# Development of a Virtual Visit Model Based on a Bim Model and a Game Engine


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## 1 Introduction

In recent years, the construction sector has shown a productivity lag relative to the industrial sector. Add to this the fact that construction projects are becoming more and more difficult, resulting in more complex and dynamic construction environments. To remedy this, the construction industry is increasingly implementing Bulding Information Modeling (BIM) to foster collaboration and data sharing among the various trades involved in construction projects. Besides, this approach relies on models of objects in the built environment and metadata defining their semantics, to produce a multidisciplinary and intelligent 3D model of the facility, to document and improve its design and to facilitate its operation throughout its whole lifecycle. While BIM has many benefits such as increased constructability, reduced conflicts, reduced cost estimation times and many other opportunities, there are many challenges associated with adopting this approach within the construction industry. Not all companies can adopt the associated technologies and use them in an effective way. In fact, the main BIM software are currently limited in terms of the realism of visualization, general immersion, and proposed interactions, especially for newbies [11]. In this context, to overcome these difficulties, the integration of 3D BIM models with Virtual Reality (VR) technologies is a promising alternative, to provide the non-specialist stakeholders with more intuitive visualization and interaction mechanisms [2]. Thus, according to Sidani et al. [15], researches on immersive systems and interfaces and

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BIM have produced favourable results for construction-related applications, thus improving the design, the team collaboration and the decision-making.

However, very little research has been devoted to interoperability between BIM and VR environments. Also, despite notable evolution through some commendable efforts, Virtual Reality support software such as game engines are quite inflexible and seem poorly suited to fully integrating data from BIM models. The work presented in this article is part of more comprehensive research aiming at developing and evaluating intuitive interoperability workflow between BIM tools and Virtual Reality environments. The purpose of this article is to present, as preliminary results, the development of an intuitive visualization and interaction tool based on the interoperability between a BIM authoring tool and a game engine. The article is organized into 4 main sections. The first section presents the related works, including the use of VR in construction and its association with BIM. The second section describes the methodology adopted for this research, including the main steps followed in the development and the evolution of the artefact. The third section presents the results of the research with a description of the functionalities and user navigation of the virtual tour model created. The fifth section discusses the results and presents the future works before concluding the article.

## 2 Related Works

### *2.1 Virtual Reality in Construction*

Whether for the world of video games or industrial simulation, virtual reality has a major place on the innovation scene [5]. Virtual reality is defined by Arnaldi et al. [1] as a scientific and technical field exploiting computer science and behavioural interfaces to simulate in a virtual world the behaviour of 3D entities, which interact in real-time with each other and with one or more users in pseudo-natural immersion via sensor-motor channels. [5] believes that virtual reality is a mediated experience that plunges one or more users into the heart of an artificial environment in which the user can feel and interact in real-time via sensor-motor interfaces. The user finds the experience credible, accepts to take part in the game and in response feels a sense of presence. Virtual reality has no defined limits, from electronics to computer vision, which gives several possibilities in its use and exploitation.

Several design areas are interested in the use of virtual reality. Now, as the prices of this technology become accessible to the public and especially with the use of 3D digital mock-ups by various disciplines, the use of virtual reality is becoming more and more necessary given all the possibilities that this technology can offer. Jimeno and Puerta [10] have proposed virtual reality as a computer-aided design tool. Several studies have been conducted to understand and exploit the potential of this technology within the construction industry. Firstly Cruz-Neira et al. [6] have implemented the Cave system, which is a visualization system that offers an innovative point of view.

Researchers have tried to determine an effective and productive strategy for the use of virtual reality as a design tool [9]. In the same vein, [11] proposed a study on the visualization of business knowledge and interaction with immersive devices for construction. Dawood et al. [7] have presented through their work an application of virtual reality to Islamic architecture. Others such as Yan and Culp [17] have developed a new design process with a BIM support tool to improve architectural design and visualization by combining Microsoft XNA Framework software as a game engine and Autodesk Revit Architecture as a BIM authoring application.

Other studies have gone even further by using virtual reality as a simulation tool for building evacuation situations. This is the case of Rüppel and Schatz [13] who have designed a simulation of the evacuation of building occupants in the case of fire. This simulation uses the interactivity of a game engine to identify the decisions made by these users at a given time and the paths chosen by them.

In the future, virtual reality could help to improve the collaboration and mainly the communication of the different participants in a construction project, as virtual reality offers the possibility for architects and engineers to get together to pool their work and possibly make decisions regarding possible interferences and conflicts that might exist.

## *2.2 Association Between Virtual Reality and BIM*

Virtual reality is recognized as a promising method that can improve workflow in the construction industry [15]. For example, a link between BIM models and virtual reality may be feasible with the advent of game engines such as Unity or Unreal Engine. Some works such as Boton [4] or Younes et al. [18] have addressed in their research the issue of BIM integration in virtual reality environments. Edwards et al. [8] show through their study the feasibility of using game engines to include end-users in the BIM design process. They used an Autodesk Revit plugin to communicate with the Unity game engine allowing collaboration via a network connection. Similarly, in their study, Shengyi and Jia [14] tried to propose a method for integrating BIM models into a virtual environment from the game engine by designing a virtual interactive roaming simulation. To facilitate and improve the integration processes of BIM models in virtual reality environments, several major software publishers such as Unity, Epic, Autodesk and Trimble are currently trying to develop solutions such as plugins that enable the link between BIM modelling software and game engines.

The link between BIM and virtual reality environments is a technological difficulty in this approach. Previous studies have shown that there is a problem related to the management of data flows and the transfer of information between BIM software and game engines in general. For example, 4D [4] has highlighted difficulties related to the preparation and transfer of data to a game engine such as Unity with a problem of preserving the metadata of the 3D model. Moreover, due to the different steps involved in exporting a BIM model to a virtual reality environment,

these processes often present errors such as missing material information (textures, building elements, etc.) leading to additional steps that may be necessary to complete the exported model [3]. These additional steps may be modifications that can be made in the game engine or the modeling software for a new export, complicating the entire workflow. Others, such as Tulke and Hanff [16], have found that additional developments are needed about visualization, for example, the addition of support for scaling and moving building elements in the game engines.

Despite the rapid development of virtual reality in the construction industry, there are not many models that link BIM and virtual reality, but more importantly, the industry has not yet been able to take full advantage of the potential of this approach. Moreover, virtual reality is not yet widely used in design processes in general, particularly in the BIM approach.

## 3 Research Methodology

The objective of this study is to develop a method for designing a virtual tour model that allows its users to experiment, analyze and interact in an immersive environment. The methodology proposed in this study consists of 4 main steps: statement of needs, choice of the technological tools, development of the VR model and evaluation of the results.

### *3.1 Statement of Needs*

Because of the difficulties noted in the association between virtual reality and BIM, this research project aims to propose: To propose more integrative approaches, with ease of understanding and capable of accommodating different profiles and academic backgrounds, both for the actors in construction projects and for "the general public". In this perspective, the virtual visit model created should offer an immersive experience with the possibility of being able to go through a building in all its spaces in real-time, to be able, for example, to access closed rooms thanks to interaction mechanisms and animation games, but above all to be able to make changes in real-time such as changes in texture.

### *3.2 Choice of the Technological Tools*

Within the framework of this research, we used the Revit software from the Autodesk editor. This software also allows us to make an architectural design and to be able to directly integrate structural, electrical, and mechanical graphic elements into the same model. In this logic, we were able to integrate an architectural and structural

model into a federated model. Then, we chose the Unreal Engine game engine for the design of the virtual environment considering all the possibilities and functionalities that this game engine could offer. Nevertheless, workflow management seemed to be a challenge at first, as importing a BIM model into a game engine was previously problematic for many users. Thanks to the plugin Datasmith we were able to cleanly import the model into the game engine.

## *3.3 Development of the VR Model*

As indicated, the objective of this research is to design a virtual visit model based on a BIM model. As a result, the different steps leading to the design of the model constitute a work process method explored by Natephra et al. [12] as shown in Fig. 1. We will see in more detail in the following chapter the method, but above all the different steps that have been proposed to integrate a BIM model in a virtual reality environment.

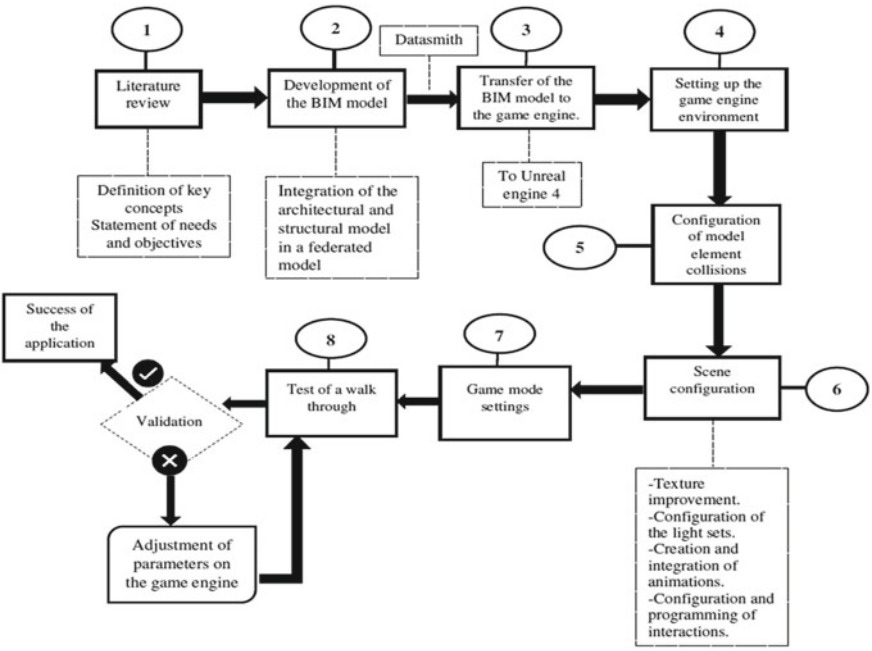


**Fig. 1** Process of integrating a BIM model in an VR environment

### 3.4 Evaluation of the Results

At the end of the design of the model, to bring an evaluation to the created application, we will be able to consider three main criteria. The first would be whether the application meets the desired needs. The second criterion would be that the model should include functionalities (animations, interactions, etc.) that are functional to meet the expectations of future users. And the third criterion would be the ease of use and navigation in the model for different users.

## 4 Development of a Virtual Visit Model Based on a Bim Model and a Game Engine

Figure 1 summarizes the different stages that enabled us to design the virtual visit model. After defining the objectives and potential needs of this research, we had to develop a BIM model that would contain not only an architectural model but also a structural model, thus constituting a federated model. This could be done using the Revit software.

Figure 2 illustrates the federated model that was designed on Revit and its import on the Unreal Engine 4 game engine thanks to the plugin Datasmith.

After importing the BIM model on the game engine, it was necessary to configure the game engine environment. The main task was to configure the visual aspect of the main character proposed by Unreal into an invisible camera that can simulate all the movements of a user in full navigation. This step makes navigation and visualization more realistic since in the standard form of the character, it is made up of bionic hands and a weapon as shown in Fig. 3.

In the next step, it was necessary to represent the physical properties and parameters that make a user's immersion more realistic. To do this, we had to parameterize collisions of each element (slab, staircase, walls, doors, fittings, etc.) of the model using the "Collision mesh" tool of the game engine, which allowed us to simulate certain physical properties such as gravity and collision, making a walkthrough more

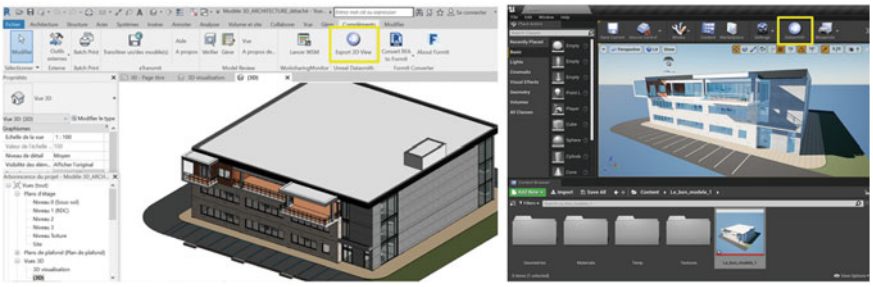

**Fig. 2** Validation of the import process on Unreal Engine

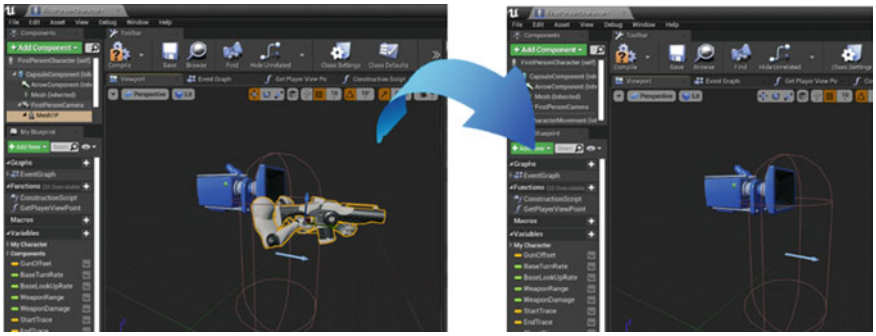

**Fig. 3** First-person configuration for game mode

natural. To obtain a good visual rendering, visual treatment of the play of lights of the scene and the improvement of the textures of certain elements of the model were necessary. In this step, it was, therefore, necessary to improve the lighting of the scene by using functions on the game engine such as Lightmass Importance Volume, Directional Light or the Reflection Environment function which allowed for more realistic and natural light effects.

The integration of video animations and interactions in the model was necessary because in a virtual reality model, a user must be able to interact in an immersive environment. After setting up the model scene and the different light effects, we set up interactions that are functional when the game starts. With the Interaction Widget tool, we can create on Unreal various interactive "accessories" such as cursors, combined boxes, and many other interactions in a virtual reality environment. Thanks to the Interaction Widget, we have therefore created various interactions to give a user the possibility of customizing different components of the model such as tiles, walls or even furniture. One of these interactions gives for example the possibility for a user to change materials for a tile in the game.

To do so, different materials (wood, ceramic, marble …) have been set up to be connected to switch buttons that allow a user to be able to change the base material of a tile in real-time during a walk-through. For these created and parameterized interactions to be functional, the application of these interactions must be programmed in the level blueprint which makes them functional during a walk-through as shown in Fig. 4.

Once the model was developed, it had to be tested to see if it met the objectives and needs that had been established. The main objectives were to improve visualization, to create new interaction mechanisms that could make design review easier. To do this, we tested the model on Unreal. Indeed, Unreal mainly offers five active play modes that allow generating visualization modes to perform a walk-through. These active play modes are Selected viewport, the Simulate mode, the two PIE modes (Mobile Preview ES3. 1 and the New Editor Window) and the Standalone Game mode. We had identified two interesting game modes that allow integrating the character in the first person (First-person), but also to be able to support the different high-resolution

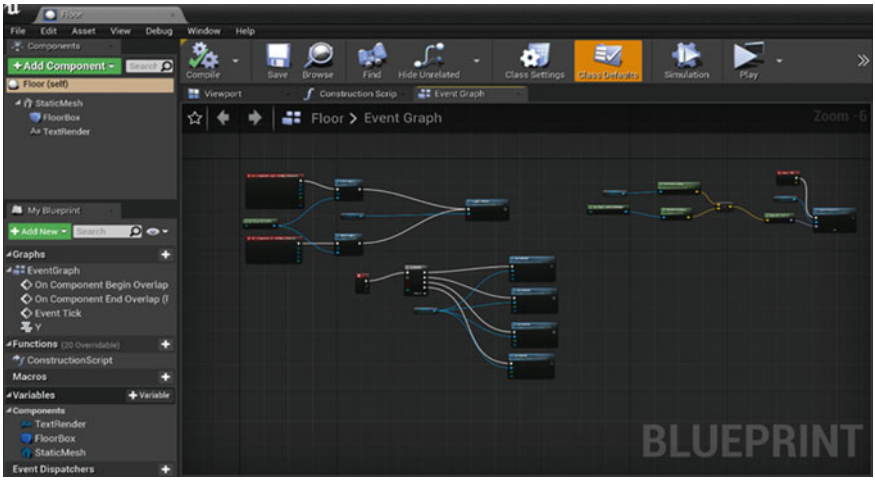


**Fig. 4** Interaction programming of material change interaction of a slab

textures that are in the model. We, therefore, had to choose between the PIE module (New Editor Window) and Standalone Game mode. In the end, the choice went to Standalone Game mode as it supports all the textures that were used in the model and brings a better visual rendering.

So during the virtual visit test of the model, we could realize that the various functionalities and interactions created and integrated into the gameplay from the Level Blueprint were present and working. From the First Person who simulates the representation of the first person in Standalone Game mode, it is possible to move around the building, to be able to access rooms thanks to the door opening animations by simply getting closer to the doors and to be able to access the different levels of the building by going up and down the stairs. It is also possible to interact on elements of the scene by clicking on combined box buttons as shown in the screenshots in Fig. 5.

This makes it possible to change in real-time the basic materials of the objects in the scene such as furniture or even elements according to the different materials offered and to see these visual changes in relation to the whole scene.

## 5 Conclusion and Future Works

Virtual reality is a developing technology that is attracting the interest of several disciplines such as simulation, teleoperation, audiovisual and collaborative work. Indeed, it is characterized by a better visualization, the immersion of these users and the possibilities of interaction in a virtual environment. From a technical point of view, BIM is based on the use of a 3D digital model. It is therefore open to the use

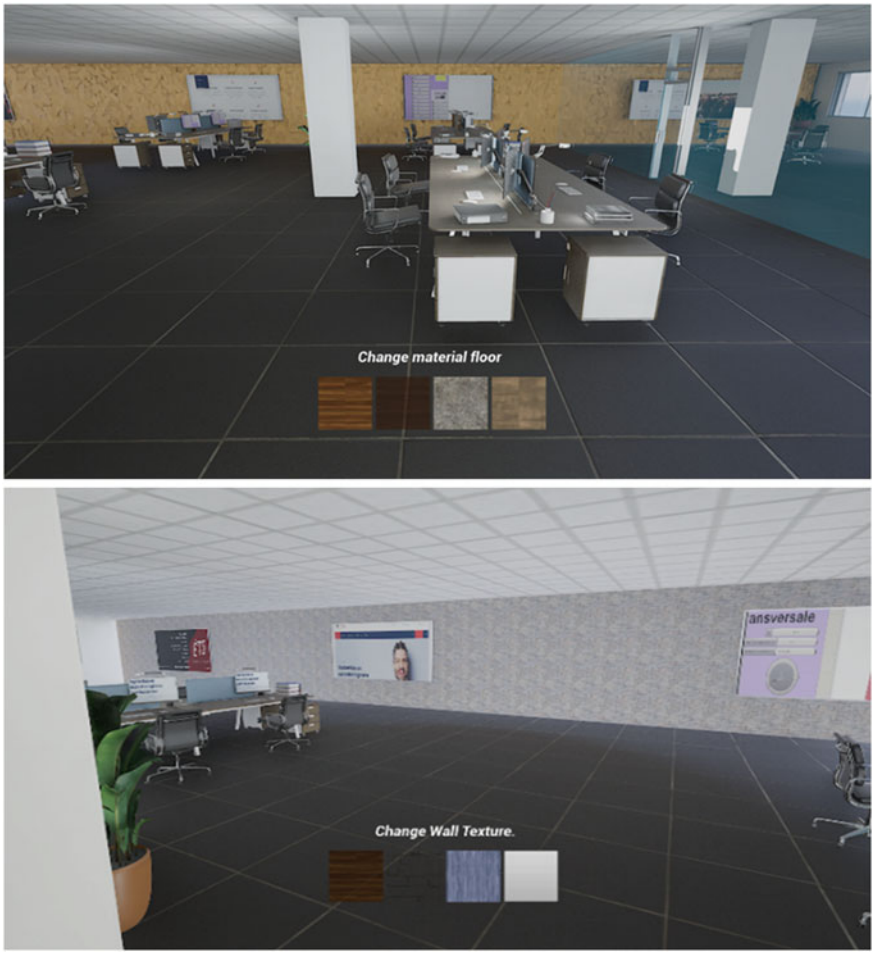


**Fig. 5** Screenshots of the interactions offered to a user during a walk-through

of new tools. In this context, the integration of 3D BIM models in RV environments would be a plus for BIM players given the advantages and possibilities offered by this technology. However, linking BIM with virtual reality environments has always been a technological challenge in the past, as the processes of transferring 3D digital models into RV support software such as game engines remain an ambiguous task due to the various errors that can be generated.

The objective of this research was to be able to suitably integrate a 3D BIM model into a game engine to create a virtual visit model that should offer an immersive experience with the possibility of being able to go through a building in all its spaces in real-time, for example, to be able to access closed rooms thanks to interaction mechanisms and animation games. In this perspective, we first presented,

through a literature review, the different applications of virtual reality within the construction industry with an analysis of the limits interfering with the link between BIM and virtual reality. Then, based on a research methodology, we presented the different steps and methods that allowed us to design a virtual visit model from the Unreal Engine game engine. The final model designed allows navigating realistically in an environment where a user can interact on objects in the scene thanks to created interactions. This research was able to provide interaction tools that could be implemented in future work in the context of 4D. However, this research was unable to link these interaction tools developed in the framework of the virtual visit model and previous work on 4Ds focused on the use of virtual reality. Future work can therefore focus on the integration of these interactions with regard to 4D, the creation of other tools such as conflict detection tools for example on game engines to further support design reviews and constructability and study meetings.

As previously mentioned, the functionalities developed in the model are all functional. It can also be seen that the model is visually more attractive than before importing from Revit. This can be explained by a clear improvement in textures and a configuration of the play of light, which may have made the model more realistic. A feeling of immersion is present when navigating through the model. Besides, during a walk-through, the camera movements follow the directions given by the user via the system controls with a certain fluidity of movement. It is also possible to observe a lack of latency between the interaction of a user on a button during the simulation and the display of the expected visual result. From the point of view of use, the model is easy for a user to use, but also allows a novice user, for example, to easily assimilate the navigation and interaction techniques available in the model. However, in the preview mode, it can sometimes be seen that certain textures are not properly supported by the system, unlike the Standalone Game visualization mode which gives it a better visual rendering. On the other hand, the model does not give the possibility to a user to select and move elements in the gameplay. The addition of this functionality could be considered as part of the possible improvement tracks.

To support future research focused on the use of virtual reality and game engines per se as Unreal, this research provides a methodology for the design of interactions and the detailed configuration of Unreal's environment. Indeed, difficulties concerning the integration of textures and the creation of certain interactions have been noted in previous work on the use of virtual reality on 4D BIM models. The use of the created model would therefore allow giving an added value to the 4D simulation prototypes already available. This would make it possible to meet the needs of project owners or clients, even more, to involve them in the design process by using the BCF (BIM Collaboration Format), for example using screenshots and comments, and to go even further in the context of supporting study and constructability meetings.

On the other hand, this study is limited by the lack of external evaluation by qualified practitioners and experts in the construction industry and to further adjust and enrich this research. Thus, in the context of future research, to validate the model's performance and functionalities with practitioners and professionals in the construction industry, the model should be applied in a real case, thus making it possible to conceptualize the expression of real needs. Therefore, based on feedback

from potential users, the latter will first be able to improve the functionalities and interactions present in the model, to recalibrate them according to the needs of the projects in particular and, above all, to compare the method used for the design of the model and the combinations of software used for the design of other models or prototypes.

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