Design of Interactive Virtual Reality for Erection Steel Construction Simulator System Using Senso Gloves

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Abstract – In steel construction, some stages demand a learning process first to understand the functions and procedures that will occur. The erection process in steel construction is a process of assembling steel components so that it becomes a unity that will be carried out in the field. When carrying out steel as part of erection activities, there are huge potential risks to employees, subcontractors, or other personnel within the construction area, therefore it requires intensive training before real work done. Various methods can be done to facilitate the teaching of the erection process in steel construction; one of them is by using a simulator. A simulator system that uses hand gesture readings and haptic feedback is the best choices of learning methods to help the learning process of erection in steel construction. Virtual reality is an option to be applied the desired simulator system. With virtual reality, users can utilize cognitive and motor skills to interact with the system. The cognitive and motor skills are increasingly driven by control devices like senso gloves that can read and display the motion at the system interface in the same time. In addition, the addition of haptic feedback in the form of vibrations at each fingertip of the glove makes the simulation closer to reality. The purpose of this study is to design the use of motion control Senso Glove as a tool in developing simulator for the erection process learning in steel construction within a virtual reality environment.

1. Introduction

The erection process in steel construction is a process that consists of assembling steel components so that it becomes a unity that is carried out in the field [1]. The steel erection process involves at least a crane to raise steel. Crane control requires learning exercises to reduce failures that can occur. In addition, erection learning in steel construction can also increase productivity. Increased productivity leads to many time and cost savings in steel structure projects [2].

During the steel erection process, project facilities and fields must consider the nature of the work, the layout of the worksite, and the condition of the project site. Routine inspection and management of steel erection activities will be carried out to ensure that hazards will not occur in work processes, materials, or equipment. Steel erection operations can pose many risks for employees, subcontractors, or other personnel involved when carrying out steel erection activities. All materials, equipment, and equipment at a height that is not currently in use must be secured from accidental removal [3].
The use of cranes to build steel structures and related components is considered the best safety practice [4]. Cranes offer different advantages over forklifts and are the preferred method for erecting and establishing steel structures and related components effectively and efficiently. To reduce the risk of accidents that can occur in the project field, crane drivers have an important role. Learning process for crane drivers can be done through a simulator. Utilization of steel construction erection simulators that focus on the use of cranes will further enhance work practices in terms of safety.

Virtual Reality is more than interacting with the 3D world. By offering user simulation of attendance as an interface metaphor, this enables operators to perform tasks in the distant real world, the world that produces computers or a combination of both. The simulated world does not have to obey the laws of natural behavior. Almost every field of human activity can be a candidate for virtual reality applications. We can identify several application areas whose benefits are more comfortable than others.

Senso Glove can be used a gesture for crane control in the erection process in steel construction. The reading of hand movements through Senso Glove will be used as input to the system. The results of the hand and finger movement readings from Senso Glove will be displayed in the Virtual Reality environment as left and right virtual hands. With virtual hands, users can interact directly with crane controls to raise steel in an erection simulation. Previous research has been conducted in the form of excavator simulation using the Leap Motion Controller [5] and anatomy learning using VIVE controller [6], but the research still has shortcomings in the form of haptic feedback [7]. With Senso Glove, it is expected that there will be appropriate haptic feedback in the simulation system in a virtual reality environment to increase interaction between humans and computers. The purpose of this study is to design the use of motion control Senso Glove as a tool in developing simulator for the erection process learning in steel construction within a virtual reality environment.

2. Material and Method

The series of steps to implement the system starts from the input data in the form of observations of hand and finger movements by Senso Glove. A three-dimensional object will be displayed following the movements of the hand, whether right hand, left hand, or both. All hand movements will be displayed as precisely as possible in the user interface. In the event of a collision in the steel when raised by the crane by the user, haptic feedback will be sent to the user in the form of vibration at each fingertip.

The input of this system is in the form of hand movements captured by Senso Glove. Senso glove is a device that supports the reading of the position of the hand with a unique precision using a three-dimensional tracker on each finger. Senso Glove is a glove that does not require an external sensor such as a camera for tracking. By using inertia sensors on each fingertip, Senso Glove can measure finger and hand movements. This is what makes Senso Glove cheap and easy to calibrate, despite sacrificing its precision [7]. Senso Glove also has haptic feedback in the form of a vibrating motor at each fingertip. Senso Glove uses a Bluetooth connection to be able to connect with a computer, so it doesn't need cable or wireless [8].

The process in this system is the appearance of a virtual reality environment that resembles a steel construction site. The user is inside a virtual crane and will operate the crane using a virtual joystick that will be grasped by a three-dimensional object that is derived from the reading of hand movements through Senso Glove. The output of the system is the process of raising erections on the steel construction through the crane by the user.

The process of displaying virtual reality is created by using an application called Unity 3D. The use of Unity 3D can connect computers with virtual reality headsets. For HTC VIVE, OpenVR library was used. In its primary state, OpenVR and HTC VIVE use the VIVE Controller as control of the system. However, the VIVE Controller is a pair of joysticks that are held by both hands on the right and left, respectively [6]. By using the Senso Glove, users can replace the VIVE Controller function. The user's hands and fingers can also move more freely as seen in figure 1. In addition, with haptic feedback it is expected the Senso Glove able to increase the level of human interaction with computers.
When the gloves and VR were used, users will feel the sensation of virtual reality that displays as on the construction site. Users are inside a virtual crane with virtual hands as control. The user's hand can move freely and does not have to touch the controls contained in the crane. When the user moves the deepest controls in the crane, the crane will move according to the function of the control device.
The construction sites, steel structures, and cranes, such as those in Figure 2, are all three-dimensional objects to enhance the immersive element of the system. The three-dimensional objects will be displayed on the screen of the virtual reality headset. The process of loading and rendering objects will be carried out when the system starts. All other objects that are only for display purpose such as background will be three-dimensional static objects which cannot interfere with the process on the system. Meanwhile, three-dimensional objects such as virtual hands, cranes, and steel are three-dimensional objects that are dynamic in nature and are given a program according to their function. The crane will move according to its control. The steel connected to the crane will follow the movement of the crane's arm. The virtual hand will follow the hand movements using Senso Glove. The dynamic three-dimensional object movements will run directly.

The user will be asked to move the crane so that the erection process in the steel construction can take place. The erection process in steel construction starts from taking steel in a location that has been provided. After the steel is connected to the arm of the crane, the user is asked to erect the steel to the steel structure that is available but not yet finished. The user then will be asked to complete the steel structure. If there is a collision between the steel raised by the crane with particular objects, feedback in the form of vibration will be felt at each user's fingertips. The system will stop when the erection process is complete, and the series of steel structures have been arranged.

3. Results and Discussion
The results of this study are a design of simulator of steel erections in a VR environment with the user's viewpoint as a crane driver. Hand movements with Senso gloves were successfully explored. Hand movements and fingers of users who use Senso Glove were used as input by the system. When the user's hand gripped one of the levers or joystick to control the crane, the lever or joystick then moved in accordance with the direction of the motion of the hand holding it.

The function of all features, including joystick and levers, are explained in table 1.

| Features            | Function                                                                 |
|---------------------|--------------------------------------------------------------------------|
| The right lever     | To move the right mobile-crane wheel                                     |
| The left lever      | To move the left mobile-crane wheel                                      |
| The right joystick  | To move the pole to go up or down when moving left or right              |
| The right joystick  | To move the anchor to go up or down when moved back or front             |
| The left joystick   | To move the top of the crane to rotate counter-clockwise when left or    |
|                     | clockwise when right                                                    |

Figure 3. VR display when the system running
In the VR view, the user only gets the display from inside the crane. Steel structures that must be completed in the system were given attention in the form of twinkling silhouettes to attract the user's attention. A part of the steel structure that has been arranged was displayed as an example of the ultimate goal of the system that must be implemented by the user. The steel structure foundation had been arranged, and the user's first task was to place the steel in a vertical position on the foundation. After all the vertical steel was placed, the twinkling silhouette for the horizontal steel leveling was displayed. The user's job was to place the steel in the silhouette. After all steel were installed using a crane, the steel erection simulation then had been completed.

There are some benefits of this research, first it produced a design of an erection simulator system on existing steel construction that is interactive and immersive with the user, it provides more understanding in implementation Senso Glove in a system and finally able to provide solution to reduce cost use compared to some erection process simulations in existing steel construction. Even so, the erection process of steel construction in the real world is far more complicated and complex than the simulators found in this study [9]. The steel erection process can not only be simulated by the use of a crane by one user. Some further research is needed to perfect the steel erection simulator that is getting closer to reality.

4. Conclusions
Applying virtual reality and senso gloves controller to design the steel construction erection simulator adds an interactive level to the system. The use of haptic feedback enhances the atmosphere of reality in a virtual environment. In addition to the sense of sight, the sense of touch can be triggered on a virtual reality system by using haptic feedback in the form of vibrations in the Senso Glove. It also supports to increase the interactive level of the system.

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