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Structural sustainability appraisal in BIM

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ABSTRACT

The provision of Application Programming Interface (API) in BIM-enable tools can contribute to facilitating BIM-related research. APIs are useful links for running plug-ins and external programmes but they are yet to be fully exploited in expanding the BIM scope. The modelling of n-Dimensional (nD) building performance measures can potentially benefit from BIM extension through API implementations. Sustainability is one such measure associated with buildings. For the structural engineer, recent design criteria have put great emphasis on the sustainability credentials as part of the traditional criteria of structural integrity, constructability and cost. This paper examines the utilization of API in BIM extension and presents a demonstration of an API application to embed sustainability issues into the appraisal process of structural conceptual design options in BIM. It concludes that API implementations are useful in expanding the BIM scope. Also, the approach including process modelling, algorithms and object-based instantiations demonstrated in the API implementation can be applicable to other nD building performance measures as may be relevant to the various professional platforms in the construction domain.

1. Introduction

Information modelling, design and management systems such as BIM are vital to the operation of Architecture, Engineering and Construction (AEC) industry. BIM is forecast as the next generation of Information Technology (IT) to replace drawing production-focused Computer Aided Drafting (CAD) and involves the processes of generating, storing, managing, exchanging and sharing of building information in an interoperable and reusable way [1]. Though BIM is still maturing and not yet fully defined in scope [2], its benefits in project implementation and information management are envisaged to be significant. As a digitized representation of the building artefact, BIM has the tendencies for continuous expansion to closely mimic the vast amount of information embedded in a typical building project. Such information, referred to as n-Dimensional (nD), include time, cost, accessibility, sustainability, maintainability, acoustic, crime, thermal requirements, health and safety etc. [3,4]. Modelling nD aspects such as sustainability require issue-specific approach and involve the extension of the building information model to incorporate the various building life cycle design information which are vast and cut across the various building professional platforms. The term extension in the context of this paper refers to new software systems that add additional functionality to BIM-enable tools through external applications relying on facilities such as Application Programming Interface (API). As such, the literature review of this paper discussed the investigation of API implementations in embedding applications in BIM-enabled environments as it is an essential part of the preliminary phase of this research. The review of algorithms and aspects on feature based modelling and information modelling have been covered elsewhere [5].

The existence of already operational proprietary BIM platforms presents a starting point for researchers to explore the possibilities of expanding the BIM scope to account for nD issues such as sustainability [6] and safety [7]; and customisation by other users. One of the software development kits available to use is API implementations. It can be adapted to different computer operating systems and has the benefit of allowing compiled codes to function without effecting any change to the system and the underlying codes that implements the API. Software vendors of BIM-enabled tools therefore have the benefit of making their products available for researchers and other users to develop prototypes to run as plug-ins. Such software platforms will serve as test-bed for Rapid Application Development (RAD) prototyping which can lead to the rapid increase in contributions to BIM expansion. However, research works taking advantage such facility in BIM implementation is yet to be fully explored. Taking advantage of API facility, the aim of this research is to investigate how the use of BIM technology can influence conceptual design decisions based on the life cycle information and the sustainability of alternative design solutions. This is targeted at quantifying the sustainability of design solutions to inform conceptual design decisions, as an integral part of BIM. This paper therefore examines the usefulness of API implementations and brings

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out how it can be used to tackle scope issues in BIM adoption. It presents an example of an API implementation on using BIM to assess the sustainability measures of conceptual structural design options. The authors argue that it illustrates how process and data modelling techniques can be used to map and model sustainability related information to inform the structural engineer's building design decisions at an early stage.

The review of literature has been carried out to establish research challenges and study aspects relating to the API implementations and BIM-enabled systems in the construction domain. It also helped in identifying and adopting information modelling approaches such as the RAD approach [8] used in implementing a prototype based on a structural sustainability assessment framework. The RAD methodology employs cycles of re-specify, re-design and re-evaluate on the prototype system from its conception to when it achieves a high degree of fidelity and completeness. The prototyping process is therefore characterized by increased speed of development and experiences of series of births rather than deadlines. The implementation of the prototype involved the utilization of information modelling representations — in the form of a process model, implementation algorithms and object-based instantiations to capture sustainability related information to inform decisions at the early stages of the structural design process. The implementation took advantage of .NET Frameworks to explore existing links of interfacing of a BIM-enabled tool such as Revit Building Design Suit with programmes created in object oriented C# programming language. This work has been carried on commercial BIM software due to its readiness in terms of required interface and availability. This is done in order to focus efforts on proving the feasibility of the API, which can later be translated to other BIM environments (such as open source BIM).

This paper features six sections. The Introduction (Section 1) is followed by the Literature review as Section 2 which discusses the investigation into BIM-related API applications and highlights the challenges with modelling sustainability decision support in BIM. Section 3 presents the conceptual sustainability modelling framework detailing its implementation process. An illustration of how the resulting prototype works is presented in Section 4. Section 5 discussed the relevance of the prototype and its limitations before concluding in Section 6.

2. Literature review

This review provides an overview of API implementation, the use of API implementation to accomplish BIM extension and discusses the challenges with modelling sustainability decision support systems in BIM. API implementation in a BIM-enabled environment makes an essential part of this research and has been used as a vital tool in demonstrating the proposed research concept.

2.1. API implementation overview

API applications are not new in ICT related research. However, novel contributions can still be made in introducing suitable methodologies to accomplish new or upcoming research tasks. API generally specifies how different software components interact with each other which may involve access to database, hard drive, disc drive, video card etc. It is based on programming source codes (high-level interface) and includes a combination of specifications for programming language routines, data structures, classes and variables. This makes it different from Application Binary Interface (ABI) which is a low-level interface between computer programmes and operating systems. API has been found to be useful in various areas of software implementation. API specifications help to accomplish the presentation of functions and subroutines in human readable formats in procedural languages such as UNIX systems and Perl. In object oriented languages such as C#, API helps to specify the interactions/handle by which objects, including their behaviours, are derived from their class definitions. The usefulness of API is also significant in the area of web development. The use of open architecture in web programming to dynamically share contents and data between communities and applications is actually an application of API technology. It is also possible to combine information from different web APIs to create a hybrid of new graphical interface, called mashups, with better visualization and aggregation [9]. Lack of standardized APIs is identified as one of the major challenges of the current evolution of the internet service delivery of cloud computing [10] which is currently being explored in distributed synchronous and asynchronous exchange/management of BIM data [11,12]. Cloud computing targets the provision of reliable and scalable on-demand computing services at distributed environments but there is yet to be a generally acceptable design guideline to tailor the APIs and usage model of providers. As such, the standardizing of APIs for commercial software applications is perhaps an area worth considering in the construction industry.

API may be released with the option of total control by its owner or making it freely available to the public. With total control, information can be protected from the general public and owners can moderate and monitor those who use the API. Major computer game vendors used this option to obtain licensing revenue from clients. On the other hand, open API is public and allows software to be written to such platforms. Microsoft windows API and Revit API are good examples in this category. It is documented that API cannot be copyrighted in the USA as it will mean that anyone could copyright one version of code to carry out a system of commands and prevent all others from creating their own different versions to perform all or part of the same commands [13].

There are many types of API implementations. Conventional API types include DirectX and ODBC for Microsoft Windows, OpenGL cross-platform Graphic, OpenMP for shared memory processing, OpenAL cross platform-sound etc. Among the varied implementations of API, the work by Buck and Hollingsworth [14] on runtime code patching (Dyninst API) is of interest. It is a post-compile programme manipulation tool with C++ class library for programme instrumentation. Variety of applications including debugging, performance monitoring and support for the compositions of existing packages can all benefit from using API to effect runtime code changes. This generally entails insertion of code into a running programme without the need to recompile, re-link, or restart. When the new block of code modified by the inserted code is executed by the programme, it will do so in addition to the original code thereby effecting corresponding changes into the programme. The Dyninst API can either be used to augment existing programmes or alter the semantics relating to subroutines and data structures at runtime. This will particularly be useful for researchers wishing to use existing BIM-enable platforms with similar API code patching capabilities as test-beds for prototyping purposes. Thus, API provides encapsulation mechanism for underlying information and serves as a means to modify underlying information schema and particular implementations without directly affecting third-party developers or end users of AEC systems [15].

API interfaces will invariably have limitations. The main limitation is the dependability of the plug-in on the software it is interfacing with. This includes the restrictions to particular software platform or operating system and the need to update the plug-in whenever the software is updated (due to issues of backward compatibility). Thus API implementation has the drawback that they have to be frequently updated to remain operational with new versions of software and new licenses.

2.2. BIM extensions using API implementation

BIM embodies much of the vision of previous academic research on data integration and management. This has been largely achieved through the reliance on data exchange standards or API level customisation for interoperability [16]. The import and export