Abstract

A Study on Field Work Support in Nuclear Power Plants Utilizing 3D Reconstruction Model and Tagging

(3 次元再構成モデルとタギングを活用した
原子力発電プラントの現場作業支援に関する研究)

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Chapter 1: Introduction

At nuclear power plants (NPPs) in Japan and other countries, there is a great need and demand for maintenance work to maintain and improve the durability of facilities for continuous operations, and for decommissioning work. In particular, because it is required a high level of safety and reliability in nuclear field, all such maintenance and decommissioning work must be performed meticulously and safely to avoid serious accidents and must be appropriately responded to in the event of an emergency.

In order to realize them, many research and development has been conducted in the nuclear field on work improvement and work support utilizing information and communications technology (ICT). Among these research and development, there is much potential for improvement and support for work errors and accidents caused by human error during work. Solving the problems will greatly contribute to reducing the risk of accidents.

In this thesis, I focused on support using a three-dimensional (3D) model as a work support for reducing human error. By using a 3D model, the 3D shapes of the work object can be easily and intuitively understood. In addition, these 3D information are available in electronic data, which facilitates confirmation and simulation on a PC. In recent years, with the spread of measurement devices such as LiDAR and rapid advances in image and point cloud processing technology, it has become possible to obtain 3D models that directly reflect the conditions of the scanned environment, called 3D reconstruction models. In contrast to conventional CAD models, 3D reconstruction models can be used to check the actual condition of equipment and even detailed facilities that are not reflected even in the CAD models.

In this thesis, I proposed a support method using “tagging” as a new idea for work support utilizing the 3D reconstruction model. In this thesis, tagging is defined as the

act of linking information to a certain facility or location. In contrast to conventional paper-based information description and confirmation, tagging on a 3D reconstruction model enables users to describe information in a real world-oriented and object-oriented way, which enables intuitive input of information. In addition, the 3D reconstruction model reflects the situation at the work site faithfully, and the user can intuitively confirm the tagged information by utilizing augmented reality (AR). In previous research, there have been research and development on the creation of databases of work information using electronic data or using CAD models, but a method that utilizes a 3D reconstruction model that faithfully reflects the work site situation as an interface to input and output data is a new approach.

In this thesis, I proposed the work support methods using tagging for two situations in NPP and evaluated the usefulness of these proposed methods. One is the application of tagging to support work planning and information sharing during maintenance and dismantling work in NPP. The other is the application of tagging in emergency drills in nuclear facilities.

Chapter 2: Evaluation of the Effectiveness of Tagging on 3D Reconstruction Models

As the first situation, I proposed and developed a work support system for work planning and information sharing during maintenance and dismantling work in NPP by utilizing tagging. This system consists of a GUI tool that enables the user to view a 3D reconstruction model of the work site from any perspective on a PC and to describe information (tagging) on the model, and an AR application that enables the user to confirm this tagged information at the actual work site during works. The usability of this system was evaluated through questionnaires and interviews.

The evaluation was conducted on six actual workers at an NPP where actual decommissioning work was being conducted. The results of the evaluation indicated from the questionnaire and interviews that tagging can reduce work errors at the work site and reduce the time spent at the work site by utilizing a 3D reconstruction model to understand the work site situation. However, several problems were mentioned regarding the operability of the developed interface, such as the speed of moving the viewpoint. In addition, it was found to be very difficult for workers to create the 3D reconstruction models that would enable tagging to be used.

Chapter 3: Development and Evaluation of Support System for Creating Taggable 3D Reconstruction Models

Since the evaluation conducted in Chapter 2 showed that it is difficult for workers to

create a 3D reconstruction model, a scanning support system was proposed and developed to enable them to easily create a 3D reconstruction model. In the scanning support system, an RGB-D camera is attached to a tablet PC. The user scans the work site by the RGB-D camera while moving around the work site, and a 3D reconstruction model is created from the scanned data. The system calculates unscanned areas that have not yet been scanned and displays them superimposed by AR on the tablet PC screen to encourage scanning so that more areas are scanned and reflected to the 3D reconstruction model.

Since it was not available to conduct a large-scale user evaluation of the effectiveness of this scanning support system for workers in NPP, a large-scale user evaluation for general students in an indoor environment such as an office was conducted. In this evaluation experiment, 16 valid data were obtained with the cooperation of 18 participants. The results showed that the scanned volume rate for a defined indoor space was 40.9±6.8% when the non-assisted scanning system was used, whereas the rate was 43.4 ± 3.5% when the developed scanning support system was used, which was significantly higher ($p<0.05$). From the interview, it was also found that the users were able to easily understand where they should scan next.

In addition, to verify the usefulness and effectiveness of the system in an actual NPP, a similar experiment was conducted at an actual NPP with actual workers. Four workers were asked to scan a defined work site using similar two systems. The results showed that the developed scanning support system had a higher scanned volume rate for all workers even in the actual work site.

Chapter 4: Development and Evaluation of AR Training by Tagging to Real Environment

As the second situation, I proposed and developed an AR training construction system using tagging for emergency drills at nuclear facilities. In this system, users can create a training scenario including various events, such as explosions, water leaks, and intruder escapes, as well as the timing and conditions of their occurrence, by combining block-like blocks called “program blocks.” Users can set the timing and conditions for these events by placing (tagging) them at the desired locations in the real space where users want to occur the events during the AR training. Users can also experience the created training scenarios in AR using a tablet PC.

Conventional training experiences using AR often have a limited number of scenarios that can be experienced, but this system enables users to create and experience a variety of scenarios by freely combining program blocks. In addition, these AR trainings are usually developed on the desktop using a text-based programming language, which

required knowledge and time and effort to create. However, this system uses building block-like blocks and creates scenarios by tagging to real space, making it easy to create content without text-based programming and knowledge about it.

In the evaluation, a user evaluation of the usefulness of the developed AR training construction system was conducted with seven workers at an actual nuclear facility. In the evaluation, the evaluators were asked to create and experience two types of AR training contents with this system: a scenario designed in advance by the experimenter, and a scenario designed by the evaluators themselves freely. A questionnaire survey and an interview survey were then conducted regarding operability and the degree of freedom of the training scenarios that could be created.

As a result, even a user with no experience in conventional text-based programming was able to create an AR training within a few dozen minutes.

This indicates that AR training can be created more easily and in a shorter time than conventional AR training construction methods by using this system. As for the degree of freedom of the created scenarios, the interviews revealed that it was not high enough, but minor modifications, such as adding types of blocks in the program blocks, could be made to achieve the degree of freedom required in the actual nuclear facilities.

Chapter 5: Conclusions

In this thesis, I proposed support methods utilizing 3D reconstruction models and tagging for NPP work, and I also evaluated their usefulness by user evaluation. As a result, it was found that the support system using 3D reconstruction models and tagging is useful in reducing the time spent at the work site in work planning support and reducing work errors in information sharing support during works at work sites. In addition, it was found that the 3D reconstruction model for tagging can be easily created by the user using the proposed scanning support system, and that even workers without expertise in scanning can scan the work sites and create 3D reconstruction models which enables users to do the tagging. Moreover, it was found that even users with no programming experience can easily construct and experience AR training with various scenarios by tagging training sites.

The technology for tagging information to real or digital space and the technology for creating taggable space or environment by scanning space to realize tagging can be expected to be used in other infrastructure fields and public spaces in the future. The findings obtained in this research will be very useful when the world in which all information in real space is reflected in digital space, as typified by the digital twin, is realized in the future.

References (Publications)

[Chapter 2]

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