Porting BIM Models to Virtual Reality Using Google Cardboard

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Abstract

Virtual Reality for Building Information Modelling (BIM) is an exciting development in the virtual design and construction (VDC) process. However, the lack of reasonably priced solutions along with lack of computing power on cellular devices has restricted its success and most people continue to use desktop solutions.

This paper dwelves into porting BIM models into virtual reality using the Google Cardboard: a low cost solution. The new perspective obtained when you view a BIM model in virtual reality will allow users to view scaled models as if they are actually in a real life structure. This, along with the relevant data attached to every 3D structure would provide users with a virtual walk-around of a BIM model. The advantage of the Google Cardboard is not only its affordability, but also its portability. For just 15 USD, anyone can insert his phone into a Google Cardboard and view a BIM model. The possibility of selectively loading sections of the model in a contextual manner from models published into a cloud service can also help circumvent the limitations of memory and computing power available on a mobile device.

Keywords : Building Information Modelling, Google Cardboard, mobile, phone, virtual reality

I. INTRODUCTION

A. Building Information Modelling

By definition, Building Information Modelling (BIM) is a process involving the generation and management of digital representations of physical and functional characteristics of places. Building information models are files (often, but not always in proprietary formats and contain proprietary data) which can be extracted, exchanged, or networked to support decision-making regarding a building or other assets. Usage of BIM models has exponentially grown over the last few years, with the application of BIM growing at 16.72% per annum [15].

While BIM models are primarily created on desktop computers using tools like Autodesk's Revit or Graphisoft's ArchiCAD, the emergence of the processing power and capability of cellular devices along with cloud computing has opened up new opportunities of viewing BIM models and other large files on mobile devices as well.

BIM is a critical component for the success of virtual design and construction (VDC) industry and LEAN construction principles. It is expected to make the construction industry a lot more efficient with better planning and resource utilization.

B. Virtual Reality And Google Cardboard

The process of replicating a proportionately scaled (e.g. 1:1), 3-dimensional environment, and stimulating a user's physical presence in this virtual replicated environment is known as Virtual Reality. A person using virtual reality equipment is typically able to "look around" the artificial world, move about in it, and interact with features or items that are depicted on a screen or while wearing a device similar to goggles. Most 2017 era virtual realities are displayed either on a computer monitor, a projector screen, or with a virtual reality device (also called head-mounted display or HMD). HMDs typically take the form of head-mounted goggles with a screen directly in front of the eyes. Some examples of HMDs used and sold today are devices like the Oculus Rift, the HTC Vive, and the Google Cardboard. The Oculus Rift is retailed at around $ 600 inclusive of all the necessary add-ons. The HTC Vive costs $ 800 for the essential system to run most virtual reality (VR) simulations.

The Google Cardboard is a low cost virtual reality solution, costing from $ 7 to $ 15 [16] per piece, making VR accessible to anyone and everyone who owns a

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smartphone. This emergence of the Cardboard has widened the prospective applications of virtual reality, allowing it to now move into fields where it can be used by large number of people like site engineers in the construction industry and in other manpower-intensive industries.

C. The Unity Engine

Unity is primarily a game engine that is widely used by mobile developers across the world today. The Unity Engine supports development for the iOS, Android, Xbox, and PlayStation platforms, along with various others. Unity was chosen as the primary game engine for this paper due to its portability and ease of use with the Google Cardboard API.

II. OBJECTIVE

The objective of this paper is to develop a prototype application and evaluate its feasibility by both testing it and obtaining industry experts' inputs on the same through a survey. This paper will result in promoting principles of Lean Construction significantly, as it enables virtual design construction and efficient completion of projects. If the project managers and other site engineers use low cost VR tools to visualize and access BIM data, it would bring more efficiency to the VDC process. BIM is commonly used today for developing object oriented models of buildings and structures, where every building element describes itself and its relationship with other elements in a database. BIM platforms allow such a database of objects to be visualized in 2 Dimensional or 3 Dimensional views. Today, BIM models are used largely to co-ordinate geometry, provide walk-arounds, visualize spaces and resources, and provide contextual data for models of structures and buildings. Most BIM models are developed and viewed on desktop computers within their specialized authoring tools, with two major drawbacks: lack of portability and high costs. The emergence of virtual reality has also led to a new realm to improve the user interactivity of BIM models; allowing users to walk around scaled versions of models in virtual reality, and dynamically access the data associated with a structure, giving them a new perspective to view the model.

However, the lack of affordable and reasonably priced mobile solutions has limited the usage of virtual reality viewing tools, with most people opting for desktop solutions to reduce costs.

This paper involves porting these BIM models into virtual reality - with a prototype software that operates using a BIM model stored on the cloud - using nothing but a high end smartphone and the Google Cardboard, providing a low cost solution to viewing BIM models in Virtual Reality. There are, of course, limitations associated with loading complex BIM models on a mobile device. However, this paper has found that the potential advantages do exceed the limitations. Using the power of cloud computing, this paper attempts to use a software which would load rooms from a BIM model stored on a cloud platform like BIMAssure [13] on a room by room basis, thus circumventing memory issues. This mechanism coupled with the United Engine can load most 3D structures onto mobile devices and run them in interactive environments [3]. The new perspective obtained when you view a BIM model in virtual reality will allow a plethora of users to view scaled models as if they are actually in a real life structure. This, along with the relevant data attached to every 3D structure would provide users with a virtual walkaround of a BIM model. The possibility of selectively loading sections of the model in a contextual manner from models published into a cloud service cloud can also help circumvent the challenges of memory and lack of computing power available on a mobile device.

III. LITERATURE REVIEW

A. Research Work

Various researches have been conducted in this field. However, one avenue which has not been explored to a great extent is the usage of low cost virtual reality platforms like the Google Cardboard. Research has been conducted on topics like cross media visualizations of BIM models [6] and even extending BIM models into Game Engines [2]. Research has also been done to integrate BIM models into cloud based collaboration platforms for AEC projects [4] along with integrating immersive virtual and augmented reality with BIM models [7].

The key difference between other papers and this paper is that this paper deals with using a low cost medium like the Google Cardboard, and also deals with the prospective difficulties and solutions which one comes across while using a platform like the Google Cardboard to view BIM models.

B. Commercial Ventures

There have been various BIM related commercial efforts in the field of virtual reality. Companies have been developing tools for both virtual walk-arounds of buildings and viewing of 3D models in virtual reality. The only obstacle here, however, is the high cost of VR tools like the HTC Vive and the Oculus Rift. The usage of virtual reality in the construction industry has not yet become commonplace, primarily due to this obstacle, which is associated with most virtual reality viewers.

A majority of VR (like the VRay [10] toolset for Revit, SketchUp and IRISVR [9]) products in the BIM space focus on virtual walk-arounds - providing consumers with a real life experience of what their property would look like after construction.

However, all of these either use tools like the Oculus Rift or HTC Vive for visualization purposes.

Some commonly used commercial VR tools are:

❖ Tools like the Oculus Rift and HTC VR are being used by companies like IRISVR and VRay to give consumers a real world experience of what a model would look like on a 1:1 scale.

❖ Graphisoft's BIMx [12] is a VR viewing tool for mobile devices. BIMx provides viewing of the 3D model without the data using various VR platforms including the Google Cardboard.

❖ Smart Reality [11] is another firm that is in the process of developing augmented and virtual reality solutions for BIM models, using triggers to launch the 3D models from BIM files into Augmented Reality.

❖ PrioVR is a motion capture device that helps one experience a VR environment with natural movements instead of a keyboard/mouse combo. The PrioVR works by attaching sensors on the user's body that feed motion data back into the VR software. This as well, is not a comprehensive VR solution to view 3D models, as it is mostly for user experience and viewing, rather than for providing data.

It is worth noting, that while some of these platforms do support viewing of models in high end mobile devices, this paper validates the applicability of a mobile application working in conjunction with a cloud based solution to load room data (from BIM models) one by one dynamically and allowing for larger models to be in the hands of users at project sites who need them in the construction process at a relatively lower cost. Most virtual reality firms involved in this space are more focused in displaying the 3D models, rather than the data attached to the elements.

IV. THIS PAPER AND THE PROJECT

This paper's primary objective, as mentioned earlier, is to port BIM models to low cost virtual reality, using the Google Cardboard. Most BIM models are built using specialized software on desktop computers, the two drawbacks of this practice being lack of portability and high cost. With the popularity and usage of BIM rapidly rising, the next step is to develop tools in such a way that they can be loaded onto platforms which can be used by the industry. Porting BIM models and their relevant data to a low cost platform such as the Google Cardboard would make them much accessible to architects, construction managers, and site engineers, to whom BIM models in VR would provide an entirely new perspective while constructing and working on a building. Referring to a model regularly in virtual reality would not only eliminate potential construction errors like clashing of services, but also would ensure timely completion with less change orders and would bring in a more efficient process. Whether it is the placement of various fittings, or the allocation of space to fixtures and ducts, the builders could be provided with a clearer idea than what they would have got with a 2D blueprint/drawing.

A. Working of the Prototype

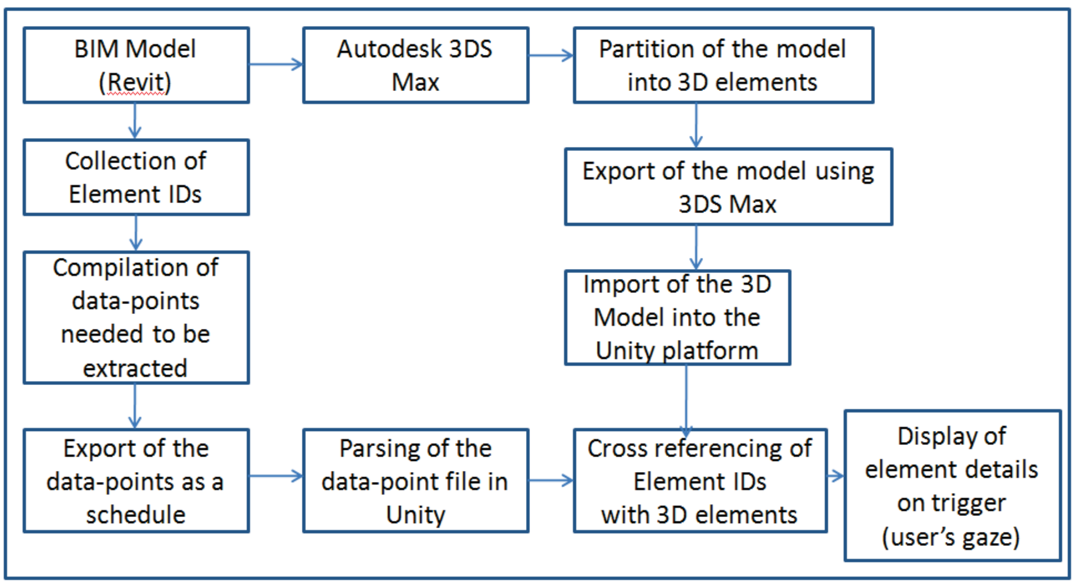
As of now, the prototype software relies on manual data transfer, with the 3D model and the relevant data having to be moved into the Unity platform manually after being exported out from Revit. The model is exported though Revit and 3DS Max in order to ensure the retention of the required textures and 3D elements of the model. The model's data is extracted in the form of a schedule from Revit along with the Element ID. The element ID is a unique value attached to every element that is not automatically available as a parameter in Revit, but one can either use an add-on called Show ID [14], or build one's own tool using Autodesk's Dynamo to extract the element IDs and store them as project parameters. This Element ID (Unique ID assigned to every element) is used later in the prototype software to match the required 3D elements back to their relevant data, and this is imperative in creating an interface which contains both the linked model data and the model itself. As demonstrated by Stefan Boeykens [3], required individual element data is extracted from Revit by exporting it in the form of a schedule, which is imported into Unity. This schedule is then read by the prototype to create an array of potential items to map, and these items of the array are traversed every time the user fixes his/her gaze on a 3D element. Then, the required data is displayed on the side of the user's screen. Thus, every model to be imported into the prototype software, first needs to be put through a particular process. It must be exported to a .3ds format using Autodesk's 3DS Max, and then must be imported into Unity along with a schedule containing all the element IDs. The same process has also been detailed as a flowchart in fig. 1.

distances. The 'GazeInputModule' property of the Cardboard API is what is used to detect when the user fixes his gaze and the Cardboard pointer on an element, and the software responds with the appropriate data [8].

The primary reason Gaze-Input was used over the Cardboard Trigger to call the software for data was to ensure that the trigger is used for customizable motion instead, with the trigger responding to being called by moving the user forward by a certain distance.

The software loads directly into a view of the pre-loaded model in virtual reality, with the user being able to walk

Fig. 1. A flowchart detailing the mechanism used by the prototype application to dynamically load data room by room



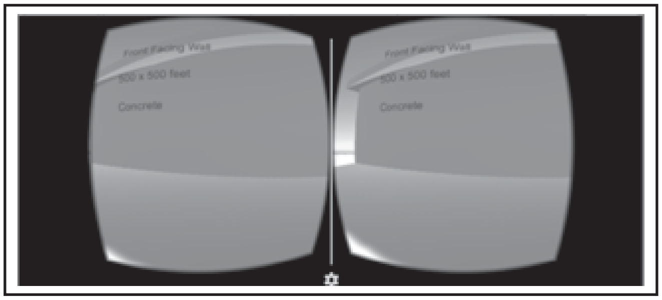
The Unity engine enables the model to be rendered in a 3-dimensional free space, and the Cardboard API provided by Google allows for the implementation of a VR view of the model. Unity's APIs are also used to add features like gravity and colliders to the model, which add to the perception that the user is actually walking around a physical property. The Cardboard API is used to set up an environment with a first person view, which acts as the user's viewer. This first person view is also attached to a 3D object (invisible to the user), so that the gravity and collider constraints applied to the Unity environment also apply to the user's viewer.

The BIM VR viewer has also been modified from a regular VR viewer, with the user being able to travel a certain distance forward every time he/she triggers the metallic trigger on the side of the Cardboard, in order to ensure that users can conduct walk-arounds in larger models without having to physically move across long

around the model and view the appropriate data as well, as shown in the below screenshots of the prototype. (fig. 2) The user's phone along with the built-in gyroscope and motion sensor detects the user's movements and reflects the same in virtual reality. This is the basic premise of the Cardboard API, which not only renders an environment in virtual reality, but also offers movement tools, which have been modified for the purpose of this paper, to allow for additional movement in the direction that the user is facing when the trigger is pressed.

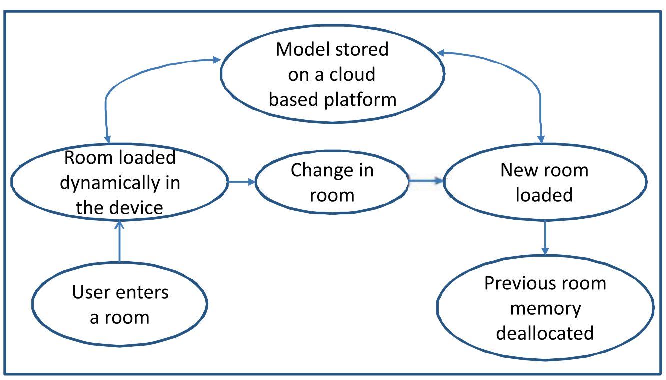
A potential limitation of the working of this initial prototype was the lack of memory and processing power of a phone, which prevents it from loading larger 3D models and their relevant data. This was overcome by storing the model and its data on the cloud, and rendering it room-by-room, using a service like BIMAssure [13] which allows the models to be accessed from the cloud. Since the model and the required data are dynamically

Fig. 2. Screenshots demonstrating the working of a prototype of the virtual reality software.



downloaded to the device one room at a time, there will be no constraints on processing power, and this will allow larger models to also be loaded onto virtual reality using the Cardboard, provided that the phone has a stable connection to the internet. As one room is rendered in VR, the previous room and views would be deallocated from the phone's random access memory, which in turn would make space for the upcoming room and its rendering. An illustration of this has been included in fig. 3 as well.

Fig. 3. A flowchart detailing the working and communication of the application with the cloud when being used.



B. Drawbacks and Potential Improvements

The drawbacks and potential areas for improvement of this prototype, if implemented on a larger scale, would primarily be the lack of automatic integration with BIM models, and the lack of editing tools, among others. As of now, the prototype works based on the data of a 3D model and the model itself imported manually into the prototype's source code, which is a process that could definitely be automated using the right Autodesk and third party APIs. This is something that would definitely be required if a variation of this solution is to be used commercially. Another possible addition is that while the app is in non VR mode, editing tools can be added to modify the data-points associated with the model which can then be reflected in the original model, thus making the software solution more comprehensive.

V. CONCLUSION

The final prototype and one end result of this paper is an application which demonstrated the feasibility of porting BIM models to virtual reality by allowing users to view a BIM model and perform virtual walk-arounds while accessing the relevant data at the same time. This allows users (architects, construction managers, site engineers, etc.) to view models with the required data in three dimensions, and walk around the scaled model. The problem of insufficient processing capability in phones was also overcome by storing the model in the cloud. [13]

A survey was also held, where the participants were shown a version of the prototype software in order to evaluate whether it was feasible and would make a significant difference to them in their respective fields. The majority of respondents were architects and software professionals (constituting approx. 42.5% and 28% each respectively) while the rest were experts in Structural Engineering, Project Management, Building Services Consultants, etc. As detailed in the summary (table I) of the survey, it was found that over 95% of the respondents saw a direct application of the prototype in the field of construction, while an estimated 55% saw an indirect application of this paper in the same space.

The purpose of the survey was to verify the need for a mobile application, and that the prototype detailed in this paper was implementable on a larger scale. The data collected is illustrated in table I.

TABLE I.

Percentage wise classification of respondents from various fields, with their opinions on this paper and its prototype's applications.

Classification of Respondents	Percentage of Respondents
People Familiar with BIM and VR (%)	93.1%
People who felt that BIM is important for the future of construction (% of 93.1)	96.6%
People who saw benefit of viewing BIM models along with their relevant data-points	91.5%
in virtual reality (% of 93.1)	55.2%
People who saw other applications of viewing BIM models in	

The future implications of this project can be immense, as it can open the door to a plethora of virtual reality viewers, which use immersive virtual reality technology to allow the industry constituents to view BIM models on low cost platforms. Potential use will be at construction sites, to get a better idea of how a certain structure and the data associated with it will appear in 3D, enabling lean construction management and reduction of change orders, to address maintenance challenges in the life cycle of a building, and to provide potential property buyers with detailed views and element data.

Hence, to conclude, while it is a start, this technology is far from complete and comprehensive. However, it is a good start towards changing how BIM models are viewed, and on that note, I would invite future researchers to work on this paper.

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About the Author

Raghav Mecheri is an enthusiastic and energetic Grade 12 Science student of Sishya, one of the leading schools in Chennai, India. As a 17 year old, he has a breadth of interests from technology to sports to debating, hobbies he has honed over the years.

He was interested in Robotics when younger and represented his school and state in several competitions. He is a proficient programmer and a coder with several apps to his credit. He started the Chennai chapter of CoderDojo, Ireland in 2016. It has 175 registrants today. CoderDojo is a global organization that promotes the free leaning of coding for children in between 7 and 17 years of age.

Raghav also took part in the Google Science Fair 2015 by developing an app that would be a citizen support ticketing system for a city and its civic body, to handle complaints and feedback about a city. He was placed in the top 90 globally and in the top 20 in the Asia-Pacific regional Google Science Fair.