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# Integrating IFC Models and Virtual Reality for Indoor Light Design

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BIM, IFC, Game Engine, VR, Light Design, Design Feedback

## Summary/Abstract

Within the field of Architecture, Engineering, and Construction (AEC), Building Information Modeling (BIM) can aid designers. For example, designers can use BIM to evaluate different designs ideas. However, some find the existing tool to be hard to use. Designers can instead use Virtual Reality (VR) and create different design layouts in a virtual environment. VR allows designers and users to wear Head Mounted Devices (HMD). These wearables let the person wearing the device to be fully immersed in the VR world. This immersion can be used for indoor lighting design.

Video game engines can create and simulate light in real-time. This makes them suitable for light design. Furthermore, the abovementioned VR works well within game engines. Previous research has developed porotypes for these types of systems, i.e. systems who use BIM, Game Engines and VR. However, they lack data interoperability - meaning that it’s hard to convert data back and forth between different software or systems.

The purpose of this study is to evaluate how to increase data interoperability by using IFC. IFC is an open source data exchange format which exchanges information between the BIM software and the game engine. The method will be based on the study conducted by Natephra, et al. (2017). It will use their *BIM-based Lighting Design Feedback* (BLDF). The primary finding will be if the data exchange format (IFC) worked or not.

## Introduction

*Building Information Modeling* (BIM) can be used to visualize the design at any stage of the processes within the *Architecture, Engineering, and Construction* (AEC) industries (Eastman, et al., 2011, p. 198). It can allow stakeholders to receive essential information before the project is completed (Azhar, 2011, p. 251). Furthermore, BIM can be implemented as a part of a *"hybrid practice"* and be used in conjunction with additional tools (Miettinen & Paavola, 2014, p. 86).

For example, BIM can be incorporated in *Building Performance Simulations* (BPS) for design evaluation (Hemsath & Timothy, 2014, p. 96). However, existing tools may not be preferred by architects due to their complexity and non-intuitive user interfaces (Paryudi & Iman, 2015, p. 81). One contributing factor is the lack of integration between design models and performance-and-simulation tools (Arayici, et al., 2018, p. 180).

According to Sampaio & Martins (2014), *Virtual Reality* (VR) can be used to reduce the aforementioned obstacles. They have shown that VR can be used within AEC. In addition, Hilfert & König (2016) demonstrates how *Head Mounted Devices* (HMD) can be used to visualize the design at a low cost. They show the implementation of *Industry Foundation Classes* (IFC) with game engines.

Conclusively, Natephra, et al. (2017) have developed a performance-and-simulation tool that utilizes HMD in a VR environment. Their own prototype system, *BIM-based Lighting Design Feedback* (BLDF) simulates daylighting and the illumination of artificial lights in buildings (see
Figure 1). However, the authors have not used any open data exchange format, such as IFC, and suggest further research in this area to be made.

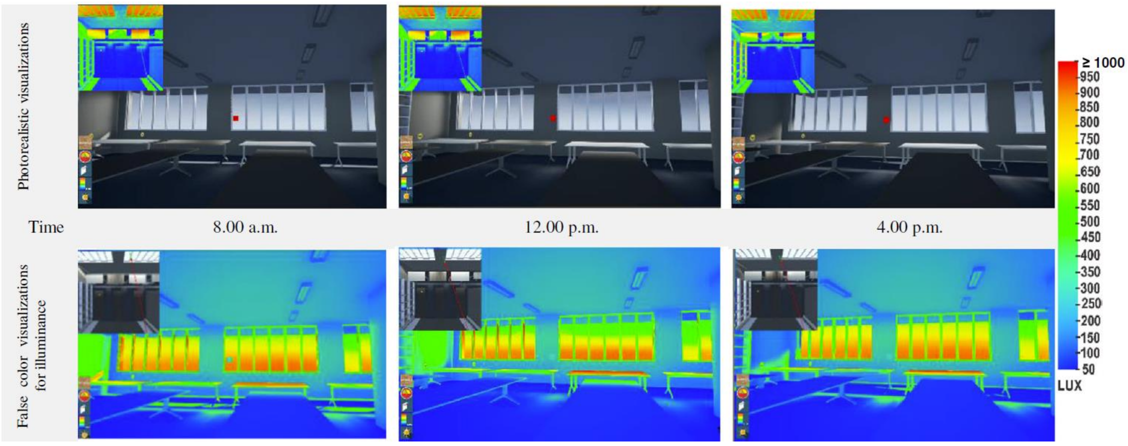


*Figure 1. BIM-based Lighting Design Feedback (BLDF) prototype system. (Natephra, et al., 2017).*

Therefore, the aim of this paper is to evaluate how the open source data exchange format IFC can be used to exchange information between BIM and a game engine for indoor lighting design.

## Literature review

As per the aforesaid introduction mentioned, this present study covers multidisciplinary topics. E.g. BIM, Light Design, Game Engines, VR, etc. This chapter will, therefore, include a methodological review where the aim is to provide knowledge of methods used within these disciplines.

Within the AEC industries, BIM tools are being used more frequently for indoor lighting design. Light simulations plugins[1] for BIM software allows the user to examine design options (Aksamija & Mallasi, 2010). Such plugins can be either, *internal* or *external*. The difference being that internal plugins are integrated in the software of choice. Whereas, external plugins require the exchange of data across different platforms (Nasyrov, et al., 2014). Regardless of which type of plugin to use, both serve to perform simulations and visualizations for indoor lighting design. Previous research has gathered both quantitative and qualitative data using both types of plugins (Sorger, et al., 2016, pp. 291-298; Özener, et al., 2010, pp. 494-496; Yan, et al., 2013, pp. 3524-3527; Kota, et al., 2014, pp. 397-402). The quantitative results have been numbers such as lumen[2] while qualitative data reflects the aesthetics of the light design. Sorger, et al. (2016, p. 298) argues that the qualitative results are problematic to quantify within research area of light design.

A game engine is used to power the graphics, physics, AI, networking, scripting, etc., of a game (Eberly, 2006). Integrating computer gaming with BIM can create an interactive environment (Figueres-Munoz & Merschbrock, 2015, pp. 338-339). Previous studies have shown many methods of integrating BIM, game engines and *Virtual Reality* (VR) for different purposes (Shiratuddin & Thabet, 2011, pp. 49-64; Wu, 2015, pp. 8-16; Goedert, et al., 2011, pp. 83-86; Niu, et al., 2015, pp. 577-579; Jalaei & Jrade, 2014, pp. 144-148; Bille, et al., 2014, pp. 4-7; Yan, et al., 2011, pp. 448-457; Hosokawa, et al., 2016, pp. 112-114; Motamedi, et al., 2017, pp. 255-261). However, they all have in common that they lack methods for fully integrating these systems with real-time light design. Though, Natephra, et al. (2017) have investigated new ways to ease light design via an immersive and interactive user experience. They have created a *BIM-based Lighting Design Feedback* (BLDF) prototype system, as depicted by Figure 2 and Figure 3.

Even though VR allows the user to be immersed within a virtual world, there are differences compared to the real world. Wästberg & Billger (2006, pp. 148-150) have observed and compared virtual against real-world experiences. Furthermore, Souha, et al., (2005, pp. 118-120) have tested two important properties of VR: immersion (perception) and interaction (action). Additional studies have used *Head Mounted Devices* (HMDs) – instead of using a computer screen - to enhance the immersion (Ciribini, et al., 2015, pp. 22-28; Scarfe & Glennerster, 2015, pp. 3-8). These studies also show the possibility for users to perceive the

[1] "A plug-in […] is a software component that adds a specific feature to an existing computer program.", (Wikipedia, 2018a).
[2] "The lumen is […] a measure of the total quantity of visible light emitted by a source". (Wikipedia, 2018b)

physical appearance of light. In conclusion, HMDs can assist users to determine which lighting design is most suitable.

Natephra, et al. (2017) method for determining light design tries to fill in the gap that previous research has left behind. More specifically, they have tried to gather both qualitative and quantitative data using a game engine with the addition of HMD in VR.

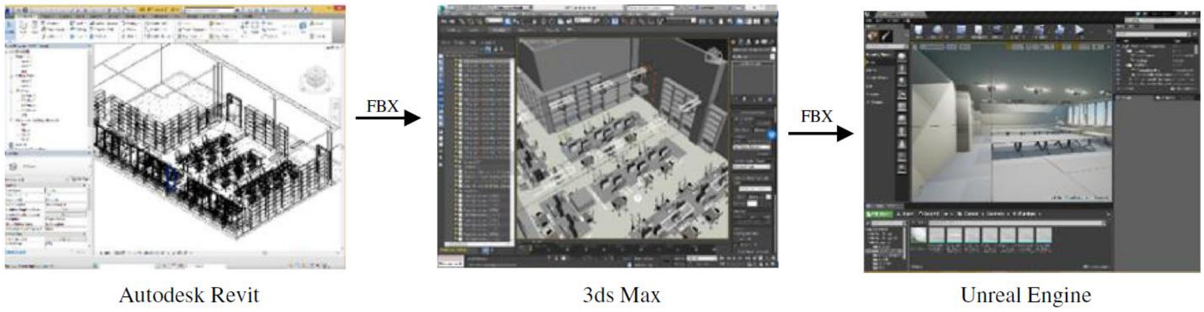


*Figure 2. How the BIM model can be transferred to the game engine (Natephra, et al., 2017).*

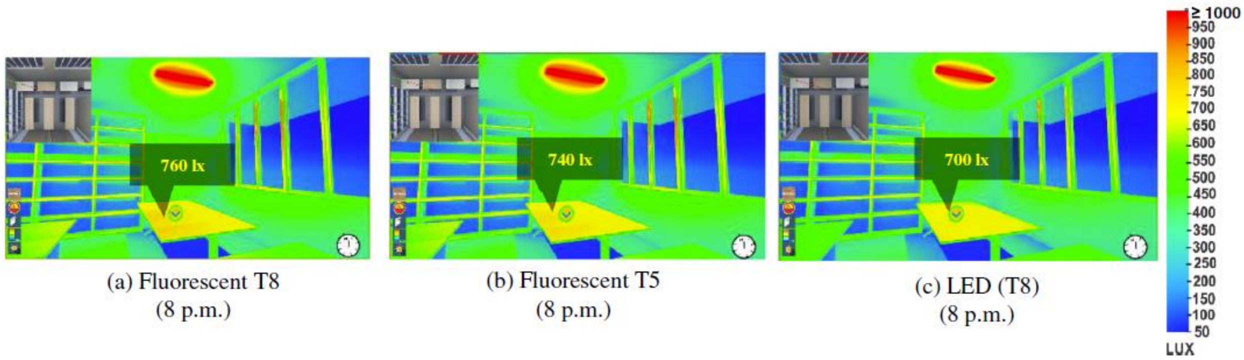


*Figure 3. How using different light bulbs change the illuminance levels (Natephra, et al., 2017).*

Figure 2 shows how the 3D model is being transferred to the BIM software to the game engine (Unreal Engine). It should be noted that the process does not use any open file format – which will be explained and discussed later. Subsequently, Figure 3 shows the BLDF prototype system being used. In this figure, the user can see – in real time – how changing the light bulbs will affect the scene.

In summary, Natephra, et al. (2017) study covers the topic that this chapter have been covering. Thus, their work will be the basis for the present study.

## Theoretical framework

According to Eastman, et al. (2011, p. 16), Building Information modelling[3] (BIM) is “a modelling technology and associated set of processes to produce, communicate, and analyze building models”. Khosrowshahi (2017) lists some common file formats for AEC software such as IFC (Industry Foundation Classes), DXF-DWG (Autocad Drawing), PDF (Portable Document Format), and XML (Extensible Markup Language).

To mitigate the lack of data interoperability, open standard to BIM have been developed. BuildingSMART have created the open object-based exchange file formats called *Industry Foundation Classes* (IFC). The word *open* refers to the IFC being “A free file format is a file format that is both (1) published so that anyone can read and study it in its entirety and (2) not encumbered by any copyrights, patents, trademarks or other restrictions so that anyone may use it at no monetary cost for any desired purpose” (The Linux Information Project, 2007).

It should be noted that not every BIM software fully supports IFC. However, according to Nisbet & Dinesen (2010), IFC offers great potential for data exchange. They argue that it should be used as a common denominator for software to use.

Design of indoor lighting depends on specific scientific principles. Chief among them being illuminance, diffusion, correlated color temperature (CCT), brightness ratio, and glare. Amongst these principles there are standards and conventions to be followed. For example, International standards specify the level of illuminance to facilitate human visual comfort. Furthermore, the designer needs to incorporate other factors, such as energy savings and cost (Deru, et al., 2005). For the end user, the designer needs to have two principles in mind, CCT and illuminance level. These principles have a significant influence on the user’s perception of the environment.

[3] “The terms *Building Information Model* and *Building Information Modeling* are often used interchangeably” - (Eastman, et al., 2011).

## Methods

The proposed method will heavily rely on the works of Natephra, et al (2017). In order for the end user to visualize the proposed design, interdisciplinary mechanics need to be configured. The methods include data interoperability between two different systems - a BIM software and a game engine – as mentioned previously. Within each system, several steps are carried out as depicted in Figure 4.

The goal of the present study is to develop a system for visualizing lighting design that allows users to experience, analyze, and assess the lighting quality of their designed space in an immersive environment. The proposed method different steps, as shown in Figure 4. The validation step, *"View and analyze output"*, is above-mentioned studies such as Sorger, et al. (2016, p. 293).

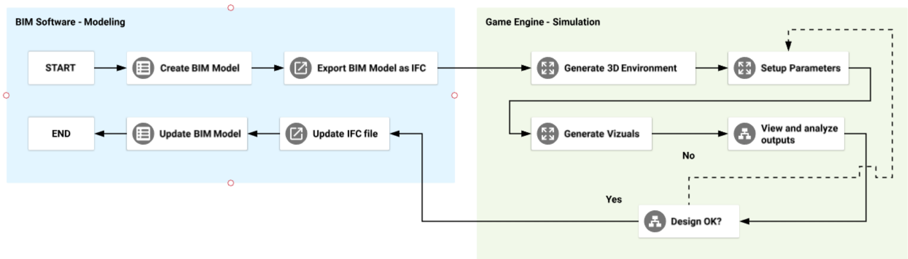


*Figure 4. Overview of the proposed method (Amended from Natephra, et al., 2017).*

Since Natephra, et al (2017), have already concluded that the system allows design stakeholders to better perceive and optimize lighting conditions, there's no need to redo that part. Instead, this paper will focus on collecting quantitative data similar to how Sorger, et al. (2016, p. 292) did. The collected data should be real life sensors readings – a case study - of illuminance levels (lux) paired with values from the virtual environment. The method for collecting data from the virtual environment has been explained in previous studies. Hosokawa, et al. (2016, pp. 113) shows the basis for the experiment setup. However, a more **detailed** process is show in Figure 5.

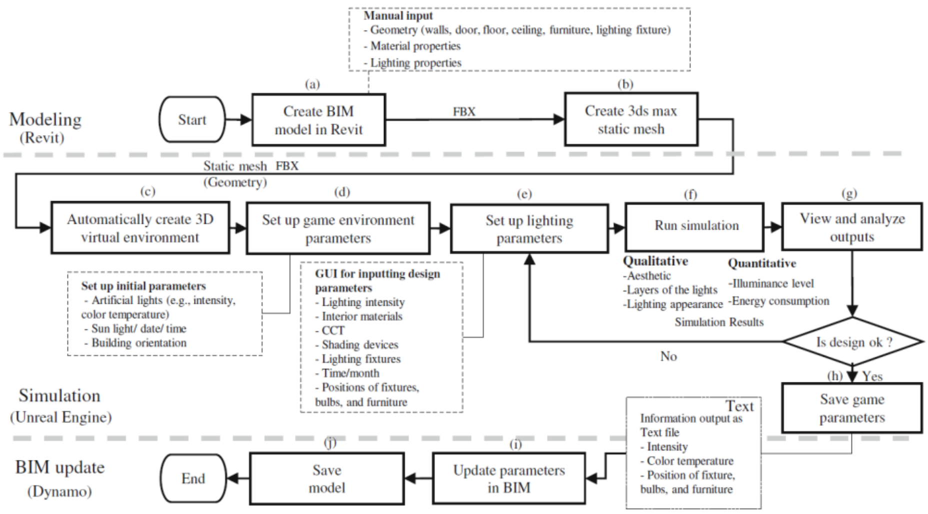


*Figure 5. BLDF's usage process flow (Natephra, et al., 2017).*

## Expected Findings and Implications

The expected findings are close to Natephra, et al. (2017). The system should allow for realistic indoor lighting visualization and energy consumption calculation. However, the main finding should be how data exchange format work (or don't work). Thus, the implications of this study are to aid future researches who want to use IFC files. Especially, those researches who want to use IFC models and Virtual Reality for indoor lighting design.

## Limitations

There are several possible limitations. Chief among is being related to hardware, software and development tools. Further limitations in the game engine's physics – how it renders light might be troublesome. Also, the level of development might limit the scene geometry in ways that are undesirable.

## Work Schedule

Due to uncertainties regarding my thesis, I'm not able to produce a more optimized schedule. If I can get my hand on good developer tools (hardware, software and HMDs), the expected time will greatly reduce. As for now, I expect that I need to build some developer tools for my own – since the existing tools are very (!) expensive.

| Title | Start date | Deadline |
|---|---|---|
| Final Thesis | 2019-05-27 | 2019-06-03 |
| Thesis Draft | 2019-05-13 | 2019-05-27 |
| Analyze Data | 2019-04-29 | 2019-05-10 |
| Set up IFC exhange script | 2019-04-12 | 2019-04-26 |
| Set up VR HMD | 2019-03-28 | 2019-04-19 |
| Set up BLDF process | 2019-02-14 | 2019-03-14 |
| Set up development tools | 2019-02-11 | 2019-02-14 |
| Acquire development tools | 2019-01-01 | 2019-01-11 |
| Draft literature review | 2019-02-04 | 2019-02-08 |
| Finalise objectives | 2019-01-28 | 2019-02-01 |

*Figure 6. Outline of the work schedule.*

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