Nuclear Engineering and Technology xxx (2018) 1–7

Contents lists available at ScienceDirect

Nuclear Engineering and Technology

journal homepage: www.elsevier.com/locate/net

Original Article

Development of an information reference system using reconstruction models of nuclear power plants

Yuki Harazono [a, *], Taro Kimura [b], Hirotake Ishii [a], Hiroshi Shimoda [a], Yuya Kouda [c]

[a] Graduate School of Energy Science, Kyoto University, Yoshida Honmachi, Sakyo-ku, Kyoto-shi, Kyoto 606-8501, Japan
[b] SoftBank Corp., Higashisfhinbashi 1-9-1, Minato-ku, Tokyo 105-7317, Japan
[c] Fugen Decommissioning Engineering Center, Japan Atomic Energy Agency, Myojin-cho, Tsuruga-shi, Fukui 914-8510, Japan

ARTICLE INFO

Article history:
Received 2 February 2018
Received in revised form
24 February 2018
Accepted 7 March 2018
Available online xxx

Keywords:
Annotation
Augmented Reality
Decommissioning Work Support
Planning

ABSTRACT

Many nuclear power plants in Japan are approaching the end of their planned operational life spans. They must be decommissioned safely in the near future. Using augmented reality (AR), workers can intuitively understand information related to decommissioning work. Three-dimensional (work-site) reconstruction models of dismantling fields are useful for workers to observe the conditions of dismantling field situations without visiting the actual fields. This study, based on AR and work-site reconstruction models, developed and evaluated an information reference system. The evaluation consists of questionnaires and interview surveys administered to six nuclear power plant workers who used this system, along with a scenario. Results highlight the possibility of reducing time and mitigating mistakes in dismantling fields. Results also show the ease of referring to information in dismantling fields. Nevertheless, it is apparently difficult for workers to build reconstruction models of dismantling fields independently.

1. Introduction

Many nuclear power plants (NPPs) are approaching the end of their operational life spans. After the Fukushima Daiichi accident, all NPPs in Japan ceased operations. Most have remained halted. To resume operations, NPPs must meet new regulatory requirements, but most small-scale NPPs are being selected for decommissioning instead. Many NPPs must be decommissioned in the near future.

Before dismantling work, a detailed plan must be made. Because of possible residual radioactivity, workers must then follow the dismantling plan carefully. Concretely, a field supervisor, who gives work directions, first visits a work site to ascertain its condition. Based on his/her own knowledge and experience, the field supervisor then decides which parts should be cut, how the area should be decontaminated, what work procedures to use, and so on. The dismantled equipment is arranged temporarily while radioactive residues are measured. Because NPPs are known to have many narrow areas, the field supervisor also examines the routes used to convey bulky equipment. Therefore, the field supervisor must clearly understand the work-site situation. However, to reduce radiation exposure during dismantling work planning, one must decrease the number of site visits and must reduce, to the greatest extent possible, the time spent in the area itself. For actual dismantling work, workers must grasp information such as the operational status and existence of residual water in the dismantling objects. Moreover, decommissioning is long-term work, lasting decades. Therefore, younger employees must inherit expertise from experienced workers.

As expected from the aforementioned section, reducing exposure amounts and work mistakes and providing expertise to young workers are important. Support systems using augmented reality (AR) are expected to increase safety and efficiency in dismantling work because users can intuitively ascertain real-world relations between objects and their related information [1]. Recently, making three-dimensional (work-site) reconstruction models of work sites has become easy. By virtue of using RGB-D cameras, which can obtain not only RGB images but also depth images, models can reflect the actual work-site situation. By capturing work-site details, reconstruction models can be produced to reflect even small facilities that do not exist in CAD models. They can also reflect current detailed situations that past CAD models have not reflected because

* *Corresponding author.*
E-mail addresses: harazono@ei.energy.kyoto-u.ac.jp (Y. Harazono), taro.kimura@g.softbank.co.jp (T. Kimura), hirotake@ei.energy.kyoto-u.ac.jp (H. Ishii), shimoda@ei.energy.kyoto-u.ac.jp (H. Shimoda), kouda.yuya@jaea.go.jp (Y. Kouda).

https://doi.org/10.1016/j.net.2018.03.014

of facility renewal. Once these reconstruction models have been made, one can verify the work-site situation at any time without a site visit. Information that workers want to refer to can be annotated on dismantling target objects of the models. Then, that information can be communicated easily by displaying it using AR. Furthermore, the information can be saved as electronic data, making past information accessible and searchable, thus providing useful guides for younger workers when planning dismantling work. The models are also useful for preparation using model-based tracking.

Using reconstruction models at work sites can help users confirm work sites and help them share and inherit information. Reconstruction models can also support AR.

This article presents the study purpose in Section 2. Section 3 explains the proposed information reference system and its three subsystems. In Section 4, the subsystems described in Section 3 are evaluated. In Section 5, a summary and future works are described.

The purpose of this study is the development and evaluation of an information reference system using reconstruction models and AR that can be available during NPP dismantling work. The developed system has the following two features.

1. By virtue of reconstruction models reflecting details of the work-site situation, work-related information can be produced and recorded without visiting work site.
2. Workers on site, using AR, can refer to work-related information with an intuitive and concrete relation to the target instrument.

For evaluation, a trial was conducted with workers doing dismantling work. The system and system-related difficulties were investigated during actual dismantling work.

2. Information reference system

This chapter explains the overall information reference system. Three subsystems and their functions in the system are described.

2.1. Overview of the system

Fig. 1 presents an overview of the information reference system developed for this study. It has three subsystems: the Modeler, Annotator, and Viewer. With the Modeler, 3-D reconstruction models are made using RGB-D images captured at the work site. The models reflect current situation details. With the Annotator, using a desktop computer, the user can virtually visit the work site and can annotate information related to dismantling work. The items and choices of information that the user can input were chosen based on opinions of workers who actually perform dismantling work. In addition, the Annotator has a function of simulating the layout of vessels used for storing dismantling wastes. Using the viewer on a tablet computer, an on-site user can refer to information annotated by the Annotator. This information is displayed superimposed with AR. Using these subsystems decreases the number and duration of site visits when considering and producing work plans. It encourages information sharing among workers and also facilitates information comprehension during dismantling work. Each subsystem is used by field supervisors and workers. Therefore, these subsystems must be developed carefully so that even workers with no knowledge of computers can use them easily.

2.2. Modeler

To produce reconstruction models, various methods are available, such as using an RGB camera [2], using an RGB-D camera [3], and using a laser scanner. For this system, we used a method with an RGB-D camera [4]; because it is a small and useful device, it can be brought into an NPP and can produce detailed reconstruction models. However, the use of this method is a trial. We are developing another method to produce future reconstruction models. Reconstruction models are downsampled using Quadric Clustering [5] to produce resolution of approximately 1 cm for each dimension and to reduce the data volume.

2.3. Annotator

Using the Annotator, a user can check the reconstruction models produced by the Modeler. The Annotator has three functions:

1 information-adding function
2 distance measurement function
3 layout-simulating function for vessels storing dismantling waste materials

These functions were chosen based on NPP worker opinions. Fig. 2 presents an Annotator screenshot. The Annotator main screen has two parts: reconstruction model view and operation window. The reconstruction model view displays reconstruction models using the Visualization Toolkit [6]. The operation window includes buttons to produce a new file, save and load files, change and reset

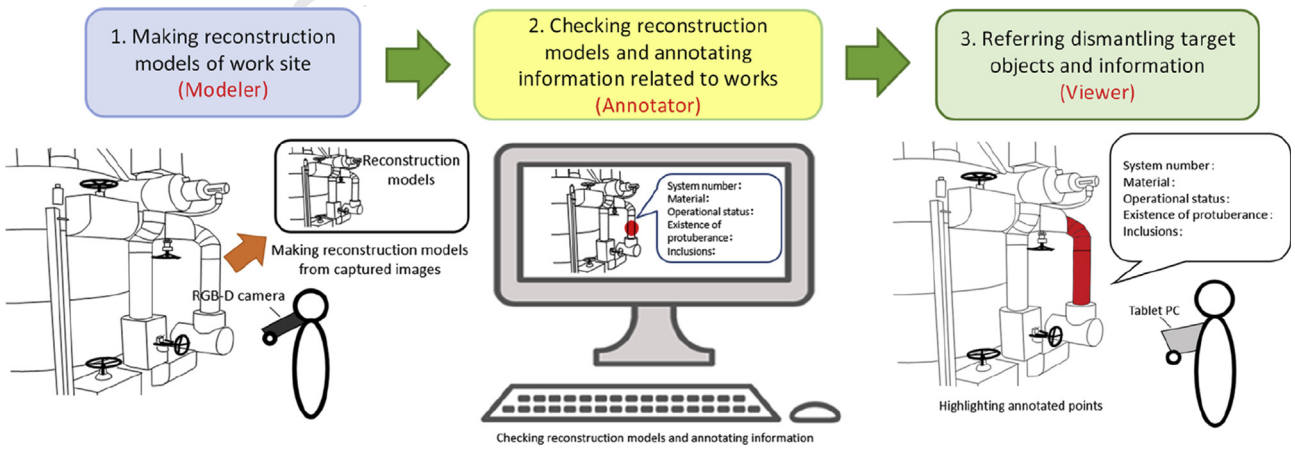

Fig. 1. Overview of information reference system.
PC, personal computer.

Please cite this article in press as: Y. Harazono, et al., Development of an information reference system using reconstruction models of nuclear power plants, Nuclear Engineering and Technology (2018), https://doi.org/10.1016/j.net.2018.03.014