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Virtual Reality in Construction

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Abstract

Virtual Reality (VR) or Virtual Environments (VEs) may affect how participants in building initiatives see and complete their assigned tasks. VR approaches may increase project effectiveness and efficiency from initial conception through scheduling and preparing, detailed design, or construction execution. The ability to examine the design as well as simulate the building process in a three-dimensional in nature interactive, as well as absorbed the environment will help understand the design's intention, the project's feasibility, and the number of modifications and abortive tasks that may be identified before construction begins.

It is possible to conduct an unlimited number of virtual walkthroughs of the facility, which will make it possible to experience, in a way that is very close to reality, what will be there after the building is finished. Research projects in both the private sector and academic institutions are already under way to investigate the potential advantages that virtual reality might bring to the building industry. The purpose of this article is to present a comprehensive analysis of current instances of the successful use of VR technology as uses for the construction industry. The article also offers an introduction of what Virtual Reality (VR) is and analyses some of the software as well as the hardware that can be used for VR applications. In addition, the study examines some of the gear and material that can be used to VR applications.

Keywords: Virtual Reality, comprehensive analysis, VR Applications, Design, Practicability

Introduction

The term "virtual" has emerged as one of the most frequently used terms in the English tongue during the course of the past twenty years [1]. According to Webster's dictionary, the phrase "having such practical or actual effect, albeit not in real fact or name" best describes its meaning. What we term the outward physical world is the foundation upon which what we refer to as truth is constructed [2]. As a result, the concept of a virtual reality appears to imply the existence of a reality that is plausible, despite the fact that it does not really exist. According to Isdale [3,] the word "virtual reality" (VR) may be construed in many different ways by a wide variety of individuals. To some, virtual reality refers to a particular set of technology, while others broaden the definition to encompass more traditional forms of media such as books, movies, radio, and other forms of communication that may provide an atmosphere that immerses the viewer or listener in its universe.

Within the context of this article, the word virtual reality refers only to computer-mediated systems. Using computers to generate and visualise 3D environments that are supplemented by audio or other sensory outputs, with which one may walk around and interact, is the focus of this activity. The capacity to navigate and explore different aspects of the 3D scene is part of the navigation, while the ability to interact with the environment means being able to pick and change the properties of various objects. Interaction to the virtual world, or at the very least, control of its three-dimensional scenes in almost real time, is an essential test for a virtual reality.

Defining Virtual Reality (VR) : Many scholars and practitioners in the field of virtual reality have come up with their own unique definitions of the term. The term "virtual reality" (VR) refers to a technology that enables users to "visualise," "manipulate," and "interact" with data that is exceedingly complicated [4]. "the depiction of a computer model or database, which may be interactively experienced and controlled by the virtual environment participant(s)," is how Barfield and Furness [5] defined virtual reality (VR).

Halfawy et al. [7] described virtual reality (VR) as computer-generated recreations of actual environments that enable people to envisage, move around, and interact with these sorts of models in a way that is natural to them. Virtual reality (VR) is also known as augmented reality (AR) and mixed reality (MR). According to Sherman and Craig's definition [8,] virtual reality is a kind of media that is comprised of highly interactive simulations run on computers that can detect the position of the user. The use of virtual reality also replaces and enhances the input received from any number of the user's five senses in order to provide the sensation of being completely immersed or participating in the simulation. One way to think about virtual reality is as a medium that provides the user with the impression of being completely submerged or physically present in the simulated environment.

Virtual reality (VR) has come a long way since the early 1990s, and it has started to provide many effective answers to issues that are extremely difficult to solve. Recent advancements include complex graphics cards and new hardware platforms that are able to provide high-end computer pictures. Other devices that provide tactile and haptic images to complete the illusionary sense have made great strides in recent years. In addition, newer, more versatile and powerful commercialised software systems that are focused towards the generation of real-time virtual environments have been available, each with improved capabilities and features.

The usage of the VE word sidesteps any potential connotation that there is an intention to alter the existing universe [2]. Additional words such as visually connected systems, synthetic settings, cyberspace, artificial the real world, virtual presence, and simulators technology have also been used. The words "virtual reality" (VR) and "virtual environments" (VE) will be used synonymously throughout the course of this article.

The next parts of this article will offer a broad overview of the many categories of virtual reality (VR), a synopsis of the current hardware including software technologies employed in VR implementations, and a discussion of the current uses of VR in the construction industry. The purpose of this article is not to give a comprehensive review or a comprehensive list; rather, the goal is to make the reader aware of the latest developments and uses of VR in construction by providing some sample representations of what is available and pointing the reader in the direction of sources that provide more specific information.

Types of VR Systems : As was just said, there is ongoing discussion on the definition of the term "virtual reality." As a result, the term virtual reality may refer to a wide variety of various kinds of systems. In this part, we will investigate many of the aforementioned classifications of systems. The distinctions between these categories may be attributed to a number of different aspects, including as the display technology, the graphics rendering algorithms, the amount of interaction of the user, and the level of integration with the real environment.

i. **Immersive VR :** The picture that most people have in their heads when they think of virtual reality is that of a person wearing a head-mounted display, also or standing within a spatially immersive display (SID). This is by far the most popular representation of VR. At least in part enveloping the user in their virtual surroundings is required for the experience to be considered "immersion." There is not just one level of immersion; rather, there is a spectrum of different degrees of immersion. For instance, a typical CAVE (section 3.1.1.2) only surrounds the viewer with content on four of the cube's six sides, so they only feel like they are half immersed in the experience.

Presence, or the subjective experience of "being there," is a notion that is similar to but distinct from presence. The physical world is supplanted as the user's "reality" by the virtual world when the user is experiencing high degrees of presence [9]. But presence may also be accomplished in non-immersive systems, or even in non-VR platforms (for example, a reader might get so engaged in a novel that she is present in the "world" of the book). An immersive virtual reality system may create greater degrees of presence, but presence can also be obtained in non-immersive structures, or even in non-VR systems.

Immersive virtual reality (VR) systems, on the other hand, often use 3D interaction approaches that are founded on whole-body input. To put it another way, when I want to view what is to my left, I twist my head and/or my body to the left; when I want to walk ahead, I take a step forward; and when I want to touch something, I stretch out my hand and grip it with my fingers. These natural approaches may also be improved in order to make them more useful or efficient. For instance, the user may be provided with a virtual arm that has a far greater range of motion than his actual arm [10]. The application of a tracking system is necessary for each of these strategies.

ii. **Desktop VR:** Desktop virtual reality refers to virtual reality experiences that are often run on desktop computer workstations rather than immersive VR devices. Desktop virtual reality systems and immersive virtual reality systems both employ 3D computer graphics; nevertheless, there are two significant distinctions between the two types of systems. To begin, the user just sees a single screen in front of them that displays the virtual world; it is not a 360-degree display like some other virtual environments. Second, the user normally interacts with the world and navigates around it by using regular desktop input devices like keyboard and mouse (although specialised 3D input tools may also be used). Third, the environment may be seen from several perspectives.

iii. **Fish Tank VR:** It is possible to use a desktop computer combined with a head tracker to provide a “window” into a small virtual world, so that users can obtain different views of the world using natural head motions. This has been called “fish tank VR” [11] because the effect is similar to looking into various parts of a fish tank by moving one’s head relative to the tank. The head tracking provides motion parallax information to allow the user to more easily comprehend the depth of 3D objects in the scene. Often, stereo graphics are used to enhance the 3D depth; this requires stereo glasses.

iv. **Image-based VR:** The majority of VR systems show entirely artificial (computer-generated) virtual surroundings. These settings include objects constructed of geometric primitives (often triangles), colours, and textures. However, it is also feasible to provide a virtual world that is just made up of pictures. The process of creating the appearance of a 3D environment using picture manipulation techniques rather than actually building the 3D scene is known as image-based rendering. A panorama is a collection of photos shot with a camera at a single location and directed in various directions. It is the most basic kind of image-based VR. The user may then gaze in any direction and view the relevant area of the picture since these photos can be "stitched" together to make the seams invisible.

One of the most widespread forms of panoramic virtual reality is provided by Apple in the form of QuickTime VR. Panoramas have the obvious drawback that the view can only be accurate when the viewer is standing in the same spot from where the photographs were shot. This is the panorama's single real constraint. Therefore, academics have started focusing their attention on the more broad image-based rendering issue. This problem asks, "Given a series of photos captured from many points and many orientations inside an environment, how can we construct the right perspective view from any arbitrary perspective in that environment?" [12, 13]. Image-based modelling has not yet had a significant influence on virtual reality (VR), but it is undeniably a method to enhance the realism of virtual surroundings, which is an essential factor to take into account in the building business.

v. **Highly Interactive VR:** Interaction is a fundamental component of virtual reality (VR) applications; this means that the user always has some say in the world around them. This is the quality that sets virtual reality apart from other forms of 3D media, such as still 3D photos or pre-rendered 3D animations. The majority of VR systems, on the other hand, are just walkthroughs or flythroughs; they provide the user with a pre-rendered world and let them to navigate (position or orient the perspective) through that area.

Users of highly interactive virtual reality systems are able to carry out additional activities inside the virtual environment (VE), including selection, manipulation, system control, or symbolic input. Users of highly interactive VR systems may now be able to complete tasks in a virtual environment (VE) that were previously only possible in 2D desktop systems (for example, planning a building in a VE instead of in a CAD software). This is made possible by the fact that users of VR systems now have access to 3D graphics. This transforms virtual reality from being a visualisation tool into a technology that can really produce effects in the real world. The development of user interfaces and interaction methods that are both practical and effective is the primary obstacle facing highly interactive virtual reality.

vi. **Telepresence:** Telepresence is related to VR, and involves interacting with real environments that are remote from the user [3]. Teleoperated systems are developed as a result of the need to interact with environments from a distance. This technology connects teleoperators—remote sensors and actuators—in the physical world with human operators who are situated far away from that setting. Through this connection, the operator may see and have some influence over the surroundings of the teleoperator. The result is a feeling of telepresence. The use of remotely controlled vehicles, such as robots, in risky situations, such as nuclear accident sites, or for deep-sea and space research are some of the current uses of telepresence.

vii. **VR Hardware :** A wide range of hardware technologies is used to realize VR systems. We provide a high-level overview of some of the most important VR devices here, beginning with output devices, including visual, auditory, and haptic displays, and concluding with input devices, including discrete, continuous, and hybrid devices.

viii. **Output devices:** The term display, in general, refers to a device that presents perceptual information. In VR systems, one goal is to involve as many of the user's senses as possible, so displays have been researched for almost all of the senses (visual, auditory, haptic (touch), olfactory (smell), and vestibular (motion) – we do not know of any research on a gustatory (taste) display). Here we present the three most common types of displays: visual, auditory, and haptic.

ix. **Visual Displays :** The visual display is the one indispensable piece of hardware in a VR system, and often the visual display is the defining characteristic of the system as well. There are four general categories of VR visual displays.

x. **Desktop Displays:** A simple desktop monitor, which can be seen in either the Desktop VR (section 2.2) or the Fish Tank VR (section 2.3) sections, is the most common kind of visual display for virtual reality. In order to enhance depth perception, these displays are sometimes enhanced with stereo graphics or stereo glasses; but, for the most part, they are identical to the displays that are employed by everyone who uses a computer.

xi. **Spatially Immersive Displays (SIDs:** A more sophisticated visual display device that enables the VE to seem to encircle the user or that covers the majority of the user's field of vision with the computer graphics is required to create immersive VR. One strategy is to physically surround the user with the display(s), known as a spatially immersive display (SID). For instance, the CAVE [17] employs four to six large projection panels that are arranged to form a cube that the user may enter. The user only sees the VE and their own body since stereo images are presented into the displays. Unlike some other VR technologies, the CAVE supports many viewers, although often only one viewer gets the right perspective view. Another form of SID is a dome or hemispherical display, which immerses the user by using only a single curved screen. An example of this kind of display is the HemispheriumTM [18]. A six-meter dome is used, positioned vertically. The user is seated in front of the dome, allowing the display to completely occupy his field of vision. Included among smaller domes is the elumensVisionStationTM. SIDs may be fairly expensive and often don't provide a totally immersive experience (with the exception of the 6-sided CAVE), but they can deliver outstanding presence feelings and high-resolution images.

xii. **Head-Mounted Displays (HMDs) :** The initial VR display was the head-mounted display (HMD) [19], which is another approach of establishing immersion. In HMDs, two tiny LCD or CRT displays are installed inside a helmet that the user wears on their head. Stereo graphics are possible because to the ability to independently control the two displays. The user can only see the virtual world since the HMD obscures their vision of the outside world. The user may look in any direction to watch the VE when the HMD and head tracker are used together. Compared to SIDs, HMDs may be far more affordable, portable, and provide total physical immersion. However, they often have a small display resolution (commonly 640x480 or 800x600), a limited field of vision (30-90 degrees horizontally), and may be bulky and heavy.

xiii. **Workbenches and Walls :** One flat, extremely big display surface is the simplest way to achieve some degree of immersion and a broad field of vision. Usually, this takes the shape of a screen hung horizontally in front of the user (like a workbench) or vertically in front of the user (like a wall). Rear-projected stereo graphics and user-wearable stereo glasses are used in the majority of workstation and wall displays. Even though it's not necessary, head tracking is also frequent. The screen may be turned on certain screens, like Fakespace's Immersive Workbench, to create a workbench arrangement, a wall configuration, or something in between. Workbenches and walls don't provide much in the way of immersion, but they do make it possible for numerous users to share the screen and give direct access to the data being shown.

VR in the Construction

Recent Investigations and Their Work What kinds of things may participants in a building project accomplish in a 3D virtual environment? They are able to "crawl inside" a structure and see its many characteristics and parts from any visual angle. This allows them to assess the design and make adjustments as necessary. They are able to digitally "disassemble" the components and "reassemble" them several times in order to practise the building procedure, define a construction sequence, evaluate the ability to be built of the design, and discover possible interference issues.

They are able to take an endless number of virtual inspections of the facility and experience, in a manner that is quite similar to reality, what they may anticipate when the building is finished. In this part, we will examine some of the ways that VR may be used in the construction industry. The purpose of the work described here is not to compile an entire list, but rather to provide a forum for discussing and analysing a wide variety of virtual reality (VR) applications, as well as the ways in which the technology is used in this industry.

Use of VR in Building a House

In a survey looking at technological systems used for product design, development modelling, marketing sales in the British house construction business, more than half of respondents said they had previously seen a virtual reality (VR) demonstration in the building sector. Furthermore, 76% of the the inquirer respondents said that it would take little over five years for it to be beneficial for their firm, while 82% of the the inquirer respondents thought it may be. Here are some particular outcomes:

i. Using 3D modelling and virtual reality (VR) technology early on in the conceptual design phase may be useful; this allows for the automated generation of detailed construction drawings.

ii. They were concerned that users might be exposed to views from sensitive and unrealistic angles if they were given complete freedom of movement around models in a virtual reality environment. Housing developers had mixed opinions about allowing users absolute freedom of movement around models.

iii. When communicating with local authorities, virtual reality (VR) and sophisticated visualisation techniques should be utilised with caution in order to avoid exposing the design or construction to additional problems. Whyte & Bourchlaghem [40] reported on a research trip to Japan, during which three case studies were carried out to evaluate the usage of virtual reality (VR) by Japanese home builders. According to the findings, Japanese homebuilders have recognised the value that virtual reality (VR) can bring to the building industry and have been making use of VR technology for more than three to four years.

VR in Construction Safety and Training

According to Neville [41], training is essential since it aids in preventing mishaps and harm and is beneficial for rehearsing reasons. The interactive simulated training model SAfety while constructing with virtual reality (SAVR) was developed by Barsoum et al. [42] with the goal of instructing construction workers on how to avoid falling from forum-metal scaffolding. Users have the opportunity to interact with the VE and identify potentially hazardous conditions (such as missing guardrails, sagging, weak, or uneven boards, shoddy connections between scaffolding components, and broken components) in order to attempt to fix them. HMDs are required for this interaction. The effectiveness of the participants' performances is rated using a scoring system. The SAVR system has two primary components: an erect module and an inspection module. This lesson is meant to illustrate the necessary practises that should be followed while erecting scaffolding.

The inspection tool is used to identify and address any possible issues that might result in a fall. Information in the form of 2D text and audio was included into the model to represent the Occupational Safety and Health Administration's (OSHA's) requirements. When a user approaches an operational structure in the VE from which they might fall, warning messages (also known as needed safety standards) are shown or broadcast. These messages provide the required safety standards.

Using VR for Project Planning and Monitoring

Even if contemporary software for managing projects makes it easier to generate and evaluate project schedules, the 2D symbolic representations of these plans make communication amongst the parties involved challenging and prone to error. Retik [44] came up with a strategy to address these problems by using a computer-based system for visual scheduling and tracking of the various building stages. The technology enables the generation of a "virtual construction project" based on a timetable, as well as the subsequent observation of and involvement with the simulated project's progression.

The Virtual Construction Site (VIRCON) is currently being developed as part of ongoing research at the University of Teesside in the United Kingdom [45]. VIRCON is a prototype programme that allows for the assessment, visualisation, and optimisation of construction schedules inside a virtual reality interface. A project database, analysis and decision support parts to process time critical and space critical tasks, and a visualisation component to communicate the project's database and evaluation results through an array of interconnected graphic windows are the three primary components that make up the structure of the VIRCON system.

The creation of integrated building management systems in a virtual reality environment was described by Mahachi et al. [46]. This was made feasible by the incorporation of a cost forecasting approach into the project management scheduler as well as the use of genetic algorithms for the purpose of site-layout design. The virtual reality (VR) component of Primavera P3TM is integrated to make it possible to simulate construction scheduling in real time. This gives the project planner the ability to monitor the development of the building operations on site. A Construction Visualisation System (also known as 4D-VR or 4 Dimension-VR) was suggested by Kim et al. [47].

The system was developed with the intention of being used for the administration of milestone schedules and comprehensive activity control throughout the execution of big and complex projects. The software architecture of the system is composed of five distinct modules, which include 3D CAD modelling, VR modelling, processing of schedule data, integrating graphic data to schedule data, and visualisation output modules.

VR for Site layout Planning

Boussabaine et al. [49] developed and constructed a functional prototype system for virtual reality use to mimic the arrangement of amenities at a building site. The prototype is designed to be of assistance to project managers in the process of creating a site that is both safe and efficient. Users are given the ability to construct their own site plan environments inside the system, manually choose and position items that represent the facility and equipment, and generate walk-throughs to inspect the virtual facility.

VR as an Analysis Tool

In order to provide a solution to the issue that the pre-cast concrete products sector is now dealing with, Dawood with Marasini [50, 51] devised a model that incorporates visualisation and simulation. On the stockyard, there are issues with space congestion and lengthy truck waiting times, which are problems for both the storage of concrete goods and their recovery. The visualisation model was built with the help of ILOG Views, and the simulation model was developed with the help of ARENA / SIMAN, which is a general-purpose simulation language.

Conclusion

By creating a computer code in a programming language (like C++) or by using any CAD software (like AutoCADTM), you may resolve a problem in computer graphics that involves drawing three-dimensional (3D) objects. In a computer animation challenge, the fourth dimension of time is introduced, and the goal is to make objects move in a three-dimensional visual environment. Writing high-level programmes is required to implement anything, but in most cases, computer graphics libraries are used to make this process easier. Because it enables the modelling and animation of objects inside the same environment, an integrated animation system has the potential to make the development process simpler. Virtual reality challenges are much more challenging to address since they call for the development of a 3D environment that is not just animated but also dynamic and operates in real time. Virtual reality involves the potential for actual engagement with all of the elements of the virtual domain, rather than just moving about in a virtual environment to see a model from a different angle [2]. This might mean touching things directly, moving them to other spots, altering their sizes, modifying the lighting, and other similar actions. In this article, we took a look at some of the work that is presently being carried out to adopt VR in the construction industry. Because of constraints on both time and space, this article does not go into detail on the vast majority of the other work that is currently being done. However, there is a significant amount of work that has to be done in this subject in order to explore its vast possibilities, which may be of significant value to the building industry as a whole.

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