Development of Educational Content Based on Augmented Reality for Light Maintenance of Railway Vehicle

Jae Hwan Cha, Kyung Sik Kim, Chul Su Kim*, and Hwi Jin Kwon*

***Abstract*—Railway vehicle maintenance is performed in a work environment that requires high adaptability and expertise. Therefore, it is very important to systematically educate maintenance operators. However, maintenance education has been inefficiently conducted using booklet-type resources. Maintenance training should be conducted efficiently by visualizing the maintenance process in three-dimensional by applying the augmented reality (AR) technique. In this study, AR-based educational content was designed for a block brake device that induces an accurate position stop during train operation. To prove the effectiveness of the content, user experience evaluation was conducted through a survey consisting of 8 questions.**

***Index Terms*—Eletric multiple unit, block brake unit, augmented reality, maintenance oprator**

I. Introduction

The block brake device of the electric multiple units induces an accurate position stop during train operation. It is also a very important device that affects passenger safety and comfort. As shown in Fig. 1, this transfers the frictional braking force to the wheel tread by compression of the brake shoe. The block brake device maintenance training of urban railway operating institutions has been conducted with maintenance manuals and operation videos in accordance with the guidelines of each institution. However, bulky parts drawings and maintenance manuals are difficult to carry, and it is difficult to share information among maintenance operators in the field. A three-dimensional visualization of maintenance processes solves these problems and improves readability more than traditional manuals [1].

Fig. 1. Block brake unit.

Therefore, it is very important to develop augmented reality (AR)-based educational content based on a 3D model to increase the proficiency of maintenance operators on block brake unit.

AR maintenance content have been produced in various industries. A. Jalil et al. used augmented reality technology to support maintenance in the oil and gas industry [2]. As a result, maintenance costs and mean time to repair were reduced. S. Coscetti developed an augmented reality interface on a paper production lines [3]. This improved factory safety and increased the efficiency of the production line. However, in the field of railway vehicles, the development of augmented reality-based content is insignificant.

In this paper, to improve the proficiency of maintenance operators for block brake device of the electric multiple unit, AR educational content exclusively for mobile devices were designed according to the maintenance manual.

II. Maintenance of Blokc Brake Unit

A. Light Maintenance of Block Brake Unit

The light maintenance procedure for the block brake unit includes external inspection and dimensional inspection. Maintenance operators check whether the bolts and various components connected to the block brake unit work properly before and after the train runs. They also measure the brake shoe dimensions and check the limit of use. To learn such a light maintenance procedure, information such as device specifications, bill of materials, and equipment are required in addition to the light maintenance procedure.

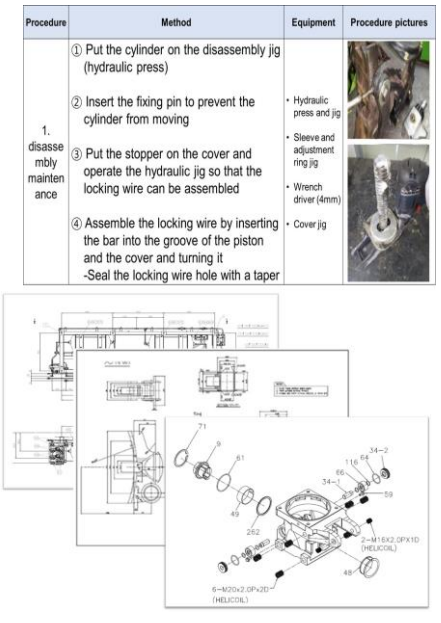

Fig. 2. Educational resource.

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B. Maintenance Education for Block Brake Unit

Fig. 2 is an example of an educational resource for maintenance of the electric multiple unit implemented by urban railway operating institutions. On the left is a maintenance manual, which lacks a three-dimensional effect because the work procedure is only displayed in photos. On the right is a two-dimensional parts drawing book, which is inconvenient to carry a heavy entire drawing book. Therefore, to improve the inefficiency of the existing education method, it is important to develop content for mobile devices that are easy to carry and have improved readability.

III. AR Education Content Design

A. Modeling and Storyboard

The shape data was collected with a 3D scanner by visiting the site where electric multiple unit maintenance was performed to produce an accurate model. These models were compressed using SAP 3D Visual Enterprise Author 9.0 and then converted into apk format for use in Unity [4, 5].

Fig. 3 is a mind map of the necessary information for block brake unit maintenance education. The upper layer consists of device general, bill of materials, and light maintenance procedure. The lower layer is subdivided into about 15 parts. Fig. 4 is a storyboard based on mind map. This represents the composition of text and animation. It is also organized step by step according to the estimated required time.

Creators use unity to create are contents based on storyboards. During this process, it is reviewed whether the required time and stage composition of the animation are natural and smooth. In addition, revisions are made by reflecting the opinions of experts in the field of railway vehicles and are contents.

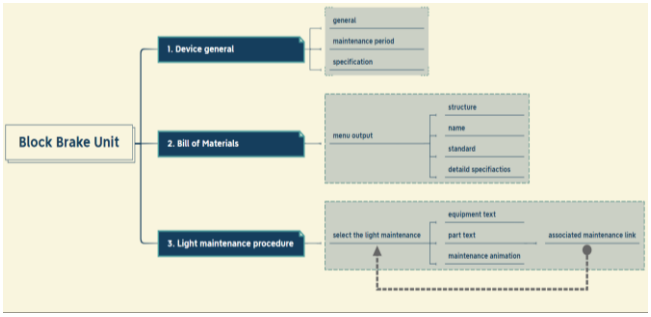

Fig. 3. Mind map.

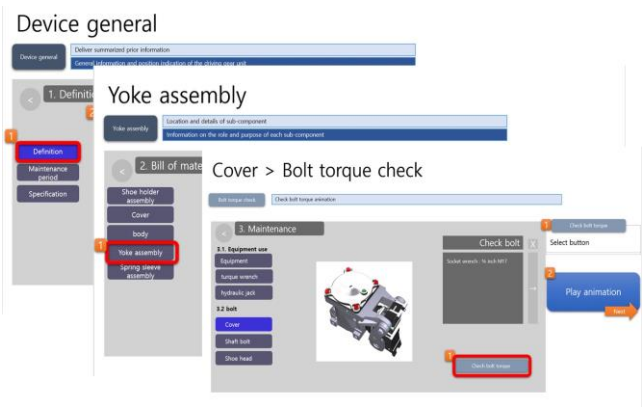

Fig. 4. Stortyboard.

B. Approache and User Interface

The are content adopted the marker less method. When the user touches the plane created when the app is running, an object appears on the screen of the mobile device. Fig. 5 shows the user interface composition of AR content. It consists of a main menu on the left, and a side menu on the right. The user selects each button in the main menu to learn details. On the right, a different angle view of the device is shown. In the center of the screen, animations for each maintenance process are implemented.

C. Content Organizaiton

Fig. 6 is an example of the equipment and supplies used in the maintenance process. As shown in the figure, a picture of the actual equipment was inserted and the specifications are also indicated. Supplies and spare parts are shown together. The location of the device can be checked by clicking on the chech drawing button in the main menu. The block brake unit is displayed in red to increase visibility.

Fig. 7 shows the detailed names of the device. Users learn the structure by changing the position, size, and rotation of the model using touch gestures. The touch gestures for using this content are the same as Table I.

Fig. 8 is an example of implementing an animation that measures the limit of use for a brake shoe. As shown in the picture, the location and number of measurements were visualized. The limit of use is clearly indicated in the text to increase the learning effect.

Fig. 9 shows the dangerous procedure in which an actual accident occurred. Precautions are highlighted in separate text. In addition, the realism of the animation was enhanced by using a hand model.

Fig. 10 is an example of loading this content on the mobile phone, tablet and utilizing it before starting maintenance work. Maintenance operators do not need to carry maintenance manuals and parts drawings, and learn procedures through personal mobile devices. In addition, because repeated learning is possible for each process, maintenance procedures can be understood more effectively than existing booklet-type manuals.

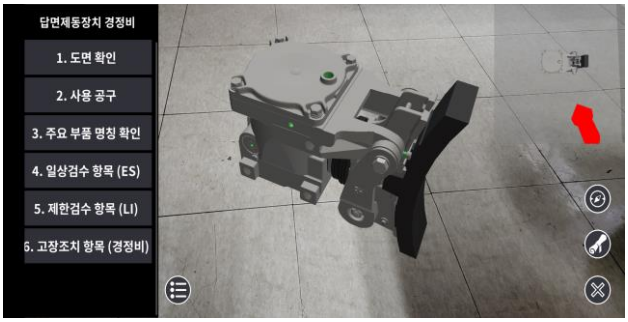

Fig. 5. User interface of AR content.

Fig. 6. Equipment and supplies.

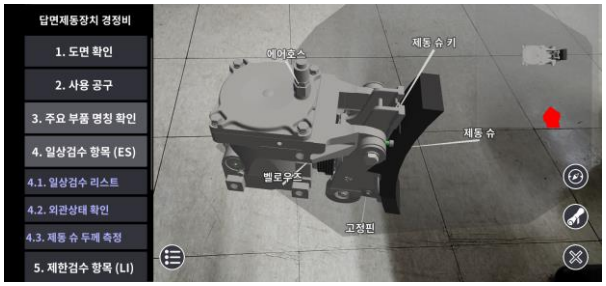

Fig. 7. Detail name of block brake unit.

TABLE I: TOUCHGESTURE FOR USING CONTENT

Value	Touch gesture	Content
Position		Touch on finger to move model position
Scale		Touch two fingers to increase/decrease size of model
Rotation		Touch two fingers to rotate model

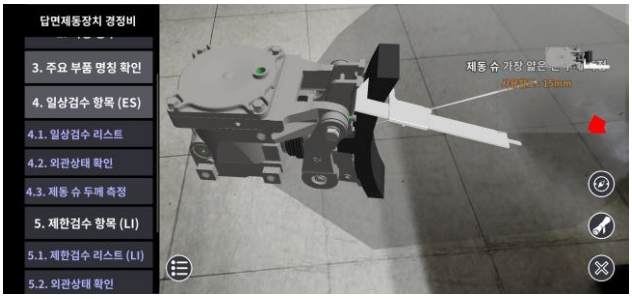

Fig. 8. Measures the limit of use.

Fig. 9. Dangerous procedure.

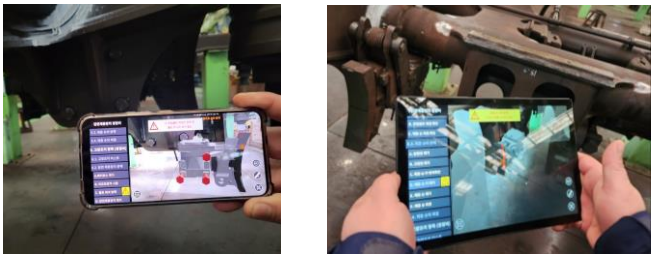

Fig. 10. Loading AR content on mobile device.

IV. USER EXPERIENCE EVALUATION

Shin *et al.* [6] developed a survey to evaluate the user experience of educational content. The research team conducted user experience evaluation by reorganizing the survey according to the AR content topic. The evaluation parts focused on learning elements for AR content and divided them into the following four categories: immersion, presence, satisfaction, and usability. Each part consisted of two questions. Responses to each question are composed of the Likert scale, where a score of 5 represents "strong agree" and a score of 1 represents "strong disagree". The questions for each part are as follows.

A. Immersion

- When using AR content, active learning is possible by selecting each learning part.
- It was easy to grasp the entire learning scenario of the educational content, and all parts could be learned without missing parts.

B. Presence

- When using AR content, it feels like experiencing actual light maintenance work.
- When using AR content, I thought that I would like to experience the maintenance procedures directly using my body.

C. Satisfaction

- Through touch gestures, it was possible to freely manipulate models and UI. And it was also easy to switch screens.
- The overall structure of the AR content is well structured for ease of learning. In addition, the maintenance procedures were implemented as three-dimensional animations for easy understanding.

D. Usability

- The movements of the models in virtual reality were natural and uninterrupted.
- The graphics provided in the AR content were overall uncluttered and consistent.

To confirm the usability of educational content, the evaluation target was those who worked in a company related to maintenance of the electric multiple unit. The participants consisted of 40 people who had no experience of performing light maintenance work for block brake unit. The researchers informed the participants that the assessment data would be used in an anonymous form and for research purposes only. In addition, the purpose of the user experience survey, the composition and usage of the overall content were explained. Participants responded to the survey after learning the AR content for 20 minutes using the tablet prepared in the practice room.

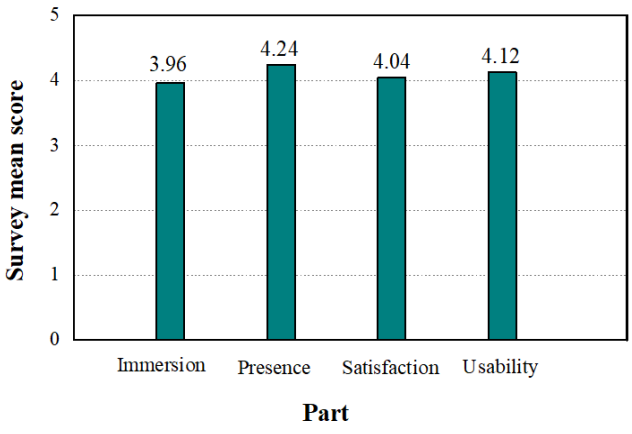

Fig. 11. The graph of survey result.

Fig. 11 is the survey result of 4 parts. The overall mean was relatively high at 4.09, showing the possibility of utilization as educational content. Specifically, the score of the presence part was the highest with 4.24. This is because the equipment used in actual light maintenance work was implemented in AR. In addition, text is displayed by color to make users feel interested. Scores for other parts were relatively high in immersion 3.96, satisfaction 4.04. and usability 4.12.

V. Conclusion

In this study, user experience was evaluated through a survey on AR content, which has recently attracted increasing interest. The content was designed for the maintenance procedure of the block brake unit to be used in the railway vehicle maintenance field. As a method of evaluating ar contents, methods such as System Usability Scale (SUS), Usability Satisfaction Questionnaire (USQ) are widely used [7, 8]. In this paper, the evaluation was conducted by directly modifying the survey to fit the subject of ar contents. The result of the survey consisting of 8 questions was 4.09 on mean, proving its value as educational content.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

JH served as technical consultant, KS conducted the experiments, CS, HJ collected the dataset and served as documentation committee; all authors had approved the final version.

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