complete and covers all stages of the BIM process. However, lately we have the Edificius software in architectural BIM design and BIM Vision as Industry Foundation Classes (IFC) model viewer that try to attract as many users as possible. These tools are free and they could well be used for the digital reconstruction of cultural heritage.

Key words: BIM, cultural heritage, digital documentation, open source software, free software, 3D modelling

1. Introduction

Over the last few years, in Architecture, Engineering and Construction (AEC) industries, an increased use of specific software that processes building information models for visualisation of construction projects is observed. These are BIM tools and, nowadays, make it possible to preserve cultural heritage.

Using modern modelling tools, such as ArchiCAD, Revit Architecture, Allplan Architecture, etc., the models produced by the users have evolved from traditional 2D drawings and written specifications to parametric object oriented 3D models, embedded with information to describe any historical structure in detail (Singh, Gu, & Wang, 2011).

As a digital visualisation of the functional and physical characteristics of the structure, BIM serves as source of information supporting many applications along the processes of visualisation or reconstruction, including structural analysis, cost estimation and specification management. In addition, BIM concept fosters the use of real time visualisations as a tool to communicate concepts and sharing information between stakeholders in a cultural heritage project (Eastman, Teicholz, Sacks, & Liston, 2008).

Nowadays, software developers have created many BIM tools dealing with various categories of historical structures information, such as the representation of cultural heritage. Mainly, these tools are quite expensive and inaccessible. This reason led the users to face major challenges; to choose what tools they can use, in which construction/restoration activity and how to use them effectively.

However, there are many BIM model viewers available that show interactive presentations and design reviews of the cultural heritage model. During the visualisation process, the interactive 3D model becomes a common reference frame supporting a shared understanding across the collaborators team, thus creating a single source of data (Johansson, Roupé, & Bosch-Sijtsema, 2015).

This paper explains the BIM software that is used for collecting, processing data, parametric modelling, and evaluating the historical model across the process to finalise a cultural heritage project (Fig. 1).

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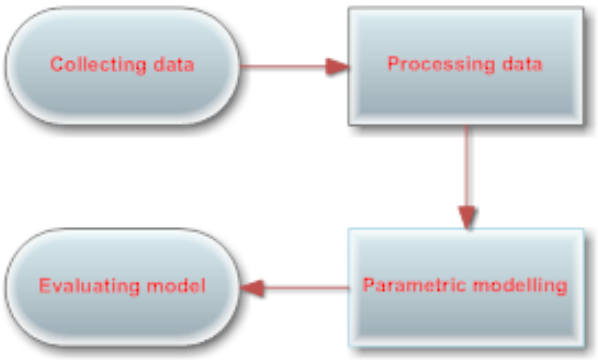

Figure 1: Stages on completion of a cultural heritage model in a BIM environment.

We emphasise on few free and OSS that are more affordable and customisable to the real needs of the end-users.

2. BIM software groups for cultural heritage

The widespread use of Computer Aided Design (CAD) systems, the increased needs for cultural heritage objects representation and the level of automation for reconstruction processes, provide new methods for the design and interoperability of the 3D CAD data. The needs for an integrated representation of various information types for understanding and managing an object, the smart connection of these components with the timetable and information related to the costs, led professionals to use BIM systems (Saygi, Agugiaro, Hamamcıoğlu-Turan, & Remondino, 2013).

BIM can be considered as an advanced CAD approach, which extends the capability of the traditional design methodology by applying and defining intelligent relationships between the elements in the designed model. BIM models include both geometric and non-geometric data such as object specifications and attributes. The creation of these models enables the various project participants (designers, architects, conservators, engineers, etc.) to visualise both the activities and the progress. This project management technique with BIM tools has the potential to improve management and delivery of the digital documentation, concerning any size or complexity of a cultural heritage object (Singh et al., 2011).

In the case of cultural heritage documentation, the objects consist of components and materials whose geometry and characteristics are not represented by libraries of typical software and thus there is a need to introduce the Historic BIM (HBIM) approach (Logothetis, Delinasiou & Stylianidis, 2015). HBIM is the process by which the architectural elements collected using a terrestrial laser scanner and produced photogrammetric survey data are converted into parametric objects (Dore & Murphy, 2012; Nieto, Moyano, Delgado, & García, 2016).

The BIM tools are distinguished into 3 basic categories depending on the licence that is a legal instrument governing the software use. The tools categorised into commercial, and free and open source software (FOSS).

Moreover, depending on the software use and purpose, these can be categorised into 3 types:

- Visualisation software (authoring tools and viewers).
- Tools for file sharing - collaboration (BIM servers).
- Analysis tools.

2.1. BIM visualisation software: BIM authoring tools and BIM viewers

This category concerns all the tools which enable the users to provide a 3D virtual representation of the cultural heritage objects. These tools can provide renderings, walkthroughs, and sequencing of the model for better understanding of what the final structure may look like. The software is divided into BIM authoring tools and BIM viewers.

BIM authoring tools are specific softwares that allow users to produce structural models that consist of parametric objects for creating the actual model. They also include all the tools that are used during the design phase until the documentation phase (Eastman et al., 2008).

On the other hand, BIM viewers are softwares that can access data connected to the BIM structural model without the need to extract the entire model. The most common file used is IFC developed by buildingSMART (buildingSMART, 2016) in order to provide an interoperability solution between different software applications. The format establishes an international standard to export and import objects and their properties (Eastman et al., 2008).

2.2. File sharing & collaboration tools: BIM servers

As a collaboration platform, a BIM server manages, archives building data, and allows applications to export and import files from the database for checking, viewing, modifying and updating the data model. BIM servers allow the exchange of 3D model data between the various applications involved in a BIM project life cycle (Fig. 2), including analysis tools, design tools, Facility Management (FM) tools, Document Management Systems (DMS), etc. (Singh et al., 2011).

Figure 2: BIM project life cycle (Syncronia 2011).

In the case of BIM for digital documentation of cultural heritage, in the Fig. 2, the phase "Build" can be replaced with the term of 3D reconstruction or documentation. Therefore, it is not necessary to use specific BIM software during this phase of the above lifecycle.

2.3. BIM analysis tools

BIM analysis tools are softwares used for modelling behaviour analysis and also for modelling validation to be compliant with specific standards. Normally, these tools are used in the preliminary design phase until the construction phase or the final 3D reconstruction (Quattrini & Baleani, 2015). BIM analysis tools provide easy access to the 3D model, measure project performance, conserve energy, etc. Priority is also given to the investments as well as the evaluation of proposals so as to reduce the operating costs, which are rarely used when there is only interest in cultural heritage documentation. These tools are useful when a partial repair or reconstruction of a historic monument is needed (Autodesk White Paper, 2010).

3. OSS and free software solutions for cultural heritage

OSS means that the source code, i.e. any group of computer instructions written using a human-readable computer language, is freely accessible by everyone interested in. The software can be freely used, improved, changed, copied and distributed by anyone and for any purpose (Statskontoret, 2003).

Free software is a term coined by a programmer in MIT Artificial Intelligence Lab, namely Richard Matthew Stallman. According to Stallman, free software means the freedom that can get everyone to use the software. Without any permission required, the software can be freely used, modified and redistributed (Ambar, Debashish, & Sitanath, 2010).

OSS and free software do not have to be absolutely free of charge. Besides being able to build business models around the commercial software, a company can receive payment using a large number of licensing models and schemes. These models can also be included in the definition of what we mean by OSS and free software. However, the most important here, is the fact that the source code is available to the user (Statskontoret, 2003).

Software should satisfy the following criteria in order to be called as free or OSS. These features have been introduced by Richard Stallman creator of GNU General Public License (GPL) (Kuhn, 2001):

1. The freedom to execute the program for any purpose.
2. The freedom to research how the program works and can adapt to the users' needs.
3. The freedom to redistribute copies so you can help your fellow man/woman.
4. The freedom to improve the software and publish the improvements you have made to the general public so as to benefit the entire community.

In the field of cultural heritage documentation,3D BIM viewers FOSS are mainly used in most research papers.

San José et al. (2013) used CityGML, an open standard data model which is based on geometry, for representing 3D urban objects.

Saygi et al. (2013) used Trimble SketchUP for the creation of 3D models, BIMserver as a platform to handle IFC data and OpenBIM for attribute data enrichment, related to building elements, zones or complete buildings.

Zheliazkova, Naboni, & Paoletti, (2015) used Grasshopper 3D as a graphical algorithm editor integrated with Rhino's 3D modelling tool. Moreover, they used MeshLab as an open source system for the processing and editing of unstructured triangular meshes, which also deals with automatic 3D reconstruction. They also used AgiSoft Photoscan, which is commercial software for creating dense point data cloud from images.

3.1. Software groups

The BIM software is used by enterprises, government agencies and individuals, who can design, reconstruct, maintain and operate with cultural heritage objects. Thus, we have three different software groups:

- commercial
- open source software
- free software

The criteria of different BIM tools are identified to obtain knowledge about the benefits of using these tools. The primary criteria considered are of several applications, such as structures, architecture, mechanical, etc. Also the various tools used in the different departments; the different professionals involved such as architects, landscape architects, surveyors, engineers, designers and cost consultants. Key aspects of these tools are: interoperability, the association of BIM with different programs, the construction stages and the domain in which the softwares can be used. The final criterion is whether the BIM softwares are either free, open source or commercial.

With the above criteria set and the references from the UK, the National Building Specification (NBS, 2015) established the most widely used for BIM softwares. These are Microstation, Revit, AutoCAD, Bentley Building Suite, ArchiCAD, Vectorworks, Allplan, Trimble SketchUp (formerly Google Sketchup), Edificius and BIM Vision (Kurul, Abanda, Tah, & Cheung, 2013). The summary of the review of these tools are presented in Table 1.

3.2. Benefits of using FOSS

According to Peeling and Satchell (2001), open source and free software holds several fascinating advantages:

1. Cost: The first perceived advantage is the fact that FOSS is made available cost-free or at a low cost. Unlike most commercial packages that are expensive enough and inaccessible for many businesses.

Table 1: Comparison of the common BIM tools in the UK construction industry

Product Name	*Stage*	*Domain*	*Users*	*Links with other software*	*Interoperability*	*Open source*
Revit Architecture	Planning and Design	Architecture	Architects and drafters	AutoCAD, Google SketchUP, Excel, ODBC, Google Earth	IFC, gbXML, DWG	No
Revit Structure	Planning and Design Construction	Structure	Structural engineers	Ecotect, Green Building Studio	IFC, DWG	No
Revit MEP	Planning and Design	MEP	Mechanical, Electrical and Plumbing Engineers	Ecotect, Green Building Studio	IFC, DWG	No
ArchiCAD	Planning and Design Construction	Architecture	Architects	Revit	IFC	No
Allplan Architecture	Planning and Design	Architecture (3D design)	Architects and drafters	Google SketchUp, Google Earth, Microstation. 3ds-Max, AutoCAD	IFC, DWG,DXF, PDF	No
Allplan Engineering	Planning and Design Construction	Structures (3D design for structural design)	Structural engineers	Google SketchUp, Google Earth, Microstation. 3ds-Max, AutoCAD	IFC, DWG,DXF, PDF	No
Allplan Facility Management	Operations	Facility Management	Facility managers	Google SketchUp, Google Earth, Microstation. 3ds-Max, AutoCAD	IFC, DWG,DXF, PDF	No
MicroStation	Planning and Design Construction Operation	Architectural Design	Architects, engineers, contractors, planners, GIS professionals	AutoCAD, Google SketchUP, Revit, IES, Google Earth	DWG, DXF, PDF	No
Vectorworks	Planning and Design	Landscape design	Planners and Landscape Architects	Google Earth	DWG, DXF	No
Bentley suite	Planning and Design Construction	Architecture, Structures, MEP	Architects, MEP and Structural Engineers	SketchUp	DWG, gbXML, IFC, PDF	No
Trimble SketchUp	Planning and Design	Architectural design	Architects	Google Earth	DWG, DXF	Free for limited version, small fee for complete version
Edificius	Planning and Design	Architectural design	Architects	SketchUp	3DS, DWG, OBJ, DXF	Free UPP (Free Use Pay Print)
BIM Vision	Planning and Design	Architectural model viewer	Architects	BIMestiMate	IFC	Free – Open Source

2. Quality: Open source software is closer to the professional users' needs. The software manufacturers such as Graphisoft, Autodesk, etc., consider the user's needs and develop the appropriate software for them. A developer, who is also a BIM user, can create what he/she wants.
3. Customizability: The availability of the source code and the right to modify it is of high importance. In fact, it enables the unlimited software improvement or the addition of new abilities. At the same time, it is innovative since open source programs are the products of collaboration among a large number of different developers. Also, knowing how it works the BIM system is possible to add new functions according to the existing needs.
4. Freedom: With FOSS, the users make their own decisions and do what they want with the software, to suit their individual needs. Potentially, they can make the enhancements available as a public good. They also have a worldwide community of developers and users at their disposal for help.

3.3. Limitations in working with FOSS

In the last few years, the development of FOSS for BIM has expanded and the use of FOSS tends to be consolidated due to their advantages and the freedom that provide. However, it is possible to present some limitations when someone chooses to use this software category in some cases such as:

1. They are often intractable; because less attention is paid to the development of user interface and as a result they become less user-friendly.
2. Sometimes, there is data incompatibility.
3. It requires programming skills and expertise for the customisation of the application.
4. There may be also less support available and there is also no user manual.
5. Although the OSS is mostly free, there may still be some indirect costs involved, such as paying for an extra feature.
6. Small companies may not have software skills or resources to work with a few of the more complex OS used by BIM softwares or toolkits.

4. Free software

Free BIM software is a computer software that gives the users the freedom to run the software for any purpose. In the category of free BIM software we have the Free Use Pay Print (UPP) software (ACCA, 2015). Free UPP is a professional architectural, engineering and bill of quantities/estimating software with no expiry date. The user can use for free the full featured version for architectural BIM design and must pay only when there is a need for printing. Edificius (ACCA, 2015) is BIM software that belongs to this category as well and can be used in cultural heritage documentation projects.

4.1. Analysis of Edificius software

Edificius is an advanced design tool for BIM and 3D architectural design. In practice, an Edificius user can obtain different functionalities: elevation views, section views, floor plan views, tables, reports, construction details, schedules, perspective views, isometric views, renderings, animations and photo inserts. The software allows the use with custom working drawing layouts and import - export in standard formats such as DXF/DWG for CAD drawings, OBJ/3DS for 3D models, BMP/JPG for renders. Projects and professional collaborations are possible to be shared with every user; all data is stored in a single file that anyone can open and work with the Edificius Free UPP.

Edificius (Fig. 3) increases the BIM potential by integrating the features of other softwares:

- SketchUp (SketchUp, 2016) for solid modelling.
- EdiLus (ACCA, 2015) for structural calculations.
- PriMus (ACCA, 2015) for bills of quantities.
- Edificius-CAD for DWG - CAD drawings (i.e. construction details) (ACCA, 2015).

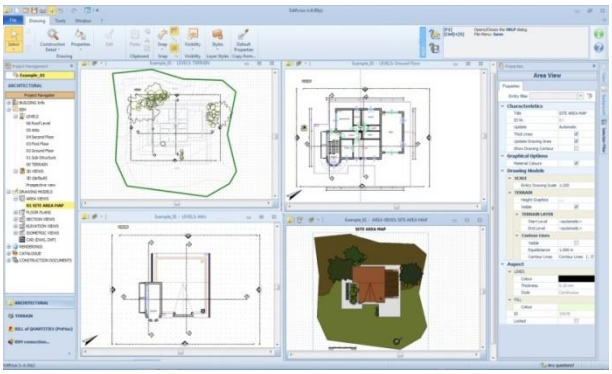

Figure 3: Edificius interface (ACCA, 2015).

Edificius, with a 2D/3D input of specific customisable objects such as walls, windows, slabs, etc. creates the model and automatically generates all needed construction documents useful for project completion. Any changes made to the model has an effect in all related construction documents which are updated automatically, even for the drawing models that were already laid out and ready for printing. The Edificius BIM technology offers a complete project management, reducing mistakes and increasing productivity (ACCA, 2015).

4.2. Edificius features

ACCA software has launched Edificius 6 only for Microsoft Windows operating system. By using Edificius, the users have the ability to create 2D & 3D models with a variety of modelling and design features. The main functionalities offered by this specific software are: simulation, analysis, animations & rendering, cost estimation, documentation and architectural design. Edificius is multi-lingual and supports different languages such as English, French, Portuguese and Spanish, while at the same time the software supports different formats: EDF, STL, DWG, DXF, DAE, PLY, IFC, SKP and OBJ (ACCA, 2015).

5. OSS selection and future development

The OSS that we selected for future development is an IFC model viewer, the BIM Vision from Datacomp (BIM Vision, 2011). It can be used for providing documentation of cultural heritage projects. BIM Vision is a freeware IFC model viewer that allows users to view the virtual models coming from BIM systems like Archicad, Revit, VectorWorks, Tekla, Bentley, etc. without having commercial licenses of these systems (Kogut, 2015). The main reason BIM Vision was chosen for further development, is the ability to create plug-ins that allows extension to the existing functionalities and integration with other applications. In addition, there is an application programming interface (API) that allows users to create plug-ins for BIM (BIM Vision, 2011):

- functionalities extension
- cooperation with other applications
- gathering additional data that comes with OpenBIM IFC file standard

- creating a new visualisation tool for additional data extraction from cultural heritage objects and for any other needs

In computer programming, an API is a set of protocols, routines and tools for building software applications. The programming languages that could be used to create plug-ins are C++, C# and Python (Ko, 2010).

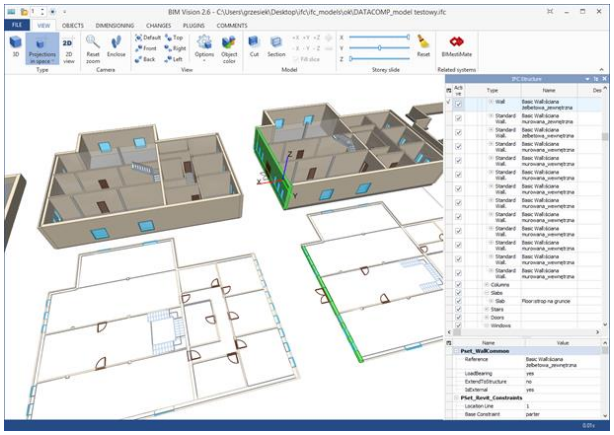

Figure 4: BIM Vision software interface (BIM Vision, 2011).

The main features of BIM Vision (Fig. 4) are presented in Table 2 and briefly below (BIM Vision, 2011):

- model views using the structure of the design, element types and layers;
- different colouring of elements depending on type;
- setting of transparency level, cutting and cross-section options;
- 2D and 3D object presentations and projection views;
- viewing properties assigned to the element in the IFC file;
- on-screen digital take-off of the volume, area, distance and length;
- models comparison showing the changes in geometry and element properties;
- support for touch screen, multi touch and tablet mode option;
- application interface for developing new plug-ins;
- reads IFC files and exports calculated amounts of works directly to the costing program BIMestiMate (data exchange with the cost estimation software).

Some of the future investments in the software BIM Vision could be:

- adding support for extra file types e.g. Trimble SketchUp (.SKP) models;
- exporting individual cultural heritage data files such as walls, floors, roof, layers, volumes, areas, etc.;
- running conflict checks of the different project's parts.

Table 2: BIM Vision features (BIM Vision, 2011)

Model view	2D, 3D projections in space
Language	Polish, English, Spanish
File format	IFC
Transparency	solid, partial + full transparency
Viewing options	cross-section, hiding elements, cutting, storey slide in X,Y,Z surface, selecting objects
Element list display form	IFC structure, types of elements, model zones, model layers
Mode of taking dimensions	volume, area, edges, line length by selected vertices, various distance measurements modes, weight of elements
Measuring method	single element quantity, multiple selection of chosen elements, automatic quantity by groups of elements
Advanced options	comparing models (old &new IFC files), finding elements, filter elements, adding comments
Export/import	fully integrated with BIMestiMate andDDS-CAD (system for electro and HVAC design)

6. Conclusions and discussion

This paper presents a review of the BIM FOSS used for the documentation of cultural heritage. This study is not intended to provide a comparison of the different applications used in different stages at a HBIM process. The goal of this study is to identify and encourage the users to use FOSS for HBIM processes. Although the reported BIM software list (Table 1) is not exhaustive, an attempt was made to cover the key areas, mainly with open source solutions.

The complexity and diversity of HBIM technology is obvious in many fields and for this reason there are many specific software, mainly commercial that offers several possibilities to their users. However, in the field of open source there are no integrated platforms to cover all stages of HBIM process. The survey showed that the users prefer commercial software BIM instead of FOSS because there is not a valuable and comprehensive program that can be used for the overall cultural heritage documentation project. They use only a few BIM Viewers to visualise the final produced historical 3D model.

However, it is available one free BIM complete platform and there are some open source BIM viewers. We reported on two platforms: Edificius and BIM Vision, and we focus on the second that provides all the necessary tools to create plug-ins to expand its capabilities. This is our plan for the next research phase; to build upon this existing platform using Python programming language to create specialised plug-ins.

Moreover, we discussed the benefits of using FOSS in comparison with commercial software. Nevertheless, there is a question; can we believe the information provided on the websites about the features and functionalities of the software from their manufacturers? For open source BIM software systems is easy for users to verify, by simply downloading and testing the application. For commercial software, despite the

availability of trial versions exist, is a huge challenge as most trial versions usually have limited scope.

In the recent years, many technological advances have taken place in the field of HBIM software. However, in the field of OSS, there could be more growth in order to reduce the prices of expensive commercial solutions. Further, given the important function of plug-ins in different areas of the BIM software, it is important to create more, which could be freely available to a large community of professional designers, architects, engineers and conservators for their utilisation.

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