An Assessment of Suitable Axes for Model Assembly in the Cyber-Physical Factory by Using a Virtual Reality Platform

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Abstract: This research aims to assess suitable axes for model assembly in a cyber-physical factory by employing a virtual reality platform in collaboration with the studio program. This research involves the assembly of cyber-physical model libraries. The model libraries are factory and application, which consist of a high-bay warehouse, module drill, camera inspection, robot assembly station, module back cover, module muscle press, and module turn. In this experiment, a gyroscope sensor uses to record wrist movements and assess the experiment's satisfaction. The 30 participants had less experience using the virtual reality platform. From the results of this experiment, the participants accept that the use of the virtual reality platform is satisfactory and highly effective for virtualization. Working in a sitting position has obstacles and is inconvenient to experiment with; using a virtual reality platform can prevent damage to equipment and ensure operators' safety before actual operations.

Keywords: Assessment assembly, Cyber-physical factory, Virtual reality

1. Introduction

The industrial revolution is experiencing an automated digital transformation due to software development and information technology [1], as well as the exchange of information during production. This change is called the Fourth Industrial Revolution, or Industry 4.0, and means creating a smart factory [2] that leapt automation to fully connect to the system. It is flexible and can be adapted to suit any particular system. Industry 4.0 is the transformation of traditional manufacturing into an industrial revolution with cutting-edge innovative technology [3] and is a form of industrial management that combines information technology with industrial technology. Industry 4.0 consists of cyber-physical systems, the Internet of Things, and cloud computing [4]. These focused on the use of advanced automation machines. The machine-to-machine communication and the use of devices connect everything to the internet world [5]. It is to increase the efficiency of automation to improve communication and self-monitoring, including intelligent machines [6] that can analyse and diagnose problems without relying on humans. The development of Industry 4.0 is a new concept that requires industrial reform by developing technology to communicate with machines [7] and production systems in the form of industrial automation.

Currently, manufacturing execution systems 4 (MES 4) for cyber-physical (CP) factories are commonly used in education and industry [8].

MES 4 is a specially prepared manufacturing execution system with a new design for Industry 4.0 learning platform that can be started or finished at every station [9]. The cyber-physics factory is the science and knowledge that plays an essential role in industrial automation [10]. It is one platform that can study the simulation of the automatic control system. In addition, it can support programs or settings automatically, as well as being able to mounted and movable. The application of such technology is rapidly expanding exponentially, especially in the automotive, aerospace and other industries. Intelligent factories use interface technology and artificial intelligence as the basis [11]. The combination of these technologies creates a more realistic context that includes; virtual, augmented, and mixed reality, in which these technologies can make connections between humans and devices. Furthermore, there is a tendency to use virtual reality technology to step into the real world widely [12]. Virtual reality technology is a simulation that can be wholly similar or different from the real world, which is trending and very popular and can drive Industry 4.0. However, virtual reality technology has some limitations in different environments. Nevertheless, virtual reality technology also has many benefits for security tasks.

The research is the application of a cyber-physics factory with a virtual reality platform to assess the module assembly of a manufacturing execution system for the dummy mobile phone manufacturing process. It has a production line station consisting of 7 main stations as follows: (1) front cover black, (2) printed circuit board, (3) black front cover with printed circuit board no fuse, (4) double fuse, (5) black front cover both fuses, (6) back cover black, and (7) mobile phone assembly is complete, which is all shown in Figure 1.

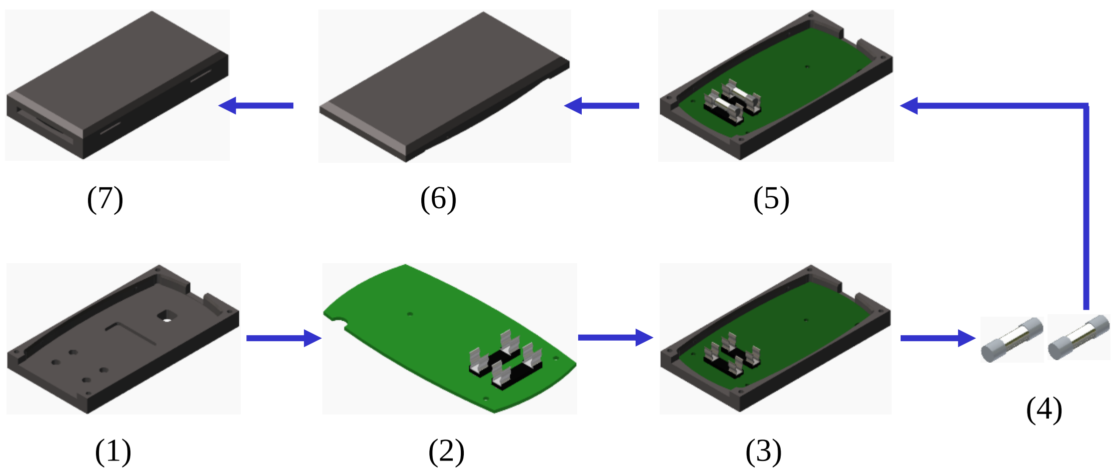

Figure 1: The dummy mobile phone manufacturing process.

Figure 1, the manufacturing mentioned above process consists of 7 main modules as follows: 1) CP factory high-bay warehouse, 2) CP application module drilling, 3) CP application camera inspection, 4) CP factory robot assembly, 5) CP application module back cover magazine, 6) CP application module muscle press, and 7) CP application module turn, as shown in Figure 2.

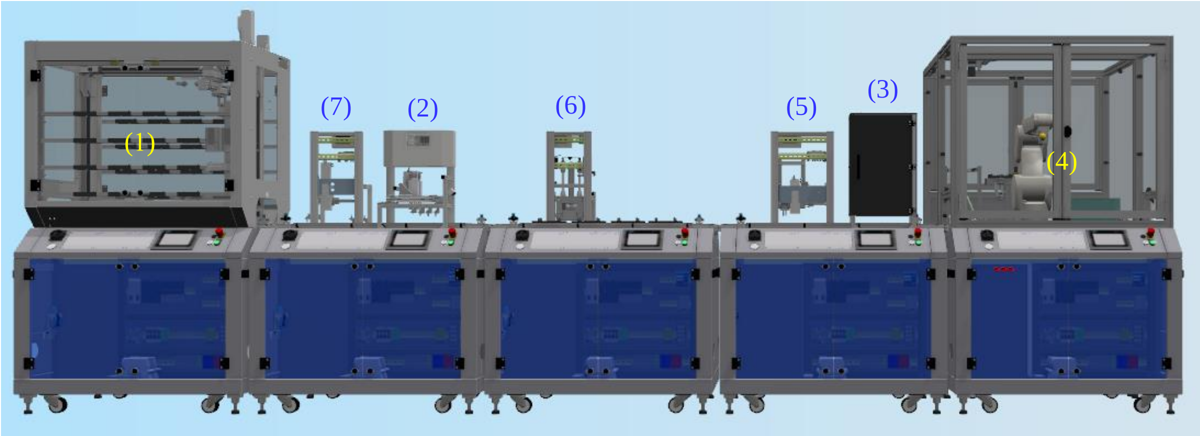

Figure 2: The cyber-physical factory for dummy mobile phone manufacturing process.

From figure 2, the assembling of the dummy mobile phone manufacturing process consists of the following steps: 1) release a defined part on stopper, 2) drill both, 3) check part with the camera, 4) assemble a printed circuit board with both fuses, 5) feedback cover from the magazine, 6) pressing with force regulation, 7) turning part, and 1) store parts from stopper.

2. Materials and Methods

Design assessment and production planning in a cyber-physical factory for the dummy mobile phone manufacturing process, which the research methodology consists of the following components: manufacturing execution system 4 & virtual reality platform (MES 4 & VRP), participants, activities conducted, system elements, and environments. The research structure and methodology are explained in detail next section, and the procedures for this research as shown in Figure 3.

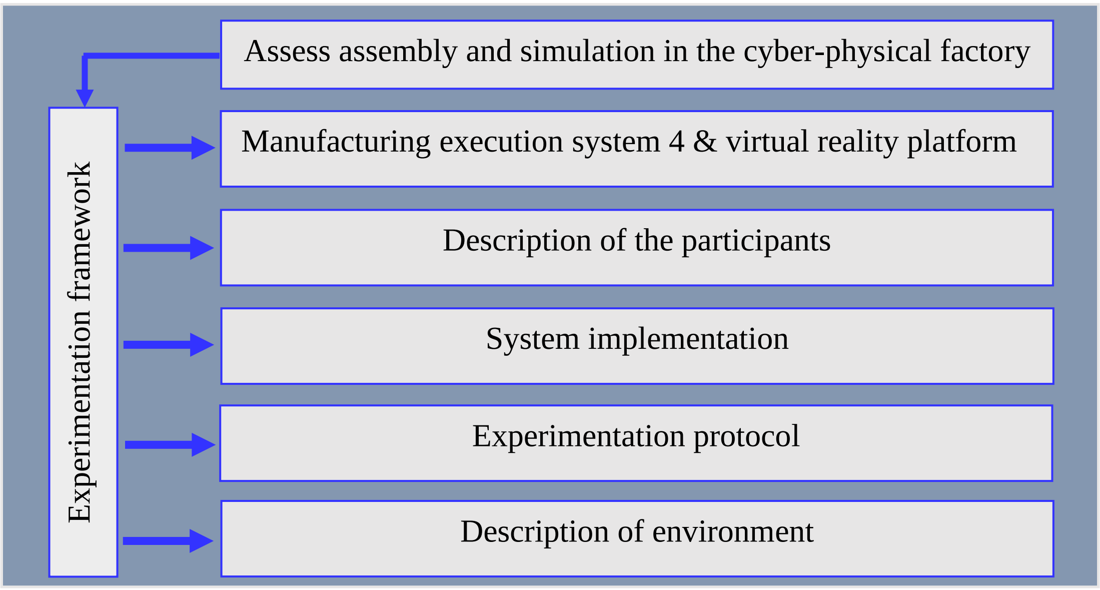

Figure 3: The structure and research methodology.

2.1 Manufacturing execution system 4 & virtual reality platform (MES 4 & VRP)

This topic is the integration of technology interconnection between manufacturing execution systems and virtual reality platforms [13]. In this context, there is a connection between the CIROS Studio and the STEAM VR program. An essential role in this context is implementing methodology to connect two systems. The aim is to enable activities to perform following the research objectives.

2.2 Description of the participants

Participants or users are students and educational personnel without experience controlling the manufacturing execution system, automation, and virtual reality platforms. The reason for choosing the inexperienced trial participants was that the validity of the assessment based on the actual characteristics of the participants or users was more transparent than the experienced individuals. The experimental participant or user receives an introductory level of training and must comply with the required conditions for the experiment protocol. To understand the working principle and the actual operation in a systematic and step-by-steeply. Once the participants understood the principles of experimenting, they began assembling the modules of a cyber-physics factory using virtual reality technology. The postures used in the experiment consisted of two poses: a) sitting and b) standing, shown in Figure 4.

a) b)

Figure 4: The postures used in the experiment.

2.3 System implementation

There are three primary components of a virtual reality system to drive research operations, which consists of the following: the primary VR devices, STEAM VR, and CIROS Studio software. *The first*, primary devices used with the Steam VR program include the following: head mounted display, base stations, and controllers. These devices can be created from anywhere in a 3D space into a virtual system and display the device status and real-time display. *The second*, STEAM VR will provide a system for connecting virtual reality interaction devices with humans and environment. *The third*, CIROS Studio software is a professional module modelling tool for creating the world's most efficient development platform industry. In addition, CIROS Studio software can integrate into one tool for 3D modelling, simulation and programming.

2.4 Experimentation protocol

Activities carried out in this research include assembling various modules of the cyber-physics factory according to the specified conditions. Before conducting the experiment, participants must be trained to learn the experimental procedures clearly from an expert. Once the participants understood the experimental process. The experts then advised participants to complete at least a few rounds of the experiment, but data or results were not recorded. When the participants are fully confident, they are then allowed to perform actual experiments and record their experimental data. Incidentally, the assembling modules of the CP-Factory by adding models from the Manufacturing Execution System 4 (MES 4) program contained in the primary model libraries model named "CP Model library V.04b". There are two main types of CP-Factories which are: CP-Factory and CP-application. The experimental participants were to perform the following methods and procedures, as follows: *The first step*, the participants had to prepare their workspace on the computer screen by setting the standard view. Furthermore, downloading the entire CP-Factory models with placing it in the top view position, which includes the following models: 1) CP Factory High-Bay Warehouse (CP-F-ASRS32-P) quantity 1 model, 2) CP Factory Conveyor Belt (CP-F-LINEAR) quantity 3 models, and 3) CP Factory Robot Assembly Station (CP-F-RASS) quantity 1 model, which such activities are shown in Figure 4.

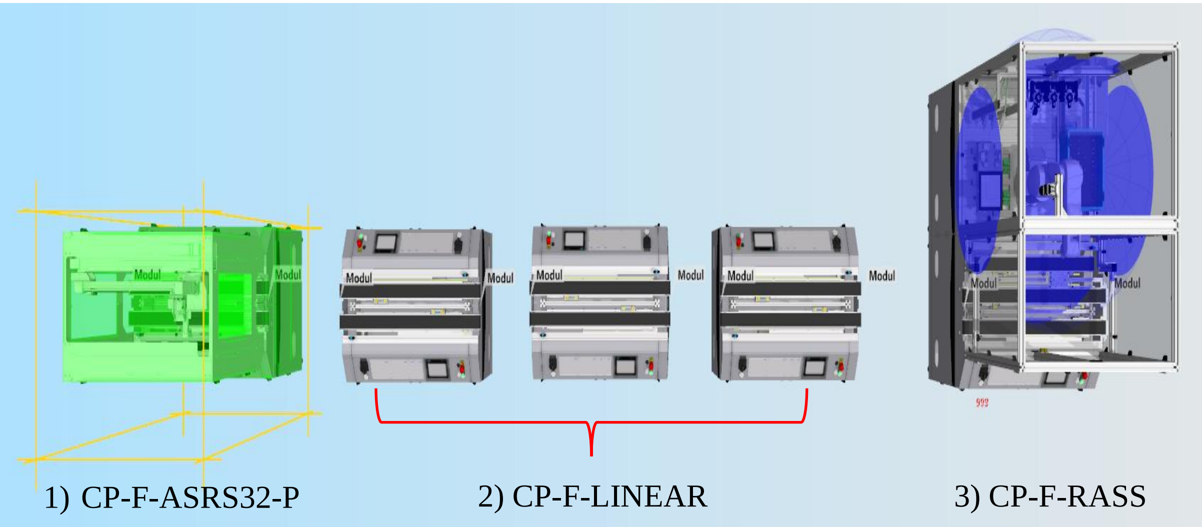

Figure 4: The CP-Factory models are in the top view position.

In the second step, the participants downloading the entire CP- Application model with placing it in the front view position, which includes the following models: 1) CP Application Module Turn (CP-AM-TURN), 2) CP Application Module Drill (CP-AM-DRILL), (3) CP Application Module Muscle Press (CP-AM-MPRESS), 4) CP Application Module Back Cover Magazine (CP-AM-MAG_BACK), and 5) CP Application Camera Inspection (CP-AM-CAM), which such activities are shown in Figure 5.

1) CP-AM-TURN, 2) CP-AM-DRILL, 3) CP-AM-MPRESS, 4) CP-AM-MAG_BACK, 5) CP-AM-CAM

Figure 5: CP- Application models

In the third step, the participants had to download and position the CP- Application model from Figure 5 over the CP-Factory models from Figure 4, as shown in Figure 6.

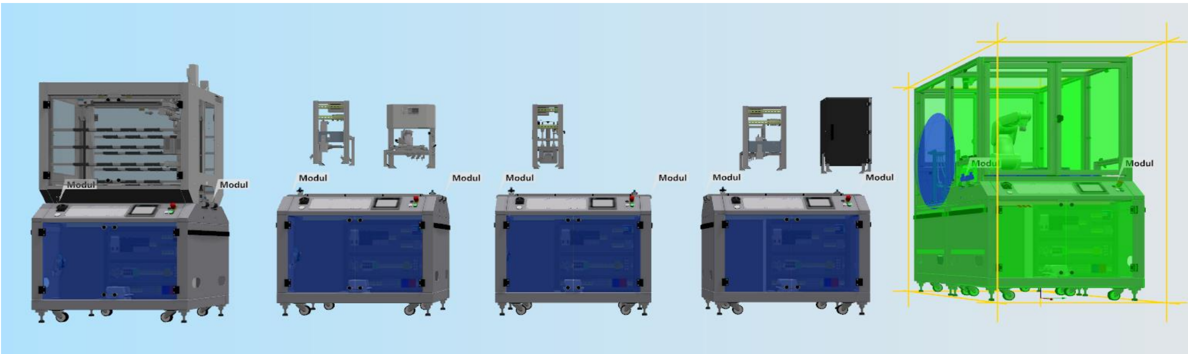

Figure 6: The cyber-physical factory for the dummy mobile phone manufacturing process

As a final step, the participants are free to assemble the model. They can assemble the model without sorting by function and complete it, as shown in Figure 7.

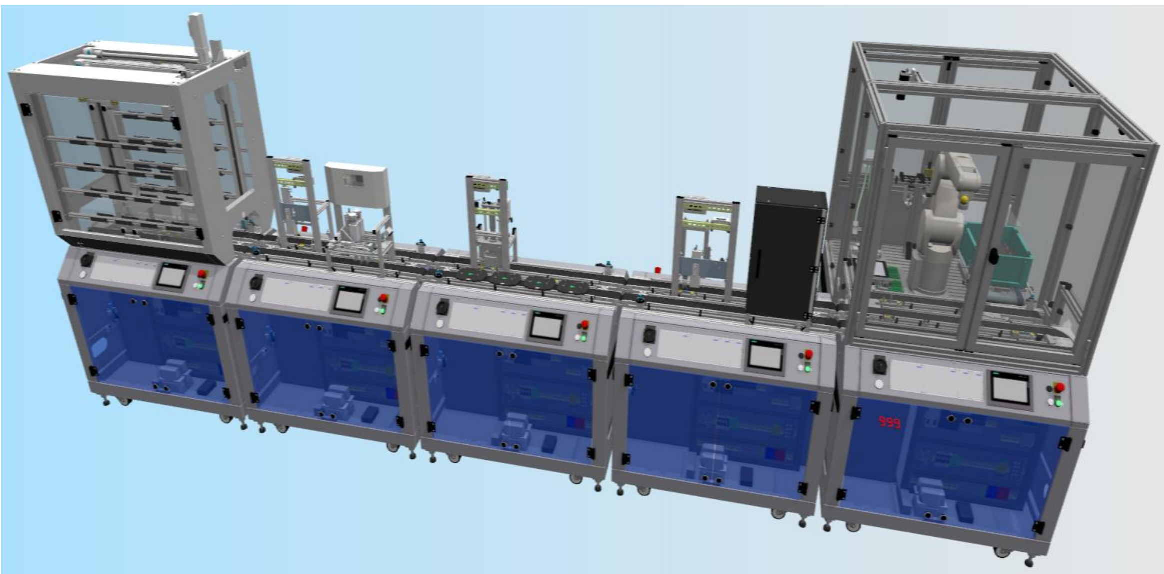

Figure 7: The module production line was fully assembled.

2.5 Description of environment

The environment for this research is the cyber-physical factory environment, which can execute two formats as follows: 1) The physical environment created from the model library with CIROS Studio Software, which can be downloaded in the cyber-physical model library v4.04b includes the cyber-physical application and cyber-physical factory. 2) The physical environment is created by the resources of master data with MES 4 Software, which includes the cyber-physical application and cyber-physical factory as well. A complete cyber-physical environment can perform experiments, as shown in Figure 8.

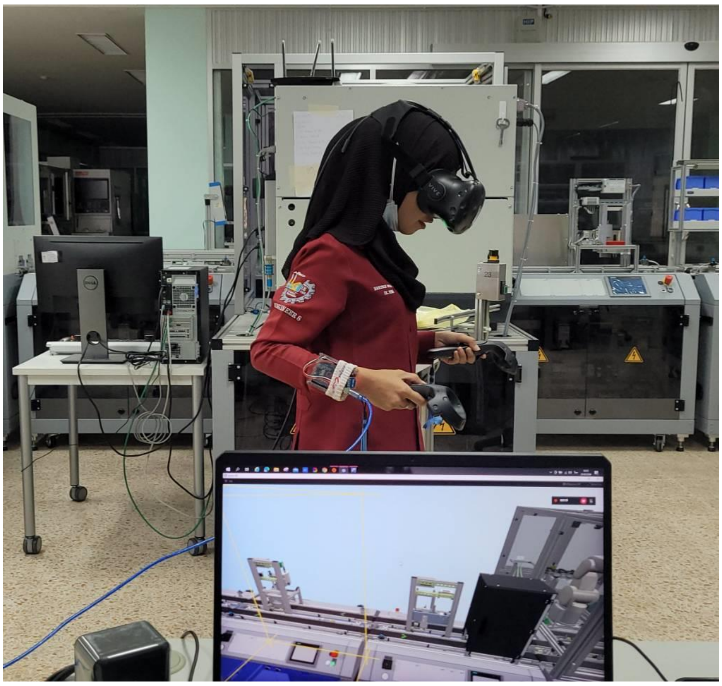

Figure 8: A complete cyber-physical environment with equipment can conduct experiments.

3. Results and Discussion

The experiment consisted of 30 participants for a comparative assessment of behaviour performance in a virtual reality platform. The stability measurement during the participant experiment used an angular velocity and accelerometer sensor (gyroscope). Standing and sitting are the most common basic postures used for assessing assembly in a cyber-physical factory. The raw recorded files have been processed with essential statistics to get gesture stability, which is the mean of all experiments, as shown in Table 1.

Table 1: The mean stability measures the posture during the experiment of the participants.

The posture during experiment					
Standing posture			Sitting posture		
X	Y	Z	X	Y	Z
-47.84	260.53	-31.19	23.24	97.29	68.75

The experiment results from Table 1, mean stability measures the posture during the experiment of the participants. The data is generated as a 3D pie graph to make it easier to analyses and more apparent, as shown in Figure 9.

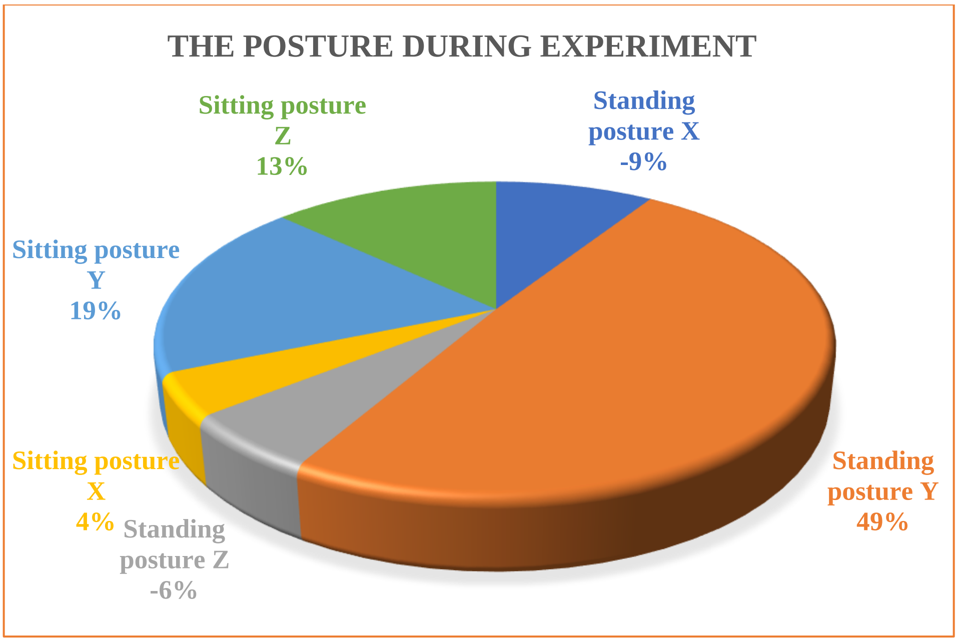

Figure 9: A 3D pie graph of the posture during the experiment.

The 3D pie graph in Figure 9 shows that the sitting posture is more stable than the standing posture because the sitting posture has the value of all axes very close (X, Y, Z = 4%, 19%, 13%). Compared to the experiment in standing posture, the values of all axes are very different (X, Y, Z = -9%, 49%, -6%). Therefore, this experiment concluded that the sitting posture was more stable than the standing posture. Considering the experiment with both gestures. It can be seen that the y-axis is greater than the entire axis, which means the module assembly is very fluent in the Y axis, if there is a comparison with other axes.

4. Conclusions

In this research, it can be concluded that the model set should allow the Y-axis to be assembled as much as possible. Because of the ergonomics, it is most convenient to move the hand forward. This experiment can help engineers and technicians decide the direction or core for assembling the model in the virtual platform. The application of virtual reality technology can be experimented with or tested to determine the speed of operation. It can also be used for training in various fields.

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