210 King Street: A Dataset for Integrated Performance Assessment

Ramtin Attar[1], Venk Prabhu[2], Michael Glueck[1], Azam Khan[1]

[1]Autodesk Research
210 King Street East,
Toronto, Ontario, Canada M5A 1J7
{firstname.lastname}@autodesk.com

[2]Carleton Immersive Media Studio
Carleton University
Ottawa, Ontario, Canada K1 5B6
vprabhu@connect.carleton.ca

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Abstract

This paper presents a Building Information Modeling (BIM) re-creation of a designated heritage building located in Toronto, Canada. By taking advantage of BIM as a centralized database, which describes both geometric and semantic aspects of a building, this model can be leveraged as a source of input for many forms of analysis. In addition to the BIM model, we present a comprehensive point cloud dataset gathered using terrestrial laser scanning technology. Based on an existing and a living building, this model is an ideal candidate for simulations that can be cross referenced with information gathered on-site.

1. INTRODUCTION

As the result of an increasing emphasis on energy efficiency and building performance, we are witnessing a growing global trend calling for further integration of sophisticated computational analysis and Building Energy Performance Simulation (BEPS) to support design decisions. Simulation is a powerful method for gaining insight into the behavioral characteristics of a system and it is becoming an integral part of the design evaluation process. Numerous projects are attempting to define the qualitative and quantitative measures of sustainability and "greenness" of a building. This is a complex task and many different kinds of data are needed to implement and asses these measures.

In the context of architectural design and urban planning, there is currently no common method for describing and representing data required for simulation analysis [Hand et al. 2005]. In order to integrate simulation as a core philosophy throughout the life-cycle of a building, we need to enable more effective mechanisms to create, distribute and cross validate information critical to simulation. In this paper, we contribute a comprehensive and high quality dataset of an existing structure to provide a basis for ongoing analysis within the simulation community. While noting that the overall performance of a building can be characterized as a trade off among many different attributes and aspects of design, our dataset can provide an opportunity for comprehensive cross validation among various methods of analysis performed on a shared model. Furthermore, we hope that this kind of data sharing will foster more collaboration between the scientific and design research communities.

2. DIGITAL 210 KING DATASET

This dataset is a digital re-creation of a designated heritage building situated at 210 King Street East in downtown Toronto, Ontario, Canada (see Figure 1). This eclectic workspace is the current home of Autodesk's Toronto office and it spans four historic Toronto warehouses, built between the 1930s and 1960s, with a total 145,000 square feet of office space. Toronto architecture firm Kuwabara Payne McKenna Blumberg was commissioned to carry out the integration and renovation of the warehouses, which was completed in November 1997. At the time, the company was called Alias|wavefront and was subsequently acquired by Autodesk in January 2006.

Figure 1. 210 King building combined with 204 and 214 King Street Warehouses.

Three of the warehouses, including 204 and 214 King Street East, are designated as heritage buildings, requiring that original features of the buildings be preserved. 210 King Street East, on the other hand, suffered damage from a fire and did not receive the same designation, making it an ideal candidate for the main entrance to the office. This space was renewed through the creation of an expansive two-storey lobby and striking steel staircase, the signature feature of the office. In 2009, growing out of an interest to foster awareness towards energy consumption and to promote more sustainable practices for existing buildings, the 210 King building was chosen as a living laboratory to analyze and investigate factors involved in building performance and energy efficiency. We started the process by digitally reconstructing (reverse engineering) the existing building into a BIM model using laser scanning, collected architectural blueprints and site inspection.

2.1. Point Cloud

Terrestrial laser scanning is a powerful and relatively fast survey method for collecting 3D information at a large scale. The first digital dataset we present in this paper consists of an accurate geometric documentation of the 210 King office building by collecting real-world spatial data as points in 3D space. We limited the scope of the scanning to the entire fifth floor interior and the rooftop terrace, as well as the lobby and the exterior of the building. In total, we carried out 53 individual scans, which were combined to produce a dataset containing over 1.3 billion data points (see Figure 2). These point sets were registered in terms of coordinate systems and elevation above the sea level by a survey team. This allowed for geo-referencing of the entire dataset by knowing the precise position of each point in terms of real-world coordinates.

Figure 2. The combination of 53 scans as one dataset.

2.2. Building Information Model (BIM)

In addition to the point cloud representation of our office building, our dataset includes a comprehensive Building Information Modeling reconstruction of the 210 King office building using Autodesk Revit. Due to the complexity of reverse engineering an existing structure, we treated the creation of our BIM model as an iterative modeling exercise. Our first attempt was a tremendous exercise in filtering through the mountain of information we collected from laser scans, hand drawn sketches, AutoCAD drawings, and on-site inspections.

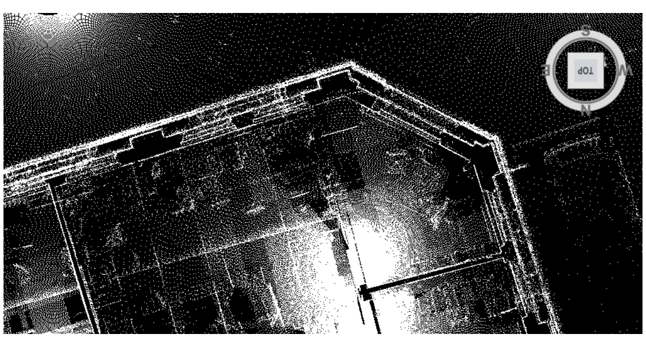

Figure 3. Plan of building envelope in Autodesk Navisworks after combing interior and exterior scans.

We used the AutoCAD drawings of the building from the time of renovation as a basis for our model and integrated measurements from the other sources to fill in missing information, such as wall thickness measurements and the composition of brick walls (see Figure 3). Through a layering approach, we built our first iteration of the model from bottom up by compiling all the CAD drawings in appropriate levels while cross referencing them with our laser scans and site inspections.

The first version of our model provided a great environment where we could compare and reconcile the complexities of the many existing datasets. However, we found that our approach to the problem of modeling an existing building needed to be reviewed. We approached the first model by considering the existing office building as a whole from the very start, which resulted in a lack of conceptual clarity among the four buildings. Since our digital reconstruction involved four different buildings built at different times, the interaction between the buildings themselves had to be understood beyond simple connecting blocks. Accurately capturing these interactions would not be easy, since the overall geometrical and structural configuration of the four buildings could not be simply rationalized into one method. Thus, in our second attempt, we thought of this task as if we were designing four new buildings that would later interact. We started the model by constructing the major party walls defining each of the four buildings, thus embedding a clear conceptual separation among the four existing structures. With each building still being considered separately, we added internal structural components: the pillars, the floors, and major interior walls. As a final step, we created openings in the walls where the buildings now connect to one another (see Figure 4).

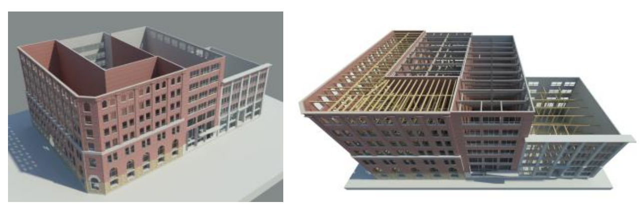

Figure 4. (left) Completed envelopes and (right) structural framing of the four buildings.

BIM provides a powerful mechanism for the assembly of components that can be repeated and placed in different locations. However, one of the key challenges in using BIM for an older building was how to best reconcile between traditional methods of construction and the family-based (component-based) approach of BIM. In the case of the 210 King project, we were faced with many interior elements that could not simply be reduced to repeatable component families since most of these elements had been thought through and designed on-site in order to fit a specific location. Therefore, most of these elements had to be treated as the assembly of much smaller components that were combined together based on their local configuration. By establishing the entire building's structural grid and each individual building's structural wall as a datum, we were able to create an overall anatomical setup for interior modeling. Additionally, we paid more attention to the visual fidelity of our model by creating drawings and rendering outputs throughout the process. In particular, the laser scan data proved invaluable for refining measurements of difficult to reach areas, such as the building envelope.

3. VALUE TO THE COMMUNITY

Despite significant advances, simulation programs still require a tremendous amount of user input about building components. Additionally, there is generally little information about how a dataset was created, how it is maintained and what purposes it is suited for [Hand et al. 2005]. Furthermore, full access to a comprehensive dataset that can be utilized for many different simulation tools is still rare to find. For this project, all the collected and authored materials are published for unrestricted use at www.210king.org.

Given the natural ability of BIM to maintain different kinds of information pertaining to the assembly of a building, spatial zoning, operational management and additional metadata, we can expect a more efficient and reusable dataset that could save a tremendous amount of manual input work. Based on a living building, BIM allows for semantic data, such as operational and contextual information, to be captured within an integrated information model shared by various parties and stakeholders.

While BIM acts as a powerful database of a building, no simulation tool supports the detailed level of attributes inherent in a BIM model. Therefore, there are many factors to be considered from the outset. In the context of the digital reconstruction of an existing building, a key factor is to determine a balance between the immediate function of an asset and its long term re-purposing in other contexts [Jemtrud 2006]. Therefore, we decided to approach our model as a comprehensive repository of data by choosing BIM as a scalable-integrated approach to life cycle information management and building performance analysis. BIM has already been utilized as the initial step in creating energy performance models and thermal performance management, for instance, is one of the most adopted use case scenarios of BIM models [Laine et al. 2007]. BIM has also been extended to different simulation scenarios, such as crowd simulation [Eastman et al. 2008]. As Eastman has noted, the use of BIM has long term advantages due to its capacity to store accurate 3D input and metadata required by simulation tools.

A key obstacle is that simulation is often performed on a completely different platform outside of the design environment. Another important goal of using BIM is to help the research community toward a better understanding of the mindset of a designer. There is a broad spectrum of models for measuring the energy performance of a building. On one side of this spectrum are specialist research users who develop a model for a very specific research task and on the other side are architects and engineers who make use of models as a design tool. The quality and efficiency of a model is domain-specific and it depends largely on practical knowledge and tolerances specific to a field. Thus, it is crucial to share the datasets as an open source assets in order to create an ongoing discussion among various disciplines. Furthermore, performing simulation on a common dataset can help to reveal certain aspects of each simulation product through cross validation while promoting a more holistic understanding of simulation in the context of design.

3.1. Heritage/Retrofit

The application of BIM as an integrated design method has brought significant advances to design and delivery of new construction projects. In this project we aim to extend the concept of BIM to an existing heritage complex where we can analyze the behavioral and performance characteristics of our building as a living system. In recent years, there have been a number of precedents [Penttila et al. 2007] that have explored the use of BIM in retrofit projects and we expect to witness a growing trend in integrated-performance assessment as our existing buildings are being scrutinized for their energy consumption and operational performance throughout their life-cycles.

3.2. To Support Validation

Measuring a building's performance has many practical challenges and different kinds of data are required from both the actual condition of the building and results of a simulation model (performance model). While for some metrics it is relatively easy to obtain performance data from existing conditions, for others mathematical models and estimates are more practical. Our interest in creating a dataset based on an existing building was to take advantage of the analytical possibilities of a 3D digital model by setting the real building and its digital proxy into parallel analysis and cross validation.

4. HOW TO USE THE DATASET

Our BIM model acts as a repository of data that describes different aspects of the 210 King building. The main motivation behind using BIM is to centralize the building data while leveraging it for various analysis purposes. This would minimize the task of making input files for simulation since we can virtually incorporate any form of metadata into our BIM model. There are already a number of existing workflows among Autodesk Revit and some commercially available simulation software. For instance, using Autodesk Revit, one can export an analytical model that can be used either in conjunction with Autodesk Green Building Studio to evaluate the energy profiles and carbon footprints of the building, or it can be imported to Autodesk Ecotect to perform a full range of environmental analysis and simulation [Autodesk]. This workflow is facilitated through the gbXML extension, which focuses on a very specific set of definitions and data requirements for energy analysis. Alternatively, a similar workflow can be followed to interface with other simulation engines such as EnergyPlus.

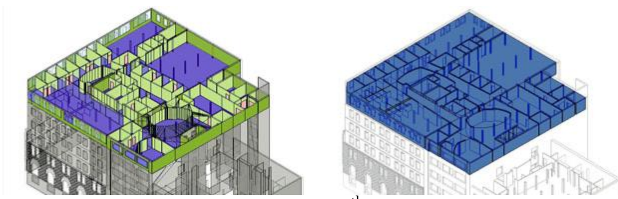

Figure 6. Analytical models of 5^{th} Floor using gbXML.

It is important to note that our analysis is not limited to energy modeling and environmental analysis. All the elements in a Revit model are described with architectural semantics and we can assign additional data to each element or family of elements. BIM's geometry and semantic data model can also be extended by adding behavior patterns through its Application Programming Interface (API). This method allows external simulation platforms to perform more sophisticated simulation analysis concerning building usage and post-occupancy user analysis. For example, Yan and Liu [2007] combines a BIM model with a simulation engine built with Microsoft XNA Game Studio Express for path-finding simulation and visualization while integrating different kinds of simulation components such as fire and smoke. This would make the BIM model an ideal dataset for running other forms of analysis such as crowd simulation or fire evacuation. In general, our BIM model can be scaled or altered to fit a specific analysis.

4.1. File Structure

In general our dataset is divided into two groups: laser scan and BIM files. We have also converted our datasets into several common formats.

File Name	Use Case
210King-Pointcloud-Combined.xyz	This file has combined all 53 scans into one large dataset of points in ASCII text format.
210King-BIM.rvt	This file is created in Revit Architecture 2010 and it contains all the BIM data for our project.
210King-Sheets.PDF	This file is a set of architectural drawings of 210 King that can be used for quick inspection and review of the project.
210King-IFC.ifc	Industry Foundation Class export of Revit file.
210King-Thermal.xml	This file is a thermal model exported from Revit MEP that can be used for analysis in Ecotect or Green Building Studio. Alternatively you can use the Revit file to re-appropriate this file.
210King.obj	This is a basic Wavefront OBJ file that can be used in most 3D applications.

Table 1. Files included in the 210 King dataset.

5. CONCLUSION AND FUTURE WORK

In this paper we have presented a comprehensive dataset going beyond the geometrical and superficial description of an existing building by digitally reconstructing an accurate, high-resolution model. Within this context, a combination of old hand-drawn sketches and CAD drawings had to be studied and sorted in order to digitally reconstruct the building. An accurate geometrical documentation was performed using laser scanning technology and a comprehensive BIM model has been assembled to support various simulation analyses.

Our BIM model currently does not include some subsystems. As future work, we would like to complete our dataset by accurately modeling all the HVAC, ducts and electrical systems. By incorporating sensor networks, we are also planning to provide robust building performance data based on existing conditions that can be used for validation and calibration of simulation outputs.

The application of BIM for existing buildings, especially heritage buildings, is a new area of research. There is much work to be done in order to develop guidelines and efficient methods of how to model existing buildings that often lack sufficient architectural documentation. Our current process of modeling is not efficient, especially as far as taking advantage of powerful datasets such as laser scans. Therefore, we would like to further investigate more efficient and automated methods of working with laser scans and CAD models.

Acknowledgements

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