Green2.0: Enabling Complex Interactions Between Buildings and People

Manos Papagelis
University of California, Berkeley, United States
papaggel@berkeley.edu

Theohar Konomi
University of Toronto, Canada
konomi.theohar@gmail.com

Thomas F. Krijnen
Technological University of Eindhoven, Netherlands
t.f.krijnen@tue.nl

Roy Fang
University of Toronto, Canada
royfang@hotmail.com

Mohamed Elshenawy
University of Toronto, Canada
mmelshenawy@gmail.com

Tamer El-Diraby
University of Toronto, Canada
tamer@ecf.utoronto.ca

CSCW '16 Companion, February 27–March 02, 2016, San Francisco, CA, USA

http://dx.doi.org/10.1145/2818052.2874330

Abstract
Professionals and researchers of the Architectural, Engineering & Construction (AEC) industry are challenged by the increasing complexity of designing, constructing and operating a building. This typically requires close cooperation of actors having different backgrounds and interests. Traditionally, this cooperation happens in an ad-hoc way and information exchange occurs through conventional general-purpose communication channels, such as paper or email. This communication and collaboration process can be inadequate and inefficient, as it makes room for many different interpretations, mistakes and errors and can eventually lead to schedule and cost alterations. We present *Green2.0*, a system that tries to leverage advancements in building information modeling to facilitate the collaboration process. The system integrates energy-efficiency simulation tools, and methods for online social network analysis to enable a data-driven approach to building design, construction and operation. By sharing all information online, all project actors can access relevant information when they need so that everyone can work efficient together. The system aims to advance the current state of the art by bringing about a fundamental shift in the way that AEC professionals work together throughout a building's lifecycle.

Author Keywords
BIM; Sustainability; Collaboration; City Science; Open Data

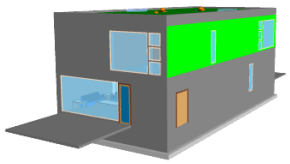

Figure 1: Example BIM.

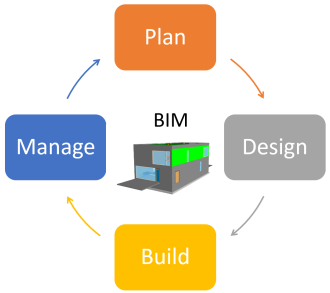

Figure 2: BIM throughout the life-cycle of a building.

ACM Classification Keywords

H.3.5 [Information Storage and Retrieval]: Online Information Services; H.5.3 [Group and Organization Interfaces]: Computer-supported cooperative work

Introduction

The building industry is divided into many specialized disciplines in order to design, construct and operate a building. These disciplines, with different backgrounds and interests, work together in ad-hoc formations for specific projects. Traditionally, in such processes, information is exchanged on paper or is shared through conventional general-purpose channels of information exchange, such as email. This way of communication and collaboration can be inadequate, as it makes room for many different interpretations, mistakes and errors and can lead to schedule and cost alterations. These factors complicate communication and urge for the exchange of structured semantic knowledge models [5].

A Building Information Model (BIM [2]) is a digital representation of physical and functional characteristics of a building project (Figure 1). Each object in a real building is represented by an equivalent digital object in a BIM. These objects are characterized by geometrical representations and semantic and relational metadata. BIMs can be exchanged or shared among all actors and stakeholders to support and facilitate collaborative behaviors and decision-making. Use of BIM goes beyond the planning and design phase of the project, extending throughout the building life-cycle (Figure 2). By sharing all information in one open format all project actors can access relevant information when they need so that everyone can work efficient together. BIM carries potential towards implementing more sustainable design construction and operation [6]. Consequently, standards and services are originating around BIM that enable a more collaborative context [7]. Furthermore, it is recognized that the

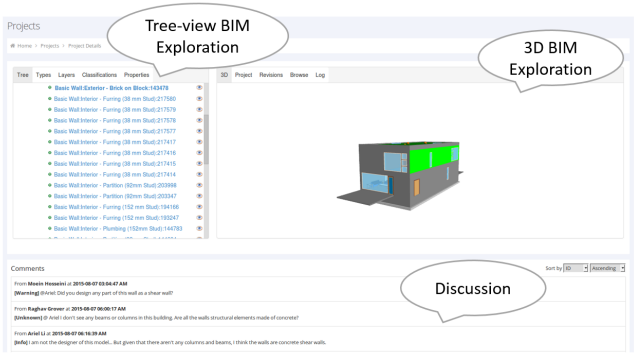

Figure 3: BIM exploration & interaction in *Green2.0*.

exposure of such systems on the web enables more detailed analysis of stakeholder interaction and the evaluation of design processes [4]. In particular the need for comprehensive web-based tools is recognized [8].

We present *Green2.0*, a system that tries to leverage recent advancements in building information models, energy-efficiency simulation tools, and social network analysis methods for enabling online socio-technical analysis of buildings in *an integrated environment* [3]. In the next sections we provide an overview of the system features and a brief overview of the system design and architecture.

System Overview

Green2.0 brings together recent developments in order to advance multi-disciplinary collaboration, socio-technical analysis, comprehensive simulation and stakeholder participation in an integrated and comprehensive web-based environment towards the goal of sustainable building design. Central to the system is the notion of a BIM project that a project actor (user) can operate on. A user can either be the *owner* of a BIM project or can be an *invitee* - invited by an owner to join a project. As an *owner*, a user

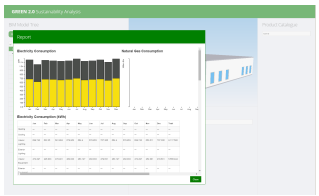

Figure 4: A sustainability report is generated on-demand for an updated BIM model.

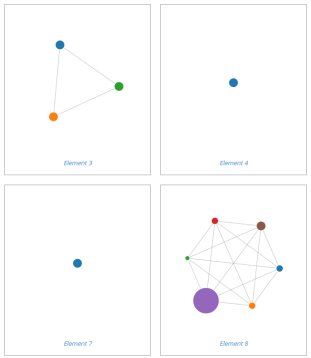

Figure 5: Visualization of trending discussions.

has unrestricted access to the projects she owns. The main functionality of the system is described below:

- Creating BIM projects. A BIM project is associated with an IFC file that the user needs to upload to the system from a local computer. Most BIM software provides an interface to export a BIM model to IFC.
- BIM Exploration. Once a BIM model is uploaded, a user can visualize it as a 3D model. The 3D model is interactive, allowing the user to zoom in/out, rotate the model in any direction, select specific BIM elements, and explore their properties (see Figure 3).
- Sharing BIM Projects and Collaboration. A user can share a project with other users and start collaborating by participating in discussions about BIM elements (see Figure 3). User feedback allows project owners to update the model in a timely manner and look for further feedback. The outcome of this iterative refinement process is increased coordination due to easy retrieval of information, speed of delivery and reduced costs, therefore improved overall productivity.
- On-demand Sustainability Analysis. A user can interact with the building by substituting specific BIM elements with alternatives that are available in an interactive inventory. She can also perform an on-demand energy analysis and obtain a detailed report of the energy efficiency of the building in relation to the alternative designs (see Figure 4).
- Monitoring Activity and Trends. A user can monitor the collaboration activity and participate as required. Trending discussions and useful network insights are visualized that can reveal interesting patterns of communication, therefore enhancing monitoring capabilities and better supporting decision making (see Figure 5).

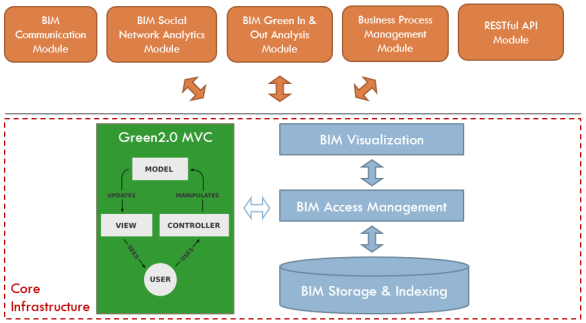

Figure 6: High-level Architecture.

System High-level Architecture

In this section we describe the high-level architecture of the *Green2.0* system. Figure 6 illustrates the three components of the architecture and how they relate to each other. We briefly describe these components in the next paragraphs.

Green2.0 MVC (Green)
The main part of the Green2.0 core infrastructure is a web service that is based on a *Model-View-Controller (MVC) web architecture*. This component is responsible for managing all user interactions and domain-specific functionality. It is also responsible for integrating the BIM open source technologies, and facilitating the communication with the various independent modules of the system.

Green2.0 BIM Management (Blue)
The most critical functionality of the *Green2.0* system's core infrastructure is the efficient management and visualization of BIM models. Towards this end, *Green2.0* relies on a number of tightly-knit open source BIM technologies:

- BIM Storage & Indexing (*BIMServer*): The BIMServer [1] enables to centralize the information of a building design project. The core of the software is based on

the IFC (Industry Foundation Classes[1]) open standard. The BIMServer uses a model-driven architecture approach that allows to query, merge and filter the BIM-model and generate IFC files on the fly.

- BIM Access Management (*Service Interfaces*): The Service Interfaces is a set of defined interfaces for interaction with BIMserver. *Green2.0* uses a JavaScript Object Notation (JSON) interface to connect to the BIMserver and access the various interface methods.
- BIM Visualization (*BIMSurfer*): BIMSurfer[2] is an open source web-based viewer for the visualization of BIM models described as IFC models, based on WebGL[3].

Green2.0 Modules (Orange)

The *Green2.0* high-level system architecture emphasizes separating the functionality of the system into independent modules, such that each contains everything necessary to execute only one aspect of the desired functionality. Currently, *Green2.0* consists of five modules (Figure 6).

Conclusions

BIM is a relatively new technology in an industry typically slow to adopt change. Yet many early adopters are confident that BIM will grow to play an even more crucial role in a building's life-cycle. Its proponents claim that BIM offers increased speed of delivery and reduced costs, so governments around the world are starting to mandate the use of BIM in large public projects. Critical to these initiatives and directives is the design and development of systems that will allow the adoption of collaborative behaviours and will open new more efficient ways of working together at all stages of a building project life-cycle. *Green2.0* describes a significant improvement over current practice and tries to advance the current state of the art in building design towards sustainable development. The premise of our work is that by opening the building design process to the world and enabling complex interactions between building and people we facilitate the study of aforementioned large-scale socio-technical systems to unprecedented levels.

[1] Official International Standard ISO 16739:2013.

[2] http://bimsurfer.org

[3] https://developer.mozilla.org/en-US/docs/Web/API/WebGL_API

References

[1] Jakob Beetz, Léon van Berlo, Ruben de Laat, and Pim van den Helm. 2010. BIMserver.org–An open source IFC model server. In *Proc. of CIP W78 conference*.

[2] Chuck Eastman, Charles M Eastman, Paul Teicholz, and Rafael Sacks. 2011. *BIM handbook: A guide to BIM for owners, managers, designers, engineers and contractors*. John Wiley & Sons.

[3] Tamer El-Diraby, Thomas F. Krijnen, and Manos Papagelis. 2016. Green2.0: Socio-technical Analytics of Green Buildings. In *Proc. of ICSIC*.

[4] Malak Al Hattab and Farook Hamzeh. 2015. Using social network theory and simulation to compare traditional versus BIM-lean practice for design error management. *Automation in Construction* 52 (2015).

[5] Yehuda E Kalay. 2001. Enhancing multi-disciplinary collaboration through semantically rich representation. *Automation in Construction* 10, 6 (2001), 741 – 755.

[6] Akponanabofa Henry Oti and Walid Tizani. 2015. BIM extension for the sustainability appraisal of conceptual steel design. *Adv. Engin. Informatics* 29, 1 (2015).

[7] Leon van Berlo and Thomas Krijnen. 2014. Using the BIM Collaboration Format in a Server Based Workflow. *Procedia Environm. Sciences* 22 (2014), 325 – 332.

[8] Johnny Kwok Wai Wong and Jason Zhou. 2015. Enhancing environmental sustainability over building life cycles through green BIM: A review. *Automation in Construction* 57 (2015).