A new-type PLC Wiring Training using Augmented Reality: a hybrid learning for technology education

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Abstract

With rapid developments in the manufacturing industry, there has been increasing attention on PLC training for implementing factory automation. In order to meet the increasing demand for PLC training, this paper proposes a new-type PLC wiring training using AR. The proposed training is a hybrid learning for technology education, dedicated to wiring practice, the input part of PLC. Cases for wiring practices are studied and categorized as three groups for the implementation. The system implemented for PLC training is presented and some trainings are given using it.

Keywords: PLC training, wiring practice, AR-based virtual wiring guide

1. Introduction

Augmented reality (AR) is a technology for presenting real-time overlay of virtual computer graphics image on top of actual image captured by the camera. AR is a compound virtual reality technology that adds computer graphics data to the actual image viewed by the user in real time. Applications of AR include medicine, product processing, construction, game and broadcasting [1,2]. With remarkable advances in science, latest technologies are being incorporated in training and education. The cutting-edge aspect of training is giving rise to demand for new training systems, and there have recently been active studies on training and education based on AR [3][4]. There is a wide range of AR-based training applications from wiring to military equipment maintenance [5][6]. In machine maintenance, it has been confirmed that AR-based maintenance training is much more effective than training performed using computer manual [7]. With rapid developments in the manufacturing industry, there has been increasing attention on PLC training for implementing automated production facilities. 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. PLC training mainly consists of sessions in wiring and programming. Wiring between components becomes increasingly important and more sophisticated. In the manufacturing industry that uses expensive and latest automated production facilities, incorrect wiring can result in equipment malfunction, mechanical damage, major accidents or significant financial loss. Therefore, it is necessary to pay close attention to providing proper training and practice for wiring.

In order to meet the increasing demand for PLC training, this paper proposes a new-type PLC wiring training using AR. The proposed training is a hybrid learning for technology education, dedicated to wiring practice, the input part of PLC. The proposed method involves augmenting virtual wiring guide on the training board to enhance the learning experience for the trainee and to allow even novices to easily acquire the methods and techniques of wiring. Case studies for wiring practices are given and then generalized as three cases for the implementation. The system implemented for PLC training is presented and some trainings are dealt.

2. Conventional PLC Training System

Figure 1 shows a conventional frame for PLC training, mostly used in South Korea.

Figure 1. A conventional PLC training system (mostly used in South Korea)

The trainee first learns about the theories related to the training practice session, performs programming based on the acquired theories, and performs PLC wiring according to programming. However, a novice in PLC experiences difficulty even with the most basic order of wiring. As PLC training becomes more sophisticated and moves into intermediate and advanced levels, wiring becomes complex and the trainee has to rely increasingly on books or web-based manual for the order of wiring. Figure 2 shows a snapshot of conventional (real) wiring practice for PLC training. The trainee conducts wiring while looking at the manual to verify whether his wiring is correct. If an error is found, the trainee performs wiring again, and if everything is in order, he moves on to the next step. Since this process involves the trainee verifying the correct connection and order of wiring while looking back and forth between wiring and the manual, he cannot focus on wiring practice.

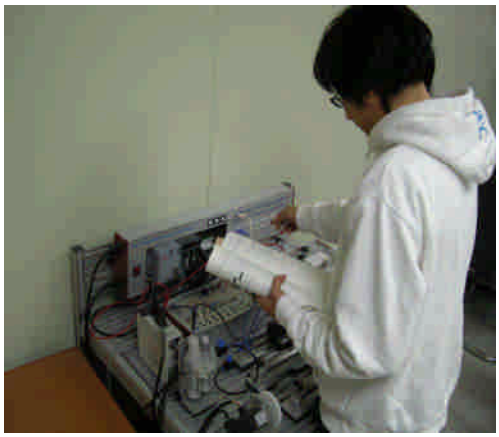


Figure 2. A snapshot of conventional wiring practice

3. The proposed PLC Training System using Augmented Reality: a hybrid learning for technology education

3.1 Case studies on wiring practice and preliminary implementation

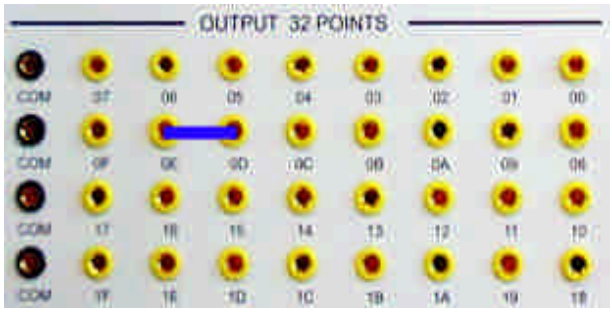
As mentioned above, the method proposed in this paper involves using AR to sequentially augment a virtual wiring guide on the training board like the one shown in Figure 1, replacing the book or web-based manual for practicing simple basic to complex wiring and helping the trainee to easily acquire wiring techniques. Unlike conventional PLC wiring practice, the proposed AR-based PLC wiring practice system augments a virtual wiring guide on the PLC board, allowing the trainee to perform wiring by looking at the wiring guide. This enables the trainee to focus entirely on wiring and know exactly which contact point or port has to be wired at that particular moment, expediting the practice session.

Regardless of the level of difficulty, PLC wiring practice can be categorized into the following cases (Figure 3).

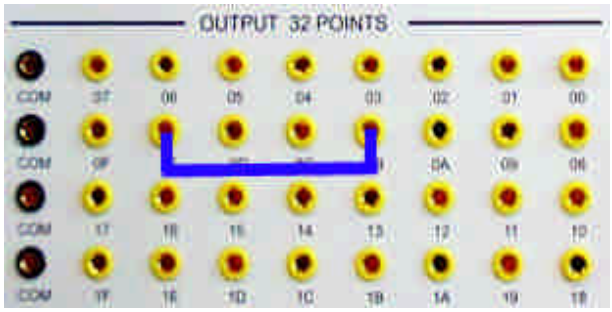
(Case Ⅰ) Wiring two adjacent ports (points)

(Case Ⅱ) Wiring two non-adjacent ports without crossing over an intermediate port.

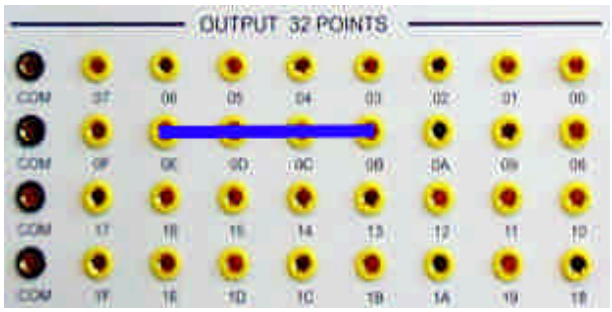
(Case Ⅲ) Wiring two non-adjacent ports by crossing over an intermediate port.



(a) Wiring two adjacent ports (points) (Case Ⅰ)



(b) Wiring two non-adjacent ports without crossing over an intermediate port (Case Ⅱ)



(c) Wiring two non-adjacent ports by crossing over an intermediate port (Case Ⅲ)

Figure 3. Three generalized cases of wiring practice for PLC training

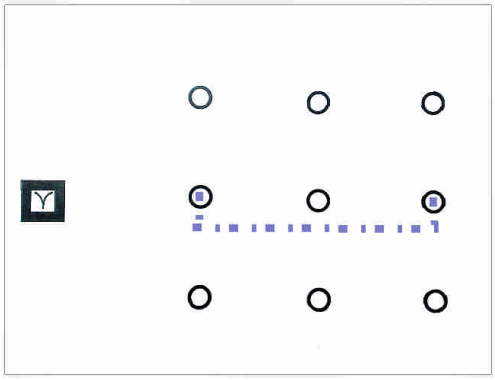
A virtual wiring guide of above three cases implemented and augmented on a PLC practice board. As shown in the following figure, the 9 circles on the virtual PLC board indicate the ports that should be wired. Wiring function for the three wiring cases using the AR-based virtual wiring guide is examined according to the following procedures.

Step 1) The image captured by the camera is converted into binary code and the coordinates of the ports are stored.

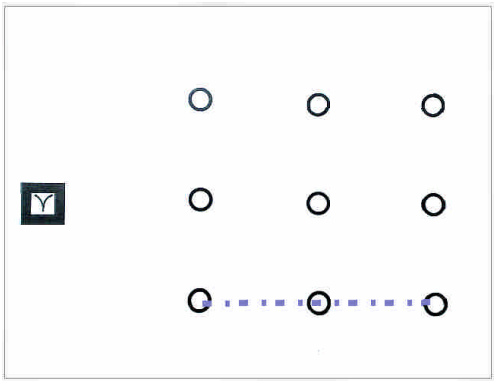
Step 2) Detects whether there is wiring of ports

Step 3) Determines whether port wiring is accurate.(If ports are wired correctly, move on to the next step in wiring practice.)

(a) Implementation result of Case Ⅰ



(b) Implementation result of Case Ⅱ



(c) Implementation result of Case Ⅲ

virtual wiring guide (the dotted line is the AR-based virtual wiring guide)

For example, in the case of wiring two adjacent ports (case Ⅰ), points that need to be wired are augmented as a virtual wiring guide (he dotted line) and presented to the trainee. After the trainee performs actual wiring (the solid line) by following the augmented wiring guide, the system verifies the internal link. If wiring is correct, a message is displayed to indicate wiring has been successfully completed, and the next virtual wiring guide is augmented (Figure 5). Cases Ⅱ and Ⅲ are performed with

the same procedures. Performing wiring practice with the proposed method for Cases 2 and 3 are shown in Figures 5 and 6, respectively.

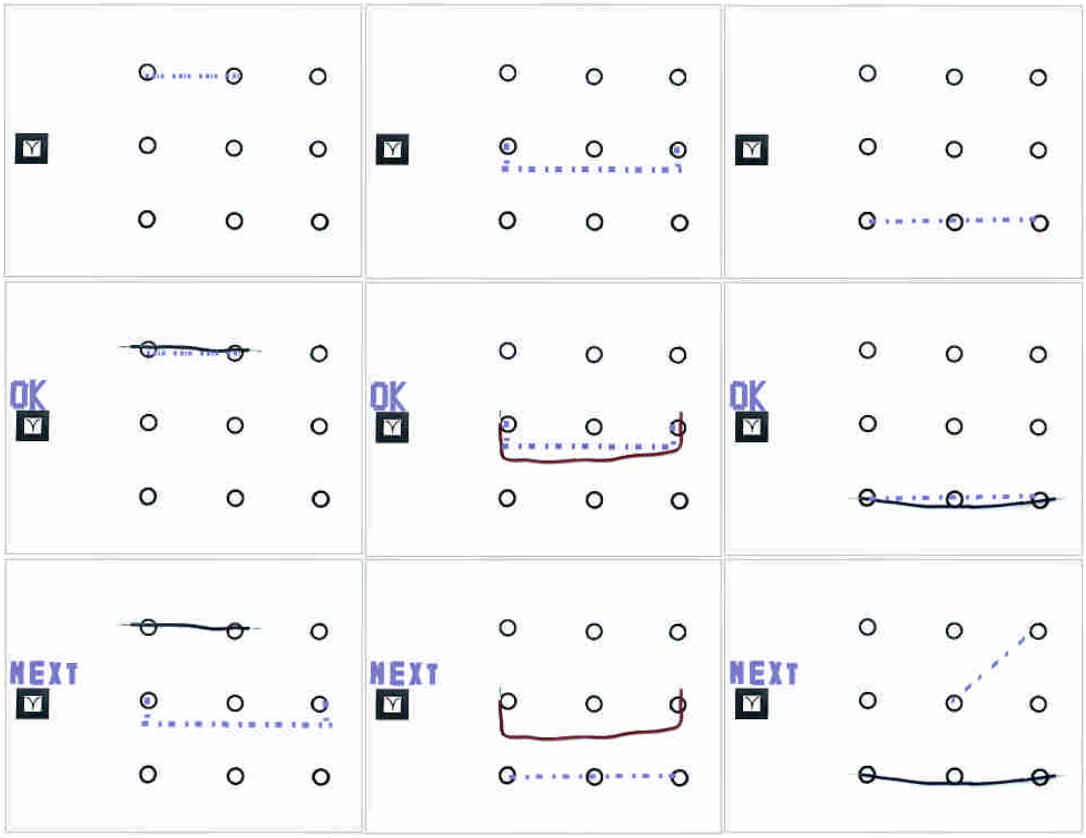


Figure 5. Consecutive wiring practice results on Case Ⅰ, Ⅱ and Ⅲ (from left)

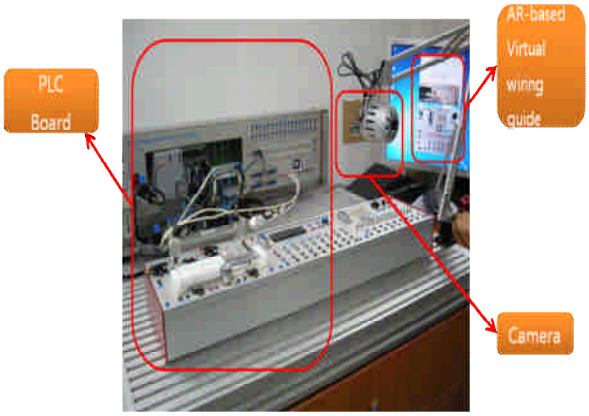
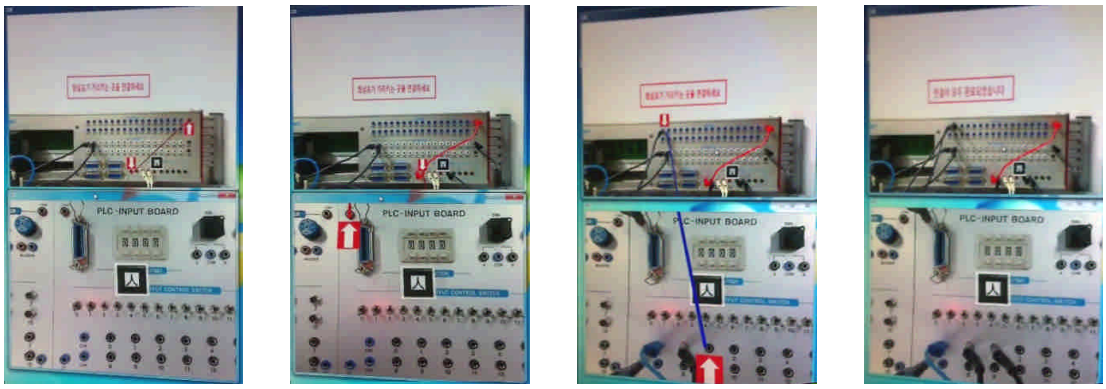


Figure 6. The proposed PLC training system providing the AR-based virtual wiring guide

3.2 A new-type PLC training system dedicated to the wiring practice

The feasibility on the AR-based virtual wiring practice for PLC training was investigated in the previous section. In this section, based on the result of the cases studies and preliminary implementation, a new-type PLC training system is proposed. Figure 6 shows the proposed PLC training system providing the AR-based virtual wiring guide. Some PLC trainings are performed for the validation of the proposed system. Among them, a PLC training running double-acting cylinder is given as an example, and figure 7 shows the screen shots of consecutive wirings performed for the PLC training (for running double-acting cylinder) using the proposed system.



(a) (b) (c) (d)

Figure 7. The screen shots of consecutive wirings performed using the proposed system (the PLC training for running double-acting cylinder)

By augmenting the virtual wiring guide (the arrows in red) on the training board, the proposed system provided a hybrid learning opportunity which could enhance the learning experience for the trainee, and allowed even novices to easily acquire the methods and techniques of wiring in order as shown in the figure 7.

4. Conclusions

In this paper, a new-type PLC training system using the AR was proposed. The proposed training is a hybrid learning for technology education, dedicated to wiring practice, the input part of PLC, which involves augmenting virtual wiring guide on the training board to enhance the learning experience for the trainee and to allow even novices to easily acquire the methods and techniques of wiring. Case studies for wiring practices were given and then categorized as three cases for the implementation. Based on the result, the new-type PLC training system providing a hybrid learning was developed. Some PLC trainings were performed for the validation of the proposed system. Some results were given and the results on the effectiveness for technology education using the proposed system are being analyzed and be given in the next presentation.

5. References

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