Estimation of Decommissioning Quantity Based on 3D Intelligent Model – 17075

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ABSTRACT

A decommissioning support system for estimating waste quantity was developed on the basis of three dimensional models for projects to decommission nuclear power plants. On the basis of the developed system, the spatial distribution of the dose rate surrounding equipment and piping components can be visualized, and the number of containers required to store segmented waste objects can be counted. We confirm that the developed system can support decommissioning engineering systematically and effectively because of its ability to map radioactive inventory data to 3D objects to automatically calculate the dose rate and generate waste container models.

1. INTRODUCTION

The number of decommissioning projects for nuclear power plants (NPPs) that have been in operation for many years will increase. It is important to safely carry out decommissioning projects for NPPs, efficiently, and economically.

In the past thirty years, several decommissioning projects have been implemented, and related project management systems have been developed. Regarding research on reactors, The Japan Demonstration Power Reactor (JPDR) database, the database for dismantling and the evaluation of workload, radiation exposure dose, waste weight, and schedule of dismantling processes was managed by the Computer Systems for Planning and Management of Reactor Decommissioning (COSMARD) [1]. Research institutes of Japan and Norway have developed a decommissioning engineering support system (DEXUS) to identify the appropriate dismantling plan in the decommissioning project [2]. For simulating and planning of dismantling work in a radioactive environment, virtual reality (VR) methods have been applied to VRDOSE [3]. The dose-rate distribution can be computed with a numerical code considering source types and locations and the environment's geometry and characteristics of materials [4,5,6]. A cutting-process simulation has been developed and tested [7] regarding the waste from equipment and piping components.

We have been developing a decommissioning engineering support system on the basis of 3D CAD models [8, 9]. There are essential technologies for decommissioning engineering, such as for evaluating the residual radioactive inventory, planning for decontamination and dismantling, remotely controlling dismantling machines, managing waste processing, and measuring radiation. Decommissioning projects should proceed appropriately on the basis of these technologies. To integrate them, the 3D geometric shapes of a decommissioning plant, functional system data, and data on residual radioactivity accumulated during plant operation should be stored in a database and shared among decommissioning support systems.

2. DEVELOPMENT OF A DECOMMISSIONING SUPPORT SYSTEM

A Decommissioning support system have been developed for estimating radioactive-waste quantity, planning for cutting up equipment and piping components, determining carry-out paths for large equipment, and evaluating the accumulated doses in the environment with regard to worker safety (Fig. 1).

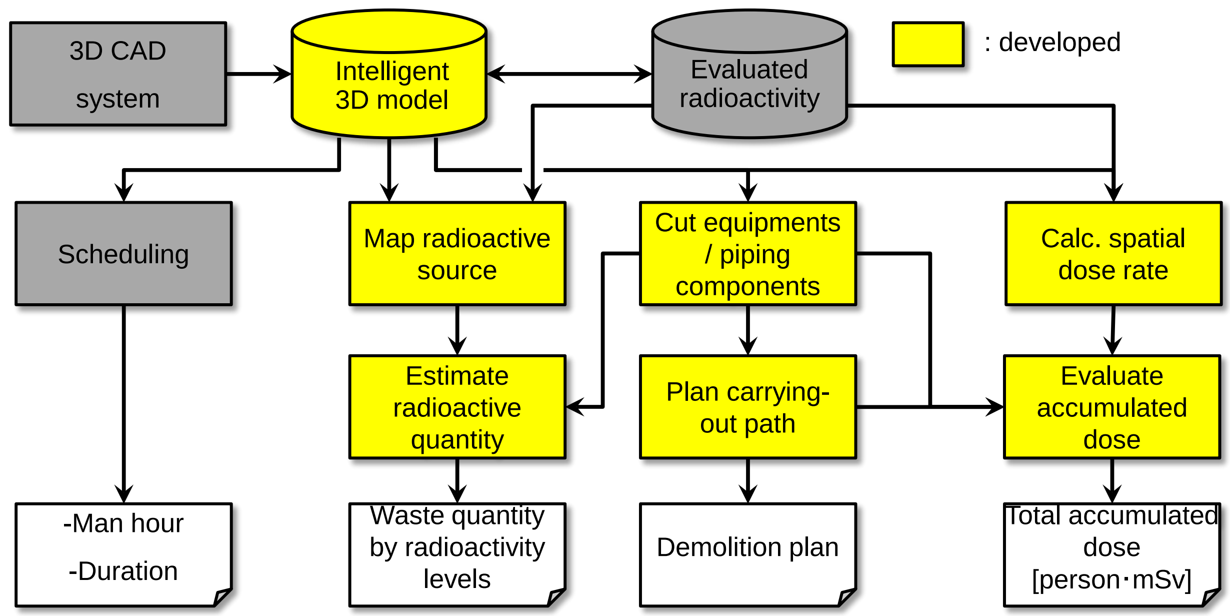

Fig. 1. System configuration

2.1 Estimation of waste quantity

In the decommissioning support system, radioactivity data are automatically mapped onto the inner surfaces of equipment and piping components as radioactive source data. Using the 3D radioactive source data, the spatial distribution of dose rates is calculated with a particle and heavy ion transport code system [10]. A 3D viewer visualizes the spatial dose rate distributions on the basis of the calculated results. Then, the 3D objects of the equipment and piping components are cut up so that the segmented objects can be stored into waste containers. With these functions, the number of waste containers and amount of radioactivity and weight required for dismantling are calculated in decommissioning areas.

On the basis of the calculated results for the dose-rate distribution, transparent voxels colorized depending on the dose rate value are placed on a 3D plant model so that the dose-rate distribution for the work environment can be visualized (Fig. 2). Then, a 3D model for packaging the segmented equipment and piping components is generated and visualized (Fig. 3). Piping components are automatically segmented in either cross or lengthwise half-cut directions. Furthermore, packaging methods, such as for perpendicular or vertical packaging, and fill rate of segmented components can be varied, and the relationships between the cutting length and number of waste containers required to package the waste can be examined.

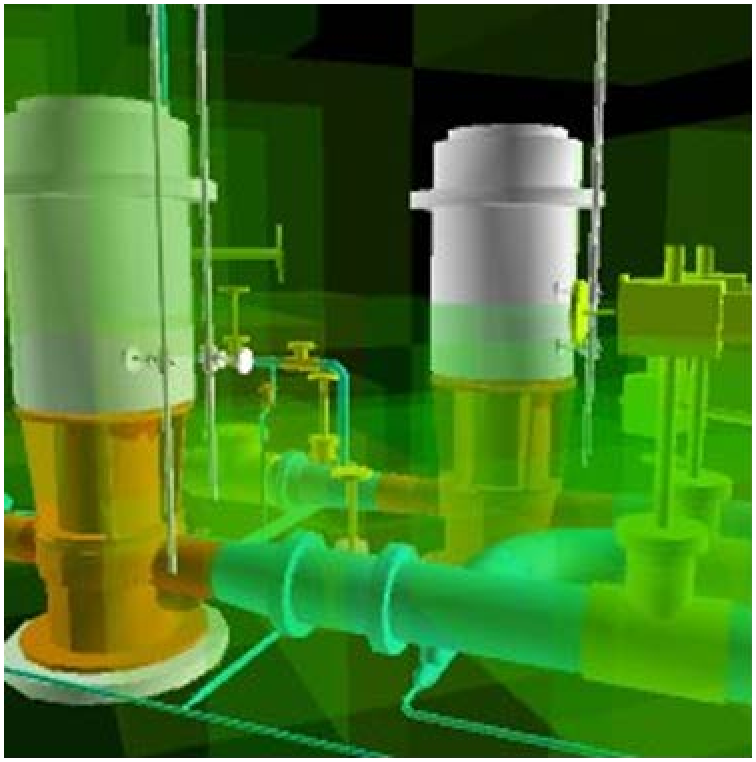

Fig. 2. Spatial distribution of dose rate around equipment and piping components

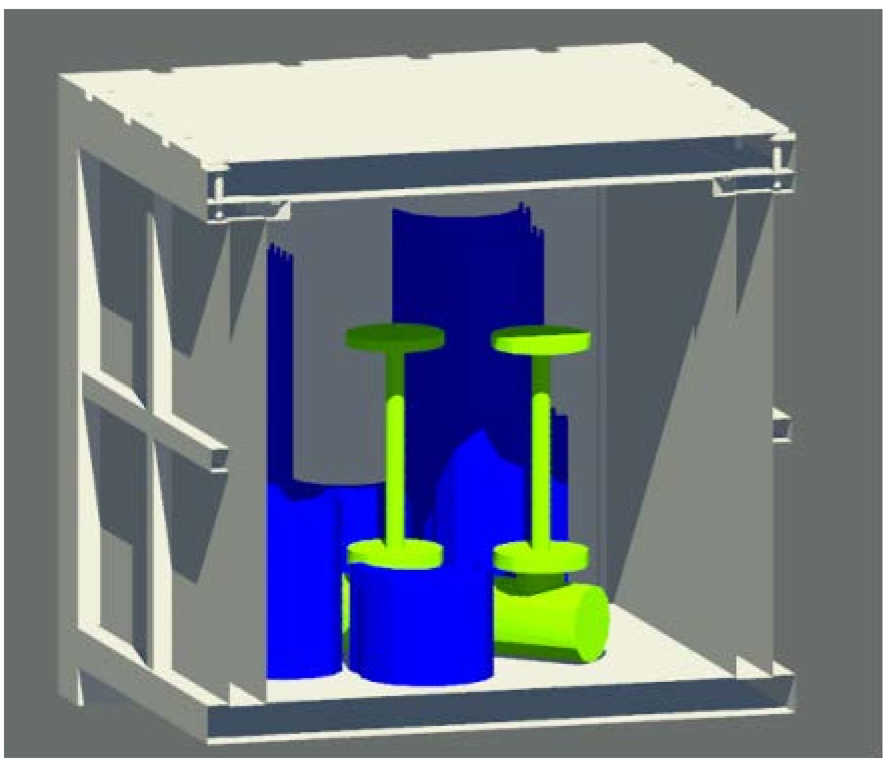

Fig. 3. Generated waste-container model

2.2 Planning of carrying-out paths

After packaging the segmented piping components and equipment into waste

containers, the containers should be transported to a storage facility. To do so, the container should be moved inside the building because the exposure dose from the container should not leak and the low dose rate outside the building should be maintained. The structures of NPP buildings are made of thick concrete walls, ceilings, and floors, and some corridors are narrow so that large equipment or waste containers are difficult to be carried out. Therefore, it is important for planners to find appropriate paths to carry out large components. We developed a simulator for carrying out large components within such complex buildings [11]. With the simulator, the starting point, ending point, and waypoints are first designated, then the carry-out paths for the equipment without interfering with other components are calculated automatically (Fig. 4). To calculate the carry-out paths, the following three requirements are taken into consideration. (1) Realization of interactive operations. To achieve this, the processing time to determine one path should be less than one minute. (2) Provision of alternative plans of carry-out paths to the plannerwith indexes, such as the sizes of space margins and number of turning points. (3) Generation of the configuration of components that should be carried out, i.e., what are the trajectories to avoid collisions with suspension-crane wires?. Due to automatic calculation of trajectories and component configurations that should be carried out, carry-out paths, number of change directions of a dolly, and configurations of components that are rigged by cranes are determined before actual decommissioning work activities begin, so that safe decommissioning planning, minimizing collisions of components with walls and structures, and visualization of interference objects can be done.
To determine optimum paths for carrying out components, indexes, such as the exposure dose and number of change directions, should be minimized, and the margin of spaces between structures and components being carried out should be maximized.

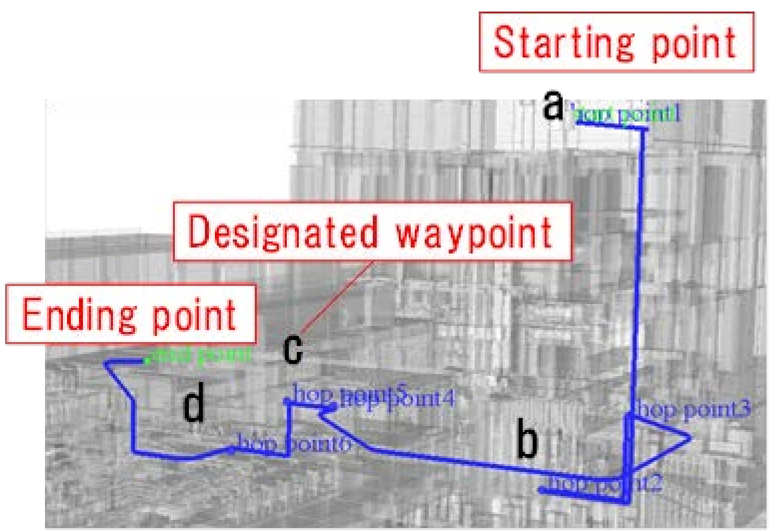

Fig. 4. Generated carry-out path of waste containers in building

Rigging dynamics are taken into consideration for cranes used for heavy equipment. Crane-rigging equipment is rigged by one link connected with one spherical joint and hung on a vertical rail with a spherical joint to lift it up or down

(Fig. 5).

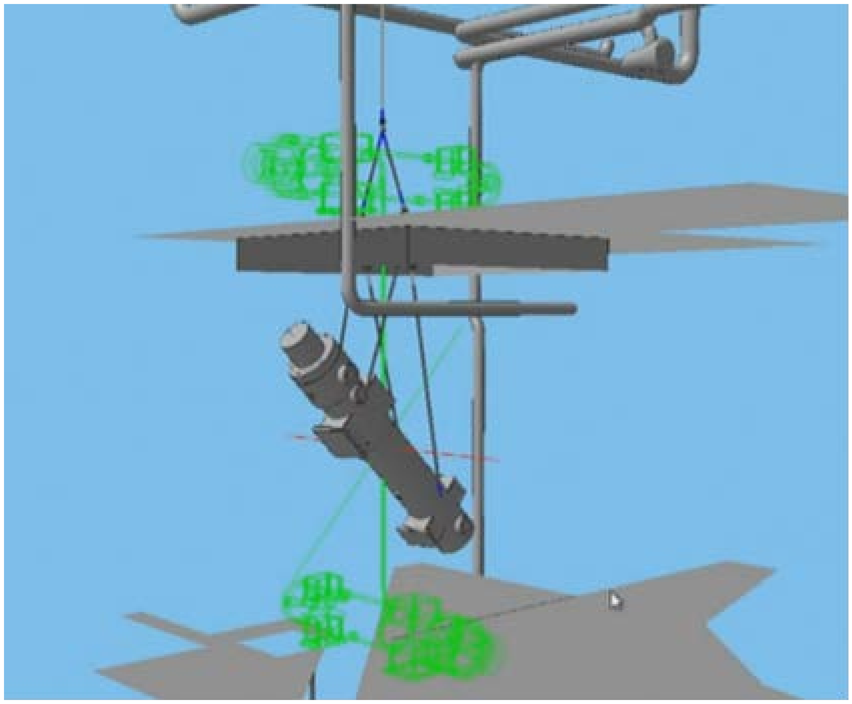

Fig. 5. Rigging-configuration simulation for heavy equipment

3. RESULTS

3.1 Calculated results regarding amount of waste and required number of waste containers

On the basis of the developed system, the relationship between the amount of waste and cutting lengths are examined. If the cutting lengths increase, the amount of waste decreases, as shown in Fig. 6. The number of required waste containers for the sample deconstruction area is two to five. To fill segmented-component waste containers at the maximum filling rate, short cutting and lengthwise half-cutting of piping components are required. In this case, the number of working hours spent on cutting and the accumulated exposure dose related to the dismantling work increase. If the hours for cutting decrease, the number of waste containers and management cost increase. Therefore, this trade-off relationship between cutting length and required number of waste containers should be optimized in terms of the accumulated exposure dose and total management cost of waste containers in conjunction with carry-out paths of such containers and large heavy equipment.

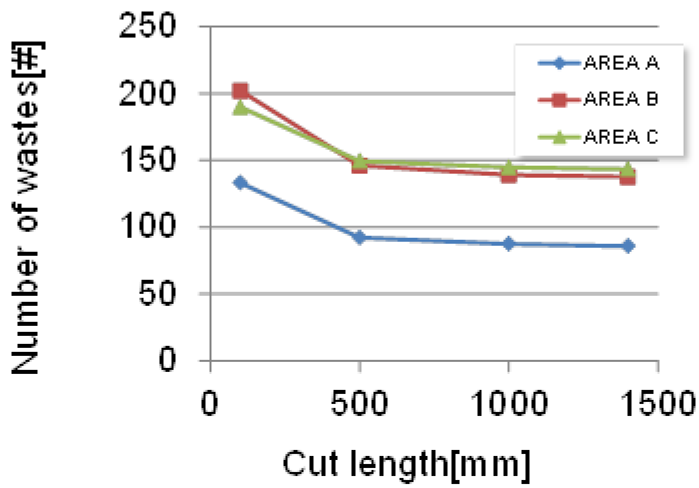

Fig. 6. Relationship between number of waste components and cut lengths

3.2 Calculation performance of carrying-out paths

Figure 7 shows the processing performance for calculating carry-out paths on a single CPU vs. a GPU. With the help of parallel processing, calculation performance becomes 300 times faster than with a single CPU. This enables interactive operations to determine carry-out paths.

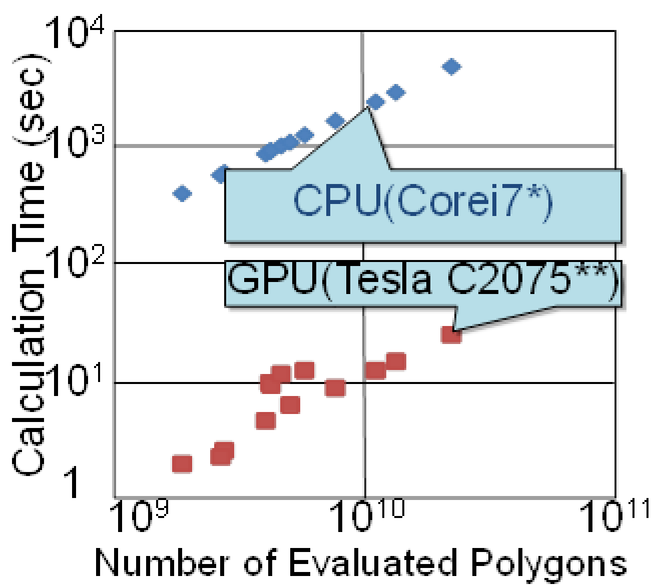

Fig. 7. Calculation time comparison with single CPU and GPU parallel processing

4. CONCLUSION

With the developed system, engineering judgments will be supported by the calculated results of required cutting lengths, required number of waste containers, and accumulated exposure dose for various dismantling scenarios. By developing the system for estimating waste and carry-out simulation, we confirm that it can support decommissioning engineering systematically and effectively because of its ability to map radioactive inventory data to 3D objects to automatically calculate the dose rate and generate waste-container models.

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