A Novel Interactive Virtual Training System

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Abstract. This paper proposes a novel interactive virtual training system that provides PLC trainees with a virtual environment that is identical to actually handling various types of equipment trainees could not access during training programs. The proposed system is applied to an actual technical training program, and the results are analyzed to examine its propriety and applicability.

Keywords: virtual training, interactive virtual training, PLC, virtual PLC, virtual conveyor, virtual ladder.

1 Introduction

Virtual reality (VR) uses computer to simulate a specific environment and surrounding circumstances to deliver information regarding the environment through five human senses (sight, smell, hearing, taste, and touch), allowing people in a virtual space to engage in experience identical to that of the real world. In addition to simulating the real world, VR allows people to simulate experiences that are not feasible in the actual world. Today, VR technology is used in various fields, including military, medical, construction, design, experience, training, and entertainment [1].

Korea has some of world's highest levels of technology in industrial areas such as electric power, automobile, semiconductors, display, mobile handsets, steel, energy, and shipbuilding. The most important group of technical experts in cutting-edge manufacturing and facility industries are PLC automation professionals. Due to the nature of manufacturing and facility industries, PLC automation training requires very expensive latest equipment. However, since inadequate manipulation or programming errors by trainees can damage the equipment and there are difficulties involved in continuously replacing and providing the latest equipment, most expensive equipment are not used at all or provided only with restricted and limited use during training sessions. Accordingly, most trainees listen to explanations rather than hands-on manipulation, which places limitations compared to actually being able to operate the equipment.

In order to overcome the constraints of the training environment due to the nature of the latest automation facilities and address the importance of training, this paper proposes an interactive virtual training system based on 3D stereoscopic imaging, allowing expensive equipment to be replaced with virtual equipment. There has been hardly any research and development on the training system for PLC automation

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equipment using VR. In order to allow PLC trainees to handle virtual equipment that models actual high-price equipment such as elevators and conveyors, providing the effects of engaging in hands-on training, the virtual training system developed by this study is deployed in an actual training program and the results are analyzed to verify the feasibility of the proposed system.

2 Proposed Interactive Virtual Training System

2.1 System Overview

The proposed system consists of the object-based sensor input unit that processes sensor input, the virtual PLC composer unit that receives user's arbitrary wiring input, the virtual ladder tool unit for writing PLC ladder programs, the virtual PLC unit that replaces the actual PLC, and the object-based virtual input/output model unit that provides 3D visualization of the results that correspond to arbitrary input data. The overall block diagram of the proposed system is shown in Figure 1.

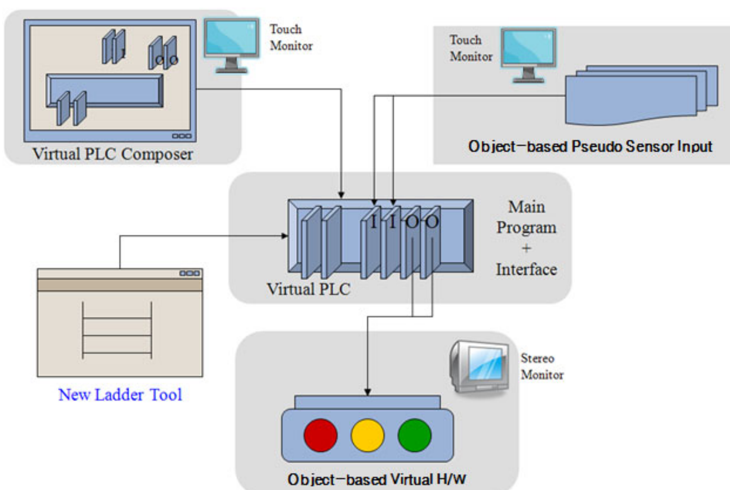


Fig. 1. Block diagram of the proposed system

2.2 Virtual PLC Composer

This unit receives the initial input from the user (trainee) and supports arbitrary wiring. Whereas most input wiring units accept only pre-assigned (correct) wiring, the virtual PLC composer unit in the proposed system accepts any wiring configuration (even incorrect wiring) from the user. The trainee can study materials related to a specific session and practice wiring using the virtual PLC composer shown in Figure 2. In order to cover various user's arbitrary wiring input, SAI(Scene Access Interface) [2,3] is used for the implementation.

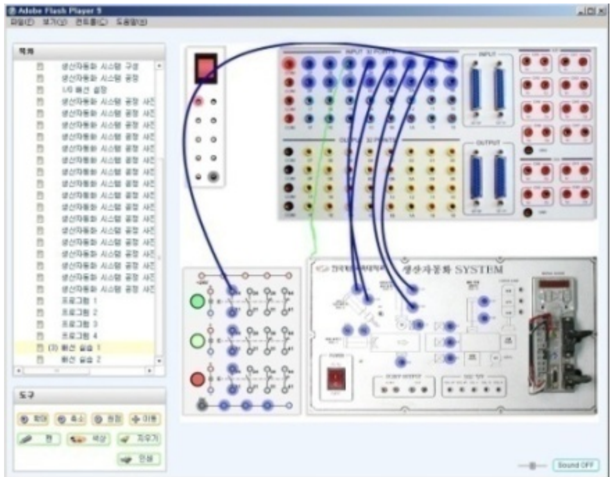


Fig. 2. The virtual PLC composer

- Screen shot of practice wiring using the virtual PLC composer

2.3 Object-Based Virtual Input/Output Model Unit That Provides 3D Visualization

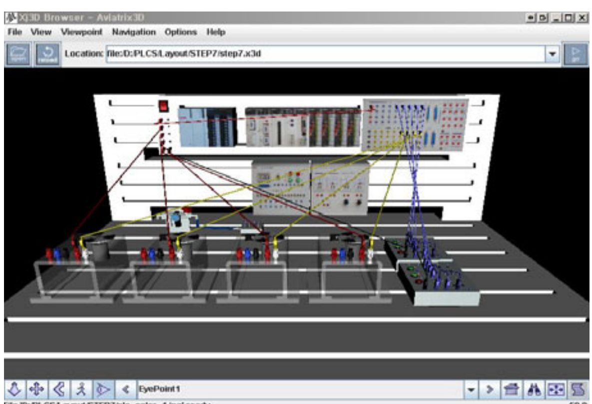


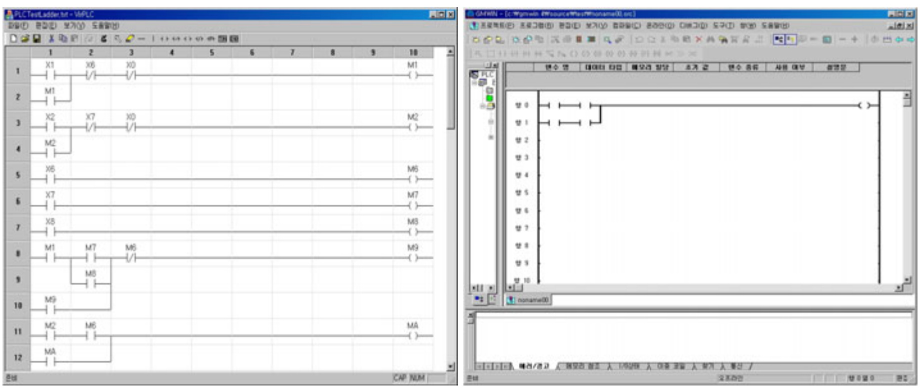
Fig. 3. The object-based virtual input/output model unit

- Screen shot of an object-based 3D input/output model and simulation of a motor sequence control

This unit converts the user wiring input configuration from the virtual PLC composer into corresponding 3D visualization and allows the user to verify the result through simulation. Accurate wiring simulates correct action, whereas incorrect wiring configuration produces a simulation result of faulty action (Figure 3). All the virtual input/output models are implemented based on X3D, the Web3D which is international standard graphic format. [4-7]

2.4 Virtual Ladder Tool

We need a virtual ladder tool that provides a usage environment similar to the actual environment while satisfying the dedicated ladder tool for virtual PLC. Based on this requirement, we developed a ladder tool for programming ladders that can be loaded into virtual PLC. Ladder diagram (LD) into instruction list (IL) can be transformed based on [8]. Specifications of the functions supported by the ladder tool are based on the international standard IEC61131-3. Figure 4 displays the generic virtual ladder tool implemented by this study.



(a) (b)

Fig. 4. (a) Screen shot of the generic virtual tool implemented by this study (b) Screen shot of virtual ladder tool simulating GMWIN, the actual GLOFA ladder tool

3 Application in Practice and Result Analysis

3.1 Application in Training Program - Experiment

After deploying the proposed system in a technical training program (GLOFA-PLC control) conducted at our university's training center, applicability and feasibility of the system were evaluated by based on the results of the survey conducted among the trainees and instructors of the program. The training session involved controlling a virtual conveyor implemented in a virtual environment to simulate a high-level conveyor, a large-scale and expensive machine that is difficult for trainees to operate for training purposes. The practice session was conducted in a sequence identical to practicing on an actual machine, as shown in Figure 5 and Figure 6.

14 trainees participated in the experiment, including professional training school teachers, industrial high school teachers, and large companies' in-house instructors. After being introduced to the proposed virtual training system, the participants were

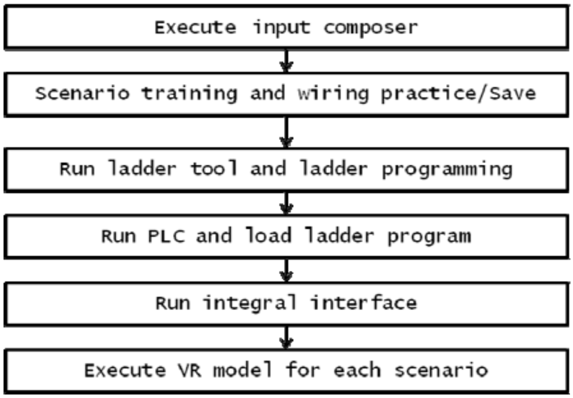


Fig. 5. Sequence of the conveyor control practice

Fig. 6. Screen shot of virtual conveyor control training session

trained in the conveyor control practice session. Upon completion of the session, they were asked to respond to a survey consisting of 10 questions, as shown in Figure 7, and display the level of satisfaction according to the Likert scale: highly satisfied (5 points), satisfied (4 points), average (3 points), unsatisfied (2 points), highly unsatisfied (1 point).

3.2 Analysis of the Results from the Training Program

Table 1 shows the statistics regarding the survey response from the trainees after the practice session using the proposed system. The overall average was close to "satisfied (4 points)", confirming applicability of the training program based on the proposed system. If we can improve on some aspects, such as user-friendliness and interface, and expand functionality, the system should be fully applicable in virtual PLC training programs.

Questionnaire regarding the training session using virtual conveyor

Number	Question	Level of Satisfaction (Please indicate with 'O')				
		Highly Satisfied	Satisfied	Average	Unsatisfied	Highly Unsatisfied
1	[Effectiveness in inducing learning motivation] Did the virtual conveyor system motivate you in terms of learning and interest?					
2	[Effectiveness of training content I] Was the virtual conveyor system helpful for understanding the materials covered in the session?					
3	[Effectiveness of training content II] Was the virtual PLC system effective compared to an actual PLC?					
4	[Effectiveness of training content III] Was it beneficial to practice controlling the conveyor using the virtual PLC system and attempt things that would not be feasible with an actual PLC?					
5	[Adequacy of amount of training] Was the amount of training you received using the virtual conveyor system adequate?					
6	[Reality of training content] Do you think practicing with the virtual conveyor system will be helpful for your field operation?					
7	[Distinction from other training materials] Was the virtual conveyor system more helpful than other training materials for understanding the training session?					
8	[User-friendliness] Was the virtual conveyor system easy and convenient to operate?					
9	[Effectiveness in replacing actual equipment] Do you think the virtual conveyor system can replace the actual equipment for training purposes?					
10	[Applicability in technical training] Do you think it would be beneficial to apply the virtual PLC system to various technical training programs?					

Fig. 7. Questionnaire used for evaluation on the virtual conveyor session using the proposed system

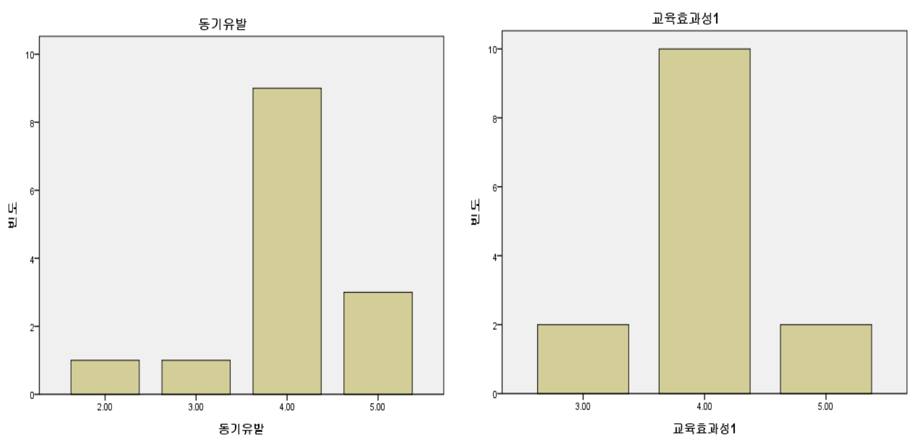
Table 1. Statistics regarding the questionnaire responses

		Motivation	Training Effectiveness 1	Training Effectiveness 2	Training Effectiveness 2
N	Effective	14	14	14	14
	Missing	0	0	0	0
Average		4.0	4.0	4.0	4.0

		Adequacy	Reality	Distinction	User- -friendliness
N	Effective	14	14	14	14
	Missing	0	0	0	0
Average		4.0	4.0	4.0	4.0

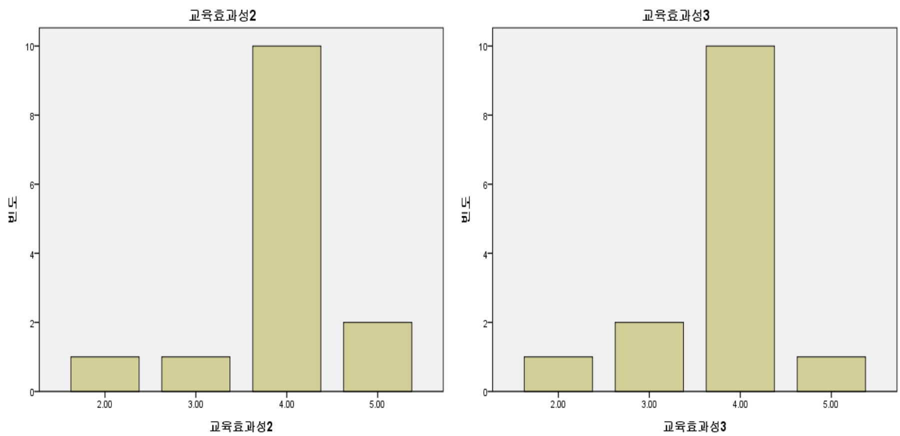
		Effectiveness as replacement	Applicability
N	Effective	14	14
	Missing	0	0
Average		4.0	4.0

Following figures display all the results of the questionnaire survey.



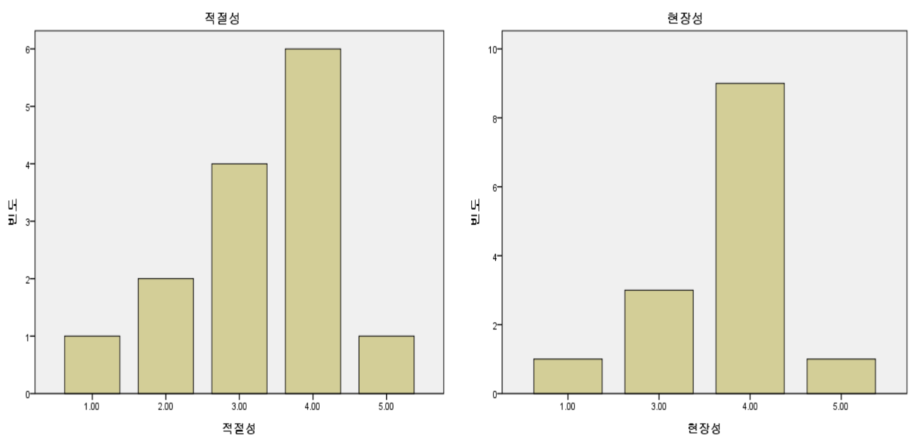
(a) (b)

Fig. 8. (a) Question 1 - learning motivation (b) Question 2 - training effectiveness I



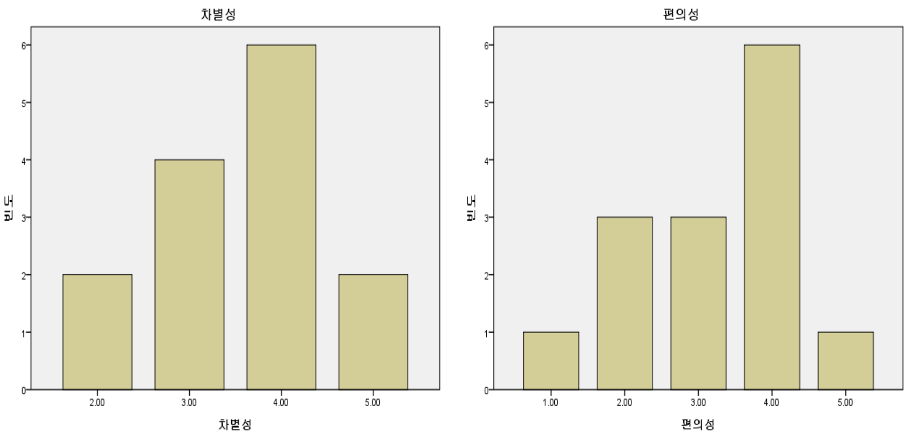
(a) (b)

Fig. 9. (a) Question 3 - training effectiveness II (b) Question 4 - training effectiveness III



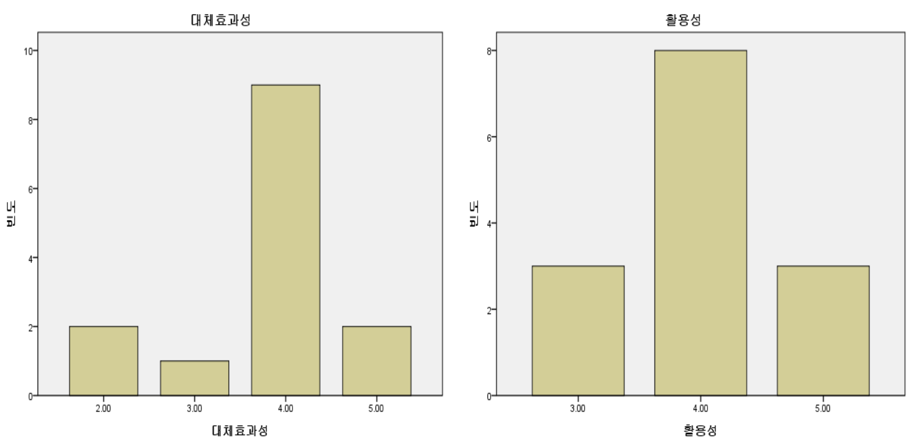
(a) (b)

Fig. 10. (a) Question 5 - Adequacy of training (b) Question 6 - Reality of training



(a) (b)

Fig. 11. (a) Question 7 - Distinction from other training (b) Question 8 - User-friendliness



(a) (b)

Fig. 12. (a) Question 9 - Effectiveness in replacing actual equipment (b) Question 10 - Applicability in technical training

4 Conclusions

This paper proposed a novel interactive virtual training system. The proposed interactive virtual training system was developed to allow PLC trainees to operate virtual equipment modeled after actual high-price machinery such as elevators and conveyors, providing experience identical to operating actual equipment. Using the virtual equipments, the proposed system could offer a training environment that allows free and unlimited repetitions in virtual space without concerns of safety and equipment damage from malfunctioning and program errors. The proposed system was applied in an actual training environment for students and teachers, and their survey responses were analyzed to confirm that the system is applicable in training programs.

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