DEVELOPMENT OF AN EXCAVATOR SIMULATOR FOR AN INTELIGENT EXCAVATING SYSTEM

Gyu Won Lee[1], Sun Im[1]*, and Eung Kon Kim[2]

[1] *Korea Electronics Technology Institute, Seoul, Korea*
[2] *Simulation Tech, Inc. (STI), Seoul, Korea*
**Corresponding author (sunishot@keti.re.kr)*

ABSTRACT: Nowadays, many safety accidents are occurring at construction sites. Excavation accidents that concern construction machines are among the leading safety hazards in construction accidents. Therefore, the need for excavation experts is increasing. In this paper, an excavator simulator is presented for training human operators and for tasking in virtual earthworks. In this system, the operator controls a virtual excavator in a control station with a joystick, pedals, a graphic display, and sound effects.

Keywords: *Excavator, Simulator, Excavation Accident, Virtual Earthwork*

1. INTRODUCTION

Excavator accidents are major hazards at construction sites. To reduce excavator accidents, many researches on automatic excavation systems have been reported globally [1, 2, and 3]. These studies cover not only improved excavation systems, but also simulation training for excavator operators [4 and 5]. An excavator operator should be cautious with regard to safety while operating the excavator at the site, because prevention of accidents is demanded of operators.

For the excavator simulator in this study, an operating environment that was the same as the actual excavator test environment was realized for the training of excavator operators. This system consists of hardware, which include the motion and control systems, and software, which is the image system.

2. STRUCTURE OF THE SIMULATOR

As shown in Figure 1, the simulator structure consists of the motion system (H/W) for the excavator operation, the image system (S/W) for the virtual environment modeling, the work station, and the total control system that includes the ADC controller.

2.1 H/W

The hardware of this simulator has image and motion systems. The image system has a 50" LCD monitor at the operator seat, which shows the motion synchronized to the operation by the operator. As shown in Figure 2, the motion system has a hydraulic motion base with 6 degrees of freedom and a seating part. SIMUINE's hydraulic motion base, which is driven by a brushless servo motor with a 1,500kg payload, was used. The motion system was 3 m long, 2 m wide, and 2.5 m high. The seat part of the actual excavator was used. The

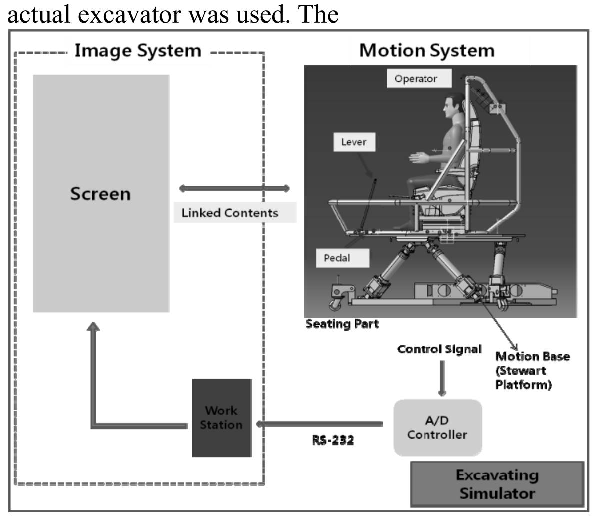

Figure 1. Structure of the Excavating Simulator

front cover was not attached to ensure the operator's good vision, and a joystick and a pedal were installed. The image system and operation in the seat part were synchronized. Two analog-type joysticks were used for the simulator.

2.2 S/W

A DX140LC excavator (Doosan Infracore Co., Ltd.) and the actual construction site were 3D-modeled and provided in 3D images. The operator can select either the window that shows the excavator's exterior or the one that shows the frontal view from the inside of the excavator. Figure 3 shows the overall process flow. The operator inputs the data, which are delivered via the motion solver to the sound system, gauge system, and motion base. The resulting motion is displayed in the screen as it is. In addition, the status data of the excavator are always displayed. Via the instructor system, an educational simulation may also be applied. The data generated in the operating seat are delivered to the motion base via an Ethernet-based simuline motion control program (SMCP) and a drive the motion system. SMCP is a program mounted to the motion control computer, which is connected to the external host program via Ethernet-based TCP/IP communication, to operate and control the motion base that is required for the integration of the simulator.

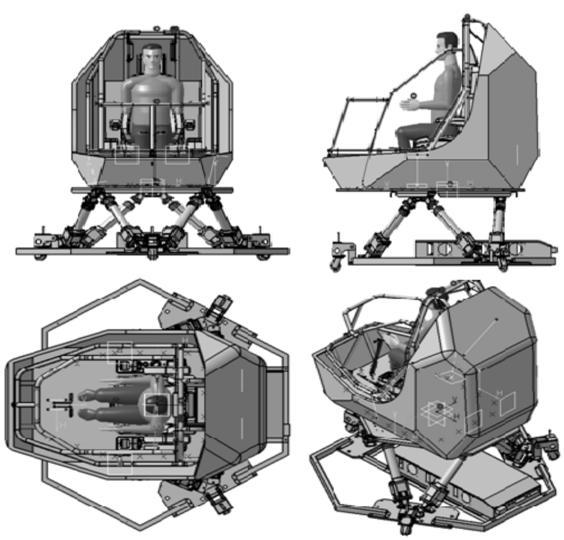

Figure 2. Motion System

The commands that are delivered to the SMCP from the host program include the command for the motion base operation, the motion drive command, and the command for obtaining the motion base status data. The program in the Ethernet-based host system can deliver the predefined commands for the operation of the motion base to the SMCP, or receive the motion base status from the SMCP, to integrate the simulator environment that the user needs to implement.

2.3 Control System

As shown in Figure 4, the control system consists of the MCU and the SMCP, which are required to control the motion base; the motion solver system, which is used to synchronize the screen, gauge, and sound; and the host system, which is used to externally control the overall system. When the operator moves the joystick and pedal in the motion system, the motion is synchronized with the image system in real time.

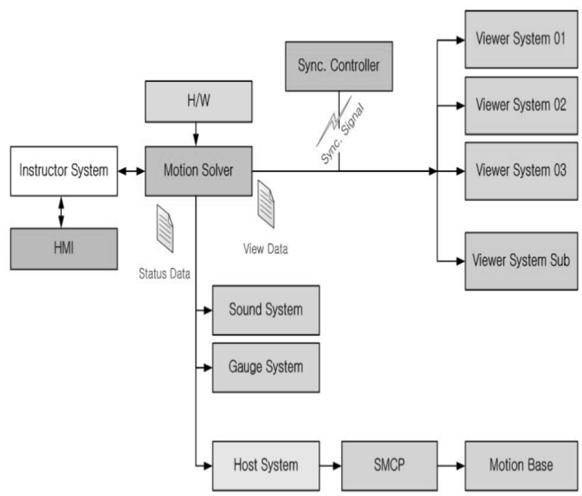

Figure 3. Software Structure

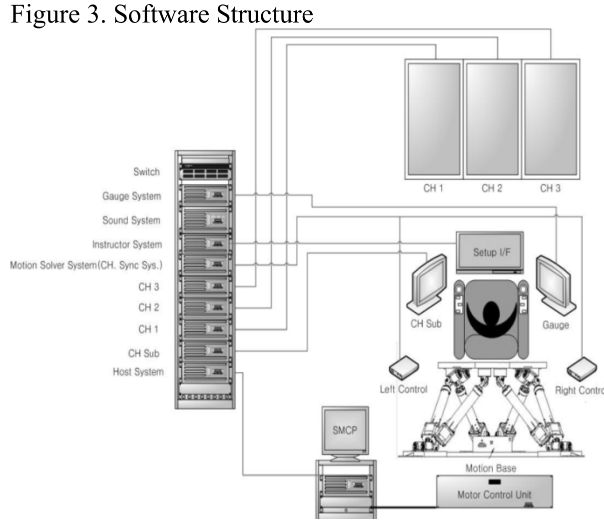

Figure 4. Structure of the Control System

3. EXPERIMENT

An actual excavation was performed using the excavator simulator. Simple digging was performed. Additional performance scenarios will be upgraded later. The operations were consecutively performed in the following order: (1) moving of the excavator; (2) adjustment of the boom, arm, and bucket; (3) soil digging; (4) turning of the excavator; (5) soil dumping; and (6) moving of the excavator back to its original location. The joystick in the operating seat was used to move the excavator to the target point. Then the digging point was checked, and the boom, arm, and bucket were lifted. After the soil was dug, only the excavator cabin was turned around, and the soil was dumped. Finally, the excavator was moved back to its original location.

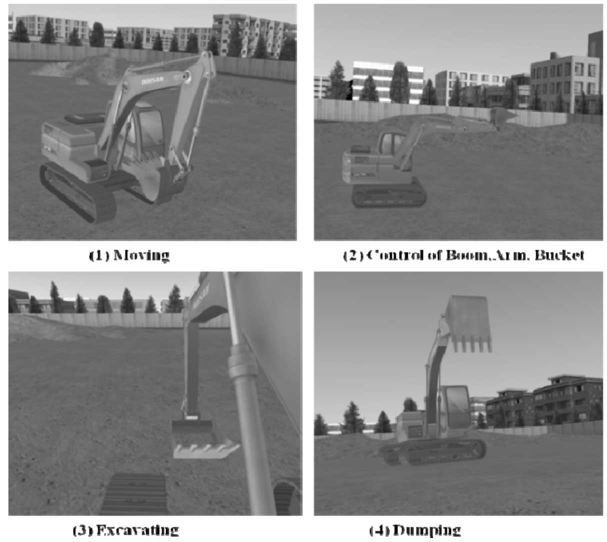

Figure 5. Excavation Procedure

4. RESULTS

The simulator in this study, which was developed for training of excavator operators, is a virtual reality system that models the excavator and construction site based on the actual design information and controls the excavator using a joystick and a pedal. This simulator is meaningful in that it can be used by experts as well as ordinary people via 3D modeling of the construction site. Not only the excavator but also its boom, arm, and bucket can be controlled as necessary to ensure smooth excavation operation. By using this simulator to train skilled operators, the fuel cost of the excavator can be reduced, and its safety can be improved. This excavator simulator will be combined with the task planning algorithm of the intelligent excavation system (IES) to improve the simulation level to that of the actual excavation work.

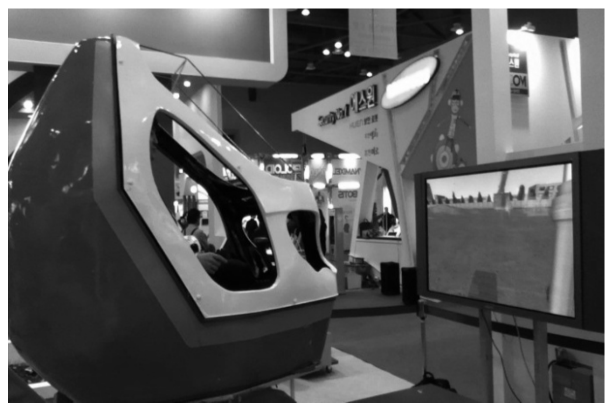

Figure 6. Excavator Simulator

Acknowledgement

The authors received assistance with this research from many members of organizations such as the Construction Robotic Control Committee. This research was supported by a grant from the IES program (project) funded by the Ministry of Construction & Transportation of the South Korean government. The authors are deeply grateful to them all for their support. The authors also wish to thank everyone who assisted them with the testing.

This research was partially supported by the program of the P-P04-P0405.

REFERENCES

[1] Tafazoli, S., S. E., Hashtrudi-Zaad, K., and Lawrence, P. D., “Impedance Control of a Teleoperated Excavator,” IEEE Transactions on Control Systems Technology, Vol. 10, No. 3, pp. 355-367, 2002.

[2] Krishna, M. and Bares, J., “Hydraulic System Modeling through Memory-based Learning,” Proc. of the 1998 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems, pp. 1733-1738, 1998.

[3] Nguyen, Q. H., Ha, Q. H., Rye, D. C., and Durrant-Whyte, H. F., “Force/Position Tracking for Electrohydraulic Systems of a Robotic Excavator,” Proc. of the IEEE Conf. on Decision and Control, pp. 5224-5229, 2000.

[4] S. P. DiMaio, S. E. Salcudean, C. Reboulet, S. Tafazoli, and K. Hashtrudi-Zaad, “A Virtual Excavator for Controller Development and Evaluation,” Proc. of the 1998 IEEE Conf. on Robotics & Automation.

[5] Tao, N., DingXuan, Z., Yamada, H., and Shui, N., “A Low-cost Solution for Excavator Simulation with a Realistic Visual Effect,” IEEE Conf. on Robotics, Automation, and Mechatronics, pp. 889-894, 2008.