Visualization of Heliostat Field of Solar Thermal Tower Power Plant Using Virtual Reality (VR) Technologies

DOI : 10.36909/jer.ICEPE.19545

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ABSTRACT

An important part of future global energy depends on the development of the solar industry. To date, we have noticed the shift from fossil fuels energy towards renewable energy. The past decade has shown significant progress in computer science and CAD is increasingly used for design and development. Visualization of the data generated from the models in the CAD program plays an important role in the creation of state-of-the-art designs. An important limitation during the design phase is the visualization of three-dimensional geometry. This article attempts to illustrate the use of VR technologies in solar thermal power plant development. This article analyzes various strategies and methods for the visualization of CAD models in virtual reality. Android phone interfaces with a desktop computer, as well as head movement control strategies, are discussed. It is concluded that VR technologies can help with visualization, as well as in the development of the field of solar thermal power plants, having minimal design-related issues.

Keywords: Virtual reality; Solar thermal power plant; Design; CAD; Heliostat.

INTRODUCTION

VR is one of the major fields of study where we can attain every design with its maximum output by computer-generated virtual relations. The latest innovations in virtual reality content platforms, hardware, and production tools have transformed virtual reality into expertise developed primarily in the video game community (Mahboob et al., 2017; Qidwai et al., 2019; Schnack et al., 2019; Tussyadiah et al., 2018). To create models that simulate visual effects and interact with processes, three-dimensional and virtual modeling methods are used (Mahboob, K. et al., 2018a; Mahboob, K. et al., 2018b). When modeling three-dimensional environments, content should be displayed explicitly when objects are displayed, and the details of each of these objects should correspond to the goals that the designer intends to use with each specific model. In addition, due to the possibility of interaction between all parties participating in each constructive event, the use of VR technology can increase the efficiency of the model, such as for solar thermal tower power plants (Ardila et al., 2018; Lorenz et al., 2016; Mahboob et al., 2021). Virtual reality allows users to recognize real situations by providing an environment for receiving information in multiple sensory modes such as vision, hearing, and exercise (Hirota and Tagawa, 2016; Laycock and Day, 2007; Rose et al., 2018; Rummukainen et al., 2018; Siegel et al., 2016). For example, if you are a person, you can walk into the lobby. Therefore, the user's perception of the virtual reality environment depends on possible actions (Bowman et al., 2008). Virtual reality allows users to enter almost-replicated scenes depicting the situation. The situation is created as a virtual machine graphical environment that can be added online to a virtual world and displayed on immersive systems such as screens or head views. This is especially useful when calculating the depth of a user's true view. In addition to signal recognition algorithms, a tracking system can also transform normal body movements into functional interaction methods (Billinghurst et al., 2015; Huang et al., 2018; Larsen et al., 2018; Turnbull et al., 2019; Wang and Chen, 2019). Some of recent VR progress and applications in different fields are presented in Table 1.

Table 1. The current progress and application of VR technologies in different fields of Science

Field	Reference	Subject	Technology	Conclusion
Academics				
Learning	(Sun et al., 2019)	Different UI design options based on VR application for enhanced learning performance in architectural education.	HTC Vive	By setting proper observation, scale UI designs based on virtual reality can contribute to enhanced learning performances.
Education	(Sorguç et al., 2017)	The VR's role in Computational design education	VLE	A virtual learning environment is implemented
Training	(Wang et al., 2018)	The Use of VR in education and training of Construction engineering	VR and AR	A detailed review of Immersive VR and AR technology in construction sector training and education is carried out
Engineering				
Design	(Kim et al., 2021)	VR applications for the design phase of engineering construction and architecture based on Building information modeling's	BIM-based VR technologies	Successfully integrated Building information modeling based VR applications' evaluation application and consistent results obtained

		evaluation framework.		
	(Özgen et al., 2021)	A comprehensive study of VR usage in the basic design education with paper-based design	HMD, Oculus Rift DK2 with two sensors and two controllers	Problem-solving activities enhanced by the use of VR technologies in the interior architecture
Product development	(Mahboob, A. et al., 2018b)	VR environments using SysML models for product evaluation	SYSML, VR	SysML model developed, simulations were carried out, and VR user cases were constructed to provide the simulation processes overview.
	(Mahboob, A. et al., 2018a)	Use-Case Scenarios during Building Product using different VR Systems	MBSE, CAVE, HMD	Compared to CAVE, HMD provided a cost-effective solution using virtual reality technologies.
Simulation	(Neugebauer et al., 2011)	The energy-efficient products development using VR tools	FE algorithm, VR	The algorithm usage in a virtual environment is carried out by programming interface implementation.
Construction	(Tretyakova et al., 2019)	Geometric modeling of building forms using BIM, VR, AR technology	QR code, VR, AR, BIM	An information building model was created with the help of a graphic program using VR and AR technologies.
Operations	(Freund et al., 2001)	The excavators' simulation using virtual reality technologies for construction machines: The usage of VR simulators from training to telepresence systems	VR	Implementation of virtual world project to reality using projective VR.
	(Mahboob et al., 2019)	The creation of product uses cases using SYSML Behavior Models in Virtual Reality	SYSML	SYSML behavior models reuse is facilitated by adopting a new modeling approach to develop different product use cases in VR.
Manufacturing	(Ong and Nee, 2004)	VR and AR applications' brief introduction in manufacturing	VR and AR	A complete book covering VR application for different manufacturing processes
Quality	(Wickman et	Combination of	CAT/VR	CAT/VR tools are used in the

control	al., 2003)	CAT and VR technologies for non-nominal geometric verification virtually	tool	virtual verification and decision-making for the rear end of a vehicle.
Safety	(Loupos et al., 2007)	VR and Human Factor Technologies use for Industrial Safety improvement	Delta 3D framework	Industrial safety factor improvement by the development of a 3D interactive distributed system
Industrial assessment	(Dücker et al., 2016)	VR environments' efficiency analysis methodology for Industrial Applications	Wave methodology for VR	VR integration into two mechanical engineering sector companies paved the way for the proposed assessment methodology.
Medical				
Therapy	(Camporesi et al., 2013)	VR solutions for the physical therapy improvement	Microsoft Kinect, Immersive setup	The VR system is implemented for both low-end Kinect and high-end Immersive
MRC	(Trelease et al., 2000)	Anatomical structures' dynamic visualization using quick time VR	QuickTime VR	For light and electron microscopy, presented the practical application.
Sports				
Physical	(Ochi et al., 2016)	The rich sports experience using Virtual Reality technologies	Kirari for Mobile	The technologies are demonstrated to show their potential application to sports.
Games	(Ferdani et al., 2020)	Historical site (Forum of Augustus) 3D construction and validation for games and immersive VR applications	HMDs (e.g. Oculus Rift)	3D assets are accurately produced using interactive, immersive VR products.
Entertainment				
Film	(Pair et al., 2003)	Hollywood set design combining techniques with virtual reality	FlatWorld, Digital projectors	FlatWorld viability to immersive simulation approach in a room

Exhibitio n	(Skulimowski and Kayumov, 2020)	Museum exhibition using VR technologies: Silk Road museums case study	Smartpho ne, HMD	Spectators accepted the technology as a complement to the traditional exhibitions
Tourism	(Karadimas et al., 2018)	AR/VR technologies' potential applications in Cultural Heritage.	BIM and AR/VR	Web/Mobile App development offering virtual site tour guiding.
Business				
Enterpris e	(Heinonen, 2017)	Different technologies of VR and AR for adoption in the enterprise	VR and AR	Adoption of VR in design is most favorable, in sales and marketing less adoption at the moment but can be increased in the future.

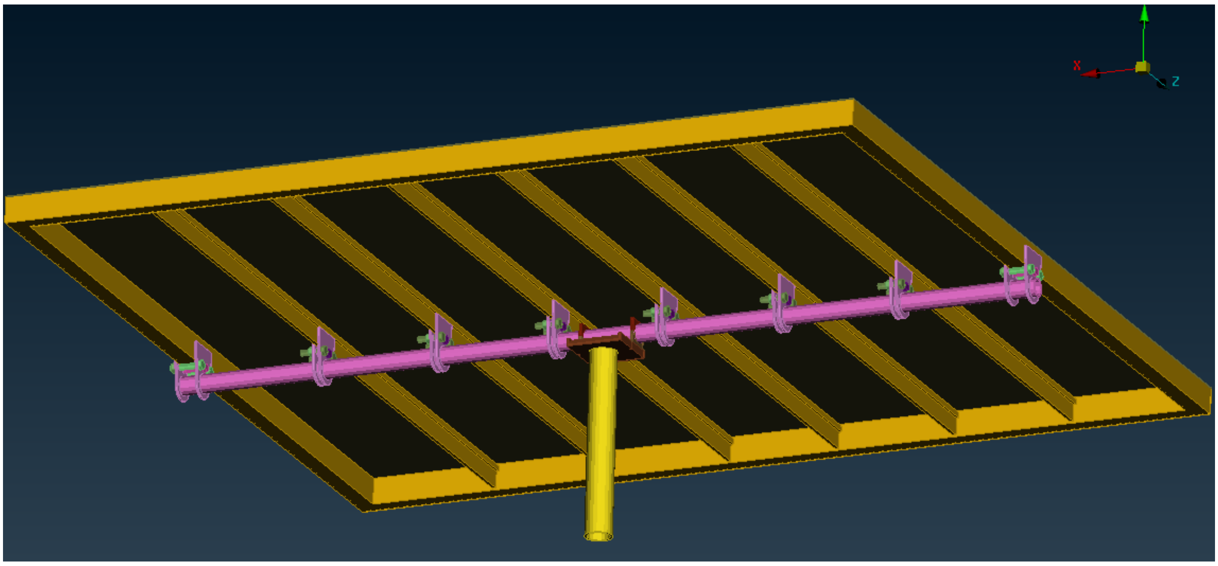

Figure 1. Heliostat of Solar tower power plant

HELIOSTAT MODELING

The modeling of different types of components is carried out using computer-aided design (CAD) software as shown in Figure 1 for Heliostat. Surface or solid modeling is performed on software such as CATIA, SolidWorks, ANSA, etc. As the assembly is made, it will help us to understand its geometry and body kinematics, which will be helpful in a detailed study. VR software accepts different types of exchange files such as Obj, VRML, STL, JT, etc. Assemblies were converted into this format using these software as shown in Figure 2.

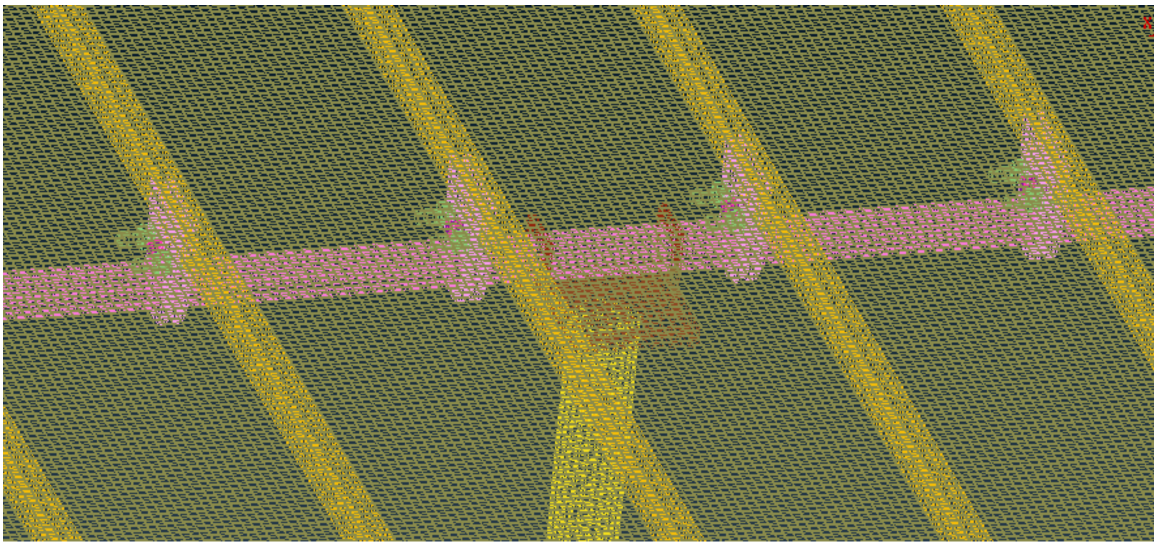

Figure 2. Heliostat Solar Obj. Model

MODELING TO 3D VISUALIZATION

If a CAD model is to be visualized into a 3D visualization, then it is necessary to understand every step to bring its format to the 3D world. First, it must be understood which file formats are required by Unity. Unity is then used for its model development, and after that, it is pushed for 3D visualization. The headset can be used for the visualization of the CAD model of the solar thermal tower power plant's heliostat.

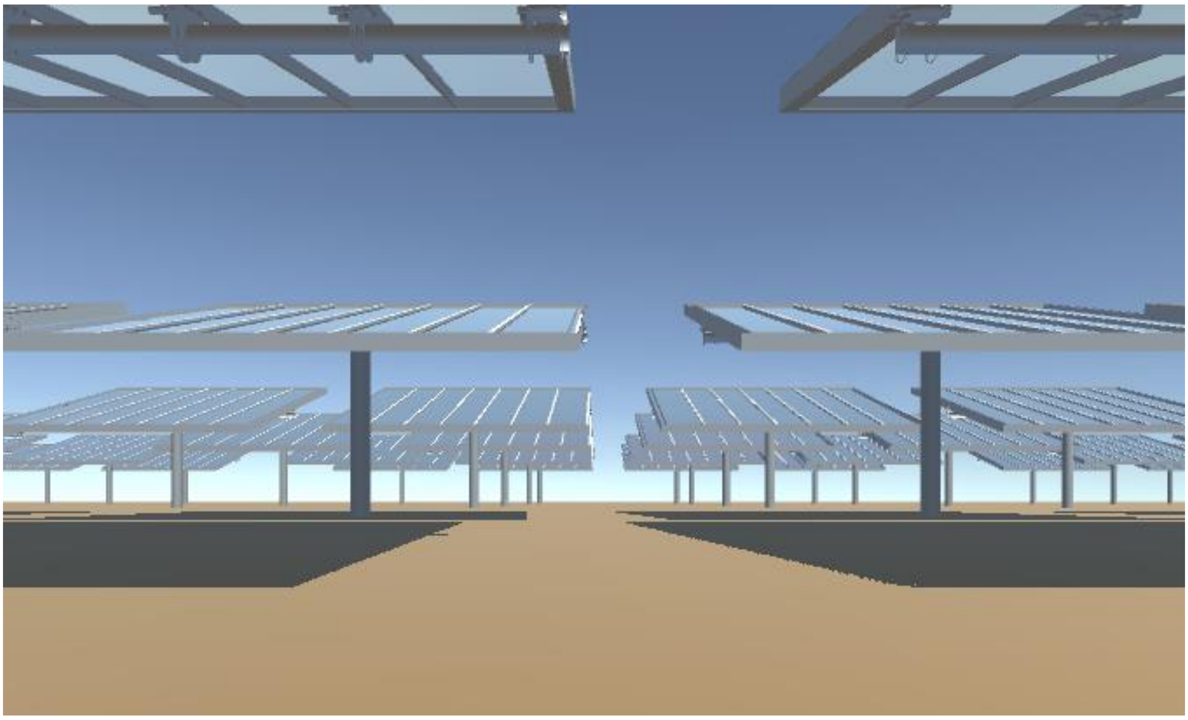

Figure 3. Solar field of CSP plant

Steps Involved for Modeling to 3D Visualization

For 3D visualization, different software can be used, but one should be used that will help us to understand every step of the kinematics in Unity. Geometry exchange formats such as VRML, OBJ, JT, STL, etc., are supported by presently available VR software.

Domain Flexibility Adjustments

For environmental variations, 3D Cube is used for its ground visualization, and its material is changed according to user demands. Static and dynamic friction has been brought to zero, which helps the smooth movement of different objects. Ground width and length are selected according to the desired area. In the field in which the model is placed, its variables are also altered appropriately. Other factors such as light and camera position, which affect visualization, are also fine-tuned.

Player Settings in Unity and Smartphone

An Android Smartphone is used to visualize so build settings are altered to Android in Unity. The smartphone is changed to developer mode to push an app to its domain. Player settings are changed by changing them to the Android nugget set, and PC settings are alternated to Android. After settings are finalized, the app is pushed to the Android Smartphone with the help of Android Studio so the model can be visualized. The app is pushed by connecting the Smartphone to the computer with the help of Unity.

Visualization Methods

<u>2D Visualization</u>

By utilizing the “build and play” feature inside Unity, the model can be visualized in the camera rendering window in a 2D setting as shown in Figure 3.

<u>3D Visualization</u>

Two techniques can be used for three-dimensional visualization. In the first technique, a three-dimensional screen is used with polarized glasses for visualization. Examples of this include cave type or power wall. The other technique involves using a VR headset, such as Google cardboard. It is evident that visualization in 3D is much better than in 2D.

MOVEMENT CONTROL

Three main properties are used to move the player or camera inside Unity. For that camera, a script is added to move it for the required motion function.

Euler Angles

Euler angles give the player or camera rotation around its axis. This code enables us to visualize the environment in all 360 degrees. Instants at the back can be seen easily.

Character Controller

The character controller moves the character without the use of a rigid body. It is limited when there are collisions, but it is not affected by environmental forces.

Simple Move

Mono behavior of the controller is given, which updates the speed of the controller and rotation speed. It is set accordingly so that it does not speed up or slow down.

Figure 4. Smartphone and computer control

INPUT METHODS

Smartphone Control

In Smartphone control, the main focus is the combination of smartphone and headset, in which movement is controlled by the Smartphone as shown in Figure 4.

Computer Control

For controlling the view in the Smartphone through a computer, computer control is used as shown in Figure 4. This helps place the objects in a required place in the correct view.

CONCLUSION AND RECOMMENDATIONS

This article discusses VR technologies and detailed applications. This study demonstrates that VR technology can be effectively used in solar tower power plant components' design processes. An inexpensive 3D method was developed using a VR headset. In addition, using VR for visualization can bring the scene closer to reality. VR technology improves design efficiency, minimizes errors that can occur during development and production. Other advantages of this technology in the field of CSP are heliostat shade visualization, cleaning strategies, space optimization, and maintenance strategy. Finally, it can be concluded that future design and development processes can be redesigned using virtual reality technology. High-resolution models are recommended for perfect visibility.

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