Development of an Information Reference System using Reconstruction Models of Nuclear Power Plants

Yuki HARAZONO[1], Taro KIMURA[2], Hirotake ISHII[1], Hiroshi SHIMODA[1], and Yuya KOUDA[3]

1. Graduate School of Energy Science, Kyoto University, Yoshida Honmachi, Sakyo-ku, Kyoto-shi, Kyoto 606-8501, Japan (harazono@ei.energy.kyoto-u.ac.jp, hirotake@ei.energy.kyoto-u.ac.jp, shimoda@ei.energy.kyoto-u.ac.jp)

2. Present: SoftBank Corp., Higashishinbashi 1-9-1, Minato-ku, Tokyo 105-7317, Japan (taro.kimura@g.softbank.co.jp)

3. Fugen Decommissioning Engineering Center, Japan Atomic Energy Agency, Myojin-cho, Tsuruga-shi, Fukui 914-8510, Japan (kouda.yuya@jaea.go.jp)

Abstract: Many nuclear power plants(NPPs) in Japan are approaching the end of their operational lifespan. They need to be decommissioned safely in the near future. By using Augmented Reality(AR), workers can understand information related to decommissioning work intuitively. Three dimensional(3D) reconstruction models of dismantling fields are useful for workers to observe circumstances of dismantling fields without visiting the fields. In this study, an information reference system based on AR and 3D reconstruction models has been developed and evaluated. The evaluation consists of questionnaires and interview surveys with 6 workers at NPP, who used this system along with a scenario. The results showed that it will be possible to reduce the time spent and mistakes in dismantling fields. The results also showed that it is easy to refer information in dismantling fields. However, it was also found that it is difficult for workers to build reconstruction models of dismantling fields by themselves.

Keyword: Augmented reality, Decommissioning work support, Annotation, Planning

1 Introduction

In Japan, many nuclear power plants are approaching the end of their operational lifespan. After the Fukushima accident, all NPPs in Japan stopped their operation and most of them remain stopped. To resume operations, NPPs need to meet the new regulatory requirements. Most NPPs which power generation scales are small are being decided to be decommissioned. Many NPPs need to be decommissioned in the near future.

In dismantling works, a detail plan must be made and workers are required to follow the plan to conduct the dismantling works because of the possible residual radioactivity. Concretely, at first, a field supervisor, who gives work directions, visits a work site and check its condition. Based on their own knowledges and experiences, the field supervisor decides which part should be cut, how they should decontaminate, a work procedure and so on. The dismantled equipment is placed temporarily and measured radioactive residues one by one. There are many narrow areas in NPPs, therefore the field supervisor also examine the route to convey a large equipment. Thus, the field supervisor has to understand clearly the situation of the work site. But, in order to reduce radiation exposure when planning the dismantling work, it is needed to decrease the number of times to visit site and reduce the time length of visiting as much as possible. In actual dismantling works, it is essential that workers grasp the information such as a operational status and existence of residual water in the dismantling objects. Furthermore, decommissioning is a long term work of decades, so it is needed to inherit expertise from experienced workers to younger employees.

Thus, reducing exposure amounts and work mistakes and inheriting expertise to young workers are important. On the other hand, support systems using augmented reality(AR) are expected to increase safety and efficiency in dismantling work because users can grasp relation between objects in real world and their information intuitively[1]. Recently, it becomes easy to make 3D reconstruction models of work site, which reflect the actual situation of work site by virtue of RGB-D camera. RGB-D camera can get not only RGB images but also depth images. By capturing work site, reconstruction models can be made. Reconstruction models reflect even small facilities which don't exist in CAD models. They also reflect current detailed situation which past CAD models can't be grasped because of facility renewal. Once making these reconstruction models, we can check the situation of the work site anytime without visiting. Information which workers want to refer can be annotated on dismantling target objects of reconstruction models. The information can be communicated easier than ever by making visible with AR. These information can be saved as electronic data, and it can be easier to search the past information. This can be useful guides for younger workers when planning dismantling works. Furthermore, reconstruction models can be used as the preparation for using model-based tracking.

Thus, by using reconstruction models in work site, user can confirm work site, share and inherit information easier. Reconstruction models can be the base when using AR.

This paper presents the purpose of this study in chapter 2. Chapter 3 describes an information reference system proposed in this study and their three subsystems. In chapter 4, evaluation of these subsystems mentioned in chapter 3 are discussed. In chapter 5, summery and future works are mentioned.

2 Purpose of this study

A purpose of this study is to develop and evaluate an information reference system that is available in dismantling works of NPPs using reconstruction models and AR. Specifically aiming at developing a system that has following two features:

1. Work related information can be made and recorded without visiting work site by the virtue of reconstruction models reflecting detail situation of the work site.
2. The work related information can be refereed by workers on site with a intuitive and concrete relation to the target instrument using AR.

For the evaluation, a trial experience was conducted by workers occupied in dismantling works. The system utility and problems arising when adopting the system in actual dismantling works were researched.

3 Information reference system

In this chapter, the overall of the information reference system is referred, and three subsystems and their functions in the system are explained.

3.1 Overall of the system

Figure 1 presents an overview of information reference system developed in this study. The system consists of three subsystem, Modeler, Annotator, and Viewer. With the Modeler, 3D reconstruction models are made reflecting current detailed situation using RGB-D images captured in work site. With the Annotator, using desktop computer, user can virtually visit work site and choose dismantling target objects and annotate information related to dismantling work. The items and choices of the information which user can input were decided by opinions of the workers in dismantling work. Annotator also has a function to simulate layout of vessels storing dismantling wastes. In the Viewer, user can refer information annotated by Annotator using a tablet computer on site. These information are displayed by superimposing with AR. Using these subsystems in turn decreases the number of times of visiting site when considering and making the work plans and the duration of visiting. It also encourages to share information among workers and to comprehend information intuitively in dismantling work. Each subsystem is used by field supervisor and workers, so we must develop these subsystems carefully so that even who don't have any knowledge about computer can use easily.

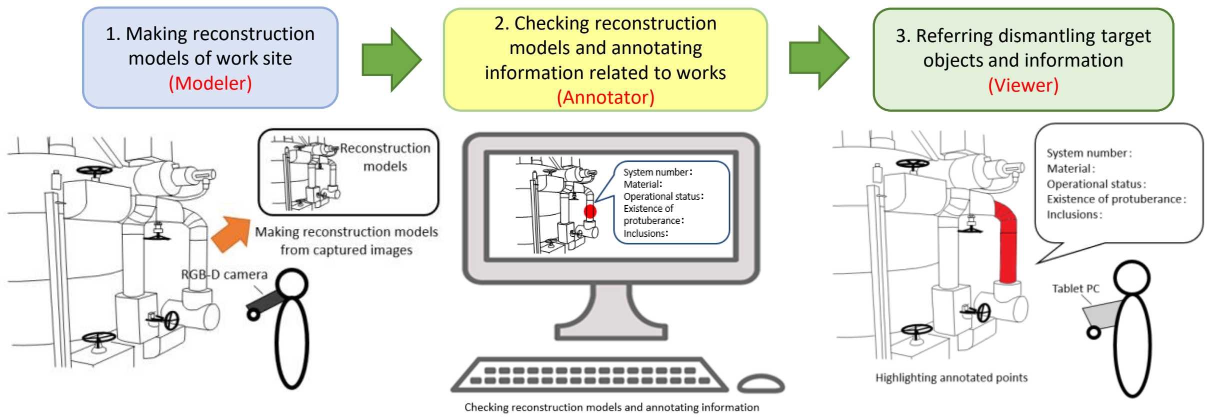

Figure 1 Overview of information reference system.

3.2 Modeler

As a method to make reconstruction models, various methods are available such as using RGB camera[2], using RGB-D camera[3], and using laser scanner. In this system, we employed a method using RGB-D camera[4] because it can be used with a small device, it can be brought into NPP and it can make detail reconstruction models. However, in this study, the use of this method is trial, and we are developing another method to make reconstruction models for the future. Reconstruction models are down-sampled using Quadric Clustering[5] so that the resolution of each dimension is about 1cm to reduce their volume of data.

3.3 Annotator

Using Annotator, user can check reconstruction models made by Modeler. Annotator has three functions.

1. information adding function
2. distance measuring function
3. layout simulation function for vessels storing dismantling wastes

These functions were chosen based on the opinions by workers in NPP. Figure 2 presents the example of screenshot of Annotator. Main screen of Annotator consists of two parts, reconstruction model view and operation window. The reconstruction model view displays reconstruction models using Visualization Tool Kit[6]. Operation window includes buttons to make new file, save and load files, change and reset viewpoints of reconstruction model view, and set floor surface. Operation window also includes information

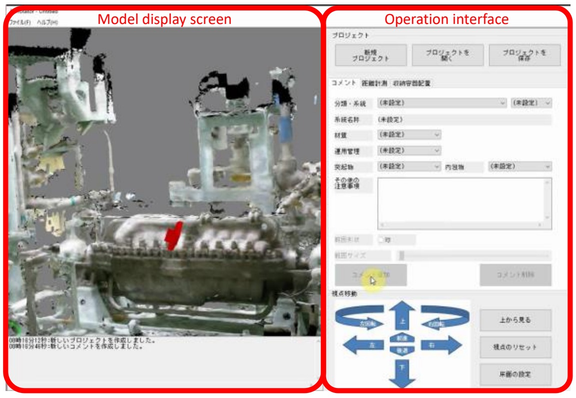

Figure 2 Screen shot of Annotator.

Figure 3 Screen shot of distance measuring function.

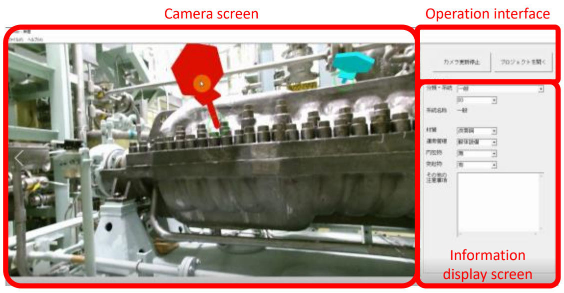

Figure 4 Screen shot of Viewer.

describing tab, distance measuring tab, and vessel layout tab.

After selecting the information describing tab, by left-click at any point of the reconstruction model, user can place the cross-shaped cursor. By pushing the button to add information, user can place a virtual tag at the point of the cursor. On this occasion, an information input form appears on operation window, and user can input the information such as notes for dismantling work. There are six items, such as 1.system number and name of facilities, 2.material, 3.operational status, 4.existence of protuberance, 5.inclusions, and 6.other notes. In order to make it easy for users to recognize the points which the tags are placed and their states, the chosen tag is colored in red and others are colored in blue and yellow in order that users can notice them easily.

After selecting the distance measuring tab, by left-click at any two points or more of the reconstruction model, circles are displayed at these points, and the distances between each points are displayed as shown in Figure 3. Although user might not be able to recognize real scale when reconstruction models are displayed on PC, user can grasp the situation in work site easily by using this function.

When selecting vessel layout tab, user can simulate to layout vessels storing dismantling wastes, but it is needed to set up where is floor in the reconstruction model in advance because the vessels are put on floor. In this system, by choosing any point of floor, floor is recognized automatically by plane recognition using RANSAC. After the recognition, by left-click at any point of the floor, the cross-shaped cursor is placed and user can place a virtual vessel. User can change type, number of tiers and direction by pulldown menu, radio button and slide bar. User also can move the vessel along the floor by drugging on model display screen. This subsystem can detect collisions among vessels and facilities in real time. When collisions happen, the color of the vessels is changed to inform user.

User can save these results to a file. Loading this file, user can refer the information at Viewer.

3.4 Viewer

Figure 4 presents an example screenshot of Viewer. Display of Viewer consists of three parts, camera view, operation window and information window. Microsoft Surface 3 is used as the hardware for Viewer. Camera view displays camera images in real time. The virtual tags and vessels are displayed on camera view according to the current position and direction of camera. Selecting tags on camera view by stylus pen, user can see the information of the selected tag at information window. In operation window, there are the buttons to load files and to stop and restart updating camera images. When watching the work places and notes with Viewer, holding camera toward the work objects may be burden for workers. Therefore, we implemented a function to stop and restart updating camera images.

In Viewer, the tags and vessels are displayed by superimposing at the correct position with AR. In this system, model-based tracking with reconstruction models is employed so that the user can use AR without placing AR markers in work site. But, as described later, we used AR markers for tracking to reduce preparation time when evaluating this system.

When using Viewer, by selecting the button to load files and selecting files made by Annotator, the selected file are loaded, and the placed tags and vessels are displayed with superimposing. The vessels are displayed with reflecting type, number of tiers and direction set by Annotator.

4 Evaluation of the system

4.1 Purpose of the evaluation

The purpose of the evaluation was to investigate its utility of the developed system in real dismantling works and what can be problems when applying it to real dismantling works.

Figure 5 Appearance of Charging pump room.

4.2 Method of the evaluation

In this evaluation, six workers at Fugen decommissioning engineering center used the developed system along with a scenario in a charging pump room in controlled area and conference room. According to heuristic method, utility is evaluated by questionnaires and interview surveys. Figure 5 presents the appearance of charging pump room.

Figure 6 presents the procedure of the evaluation. Experimenter explained about whole evaluation in advance. Then, the trial of Annotator, questionnaires and interview surveys about Annotator, the trial of Viewer, questionnaires and interview surveys about Viewer and questionnaires and interview surveys about the whole system were conducted in turn. In prior examination, we found Modeler was difficult for workers to use. Therefore, only Annotator and Viewer were evaluated. In the trial use of Annotator, reconstruction model of charging pump room was made in advance. Microsoft Kinect Sensor was used to make this reconstruction model. In the trial of Viewer, AR markers[7] were placed for tracking in order to reduce the time of prior preparation.

In the trial of Annotator, experimenter demonstrated each functions of Annotator at first. After the demonstration, six workers tried Annotator. At conference room, they used Annotator. They placed tags on the reconstruction model of charging pump room, described information which was considered to be needed, and saved these results to file. Then, they placed vessels on the reconstruction model of the room resembling work site, and saved

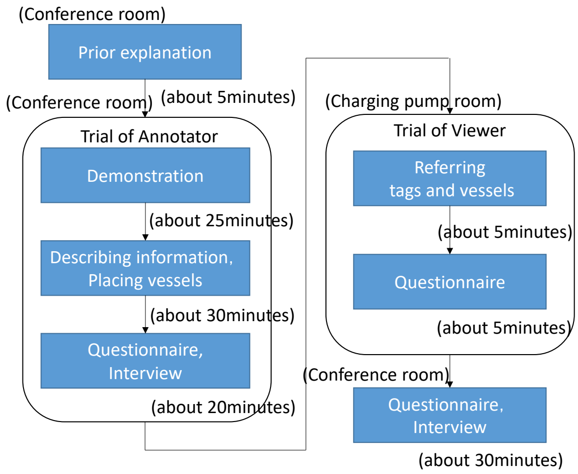

Figure 6 Flow of experimental evaluation.

Table 1 Examples of questionnaire about Annotator

questionnaires
・You could check displayed models in detail.
・You could describe information related to dismantling works easily.
・You could place vessels at the intended points.
・Who uses the system for the first time can use easily.

Table 2 Examples of questionnaire about Viewer

questionnaires
・You could understand which points the tags were placed easily.
・It was easy to refer the information by choosing tags in camera view.
・You could understand easily which points the vessels were placed.
・Who uses the system for the first time can use easily.

Table 3 Examples of questionnaire about whole system

questionnaires
・The time length of visiting work site seems to be shorter by using Annotator.
・The mistakes in work seems to be reduced by using Viewer.
・The system seems to be more effective than paper medium.

these results to another file. During this trial, they used all functions of Annotator along with the task list regardless of its order. At last, experimenter conducted questionnaires and interview surveys about usability of each functions. Questionnaires were answered on a scale of one to five. In interview surveys, experimenter interviewed about the reasons of their answers of each items. Table 1 presents examples of questionnaires about Annotator.

In the trial of Viewer, experimenter explained about each functions of Viewer at charging pump room. Then, the workers tried Viewer one by one. They referred notes and vessels at two places in charging pump room. Evaluators loaded file including notes and vessels, and they used stylus pen and selected the tag displayed by superimposing on camera images to refer notes. They also confirmed vessels displayed by superimposing on the floor of charging pump room. Then, they answered questionnaires in the charging pump room, and we interviewed about the reasons of their answers of each items at conference room. Table 2 presents examples of questionnaires about Viewer.

After the trial, questionnaires and interview surveys about Annotator and Viewer, experimenter conducted questionnaires about the whole developed system. After the questionnaires, experimenter also interviewed about the reasons of their answers of each items. Table 3 presents examples of questionnaires about whole system.

4.3 Results and discussions

In the evaluation, prior explanation took about 5 minutes, the trial of Annotator took about 75 minutes, the trial of Viewer took about 10 minutes, and questionnaires and interview surveys about whole system took about 30 minutes. Table 4 presents main results of the evaluation.

From the results of questionnaires and interview, an opinion that reconstruction models in the Annotator looked rough when user zoomed in the reconstruction model was gotten. The reconstruction models using in the evaluation were not enough to be observed in detail. In the evaluation, taking the performance of PC into consideration, reconstruction models were down-sampled by Quadric Clustering so that its data size wasn't big. We can use more detailed reconstruction models if using better performance PC.

Table 4 Main results of the evaluation

main results
・Changing viewpoints by mouse operation was easy and effective.
・Measuring distances function would be useful at narrow place and the place where it was difficult to operate dismantling devices.
・The system would be better if user also could measure surface area and volume in Annotator.
・The system would be better if user could annotate information in Viewer the same as Annotator.

In the function to change viewpoints, it was found that changing viewpoints by mouse operation was easy and effective, but by the button operation, the axis of rotation was difficult to understand, and the operation by mouse was faster than by the button. In development phase, we thought that user could change viewpoints intuitively by using buttons. It was found that the operation by mouse was more intuitive and suitable. We got also opinions that it would be better if user could change his/her viewpoint in parallel by mouse. Therefore, it would be easier to check reconstruction models by making the system in order to change viewpoints only with mouse operation.

In the function to measure distances, we got the opinion that this function would be useful at narrow place and the place where it was difficult to operate dismantling devices. It was found that this function was useful. We got the opinion that the system would be better if user could measure not only distance but also surface area and volume of facilities. We also got the opinion that the system would be better if user could place not only vessels but also scaffolding and devices for dismantling.

In Viewer, we got the opinion that the size of application screen, buttons and characters were small. Work site is dark and the visibility is bad. In addition, workers have to wear gloves. So, display buttons and characters should be bigger than when used at office. In reference of described information, we got the opinion that the placed location of tags and described information were comprehensible. But, we also got the opinion that facilities in work site were hidden by superimposed tags. So, we have to reconsider the shape and size of tags and consider the way to display, such as using wire frame models instead of solid models. We got the opinion that user could describe information which is unique to workers visiting work site, such as how workers coped with in the past cases by making the system in order to describe information the same as Annotator. So, we found that utility of the system would be improved by introducing the function to describe information in work site. But, when introducing this function, some ideas such as the fixed phrases are needed in order to describe information easily because it is needed to reduce the length of visiting work sites.

About whole system, we got the opinion that in Annotator, this system would be useful, because it could reduce the duration of visiting work sites, if the problems about interface were improved. In Viewer, we found that workers could reduce mistakes by using this subsystem. But, considering each functions in more detail, there were many technical problems such as the ways of displaying tags and the improvements such as about functions described above. In Modeler, it is difficult for workers to use this system and make high-precision reconstruction models. So, there is the need enabling to make reconstruction models easily such as the improvement of Modeler in the future.

5 Summary

In this study, we aimed to improve safety and efficiency in dismantling work at NPP. We developed information reference system using reconstruction models and AR, and we evaluated utility of the system and investigated problems arising when applying the system to actual dismantling works by questionnaires and interview surveys with workers in NPP. In the evaluation, it was revealed that the reduction of the time duration of visiting work sites and the decrease of mistakes in works can be expected. The challenges for the future is realization of the system with which workers can make reconstruction models easily.

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