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題目：

A Proposal and Evaluation of Presentation Methods on AR-based Support System for Decommissioning of Nuclear Power Plants

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Abstract

Title: A Proposal and Evaluation of Presentation Methods on AR-based Support System for Decommissioning of Nuclear Power Plants
(ARを用いた原子力プラント解体作業支援システムの情報提示手法の提案と評価)

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Abstract:

As many existing nuclear power plants reach their service life, it is necessary to do the decommissioning work safe and efficiently. Augmented Reality (AR) is a very effective and useful interface design concept for presenting augmented objects. In the previous study, an AR-based support system for decommissioning work of nuclear power plants has been developed which can detect whether a collision between a dismantling target object and the surroundings happens or not. However due to the dismantled facility itself and the limited activity area, it is difficult for the workers to understand the situation between the target object and the surroundings.

In this research, three presentation methods are proposed which can present distance and location information between the target object and the surroundings clearly even if there is occlusion problem occurred between them. The first method is Transparent Model and Pointing Line Method (Line Method), in which transparency of the target object and thickness of the pointing line, used to point the endpoints of the distance were changed to present distance and location information. The second method is Grids Model Method (Grids Method), in which additional grids are used to show the shape of the target object and the surroundings. The size of the grids used to present pointing position changes with time passing. These changeable grids may lead to a quick attention of workers on pointing area. The last method is Model Rotation and Shift Method (Moving Method), in which the target object is forcibly rotated and shifted from original location so that pointing position becomes visible without hiding its surroundings. In the first stage of evaluation, to find out a best parameter pattern in each presentation method, three presentation methods with different parameters were evaluated by 4 evaluators who scored the difficulty of understanding the location of the pointing position. Also the accuracy of pointing position understood by evaluators were evaluated. In the second stage of evaluation, best-performed parameter patterns were compared. Finally, the Moving Method got highest evaluation totally, and the Line Method were scored for a high performance in subjective assessment. Although the comparison result shows a best-performed presentation method in simulation evaluation work, other new presentation methods and parameter patterns are the future work.

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Chapter 1 Introduction

Human beings are constantly making more environmental, green and recyclable energy to be used in daily life as electricity, transportation, logistics and so on. However being limited by existing technologies, no other kind of energy performs more powerfully and efficiently than nuclear energy. Developed countries like France [1] and Japan [2] started using nuclear power energy as one of their main energies, having rich experiences of operating nuclear power plants. At the same time many developing countries attempt to construct nuclear power plants to substitute traditional thermal power plants. Although nuclear energy is a potential energy in the future, operating nuclear power plants requires high-level technologies in safety maintenance. Once machines or parts in nuclear power plants reach their service life, it becomes necessary to remove them. There are over 100 mines, 90 power reactors, 250 research facilities and many other facilities have been, or are being, decommissioned successfully worldwide [3]. These successful decommissioning works are very important experience for workers and researchers concentrating on improving the safety and efficiency of decommissioning work, because they provide useful methods of solving problems occurred during decommissioning work. Decommissioning work of nuclear power plants involves dismantling nuclear reactors and plant itself, which is followed by this list.

1. Removing radioactive materials and wastes
2. Cleaning up whole site
3. Protecting the surrounding environment from potentially harmful radioactive materials

Internal environment in nuclear power plant is very complicated so that the decommissioning work indoor is limited by its narrow space and complex surroundings. Even the nuclear power plant has been stopped operating, there are still some machines or parts working for maintaining. After a facility was dismantled, it will be moved to a place for waste treatment. It is highly dangerous to let the carrying target object has a collision with the surroundings during the movement, especially a large-scale object. A real-time location relationship between the target object and the surroundings is necessary for workers carrying dismantled facility, when moving through a narrow space or dangerous space.

Augmented Reality (AR) is a very effective and useful interface design concept which has been rapidly promoted in recent years [4]. There have been many AR-based systems created for various fields, such as medical treatment [5], maintenance work [6], outdoor navigation [7] and so on. AR-based support systems for decommissioning work of nuclear power plant have been developed [8]. Fugen Decommissioning Engineering Center (Fugen) [9] turned it into a research center for decommissioning work of nuclear power plant in 2003, after the main reactor stopped operating. Now several types of decommissioning work and safety tests are being conducted there. Amongst researches in Fugen, an AR-based support system which can increase efficiency and improve safety is developed [10]. Augmented objects and information can be displayed over the image of real-world environment using AR technology. This AR-based support system can detect whether a collision between the target object and its surroundings happens or not. If it happens, collision area turns red. However, it can not present information clearly when an occlusion problem between the target object and its surroundings occurred. Occlusion problem is that when a virtual object supposes to occlude real objects, it may cause confusion in workers' perception [11]. As it is not allowed for workers to move freely during decommissioning work, it is difficult to understand the situation between the target object and the surroundings.

In this research, to present information more legibly, presentation methods are proposed to solve the unclear distance presentation when occlusion between the target object and its surroundings occurs. After an AR-system installed with the proposed presentation methods, evaluations were conducted to evaluate which presentation method performed the best during the simulated decommissioning work.

This thesis consists of 5 chapters including this introduction chapter. In chapter 2, the background and purpose of this research is introduced, and existing AR-based support systems are discussed. In chapter 3, three presentation methods are proposed, which can present distance and location information between the target object and its surroundings even occlusion occurred. In chapter 4, evaluation of presentation methods mentioned in chapter 3 are discussed. Conclusion and future works will be mentioned in chapter 5.

Chapter 2 Background and Purpose of This Research

In this chapter, an existing AR-based support system for decommissioning work of nuclear power plants and the existing methods of information presentation are introduced. After the issues in the existing systems were explained, the purpose of this research is introduced.

2.1 Existing Decommissioning Support System

Advanced thermal reactor in Fugen, was commissioned in March 1979 and was stopped service in March 2003. After the main reactor stopped operating, Fugen was turned into a research center for decommissioning work of nuclear power plants. Amongst the researches being conducted are the safe removal of radioactive materials left behind from decommissioning works and the improving the safety and security of decommissioning exercise [9]. Decommissioning work of nuclear power plants is a difficult and technical process. Different from traditional thermal power plants, decommissioning work in nuclear power plants includes clean-up of radioactive materials and further demolition of machines in the plants. When radioactive materials or elements decayed to stable elements, main components remained in the plants, including the reactor vessel, fuel pools and others, are removed from the plants. In order to reduce the harm to workers of decommissioning works and other people by radioactive materials, a strict and safe plan is necessary before actual decommissioning work can commence.

When workers are carrying dismantled facilities to a narrow space or the surroundings are complicated, a problem is that workers sometimes can not know the situation between carrying target objects and the surroundings. This situation is dangerous because an accident may occur. On the side, when a large-scale object is being carried via a narrow space, knowing if it will collide with the surroundings is useful to workers. However, workers are confused with location relationship between the target object and the surroundings during carrying work. The distance and location information between the target object and the surroundings, is difficult to know. Invisible side between the target object and the surroundings is a common problem, also known as occlusion problem, in computer visual field.

Aimed at making a plan of a safe decommissioning work of nuclear power plants, a research about AR-based support system which can simulate decommissioning work in nuclear power plants was done by Aoyama [10]. In the research, a simulation of decommissioning work can be experienced, in which target objects were presented as CG model which presented on the real-world environment. Fig.2.1 shows an example of screen shot of AR-based support system developed by Aoyama. During the simulation, workers can move the CG model on a tablet PC installed with AR-based support system, and know the location relationship between the target object and the surroundings. When the target object collided with the surrounding, collision area turned red. It can be used in the preparation step of planning decommissioning work. For example, while carrying one dismantled target object via a narrow space, workers can use this system to verify is there enough space for the target object to pass safety.

During the process of moving facility, location relationship between the target object and the surroundings is an important information for workers. However, when the target object come in front of environment, the existing decommissioning support systems does not present among facilities clearly. The reason why it is difficult to know the situation between the target object and the surroundings is that the target object itself hides the surroundings. When this kind of occlusion problem occurred, the information such as with which the target object may collide is difficult to be presented. Moving around and viewing the target object from another location is a normal method. However, moving around a large-scale target object wastes time. And due to the complex environment inside nuclear power plant, it may not allowed to move freely. A presentation method is useful during decommissioning work, which can present distance and location information clearly without workers' moving to another place, even if occlusion problem occurs between the target object and its surroundings.

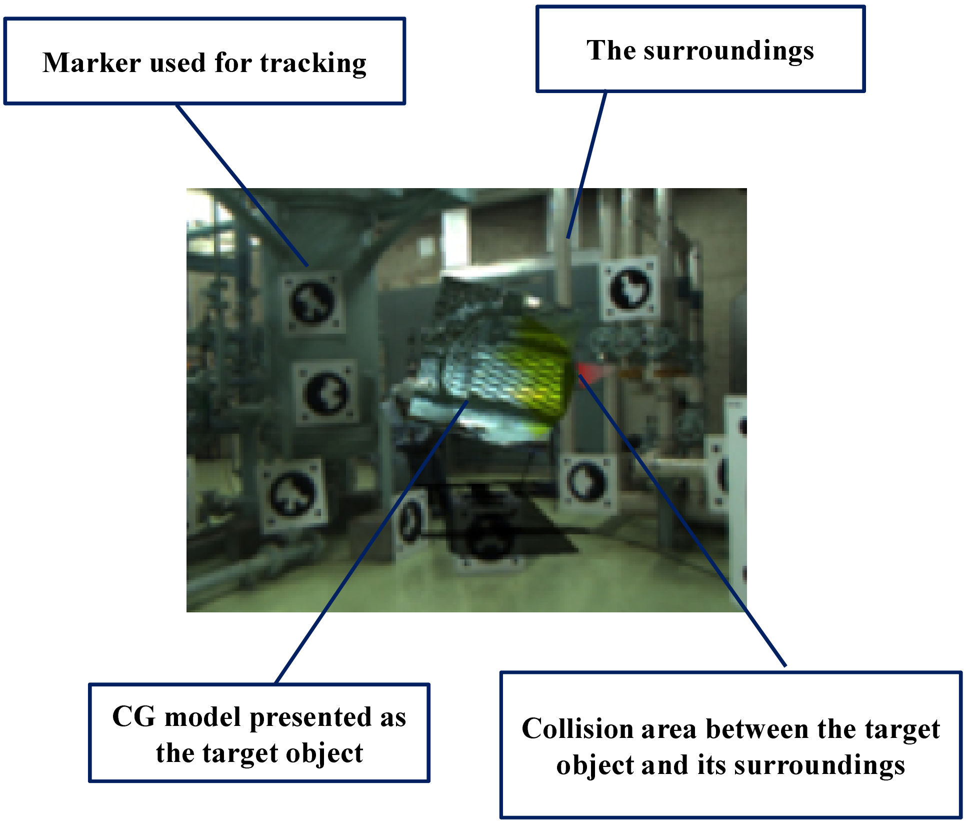

Figure 2.1: Screen shot of the AR-based support system (collision area is shown in red) developed by Aoyama [10]

2.2 Existing Presentation Methods

In order to present distance or location information by AR, many researches have been done. Leutert [12] proposed an AR interface to directly and intuitively visualize complex information. In this research, AR support function is used to present distances between workpiece and robot. Fig.2.2 is an example of the supporting system in which several colored lines and numbers are being used for presenting distance and location information. Although it shows distance between workpiece and robot clearly from side, workpiece is a small target object so that occlusion between workpiece and the robot occurs rarely. Therefore, the information presentation method when occlusion occurs was not mentioned in this research.

Raphael.G [13] introduced a novel view management technique for placing labels in AR systems. Fig.2.3 is an example of labeling on real environment by their approach. To solve the common issue in AR systems that limiting the efficient representation

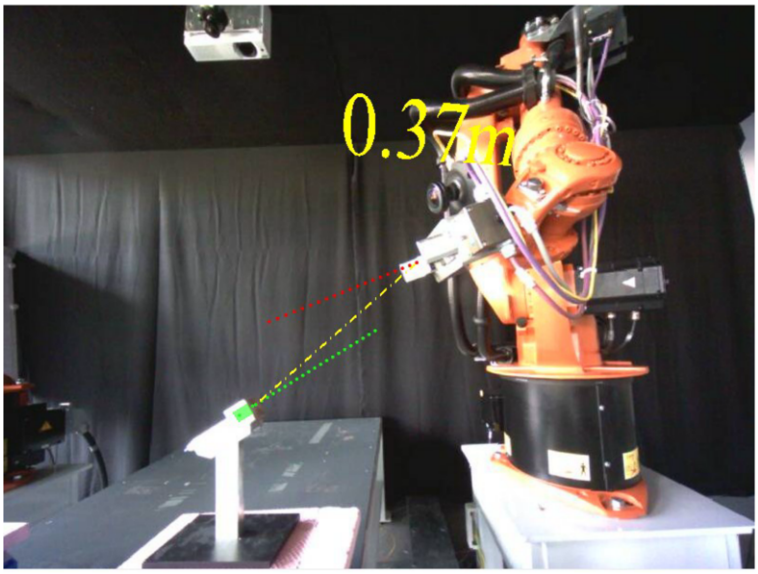

Figure 2.2: Supporting annotations for distance and location information [12]

and optimal layout of the augmented information on the real world, they discussed an adaptive representation method. Leader lines of each label is modified in lightness with the surroundings so that labels can be distinguished from the surroundings. However, the relative location relationship among objects where occlusion occurs was not mentioned in this research.

Figure 2.3: Labeling used in image-based approach [13]

Denis.K proposed an information presentation method called ghosted view which allows viewer to explore hidden structure within the real-world environment [14]. Fig.2.4 shows the objects after ghosted view with consistently modulating lightness of occluder. They consider the information of the scene before and after shown in ghosted view, and calculate adjustment of preserved occluding features to enhance the depth perception. It allows workers to see not only preserve features, but also to see features after ghosted view. This presentation method allows participants to know the shape of objects occluding the surroundings, however the relative location relationship can not be presented clearly in it.

Figure 2.4: Consistently modulating lightness of occluder [14]

2.3 Purpose of This Research

The purpose of this research is to find out a well-performed presentation method during decommissioning work in nuclear power plants, which can present augmented information such as distance and location information between the target object and the surroundings clearly even if there is occlusion between the target object and the surroundings.

In order to find out a well-performed presentation method, three presentation methods were proposed and evaluated by subjective evaluations where participants scored on each presentation method. Several parameter patterns in each proposed presentation method were being set to a evaluation test to find out which parameter patterns performed best in each presentation method. After a best-performed parameter pattern in each presentation method being achieved, a comparison among three best-performed methods was conducted.

By proposed presentation method, an AR-based support system which can make the decommissioning work in nuclear power plants more effectively and safely, is expected to be developed. Additionally the occlusion problem is a common question while using AR application, this research can be adopted not only in nuclear power plants but also in many other fields.

Chapter 3 Proposal of Presentation Methods

In this chapter, issues in decommissioning work using AR-based support system is introduced first. Then presentation methods are explained, which can present distance and location information between the target object and its surroundings even occlusion occurred. Then the details of each presentation method are explained in three aspects: details of design, advantages and disadvantages.

3.1 Issues in Decommissioning Work using AR-based Support System

In chapter 2, existing AR-based support systems and presentation methods have been discussed. Unfortunately, some realistic problems are still remaining in the AR-based support systems for decommissioning work. Fig.3.1 shows a dismantling process in decommissioning work using AR technology. A worker is using a tablet PC installed with an AR-based support system for simulation of a dismantling work. The target object shown in orange, is being set on a trolley. The trolley carrying dismantled facility will be moved via a passage surrounded with other facilities in the real-world environment. The blue arc angle represents the view angle of the camera suited on tablet PC. One function of this AR-based support system is that the location relationship between dismantled facility and real-world environment can be presented so that the workers can know whether the dismantled facility is being collision with other facilities in the surroundings during the moving process.

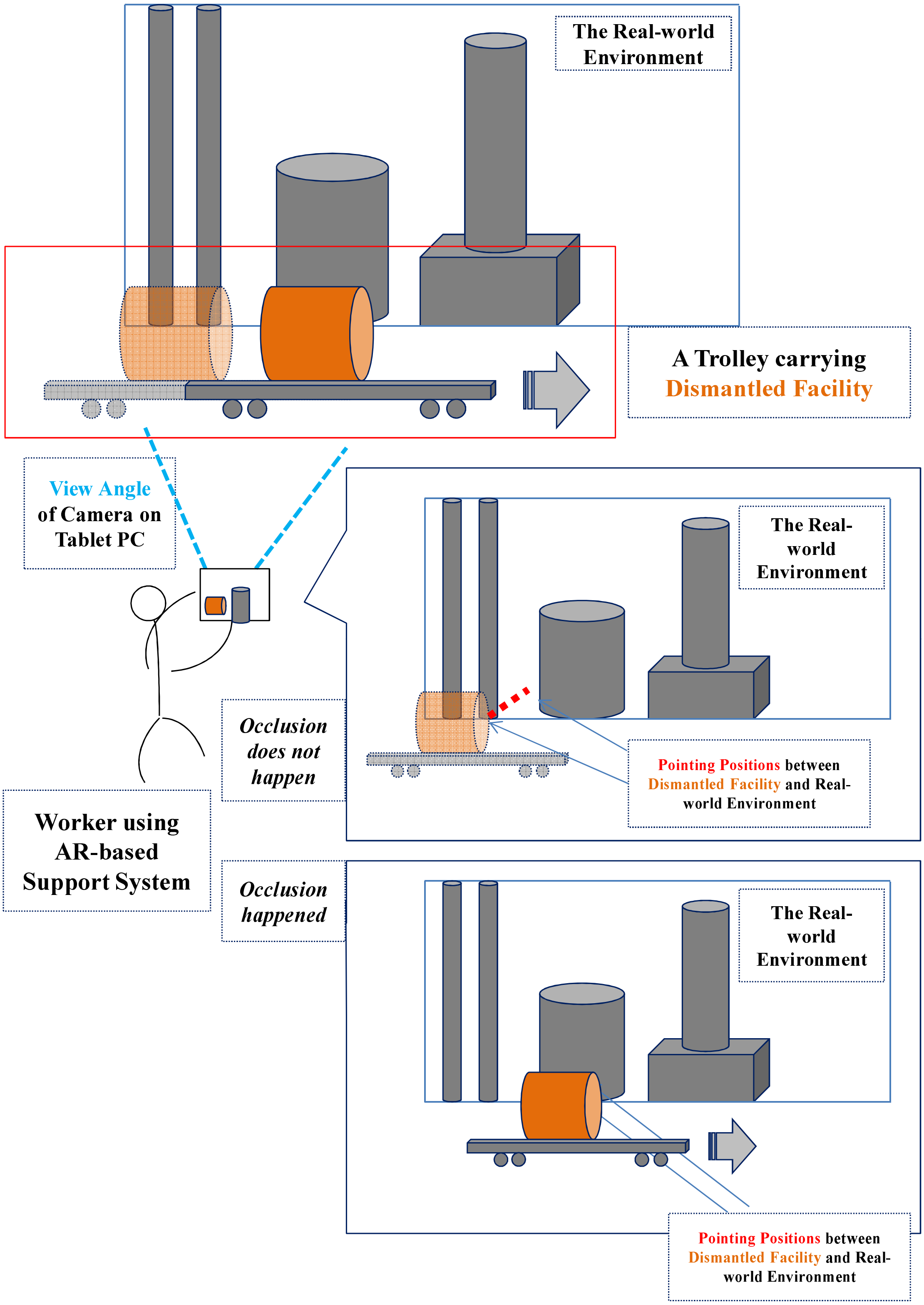

Figure 3.1: A removing process in decommissioning work

However, the trolley comes into the view angle of camera, some parts of facilities in the surroundings were hidden by the dismantled facility carried on trolley like "Occlusion happened" shown in Fig.3.1. If the workers move to another side of dismantled facility, invisible location relationship of dismantled facility and the surroundings can be seen clear as shown in Fig.3.2. However, being limited to the narrow space of nuclear power plant and other irresistible situation, it is not allowed for the workers to move freely in the decommissioning work area. Making the target object into transparency is a candidate method to present occlusion area between the target object and its surroundings. However, it is difficult for workers to understand back side of the target object due to the influence of the target object itself. To reduce the influence from the target object itself, methods that visualize the unreadable area between the target object and the surroundings are proposed in this research.

3.2 Overview of The Presentation Methods

In this study three presentation methods are proposed which can present distance and location information between the target object and the surroundings even if there is occlusion between them. Details of calculating shortest distance and position between the target object and its surroundings are not mentioned in this research. It is supposed that the distance and location information used in this research are calculated by other existing methods. To present distance and location information when occlusion problem happened, the target object, the surroundings, the middle area between the target object and the surroundings are being taken into consideration.

In order to find out a best-performed presentation method for decommissioning work in nuclear power plant, three elements are considered to solve the occlusion problems. They are the target object, the surroundings and the middle area between the target object and its surroundings. Table3.1 shows the possible methods which can deal with the occlusion problem. For the target object, it is the main reason of occlusion problem. Set the target object into transparency is a method to present back side of the target object clearly. The more transparent it is, the more clear occlusion area will be presented. However, too much transparency of the target object may cause a difficulty of understanding shape of the target object itself. It may not allowed for workers to

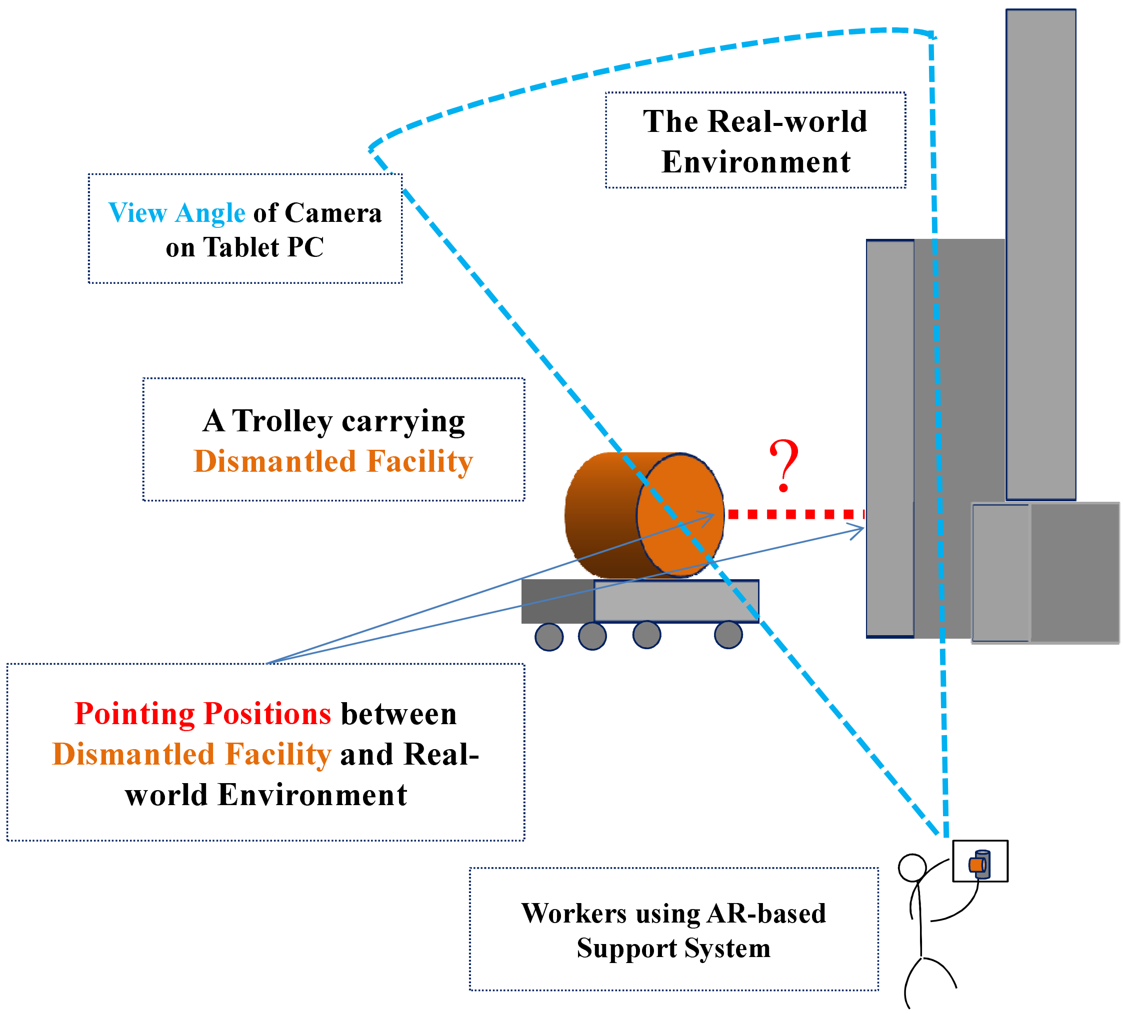

Figure 3.2: Side view of dismantled facility and real-world environment

move freely inside the nuclear power plant, the wireframe and additional cube grids are used to present shape of the target object which is set into complete transparency. For the surroundings, they are hidden by the target object which causes the difficulty to understand the distance and location information of it. Additional cube grids are used to present shape of the surroundings. For the middle area between the target object and its surroundings, a pointing line and annotation are used to present the location and the distance and location information between the target object and its surroundings.

Considered all above, in this research Transparent Model and Pointing Line Method (Line Method), Grids Model Method (Grids Method), Model Rotation and Shift Method (Moving Method) are proposed as in the following sections.

Table 3.1: Possible methods used to deal with the occlusion problem

Elements	Possible Methods
The target object	transparency, wireframe, additional grids
The surroundings	additional grids
The occlusion area	pointing line, distance and location information

3.3 Proposal of Transparent Model and Pointing Line Method

As shown in Fig.3.2 before, the main reason why it is difficult to understand the distance and location information between the target object and its surroundings is the occlusion problem occurred between them. To solve occlusion problem, Transparent Model and Pointing Line Method (Line Method) is proposed in which a colored pointing line is located between the target object and its surroundings. The ends of the line point at the shortest distance positions on the target object and its surroundings. The target object was conducted into semi-transparency in order to show a perceptive view of the target object which can present location relationship between the target object and its surroundings clearly as shown in Fig.3.3. It is expected that the target object and its surroundings can be presented clearly using the Line Method.

In the Line Method, changing transparency of the target object and thickness of the pointing line may influence the difficulty of understanding the distance and location information between the target object and its surroundings.

Considering the real-world environment in nuclear power plant is a complex and dim situation, the contrast of rectangle and text is being increased to present the text annotation clearly no matter with environment. To reduce the influence of text annotation, the position of text annotation presented on AR display is adjusted to avoid to hides the target object or the surroundings.

The advantage of this method is that back side of the target object can be seen without a movement by workers, this may help the workers to understand the real decommissioning work more correctly. Workers can see through the target object to know the location relationship between the target object and its surroundings thanks to the transparency of the target object. The red-colored line also assists workers to

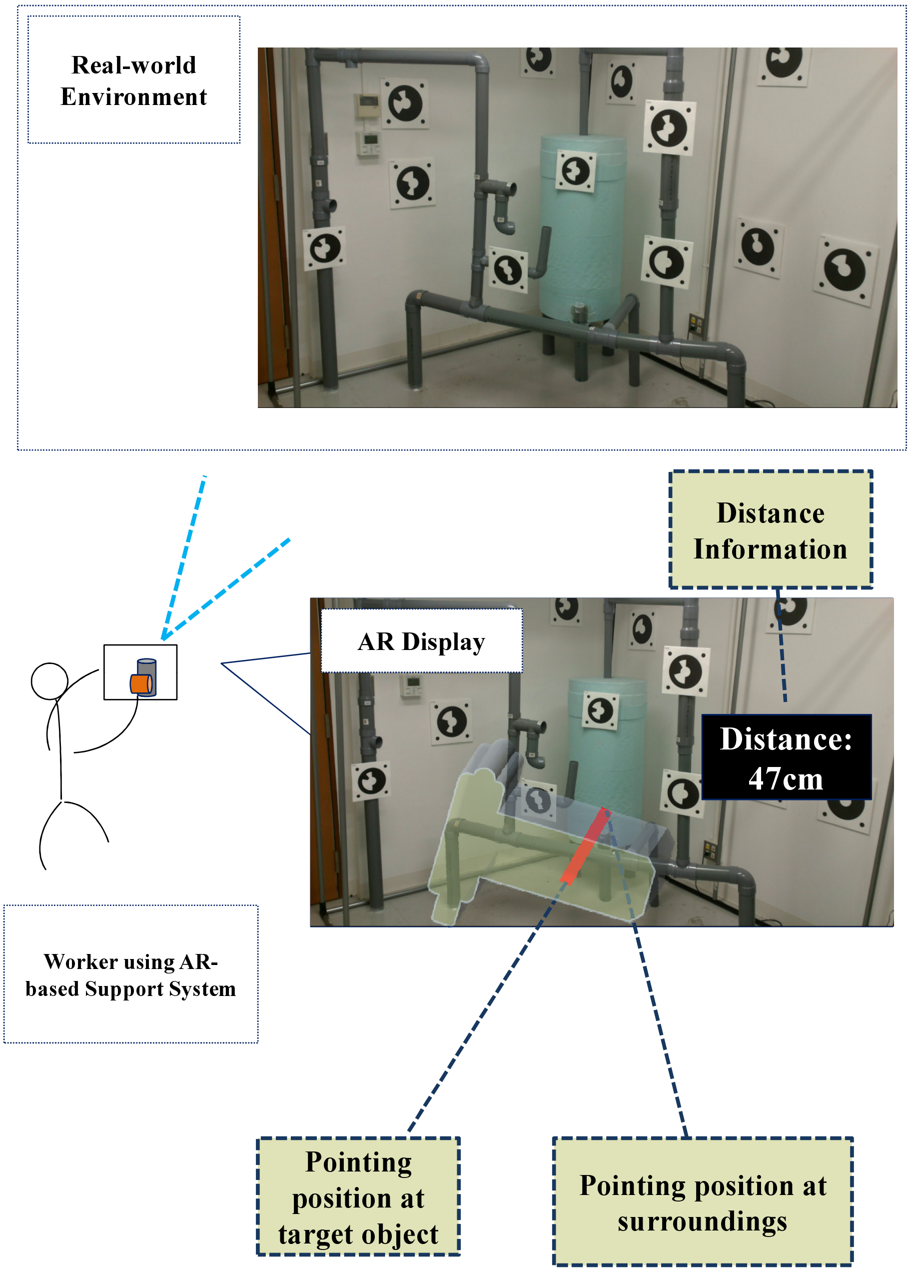

Figure 3.3: Concept of information presentation method using a Transparent Model and Pointing Line Method (Line Method)

find out the pointing position where the distance and location information is presented. The disadvantage of this method is the difficulty to present back side surface of the target object.

3.4 Proposal of Grids Model Method

Fig.3.5 shows the concept of Grids Model Method (Grids Method). The target object is set into transparency to get a good perceptive view by seeing through itself. In order to present the pointing position significantly, additional cube grids are added into the surface of the target object and the surroundings to show the shape of them. There are two kinds of grids in the method to present shape of the target object and the surroundings. Small grids are used in the surface of the target object and the surroundings to show the shape of them, and large grids are used inside the target object and the surroundings to show the pointing position and its nearby area. The large grids' size changes with time passing. These changeable grids may lead to a quick attention of workers on pointing area. To present a clear shape of the target object after it has been set into a complete transparency, wire frame was also used in this method, as shown in Fig.3.4, which fill inside surface of the target object to show the surface shape of the target object. Thanks to the additional wire frame in the target object, three dimensional sense can be presented to worker better than complete transparency without any additional element.

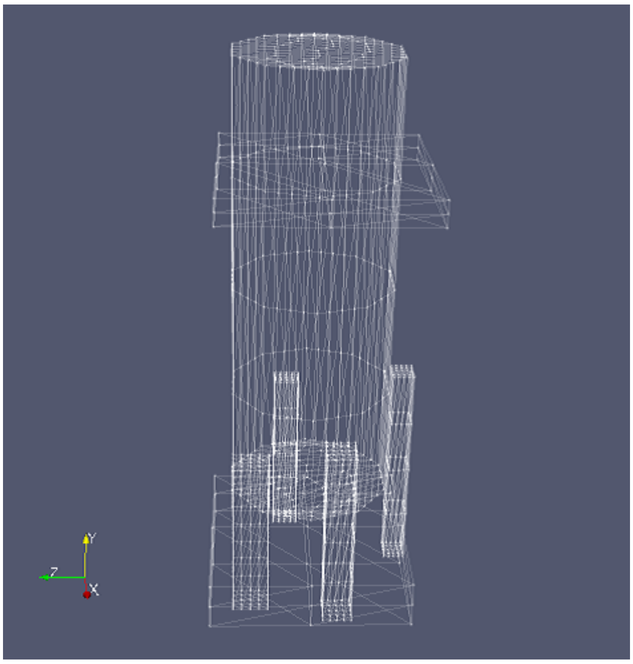

Figure 3.4: An example of wire frame of the target object

In this presentation method, shape of the target object and the surroundings can be presented clearly which may help the workers to understand the distance and location information more easily. However, in this presentation method, grids are used to present pointing position on the target object and its surroundings, similar grids may confuse worker to understand the location of pointing position.

Fig.3.6 shows that additional cube grids presented in the target object. Red-colored cube grids are the pointing position intended to present, meanwhile the orange-colored cube grids represented the area nearby red-colored cube grids. The target object is filled full of grids in same size at first. These grids are set into transparent which only the pointing area and its nearby area will be set into color. After a pointing position being set, center grid is used to present this pointing position. Then all the grids with a range of 200mm from center grid are calculated. These grids are called nearby grids. The nearby grids are set by color atlas corresponding to the distance from center grid. The real-world environment is presented with purple-colored grids on surface.

There are two parameters included in the Grids Method, which additional cube grids are being introduced. Maximum size of grids and rate of change are being took into considerations in the Grids Method. Changing maximum size of grids may influence the presentation of pointing area, becoming more easily for workers to understand. Rate of change of grids may influence the time of workers' attention on pointing position displayed.

Advantage of the Grids Method is that workers can know shape of the target object and its surroundings without moving to another place. Different from presentation methods using points to show pointing position, the Grids Method can perform a good depth perception on plane AR display. Disadvantage of this method is that the additional grids may confuse workers to understand the location relationship between the target object and grids, because dynamic grids at the target object may cause interference with other grids at the real-world environment.

3.5 Proposal of Model Rotation and Shift Method

Model Rotation and Shift Method (Moving Method) is proposed that forcibly rotate and shift the target object from original location (transparent target object in Fig.3.7) to final location (non-transparent target object in Fig.3.7, of which pointing position

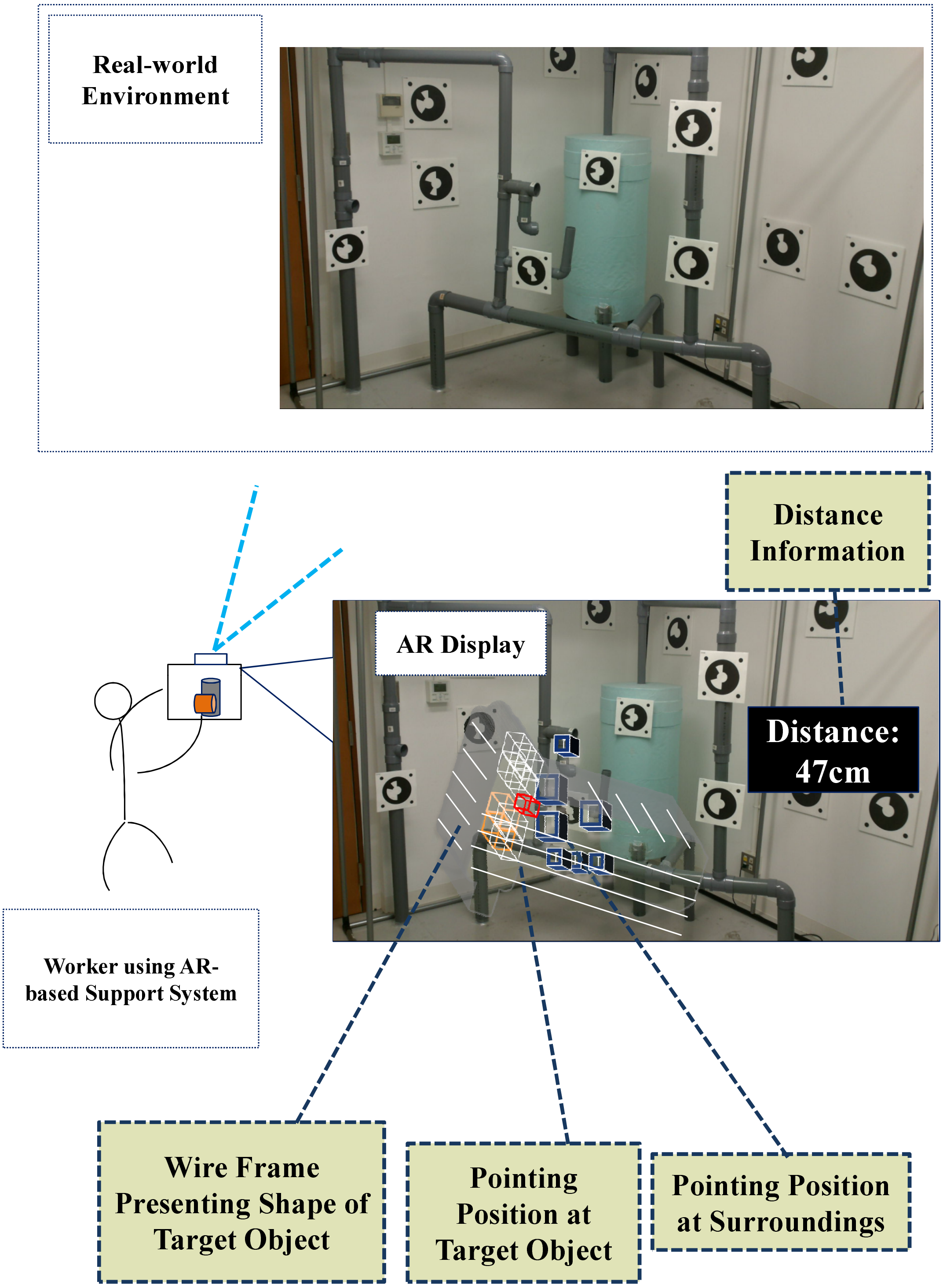

Figure 3.5: Concept of information presentation method using a Grids Model Method (Grids Method)

becomes visible without hiding its surroundings). Fig.3.8 shows the relationship between the target object and image plane.

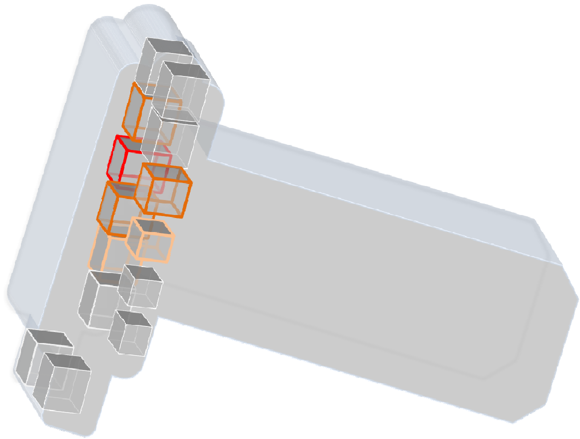

Figure 3.6: An example of additional cube grids in the target object

In this method, projection coordinate of pointing position presented by the AR-based support system on image plane is calculated firstly. If pointing position at the target object is invisible from current viewpoint, the target object is forcibly rotated towards worker slowly until it becomes visible. Once pointing position at the target object becomes visible, rotation of the target object will stop. A further shifting distance is an additional option which can show the real-world environment hidden by the target object.

Rotation speed and shifting distance are being took into considerations in the Moving Method. Changing rotation speed of the target object may present a different process for workers to understand the appearance of the target object. Adding a different shifting distance may influence the occlusion problem between the target object and its surroundings.

Advantage of the Moving Method is that rotating shows back side of the target object clearly, pointing positions on both the target object and its surroundings can be presented obviously. Shifting the target object shows the real-world environment hidden by the target object clearly. However, disadvantage of this method is the difficulty to understand the pointing position at the target object due to its shifting far away from original location. Workers need to imagine the original pose of the target object which may cause a misunderstanding of back side of the target object.

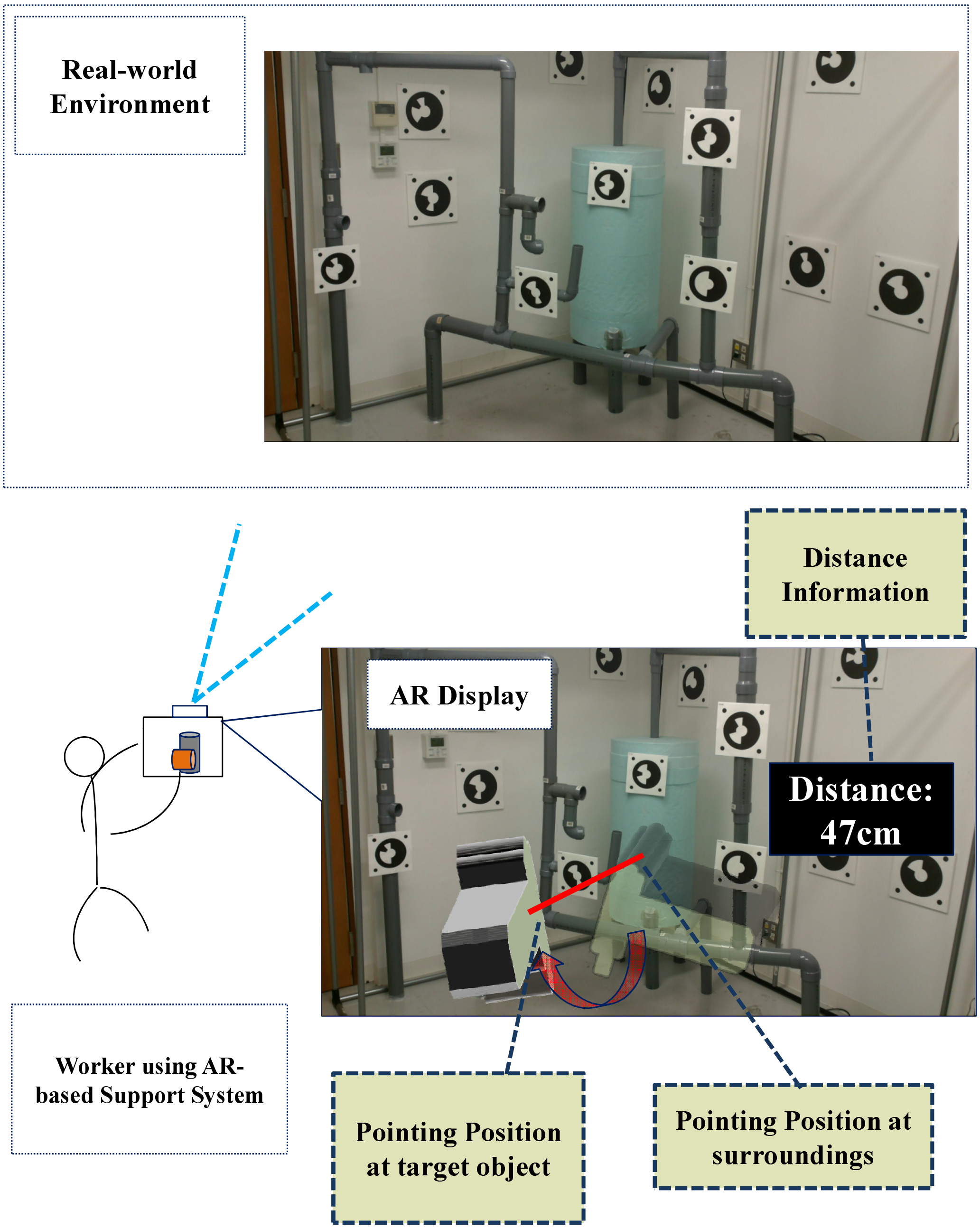

Figure 3.7: Concept of information presentation method using a Model Rotation and Shift Method (Moving Method)

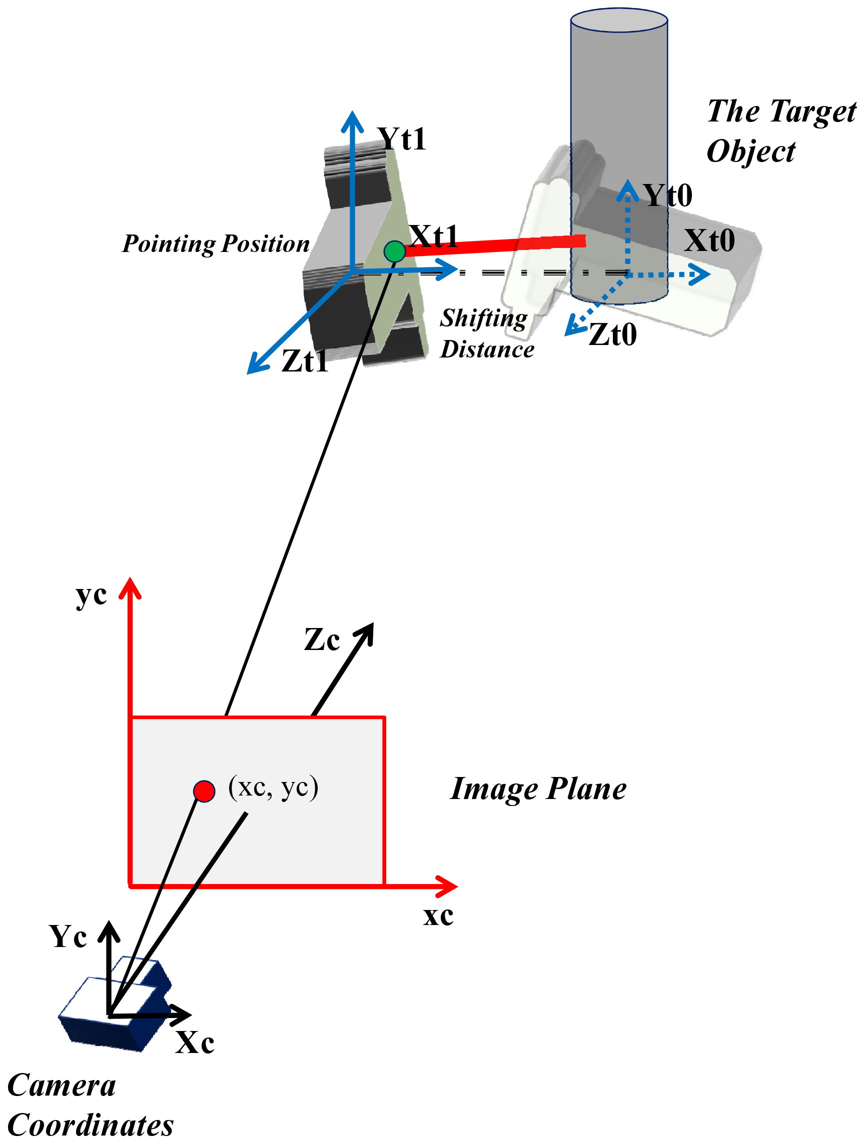

Figure 3.8: The relation between the target object and image plane

Chapter 4 Evaluation of Presentation Methods

In this chapter, the evaluation of the proposed presentation methods is mentioned. In order to find out which proposed presentation method performed best, two stages of evaluation were conducted. Both are evaluated from two aspects, one is which method presented on AR display is easy to be understood, the other aspect is position error between pointing position presented and position participants understood. As which parameter pattern in each proposed presentation method performed well is unknown, a best-performed parameter pattern of each proposed method should be found out in first stages of evaluation. After that, best-performed presentation method was evaluated among three methods with their best-pattern.

4.1 Purpose of The Evaluation

The purpose of this evaluation is to find out a best-performed method, which is the most easiest methods for participants to understand the pointing positions and present pointing position with the highest accuracy.

4.2 Overview of The Evaluation Method

In order to find out which of the proposed presentation methods perform best, two stages of evaluation are conducted by subjective assessment and error evaluation. Best-performed means the presentation method can be understood the most easily by the workers and the position error between pointing position understood by participants and presented by the system is the smallest.

Fig.4.1 shows the overview of the evaluation which are conducted in two stages. Firstly, best-performed parameter pattern in each presentation method is found out in the first stage of evaluation. It is because, although three presentation methods were proposed, different parameter patterns in each presentation method may have a different result. So evaluations to find out which parameter pattern in each presentation method performed the best was conducted.

In second stage of evaluation, experiment was conducted to find out best-performed method among three proposed presentation methods.

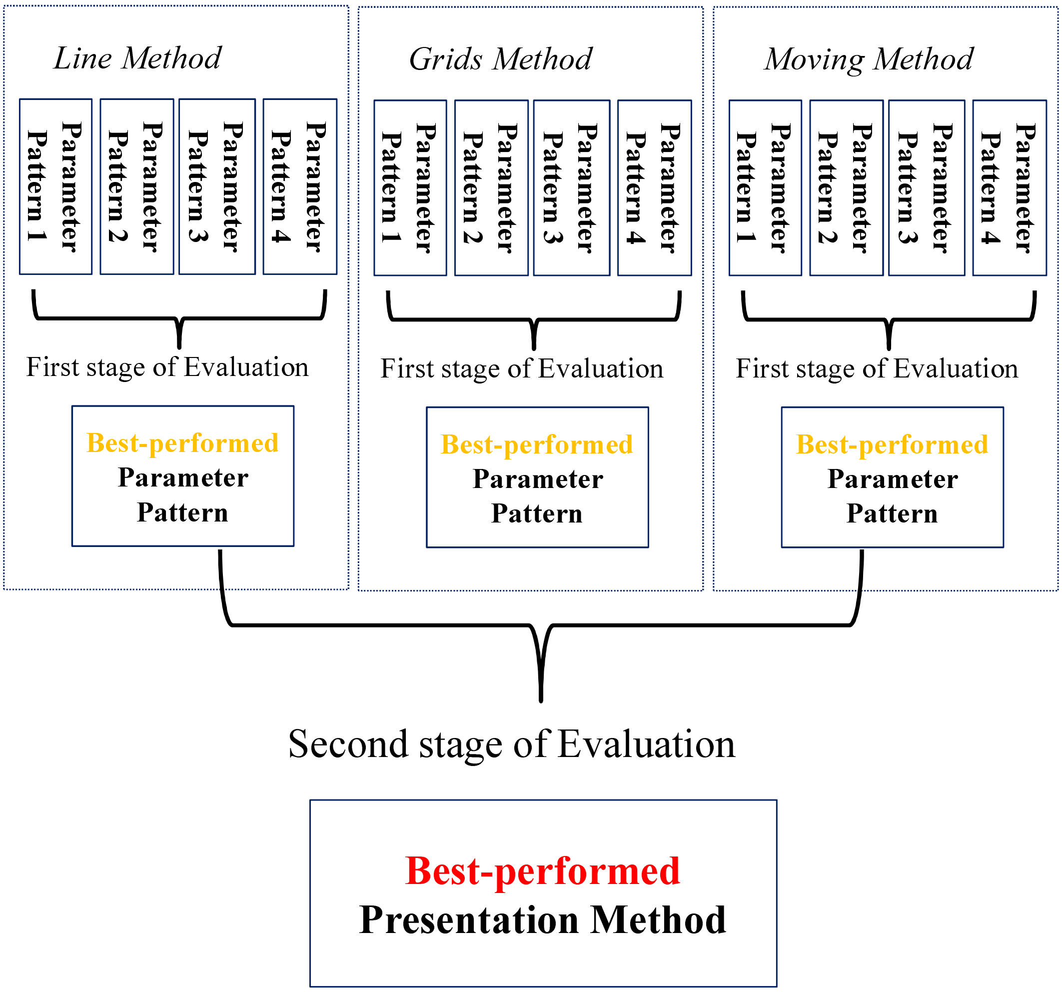

Figure 4.1: Flow of two stages of the evaluation

In order to increase efficiency of whole evaluation, the first stage evaluation of three proposed methods were conducted continuously for one participant. Fig.4.2 shows the flow of one participant joined in first stage of evaluation. Firstly, a explanation of the purpose and details of this evaluation experiment was stated by experimenter. It is allowed that participants can drop out during the evaluation. If there is no questions, participant sign on a consent form of this evaluation. Participant experiences three proposed presentation methods by the sequence of the Line Method, the Grids Method, the Moving Method. Total time for the first stage of evaluation of one participant costs about 40 minutes.

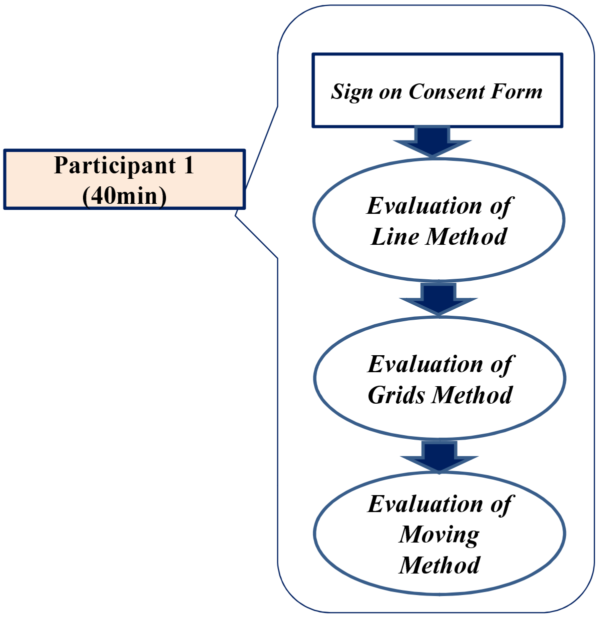

Figure 4.2: Flow of the first stage of evaluation experiment

Fig.4.3 shows the flow of one participant joined in second stage of evaluation. Three best-performed parameter patterns in each presentation method were showed to participant. Considering order effect, the sequence of presentation methods for each participant was set randomly. Total time for the second stage of evaluation of one participant costs about 30 minutes.

4.3 Environment used for The Evaluation

4.3.1 Evaluation Environment and Devices

In this subsection, evaluation environment will be introduced, including assembling of simulated decommissioning area, marker measurement for tracking and environment modeling by kinect fusion [15].

Fig.4.4 shows top view of evaluation environment. Evaluation room mainly includes Simulation Area, User Activity Area and Desk. Simulation Area is a real-world environment of carrying decommissioning work.

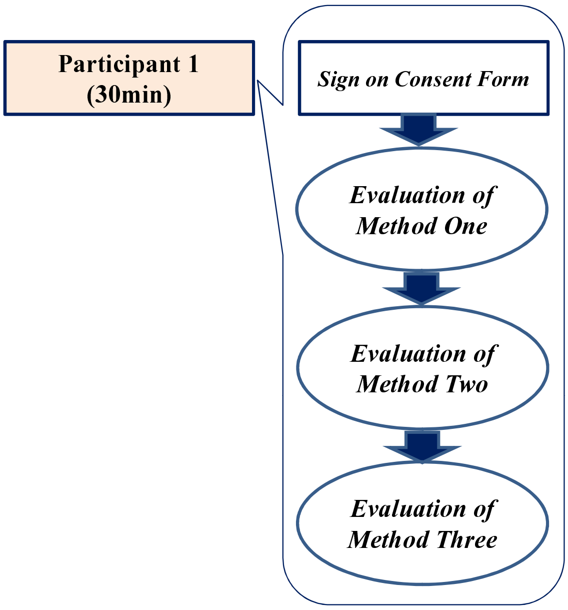

Figure 4.3: Flow of the second stage of evaluation experiment

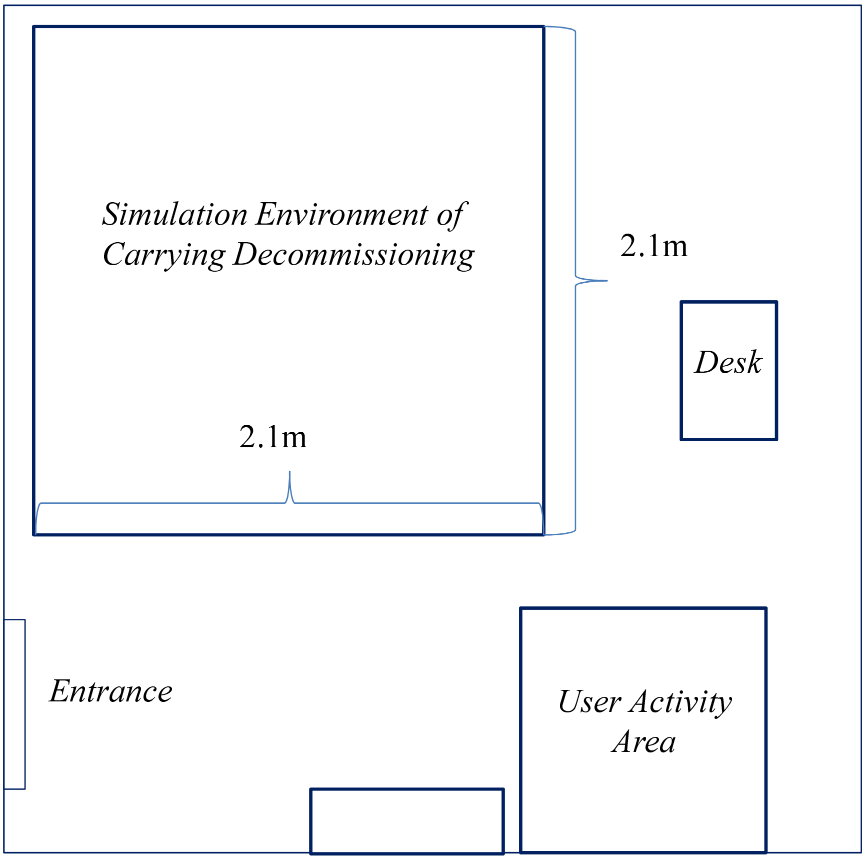

Figure 4.4: Top view of evaluation environment

Simulation environment is shown in Fig.4.5. The plastic pipes were assembled together to simulate a part of internal environment of nuclear power plant where a decommissioning work is undergoing. Markers [16] are located in the real-world environment and used for tracking. User Activity Area is where participant can move during evaluation on this AR-based support system. Setting a limitation space for participant is that it is not allowed to move freely in real decommissioning work in nuclear power plant. This user activity area is a simulation of real activity area during decommissioning work.

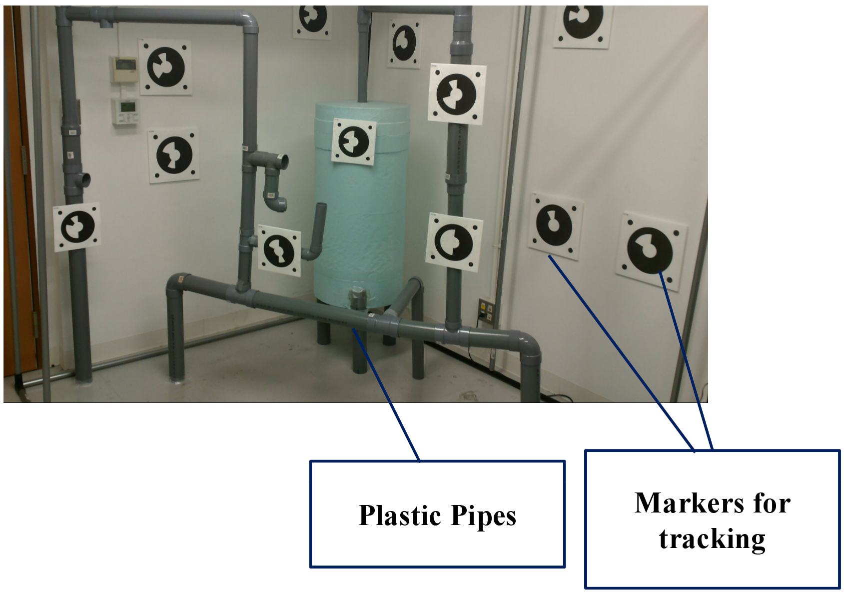

Figure 4.5: Simulation environment of carrying decommission

Fig.4.6 shows the markers arranged on real-world environment. Markers were printed on cloth so that it is hard to be affected with damp, and pasted on a same-size plastic board by glue stick. On the right of Fig.4.6 is an example of the marker used for tracking in this research. 12 markers were used for tracking including 7 pieces of 100-mm radius markers and 5 pieces of 75-mm radius markers.

Fig.4.7 shows the marker arrangement measured by Automatic Marker Measurement System. Details of tracking method is shown in Appendix A. The whole AR-based support system was developed by a notebook shown in Table4.1. Considered the complex internal environment of nuclear power plant and limited space, hand held device is a suitable device for AR-based support system. Common hand held devices have the disadvantage that the limited size of display and lower operational capability. To reduce

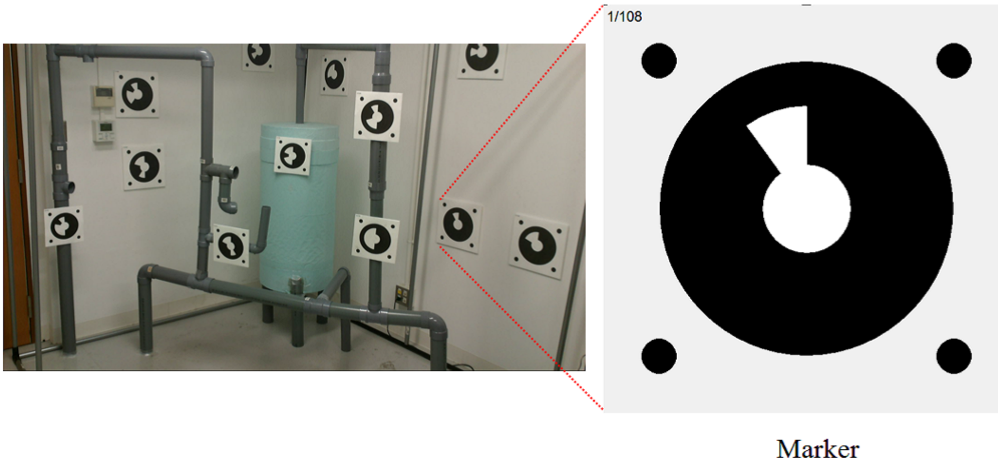

Figure 4.6: Markers arranged in real-world environment

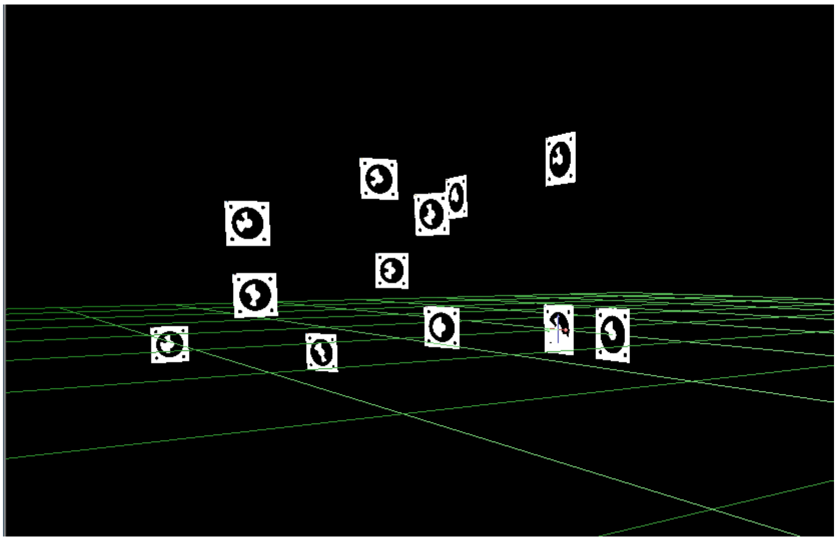

Figure 4.7: Measuring result of markers arrangement

this disadvantage, a tablet PC was used in this research.

Fig.4.8 shows the tablet PC being used for evaluation. The specification of the tablet PC is shown in Table4.2. During the evaluation, a rear camera in tablet PC is used for tracking and real-time display of real-world environment. A camera calibration tool is used for rear camera calibration, which is GML Camera Calibration toolbox [17].

Table 4.1: IDE and libraries used for developing AR-based support system

OS	Windows 7 Professional(64bit)
IDE	Microsoft Visual Studio 2010
Libraries	Boost 1.51, VTK 5.10, OpenCV 2.4.3

Figure 4.8: Tablet PC used for presentation methods evaluation

Table 4.2: Specification of tablet PC used for presentation methods evaluation

Computer type	Microsoft Surface Pro 3
OS	Windows 8(64bit)
CPU	Core i5 1.9GHz
Memory	4GB
Display Size	12 inch
Weight	800g
Rear Camera	5 MP, 1080P
Display	2160x1440 (216ppi)

4.3.2 Environment Model Reconstruction

Augmented distance information was presented over the displayed image of the environment in AR-based system. In order to present shape of the real-world environment by additional grids in the Grids Method, 3D model of the real-world environment needs to be reconstructed. InfiniTAM [18] is a multi-platform framework for real-time, large-scale depth fusion and tracking, an Open Source created on KinectFusion [15] and Volumetric Methods [18], which can integrate multiple depth images into a full 3D model. Depth images of real-world environment for using InfiniTAM are tooken by Asus Xtion Pro Live. Asus Xtion Pro Live is a 3D sensor which can be used for making motion sensing systems. Fig.4.9 shows the appearance of Asus Xtion Pro Live. Table4.3 shows technical specification of Asus Xtion Pro Live. In order to calibrate Asu Xtion Pro Live, a camera calibration tool for OpenNI based RGB-D sensors is used [19]. After camera calibrated, a capture of real-world environment was done by Asus Xtion Pro Live. It is important to take all the images slowly to ensure all the captures are clear enough for 3D model reconstruction. Fig.4.10 shows the 3D model reconstruction result of real-world environment.

Figure 4.9: Appearance of RGB-D camera used for scanning environment

Table 4.3: Technical specification of Xtion Pro Live

Interface	USB 2.0 and 3.0
Image Sensor	RGB and Depth
Max.Image Resolution	640 x 480
Video Capture Resolution	SXGA (1280*1024)
Frame Rate	30 fps, 60 fps

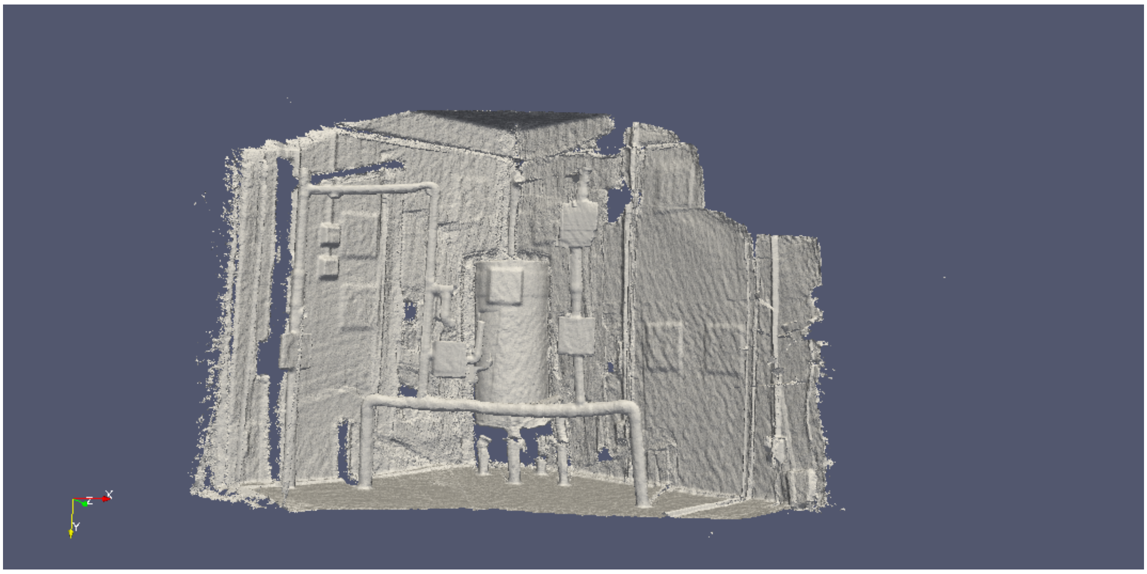

Figure 4.10: Result of evaluation environment after 3D model reconstruction

4.4 Evaluation of Transparent Model and Pointing Line Method

4.4.1 Purpose of Evaluation

The Line Method is a presentation method in which transparency of CG Model and thickness of pointing line are parameters, which will affect the performance of understanding the pointing position. As back side of the target object is invisible in existing AR-based support system, making the CG model into transparency can present back side of the target object more clearer. However, different transparency of the target object may lead to different performance result of the Line Method. Purpose of this evaluation is to find out best-performed parameter pattern in the Line Method.

4.4.2 Details of Evaluation

4.4.2.1 Protocol of Evaluation

Fig.4.11 shows the experimental protocol for the Line Method evaluation. Four parameter patterns were shown to participants. Evaluation materials is shown in Appendix B. After a participant came into the evaluation room, he sit next to a desk where evaluation materials and questionnaire are on. At the beginning, experimenter explain the purpose of this evaluation. Then experimenter explained the evaluation flow of the Line Method in 0.5 minutes, and verifying there is no question from participant, participant was instructed to stand up to use AR system installed with the Line Method. During the usage exercise, experimenter explained the interface of proposed presentation method on AR-based support system. After participant did usage exercise of the Line Method, participant sit down and glance over the questionnaire on the desk. Experimenter instructs participant to experience the support system. Once participant understand the pointing position on real-world environment and the target object, they answer the questionnaire. There are subjective questions and objective questions prepared in questionnaire. For the subjective questions, participant was asked to write the pointing position on real-world environment and the target object at prepared pictures as shown in Fig.4.12 and Fig.4.13. Fig.4.12 shows the picture for participant to write answer on real-world environment. Fig.4.13 shows the picture for participant to write answer on the target object.

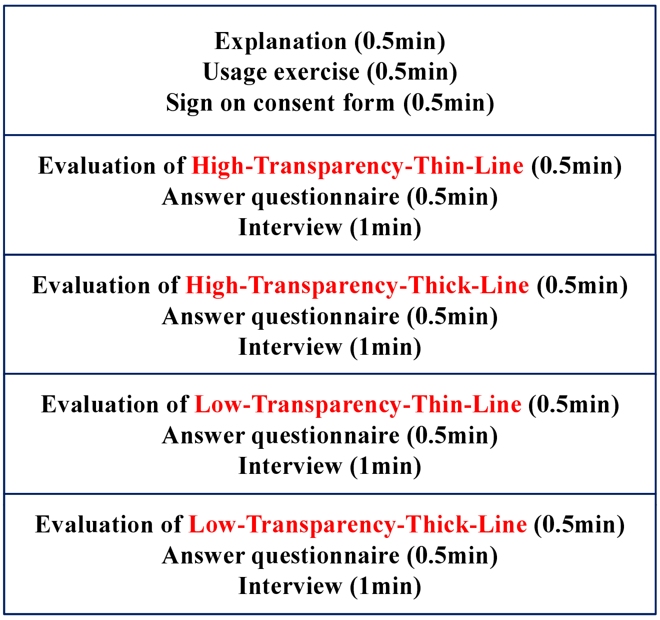

Figure 4.11: Protocol of evaluation of the Line Method

For the subjective questions, participant was asked to write how difficult to understand the pointing position presented by the Line Method. After participant finished questionnaire, experimenter review the answer and ask for the reason on the answer scored below "4". Details of categorical answers and corresponding numeric scores are

Figure 4.12: Real-world environment picture for participants to write pointing position

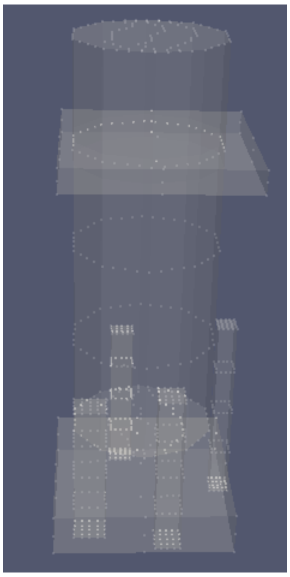

Figure 4.13: The target object picture for participants to write pointing position

Table 4.4: 7-Level likert scale and corresponding numeric scores

7-level scale	Score
Strongly agree	7
Agree	6
Somewhat agree	5
Neutral	4
Somewhat disagree	3
Disagree	2
Strongly disagree	1

shown in Table4.4. After interview, the experience of presentation method 1 in pattern 1 is completed. Participant experiences other three parameter patterns by the same way and select which pattern they preferred to.

Questions used to analyze the difficulty for participants to understand the pointing position of the Line Method are shown below.

Q1-1 It is easy to understand the pointing position presented at the target object.

Q1-2 It is easy to understand the pointing position presented at real-world environment.

Participants score for each question using points from 1 to 7, "Strongly disagree", "Disagree", "Somewhat disagree", "Neutral", "Somewhat agree", "Agree", "Strongly agree".

4.4.2.2 Parameter Patterns of Evaluation

Table4.5 shows the parameter-patterns evaluated in this evaluation. A high-transparency CG model and a low-transparency CG model were prepared in this evaluation. These four parameter-patterns were selected during the preliminary experiment and shown to every participant. Transparency of CG model was set from 0 (non-transparent) to 1 (complete transparent). Besides, to presenting the distance between the target object and the surroundings, a red-colored pointing line is be adopted.

Fig.4.14 shows the screen shot of four parameter patterns in the Line Method evaluation. A transparency CG model was presented on AR display which camera is oriented to real-world environment.

Table 4.5: Parameter patterns used in Transparent Model and Pointing Line Method

Pattern	Transparency of CG model	Thickness of pointing line
1	High(0.9)	Thin(10mm)
2	High(0.9)	Thick(20mm)
3	Low(0.1)	Thin(10mm)
4	Low(0.1)	Thick(20mm)

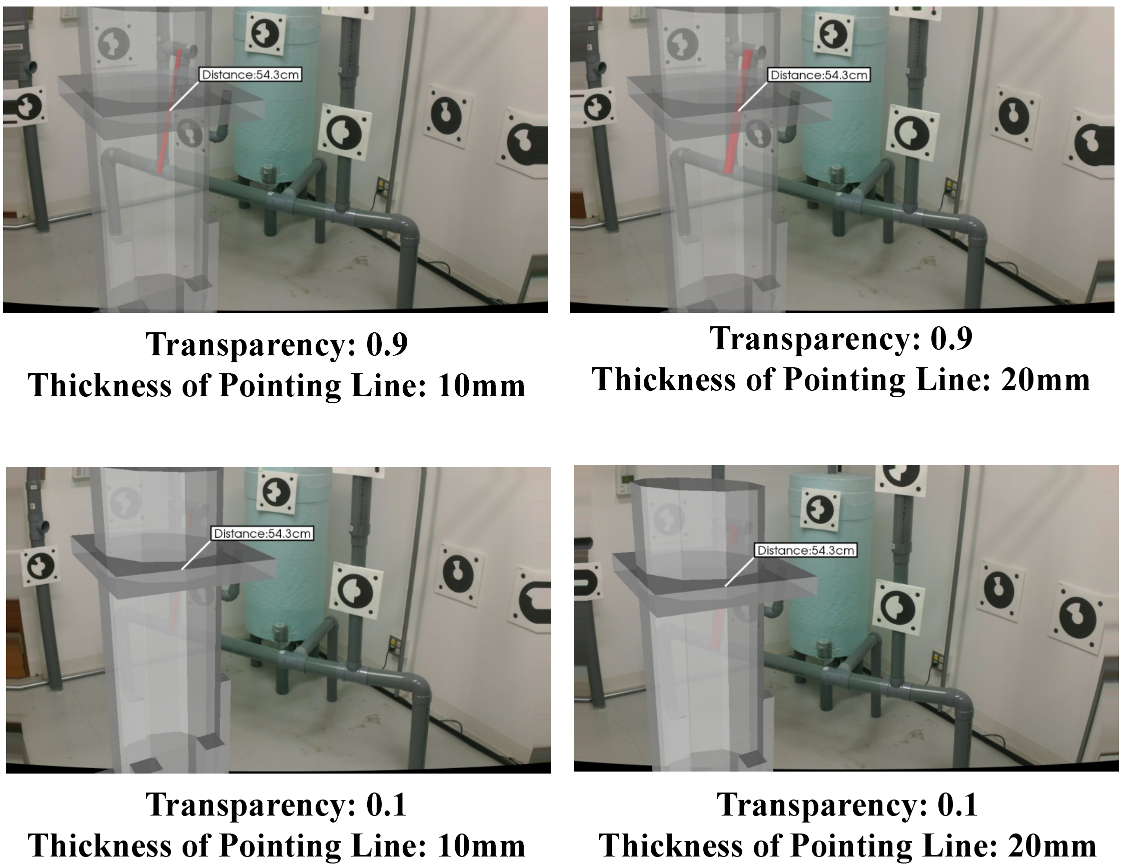

Figure 4.14: Screen shot example of four parameter patterns in Line Method evaluation

4.4.2.3 Participants in Evaluation

4 graduate students from Kyoto University joined this evaluation of presentation method.

4.4.3 Results of Evaluation

Answers of Q1-1 and Q1-2 are used for subjective assessment. Pointing positions on the environment and the target object wrote by participants are used for objective assessment.

4.4.3.1 Results of Subjective Questions

Answers of Q1-1 and Q1-2 are analyzed by using mean and standard deviation. The answer of Q1-1 is shown blue bars in Fig.4.15. High-Transparency-Thick-Line was scored highest among four parameter patterns. Standard deviation of it is the most the smallest one among all parameter patterns. The answer of Q1-2 is shown red bars in Fig.4.15. High-Transparency-Thin-Line was scored highest among four parameter patterns and the standard deviation is quite small. For standard deviation, there is no significant difference between High-Transparency-Thick-Line and High-Transparency-Thin-Line. It can be considered High-Transparency-Thick-Line performed best among four parameter patterns.

4.4.3.2 Results of Objective Questions

Fig.4.16 shows an example of measurement method using participants' answer wrote on the picture of the real-world environment. Participants write pointing position, which they understood during the Line Method evaluation on real-world environment, using a cross mark on the picture of the environment printed on the questionnaires sheet. All the pictures of real-world environment were set into same size in all questionnaires. Height (Y) and width (X) of cross mark are measured from bottom and left of the picture of the real-world environment using a ruler. Height (Y0) and width (X0) of presented pointing position are measured which uses the pointing position wrote on the picture of the real-world environment according to laser range finder. Distance (D) between the cross mark (X, Y) and pointing position presented during this evaluation

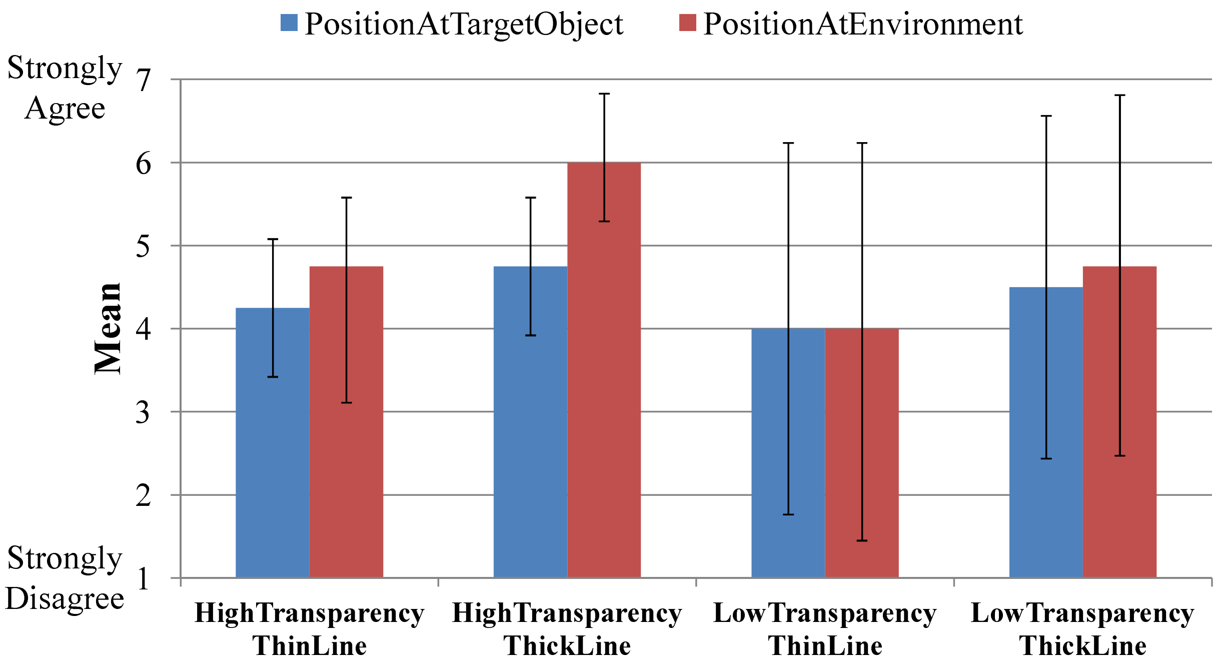

Figure 4.15: Means and standard deviations of scores for subjective questions in Line Method

(X0, Y0) was calculated and used as the distance error on real-world environment.

Fig.4.17 shows an example of measurement method using participants' answer on the picture of the target object wrote by participant. Participants write pointing position they have understood during the Line Method evaluation on the target object, using a cross mark on the picture of the target object printed on the questionnaires sheet. Fig.4.18 shows an example of measurement method of true pointing position used in the Line Method Evaluation. The target object and the coordinates of presented pointing position are shown by the 3D CG software, and a screen shot is printed from the 3D CG software.

Distance between the cross mark (X, Y) and pointing position presented during this evaluation (A, B) was calculated and used as the distance error at the target object.

Fig.4.19 shows the distance error of pointing position wrote by participants on the picture of real-world environment and the target object. For the picture of the real-world environment, distance error of High-Transparency-Thin-Line is smallest among four parameter patterns. Although error and standard deviation of High-Transparency-Thick-Line is slightly bigger than those of High-Transparency-Thin-Line, the difference between distance error of High-Transparency-Thick-Line and High-Trans parency-

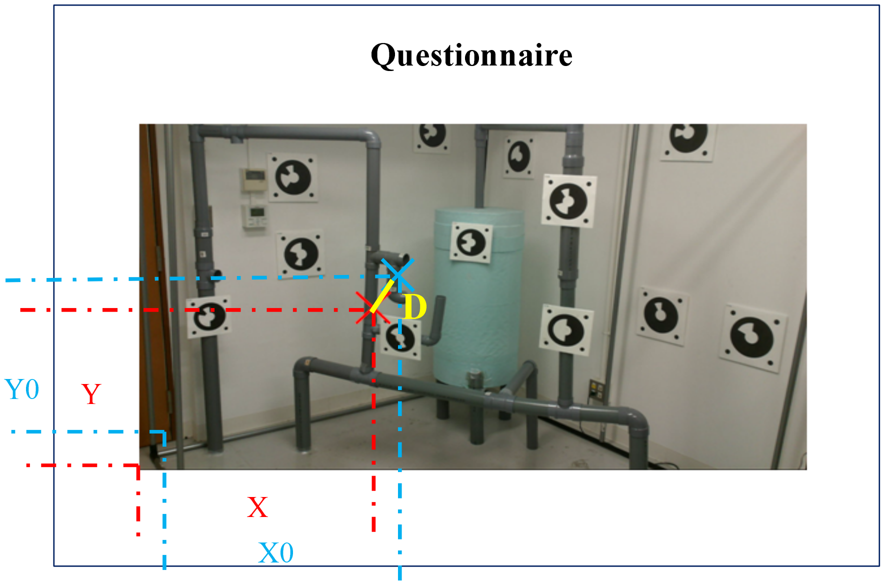

Figure 4.16: Pointing position wrote by participants on the real-world environment

Thin-Line is no more than 2 mm. It can be said High-Transparency-Thick-Line performed as well as High-Transparency-Thin-Line. For the picture of the target object, distance error of High-Transparency-Thick-Line is the smallest among four parameter patterns.

4.4.3.3 Interview Results and Analysis of Line Method Evaluation

High-Transparency-Thick-Line was scored the highest among four parameter patterns in blue, red bars in Fig.4.15 and the red bar in Fig.4.19 is the smallest. Only in the result shown in the blue bar in Fig.4.19, distance error of High-Transparency-Thick-Line is larger than High-Transparency-Thin-Line. However the difference between High-Transparency-Thin-Line and High-Transparency-Thick-Line is only a little. It can be considered High-Transparency-Thick-Line performed best totally.

As mentioned before, reasons of questions those scored under "4", is interviewed to participants. Table4.6 shows the scores answered for Q1-1 and Q1-2.

For High-Transparency-Thin-Line, there are two participants scored under "4" on Q1-1 and Q1-2. Participant 4 scored "3" for pointing position on the target object and "2" for pointing position on real-world environment. When endpoints of pointing line comes to surface of the target object or the real-world environment where no significant shape is shown, it is difficult to recognize pointing position. Participant 3 scored "4"

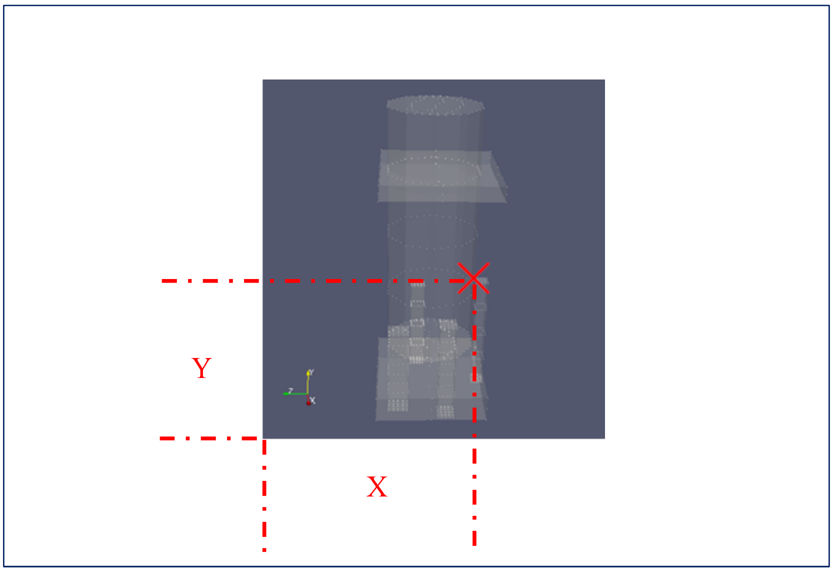

Figure 4.17: Pointing position wrote by participants on the target object

for pointing position on the target object. He said that whether high transparency or low transparency, shape of the target object can be understood well. However, when pointing line comes to vertical, it is difficult to know the location of endpoints of pointing line. He was confused with the location relationship of the target object and its surroundings.

For Low-Transparency-Thin-Line and Low-Transparency-Thick-Line, there are "1" and "2" being scored. According to interview to participants, low transparency of the target object did not reduce the bad influence from the target object itself. Back side of the target object is visible but not enough compared to high transparency.

However, high transparency of the target object is not satisfied to everyone. Participant 4 preferred low transparency than high transparency, because low transparency of the target object presents shape of the target object more significant than high transparency of the target object. A well-presented of surface shape of the target object is the main reason he preferred Low Transparency parameter pattern.

In conclusion of the Line Method evaluation, High-Transparency-Thick-Line is the best parameter pattern in the Line Method. High transparency of the target object presents back side of the target object better than low transparency of the target object commonly, because users can see through the target object and understand the location relationship between the target object and the surroundings easily. In some cases, Low

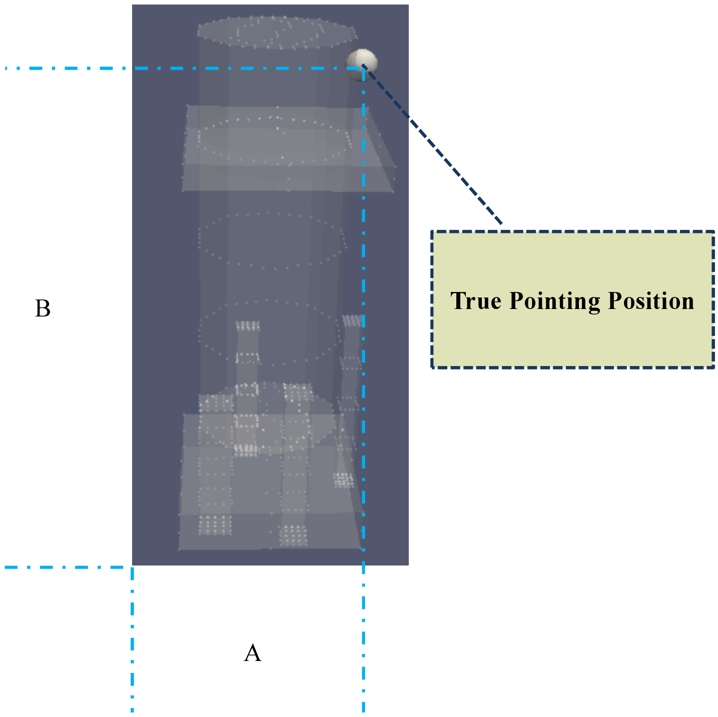

Figure 4.18: True pointing position on the target object

Transparency parameter pattern is preferred to those who want to see surface shape of the target object clearly.

4.5 Evaluation of Grids Model Method

4.5.1 Purpose of Evaluation

The Grids Method is a presentation method that additional cube grids are used to present shape of the target object and real-world environment, to present distance and location information clearly even there is occlusion between the target object and its surroundings. In the Grids Method, the target object is presented with wire frame to show its shape as well as additional cube grids to enhance three dimension. Different from the Line Method, cube grids are added both on the target object and its surroundings instead of pointing line. Pointing position on surface of the target object and its surroundings were presented with red-colored cubes. Different parameter patterns of cube size and rate of change may lead to different performance result of the Grids Method. Purpose of this evaluation is to find out best-performed parameter

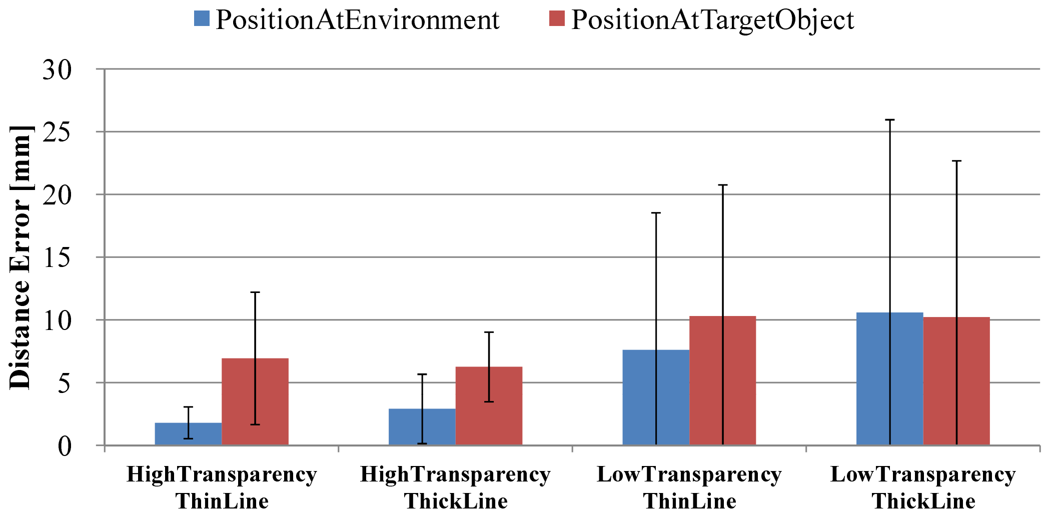

Figure 4.19: Means and standard deviations of average error of presented pointing position in Line Method

pattern in the Grids Method.

4.5.2 Details of Evaluation

4.5.2.1 Protocol of Evaluation

The protocol of evaluation of the Grids Method is the same as the one of the Line Method except the parameter patterns and subjective questions. Evaluation of the Grids Method was conducted in the same environment as the Line Method evaluation. Fig.4.20 shows the details of process in evaluation of Grids Method.

Participants write pointing position understood during evaluation on the pictures of the target object and real-world environment the same as they did in the Line Method evaluation. However, parameter patterns and questionnaires are different from those in the Line Method. Two more questions for subjective assessment are added in the Grids Method evaluation. Questions used to analyze the difficulty for participants to understand the pointing position of the Grids Method are shown below.

Q2-1 The size of cubes in red and purple is appropriate.

Q2-2 The rate of change of cubes in red and purple is appropriate.

Q2-3 It is easy to understand the pointing position presented at the target object.

Table 4.6: Scores on subjective questions in Line Method

Participant		1	2	3	4
Parameter Pattern	Questions				
A. High-Transparency/ Thin-Line	Q1-1	5	5	4	3
	Q1-2	5	6	6	2
B. High-Transparency/ Thick-Line	Q1-1	6	4	5	4
	Q1-2	7	5	6	6
C. Low-Transparency/ Thin-Line	Q1-1	1	3	7	5
	Q1-2	1	2	7	6
D. Low-Transparency/ Thick-Line	Q1-1	2	3	7	6
	Q1-2	2	3	7	7
Best-performed Parameter Pattern		B	A	ALL	D

Q2-4 It is easy to understand the pointing position presented at real-world environment.

For subjective assessment, participants score for each question using points from 1 to 7, "Strongly disagree", "Disagree", "Somewhat disagree", "Neutral", "Somewhat agree", "Agree", "Strongly agree". The questionnaires sheet is shown in Appendix C.

4.5.2.2 Parameter Patterns of Evaluation

Table4.7 shows the parameter-pattern evaluated in this evaluation. These four parameter-patterns were shown to every participant. Fig.4.21 shows the screen shoot of four parameter patterns in the Grids Method evaluation. Red-colored grids represent shape of a part of the target object. The central red-colored grid represents pointing position at the target object. Purple-colored grids represent shape of a part of real-world environment. The central purple-colored grid represents pointing position

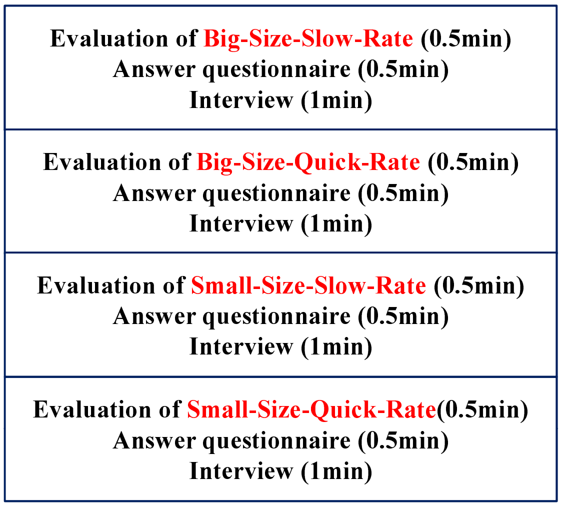

Figure 4.20: Protocol of evaluation of Grids Method

at real-world environment.

Table 4.7: Parameter patterns used in Grids Model Method

Pattern	Maximum Size of Grids	Rate of Change
1	Big(80mm)	Slow(12.5cm/s round)
2	Big(80mm)	Quick(50cm/s round)
3	Small(20mm)	Slow(12.5cm/s round)
4	Small(20mm)	Quick(50cm/s round)

4.5.2.3 Participants in Evaluation

4 graduate students from Kyoto University joined this evaluation of presentation method.

4.5.3 Results of Evaluation

Answers from Q2-1 to Q2-4 are used for subjective assessment. Pointing positions on the real-world environment and the target object wrote by participants are used for objective assessment.

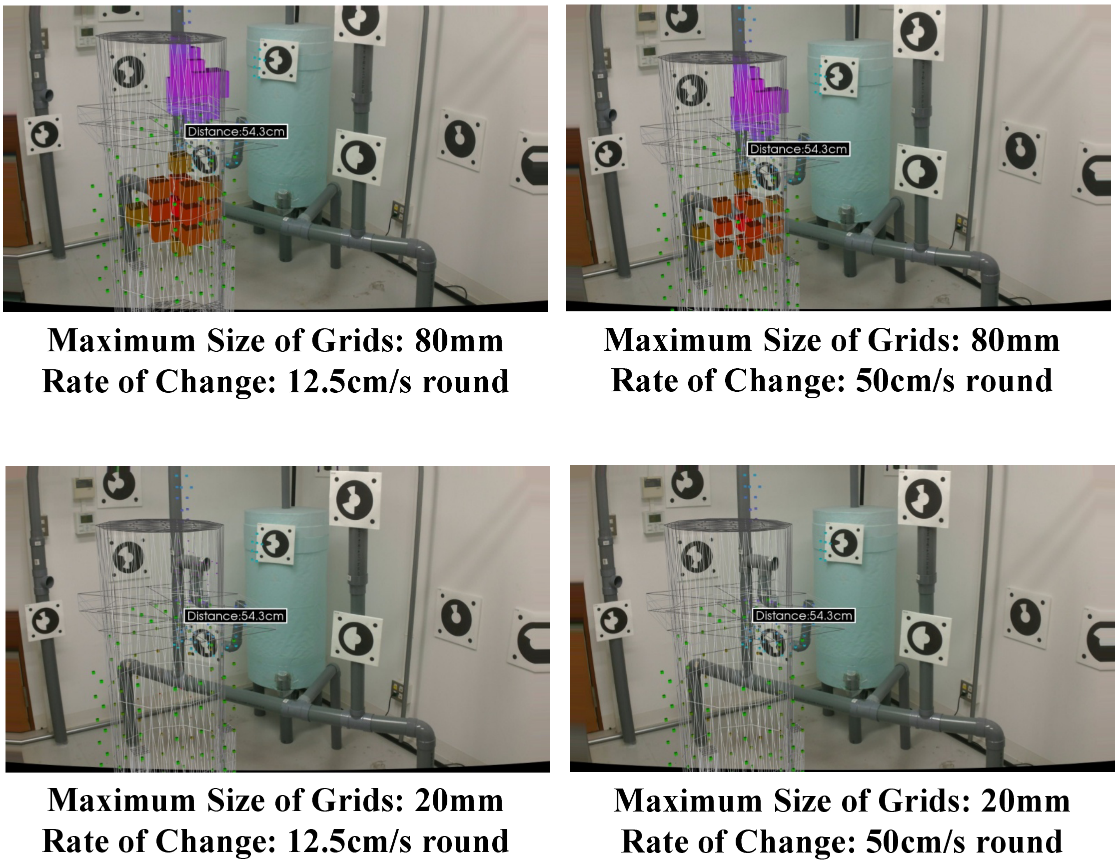

Figure 4.21: Screen shot example of four parameter patterns in Grids Method evaluation

4.5.3.1 Results of Subjective Questions

Answers from Q2-1 to Q2-4 are analyzed by using mean and standard deviation. The answer of Q2-1 is shown in Fig.4.22.

Blues bars show the mean of Q2-1 with error bars representing standard deviation. It is difficult to decide which of big-size or small-size of cube grids performed better in this graph, because Big-Size-Quick-Rate performed a slightly higher than Small-Size-Slow-Rate. Different patterns with size of grids and rate of change lead to a different results for participants to understand the distance and location information presented. Red bars show the results of Q2-2. Big-Size-Quick-Rate was scored higher than Small-Size-Slow-Rate, however, standard deviation of Big-Size-Quick-Rate is larger than the one of Small-Size-Slow-Rate. Green bars show the results of Small-Size-Slow-Rate. Although difference among four parameter patterns is no so significant than in Q2-1 and Q2-2,

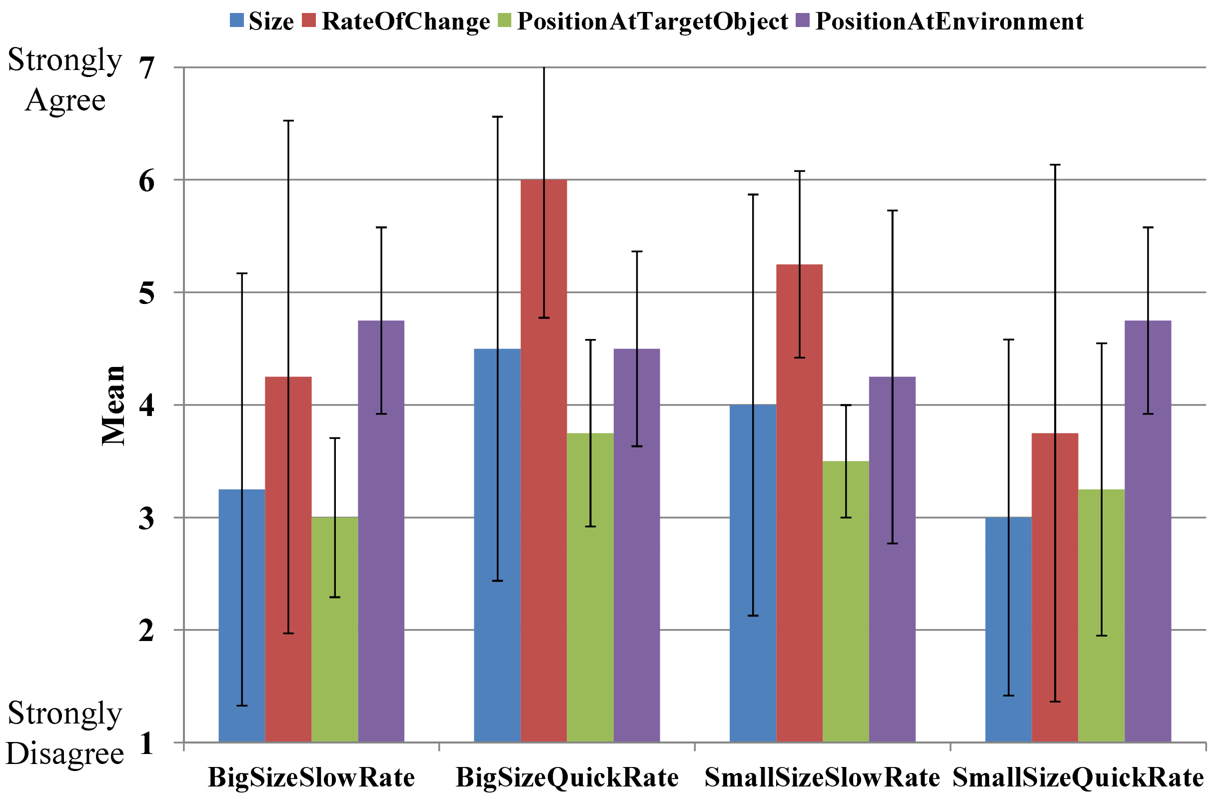

Figure 4.22: Means and standard deviations of scores for subjective questions in Grids Method

Big-Size-Quick-Rate was scored highest among four parameter patterns. Purple bars show the mean with standard deviation of Q2-4. Different from previous questions, Big-Size-Slow-Rate was scored highest as Small-Size-Quick-Rate. Both answers in Q2-4 are better than answers in Q2-3 which suggest pointing position at real-world environment is much more easily to be understood than pointing position at the target object in the Grids Method.

4.5.3.2 Results of Objective Questions

Participants were asked to draw pointing positions at real-world environment and the target object which they understood during the Grids Method evaluation. Distance error of all the answers were measured the same as the measurement method used in the Line Method.

Fig.4.23 shows the distance error of pointing position draw by participants on the picture of the real-world environment and the target object. For the picture of the real-world environment, distance error of Small-Size-Slow-Rate is the smallest among four parameter patterns followed by Big-Size-Quick-Rate. Standard deviations of distance error of Big-Size-Quick-Rate is smaller than the one of Small-Size-Slow-Rate, which represents a large difference of answers in Small-Size-Slow-Rate. For the picture of the target object, Big-Size-Quick-Rate was scored near Big-Size-Slow-Rate. Big-size of grids performed a clear shape of the target object than small-size ones.

4.5.3.3 Interview Results and Analysis of Grids Method Evaluation

Table4.8 shows the results from Q2-1 to Q2-4.

Big-Size-Quick-Rate was scored the highest among four parameter patterns in blue, red, green bars shown in Fig.4.22. In purple bars, it was scored lower than Big-Size-Slow-Rate and Small-Size-Quick-Rate. However there is a little difference among them. Although distance errors of Big-Size-Quick-Rate are not the smallest one in Fig.4.23. There is a little difference between it and the smallest one. It can be considered Big-Size-Quick-Rate scored the highest totally.

For Big-Size-Slow-Rate, there are 7 answers scored under "4". Participant 1 scored "2" in Q2-3 because it is difficult for him to understand which of red-colored grids representing pointing position. The reason is that location of grids confused him, it is

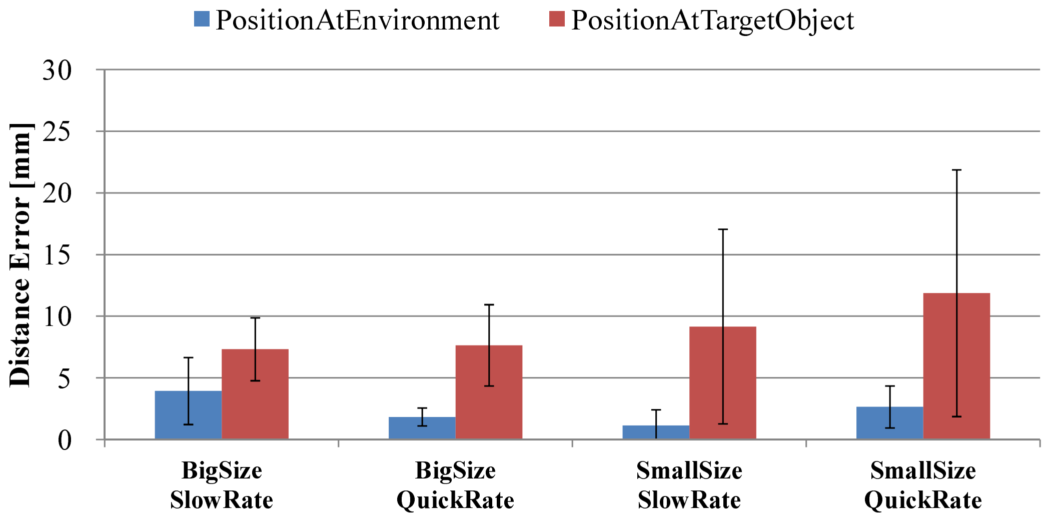

Figure 4.23: Means and standard deviations of distance error of presented pointing position in Grids Method

difficult to recognize whether grids are in front of the target object or on the back side of the target object. Participant 2 scored "3" in Q2-3 as the same reason as participant 1. Participant 3 scored "2" in Q2-1 and Q2-2, because for big-size parameter pattern, when cube grids come to the maximum size, the back side of pointing area on environment were hidden by grids. Due to the slow rate of change, pointing area on environment is invisible in a quite long time. Participant 4 scored "1" in Q2-1, "2" in Q2-2, "3" in Q2-3. Big size of cube grids lead to a bad effect on both the target object and its surroundings, when grids came to the maximum size, a collision occurred among these cube grids so that it is difficult to recognize which grid presents the pointing position. The reason "3" was scored in Q2-3 is wire frame presenting shape of the target object is too thin to recognize the surface shape of the target object.

For Big-Size-Quick-Rate, there are 4 answers scored under "4". Participant 2 scored "3" in Q2-1, "3" in Q2-3, a high density of cube grids was preferred to. It is confusing with the location of cube grids whether they are in front of the target object or on the back side of the target object. Participant 4 scored "2" in Q2-1, "3" in Q2-3. Maximum size of cube grids is too big that a bad effect was lead to among nearby grids.

For Small-Size-Slow-Rate, there are 5 answers scored under "4". Participant 1 scored "3" in Q2-3 because red-colored cube grids is too much to distinguish central cube grid and nearby cube grids. Participant 3 scored "2" in Q2-1 and Q2-4. Size of grids is too

Table 4.8: Scores on subjective questions in Grids Method

Participant		1	2	3	4
Parameter Pattern	Questions				
A. Big-Size/ Slow-Rate	Q2-1	6	4	2	1
	Q2-2	7	6	2	2
	Q2-3	2	3	4	3
	Q2-4	6	4	4	5
B. Big-Size/ Quick-Rate	Q2-1	7	3	6	2
	Q2-2	7	7	6	4
	Q2-3	5	3	4	3
	Q2-4	6	4	4	4
C. Small-Size/ Slow-Rate	Q2-1	7	3	2	4
	Q2-2	5	6	4	6
	Q2-3	3	3	4	4
	Q2-4	6	4	2	5
D. Small-Size/ Quick-Rate	Q2-1	1	4	2	5
	Q2-2	1	7	2	5
	Q2-3	2	2	4	5
	Q2-4	5	4	4	6
Best-performed Parameter Pattern		B	B	B	D

small to understand the location of pointing position.

For Small-Size-Quick-Rate, there are 6 answers scored under "4". Participant 1 felt size of grids is too small to understand the center of pointing area. Rate of change of grids is too quick for him to know the accurate pointing position. Participant 3 gave a suggestion that making grids larger and colored different from nearby grids may present information more clear.

In conclusion, three participants select Big-Size-Quick-Rate as the best parameter pattern in the Grids Method. Big size of grids show pointing area more clear than the small ones. However, too large of maximum size of grids causes back side of the target object hidden by these grids. It is easy to recognize pointing position by quick rate of change of grids. On the other side, slow rate of change causes a long waiting time and confusing with location relationship between the target object and its surroundings.

4.6 Evaluation of Model Rotation and Shift Method

4.6.1 Purpose of Evaluation

The Moving Method is a presentation method that CG model is rotated and shift a further distance from original location forcibly. When occlusion occurred between the target object and the surroundings, CG model was forcibly rotated that make back side directly perceived. To show area hidden by the target object, shifting CG model at a distance is took into consideration too. Different parameter patterns of rotation speed and shift distance may lead to different performance result of the Moving Method. Purpose of this evaluation is to find out best-performed parameter pattern in the Moving Method. Rotation speed and shift distance are two parameters evaluated in this method. Two kind of rotation speed and shift distance are set to find out the influence of understanding to pointing position on the target object.

4.6.2 Details of Evaluation

4.6.2.1 Protocol of Evaluation

The protocol of evaluation of the Moving Method is the same as the Line Method and the Grids Method except the parameter patterns and subjective questions. Evaluation of the Moving Method was conducted in the same environment as the Line Method and the Grids Method. Fig.4.24 shows the details of protocol in evaluation of the Moving Method, which is conducted after evaluation of the Grids Method.

Participants write pointing position understood on the pictures of the target object and real-world environment as the same as they did in the evaluations of the Line Method and the Grids Method. However, parameter patterns and questionnaires are

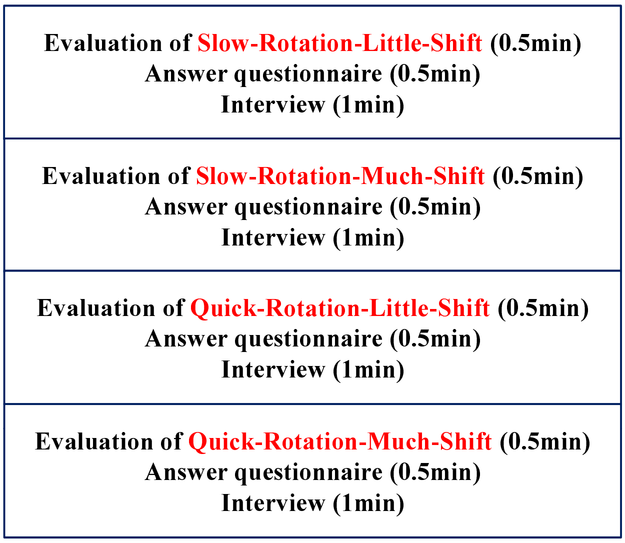

Figure 4.24: Protocol of evaluation of Moving Method

different from those in the Line Method and the Grids Method. Q3-1 and Q3-2 are different from previous questions. Q3-3 and Q3-4 are the same questions. Answers of these questions are used to analyze the difficult for participants to understand the performance of the Moving Method.

Q3-1 The rotation speed of the target object is appropriate.

Q3-2 The shift distance of the target object from original position appropriate.

Q3-3 It is easy to understand the pointing position presented at the target object.

Q3-4 It is easy to understand the pointing position presented at real-world environment.

For subjective assessment, participants score for each question using points from 1 to 7, "Strongly disagree", "Disagree", "Somewhat disagree", "Neutral", "Somewhat agree", "Agree", "Strongly agree". The questionnaires sheet is shown in Appendix D.

4.6.2.2 Parameter Patterns of Evaluation

Table4.9 shows the parameter-pattern evaluated in this evaluation. These four parameter-patterns were shown to every participant. Shift distance is the distance of the target object from original location to final location, where area and back side of the target object are completely visible. Fig.4.25 shows the screen shot of four parameter patterns in the Moving Method evaluation.

Table 4.9: Parameter patterns used in Model Rotation and Shift Method

Pattern	Rotation speed	Shift distance
1	Slow(12.5 degree/s round)	Little(20mm)
2	Slow(12.5 degree/s round)	Much(100mm)
3	Quick(37.5 degree/s round)	Little(20mm)
4	Quick(37.5 degree/s round)	Much(100mm)

4.6.2.3 Participants in Evaluation

4 graduate students from Kyoto University joined this evaluation of presentation method.

4.6.3 Results of Evaluation

Answers from Q3-1 to Q3-4 used for subjective assessment are analyzed by using mean and standard deviations. Pointing positions on the real-world environment and the target object wrote by participants are used for objective assessment.

4.6.3.1 Results of Subjective Questions

Answers from Q3-1 to Q3-4 are shown in Fig.4.26.

Blues bars show the mean of Q3-1 with error bars represent standard deviation. Quick-Rotation-Much-Shift was scored highest among four parameter patterns. From this results, quick-rotation parameter patterns performed better than slow-rotation one.

Red bars show the results of Q3-2. There is no significant difference among four parameter patterns that both little-shift and much-shift parameter patterns performed enough. The standard deviation of Quick-Rotation-Little-Shift is the smallest.

Green bars show the results of Q3-3. Quick-Rotation-Little-Shift was socred as high as Quick-Rotation-Much-Shift followed by Slow-Rotation-Much-Shift. Quick-rotation parameter pattern is more easier for participants to understand the pointing position at the target object.

Purple bars show the results of Q3-4. Quick-rotation parameter pattern was scored higher than slow-rotation pattern, though there is no significant difference between

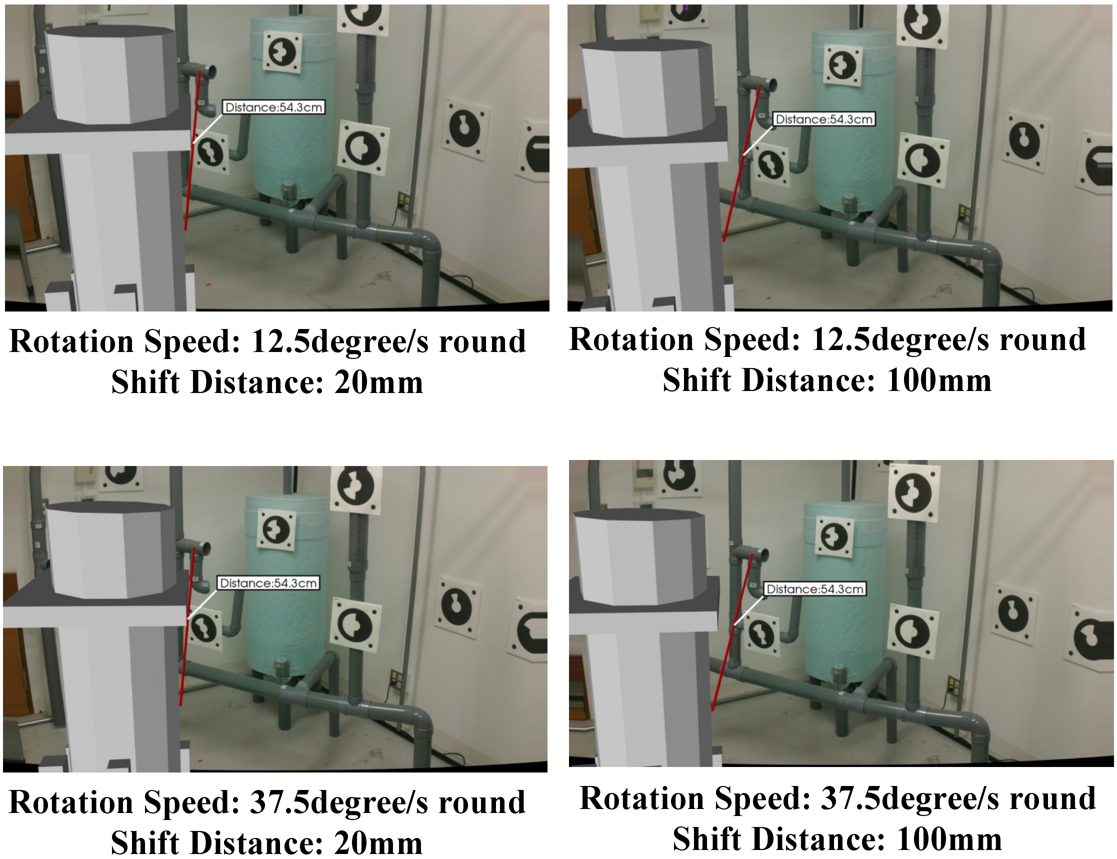

Figure 4.25: Screen shot example of four parameter patterns in Moving Method evaluation

them. Real-world environment hidden by the target object were shown completely visible in all parameter patterns, so that high scores were got in this evaluation.

4.6.3.2 Results of Objective Questions

Participants were asked to draw pointing positions at real-world environment and the target object which they understood during the evaluation of the Moving Method. Distance error of all the answers were measured using the same method used in the Line Method and the Grids Method.

Fig.4.27 shows the distance error of pointing position draw by participants on the picture of real-world environment and the target object. For the picture of the real-world environment, distance error of Slow-Rotation-Much-Shift is almost the same as Quick-Rotation-Little-Shift. Standard deviation of Slow-Rotation-Much-Shift is a little smaller than Quick-Rotation-Little-Shift. For the picture of the target object, distance

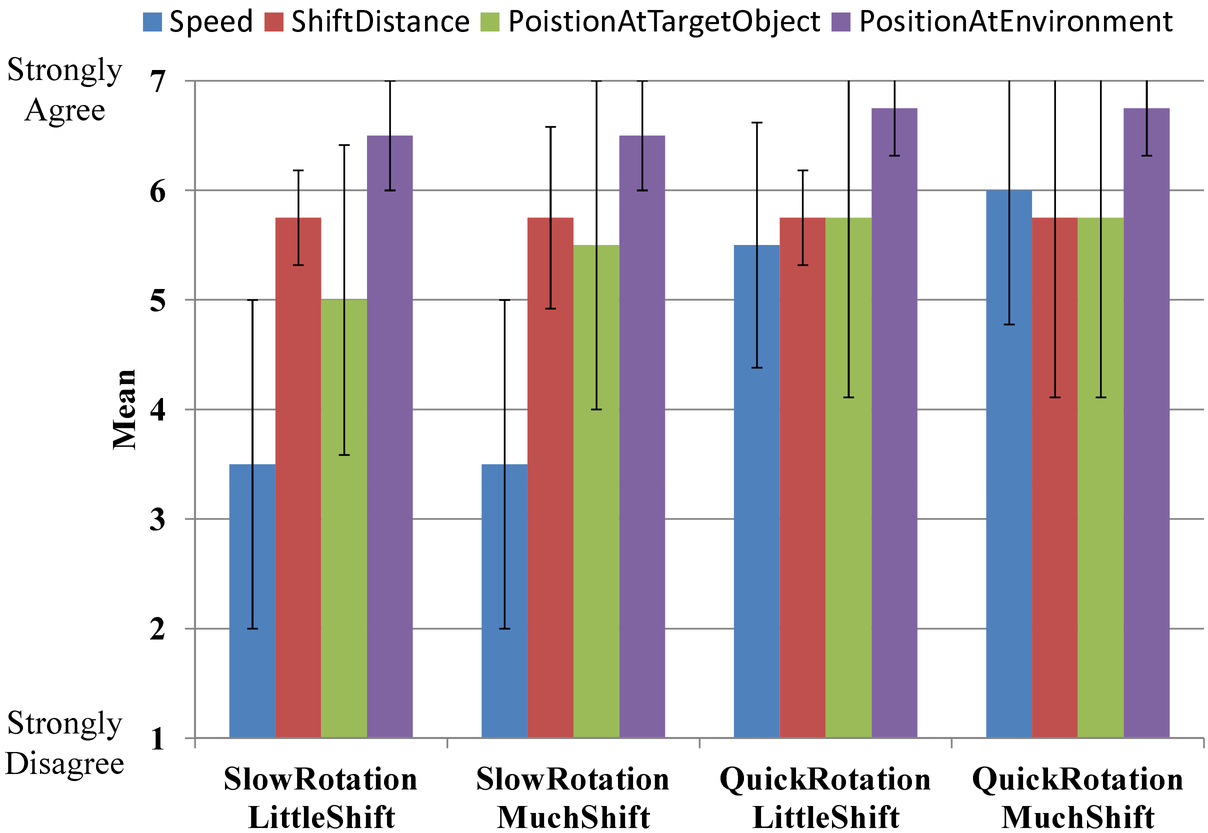

Figure 4.26: Means and standard deviations of scores for subjective questions in Moving Method

error of Slow-Rotation-Little-Shift is the smallest one among four parameter patterns.

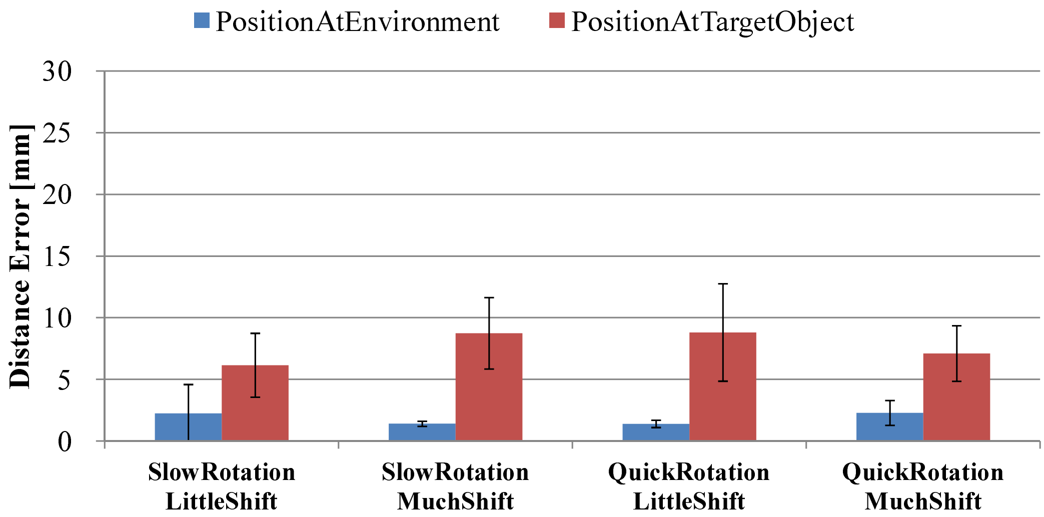

Figure 4.27: Means and standard deviations of distance error of presented pointing position in Moving Method

4.6.3.3 Interview Results and Analysis of Moving Method Evaluation

Table4.10 shows the results from Q3-1 to Q3-4.

Quick-Rotation-Much-Shift performed the best in blue bars Fig.4.26. In red, green and purple bars, it was scored the same as Quick-Rotation-Little-Shift. It can be said that quick-rotation parameter pattern presents distance and location information better than the slow one. In Fig.4.27, it performed a little worser than Slow-Rotation-Little-Shift because slow-rotation shows a slow process of rotation of the target object for participants to understand the pointing position at the target object. However, there is no significant difference between it and Slow-Rotation-Little-Shift. It can be considered Quick-Rotation-Much-Shift is the best-performed parameter pattern in the Moving Method.

For Slow-Rotation-Little-Shift, there are 3 answers scored under "4". Participant 2 scored "2" in Q3-1 because rotation and shift of the target object does not occurred synchronously. The reason is that in proposed the Moving Method, the target object is rotated firstly in order to make the pointing position on back side of it visible. If pointing position at real-world environment is still invisible after the target object rotated, a further shifting of the target object will happen. Participant 3 scored "2"

Table 4.10: Scores on subjective questions in Moving Method

Participant		**1**	**2**	**3**	**4**
Parameter Pattern	Questions				
A. Slow-Rotation/ Little-Shift	Q3-1	5	2	2	5
	Q3-2	5	6	6	6
	Q3-3	7	3	5	5
	Q3-4	7	7	6	6
B. Slow-Rotation/ Much-Shift	Q3-1	5	2	2	5
	Q3-2	7	5	5	6
	Q3-3	7	3	6	6
	Q3-4	7	7	6	6
C. Quick-Rotation/ Little-Shift	Q3-1	7	4	5	6
	Q3-2	6	6	5	6
	Q3-3	7	3	6	7
	Q3-4	7	7	6	7
D. Quick-Rotation/ Much-Shift	Q3-1	7	4	6	7
	Q3-2	7	6	3	7
	Q3-3	7	3	6	7
	Q3-4	7	7	6	7
Best-performed Parameter Pattern		D	C	C	D

in Q3-1, it is satisfying to see back side of the target object as soon as possible, there is no need for a slow rotation.

For Slow-Rotation-Much-Shift, there are 2 answers scored under "4". Participant 2 scored "2" in Q3-1 as the same reason in Slow-Rotation-Little-Shift. Participant 3 scored "2" in Q3-1 for the reason that there is no need for a slow rotation.

For Quick-Rotation-Little-Shift, there is 1 answer scored under "4". Participant 2 scored "3" in Q3-3. It is enough when endpoint of pointing line on the back side of the target object becoming visible, there is no need for a further shifting.

For Quick-Rotation-Much-Shift, there are 2 answers scored under "4". Participant 3 scored "3" in Q3-2, It is a waste of time when the target object shifted for a further distance.

In conclusion, Quick-Rotation-Much-Shift performed best among four parameter patterns. Quick-rotation parameter pattern is preferred to be a best parameter then slow one, because slow-rotation costs much time.

4.7 Summary of The First Stage Evaluation

In the first stage of evaluation, three evaluations of proposed presentation methods were conducted. Finding out best parameter pattern in each presentation method is the purpose of the first stage of evaluation. Best-performed parameter pattern was evaluated by subjective assessment and objective assessment. Table4.11 shows the result of the first stage evaluation.

Table 4.11: Best parameter pattern in each presentation method

Presentation Method	Best Parameter Pattern
Line Method	High-Transparency-Thick-Line
Grids Method	Big-Size-Quick-Rate
Moving Method	Quick-Rotation-Much-Shift

4.8 Comparison of Proposed Presentation Methods

4.8.1 Purpose of Comparison Evaluation

The purpose of this comparison evaluation is to find out which one of three proposed presentation methods performed best in presenting distance and location information between the target object and the surroundings under the situation of occlusion occurred between them.

4.8.1.1 Protocol of Comparison Evaluation

In this comparison evaluation, participants were shown with three presentation methods using best-performed parameter pattern results achieved in the first stage of evaluation.

Fig.4.28 shows the protocol of comparison evaluation and details of the process of the participant.

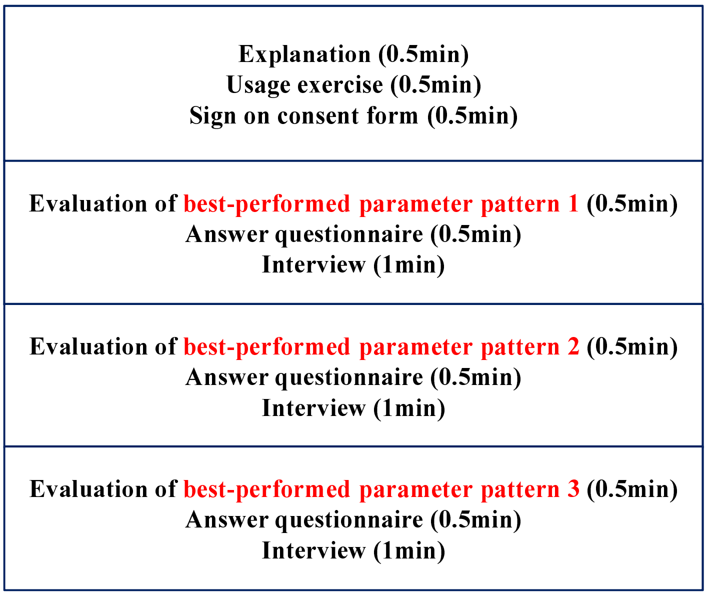

Figure 4.28: Protocol of comparison evaluation

Experimenter explained the purpose of comparison evaluation, then participants sign on consent form if there are no questions with this evaluation. Beginning of this comparison evaluation is quite the same as what was done in the first stage of evaluation. First of all, the experimenter introduce the purpose and the process of comparison briefly, in about 2 minutes. Then experience of presentation method one began with a simple explanation method one in about 0.5 minute. An usage exercise of presentation method one was followed with it and participants can glance at questionnaire. Once participants ensured the process of comparison evaluation without any questions, the comparison evaluation was started.

After the comparison evaluation started, participants were shown with best-performed parameter pattern which selected in the first stage of evaluation in different order, because showing different orders of best-performed parameter patterns can reduce the influence practice, and can improve the performance due to repeated evaluation.

4.8.2 Details of Comparison Evaluation

4.8.2.1 Participants in Comparison Evaluation

6 students from Graduate School, Kyoto University joined this comparison evaluation of presentation methods. 3 of them, who are participant 1, 3 and 6, joined the evaluation of three presentation methods before so that it means they have experience of our proposed presentation methods. The other 3 students are new for our evaluation without and experience of our proposed presentation methods.

4.8.2.2 Presentation Methods in Comparison Evaluation

According to the results of first stage of evaluation. Best-performed parameter pattern of each presentation method are shown as below.

A High-Transparency-Thick-Line in the Line Method

B Big-Size-Quick-Rate in the Grids Method

C Quick-Rotation-Much-Shift in the Moving Method

In order to reduce the understanding difficult of different pointing positions and the practice effect in this evaluation, three presentation methods in different order with random coordinates are shown to participants. Table4.12 shows the order of presentation method for each participant, for whom marked with (*) is a participant who also joined the first stage of evaluation.

4.8.3 Results of Comparison Evaluation

Questions used to analyze the difficulty for participants to understand the pointing position of three methods are shown below.

Q4-1 It is easy to understand the pointing position presented at the target object.

Q4-2 It is easy to understand the pointing position presented at real-world environment.

The questionnaires sheet is shown in Appendix E.

Table 4.12: Order of presentation method in comparison evaluation

Participant	1st Method	2nd Method	3rd Method
1*	A	B	C
2	A	C	B
3*	B	A	C
4	B	C	A
5	C	A	B
6*	C	B	A

4.8.3.1 Results of Subjective Questions

Answers of Q4-1 and Q4-2 are shown in blue bars in Fig.4.29. For pointing position at the real-world environment, the most easiest presentation method for participants to understand the pointing position at real-world environment is the Moving Method. It is because the real-world environment hidden by the target object becomes visible, thanks to the shifting of the target object. Second place is the Line Method, which was scored slightly less than the Moving Method. Thanks to high transparency of the target object, occlusion problem reduced and real-world environment hidden by the target object can be saw easily. Red-colored pointing line also helps users to understand an accurate pointing position. Although occlusion problem reduced in the Line Method, there is still interference remaining from the target object itself that users can not completely see through the target object. Third place is the Grids Method. It is a reasonable result because in the Grids Method, a group of grids presented pointing position instead of pointing line. It is easy for participants to understand the pointing position and its nearby shape of the target object. However it is difficult to know where is accurate pointing position because cube grids disturbing each other.

For pointing position at the target object, almost the same scoring result was shown as the one shown in the real-world environment.

4.8.3.2 Results of Objective Questions

Participants were asked to draw the pointing position at the real-world environment and the target object which they understood in comparison evaluation. Distance error

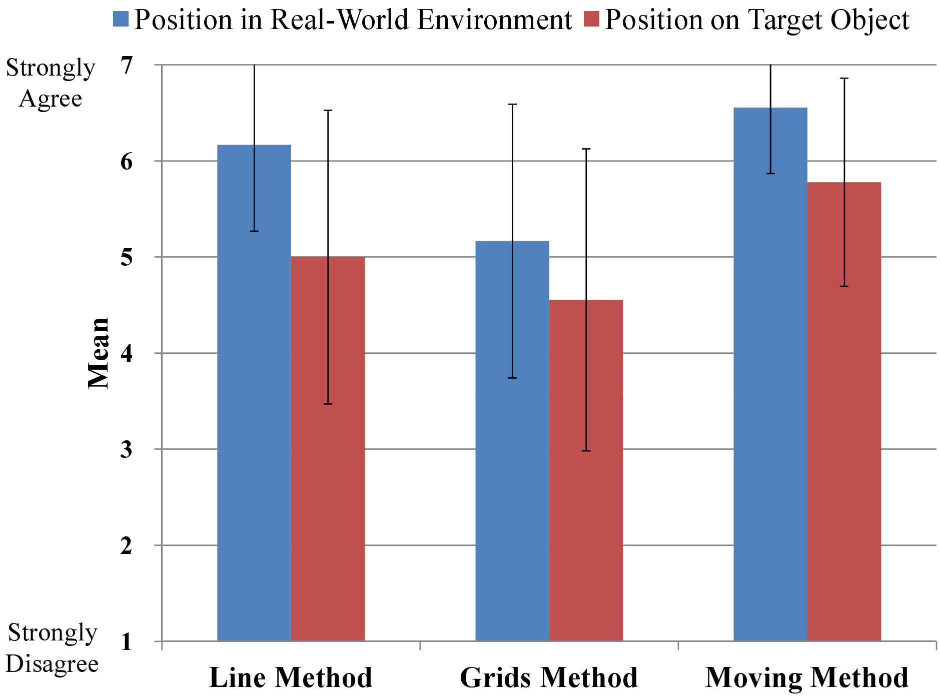

Figure 4.29: Means and standard deviations of scores for subjective questions

of all the answers were measured using the same method used in the first stage of evaluation.

Fig.4.30 shows the distance error pointing position draw by participants on the pictures of the real-world environment and the target object. For pointing position at the real-world environment, the Grids Method is first place among three methods unexpectedly. Standard deviations of the Line Method and the Moving Method is very large. Actually there are complete wrong answers both in the Line Method and the Moving Method. Participants understood pointing position falsely and wrote an answer far away from true pointing position, because the vertical pointing line confused him to a misunderstanding of the pointing position. If two wrong answers were excluded, distance error of pointing position at environment in the Moving Method is the smallest.

For pointing position at the target object, distance error of the Moving Method is the smallest. It is because all the back side of the target object is visible to users. Although rotation of the target object may confused users to a misunderstanding of accurate pointing position, this is a good method for participants to view back side of the target object.

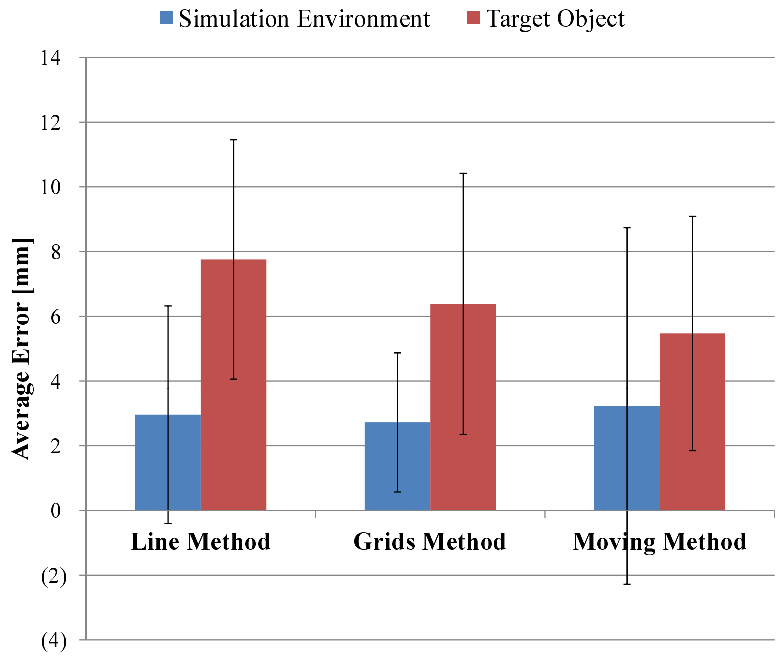

Figure 4.30: Means and standard deviations of distance error of presented pointing position at environment and the target object

4.8.3.3 Interview Results and Analysis of Comparison Evaluation

Table4.13 shows the results of comparison evaluation. There are no answers being scored under "4" in the Moving Method, which shows a high evaluation for the Moving Method. Answers scored under "4" in the Grids Method are more than those in the Line Method.

For the Line Method, a main problem lead to bad scores. The problem is the orientation of the pointing line. When the pointing line is vertical, it is difficult for participants to distinguish front and back of the pointing line.

For the Grids Method, there are two problems which lead to bad scores. First problem is interference from grids. Size of grids changed continuously, grids at real-world environment were hidden by grids at the target object when they became large. Second problem is location of grids. Grids are used to present shape of the target object in the Grids Method. When they shown on a area with flat or simple surface of the target object, it is difficult for participants to understand the pointing position at the target object.

In this comparison evaluation, the Moving Method evaluated higher than other two

Table 4.13: Scores on subjective questions in comparison evaluation

Participant			1*	2	3*	4	5	6*
Parameter Pattern	Pointing Position	Questions						
A. Line Method	1	Q4-1	7	5	6	7	6	6
		Q4-2	6	3	5	6	7	4
	2	Q4-1	7	5	7	7	6	6
		Q4-2	3	4	5	7	7	3
	3	Q4-1	5	4	7	7	7	6
		Q4-2	3	4	5	7	7	4
	Mean of Q4-1		*6.17*					
	Mean of Q4-2		*5.00*					
B. Grids Method	4	Q4-1	7	4	6	7	4	6
		Q4-2	7	3	5	6	5	5
	5	Q4-1	5	5	3	7	4	6
		Q4-2	3	3	1	5	6	5
	6	Q4-1	3	4	6	7	4	6
		Q4-2	3	3	4	7	6	5
	Mean of Q4-1		*5.17*					
	Mean of Q4-2		*4.56*					
C. Moving Method	7	Q4-1	7	6	7	7	6	7
		Q4-2	7	5	6	5	4	7
	8	Q4-1	7	5	7	7	6	7
		Q4-2	7	5	7	4	5	7
	9	Q4-1	7	5	7	7	6	7
		Q4-2	7	5	6	5	5	7
	Mean of Q4-1		*6.56*					
	Mean of Q4-2		*5.78*					
Best Presentation Method			C	C	A	A	A	C

methods. However, there are half of the participants selected the Line Method as best presentation method. In conclusion, the Line Method presented distance and location information as well as the Moving Method in subjective assessment. On the other hand, the Moving Method presented distance and location information with less error than the Line Method.

Chapter 5 Conclusion

In this research, three presentation methods are proposed and evaluated, which can present distance and location information between the target object and its surroundings even occlusion problems between them occurred. First presentation method is Transparent Model and Pointing Line Method (Line Method), in which the target object is set into transparency for showing a perspective view. A red-colored line was used to point two points of distance information. Second presentation method is Grids Model Method (Grids Method), in which additional cube grids are used to present the pointing position and shape of the target object and the surroundings. Third presentation method is Model Rotation and Shift Method (Moving Method), in which the target object was rotated to show the back side of it. To present the real-world environment hidden by the target object clearly, the target object was also shifted from its original location.

Different parameters for each presentation method may lead to a different results of evaluation. In order to find out which parameter pattern performs best in each presentation method, three evaluations were conducted in same evaluation environment in the first stage of evaluation. After best parameter patterns were got from the first stage of evaluation, a comparison evaluation was conducted in the second stage of the evaluation. Finally, the Moving Method got highest evaluation totally among three presentation methods. The Line Method were scored for a high performance in subjective assessment.

Although a best presentation method was achieved among three different presentation methods, other new presentation methods may gain a better result. For example, showing multi-windows with different presentation methods may help the workers to understand the situation clearly from different view points. Allowing the workers to adjust parameters freely may also improve the proposed presentation methods. Much more parameters and patterns should be considered in the future. To achieve an useful AR-based support system for real decommissioning work of nuclear power plant, more experiments and evaluations should be conducted inside real nuclear power plant.

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Appendix A Tracking using Markers

A marker measurement system developed by Yan [20] in this research. To tracking camera position accurately during the evaluation later, we decide the world coordinate as Fig.A.1. The orientation from No.1 marker to No.2 marker is the X coordinate axis, the orientation from No.1 marker to No.3 marker is the Y coordinate axis. The whole marker coordinate system follow with right-handed coordinate system.

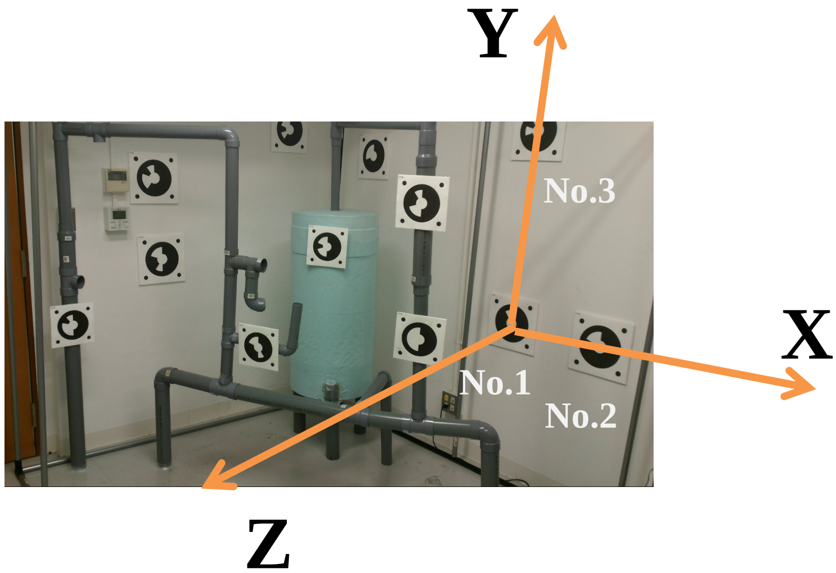


Figure A.1: Setup of world coordinate

Whole setup of laser range finder, camera and simulation environment created by pipes is shown in Fig.A.2. Laser range finder and camera are fixed on a tripod and connected to a control computer. By operating marker measurement system, we control the camera and laser range finder to measure the coordinate of every marker arranged on simulation environment.

Coordinate of every marker are calculated by a laser range finder shown in Fig.A.3. Specification of camera is shown in TableA.1.

Marker coordinate is calculated by following step.

- Set laser range finder and camera with tripod

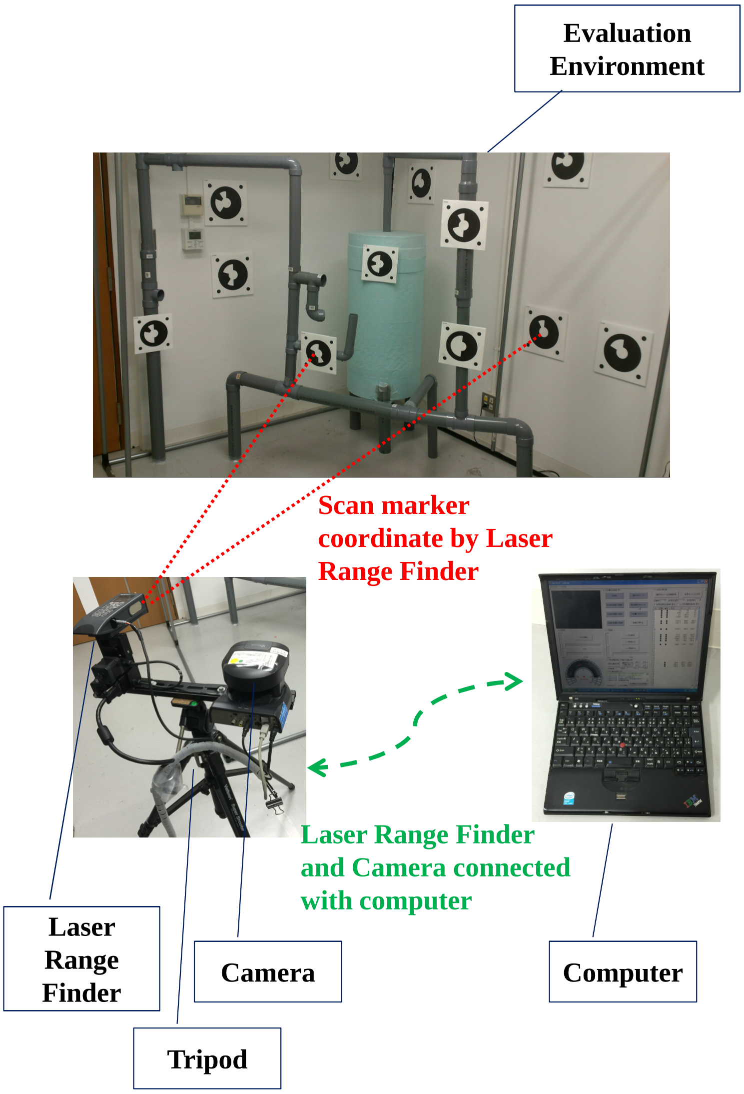


Figure A.2: Laser range finder and camera connected with computer

Table A.1: Specification of camera used for marker measurement

Camera type	Sony SRC06-USB
Size	109mm/142mm/164mm
Weight	1.2kg
Signal	NTSC
Lens	f=5.4 64.8mm

Figure A.3: Camera used for marker measurement

- Recognize every marker by camera
- Laser range finder turned to marker and calculate the marker coordinate
- Save result on computer

The appearance and specification of laser range finder is shown by Fig.A.4 and TableA.2.

Figure A.4: Laser range finder used for marker measurement

All the calculation results are saved into computer of which photo and specification is shown in FigureA.5 and TableA.3.

Table A.2: Specification of laser range finder used for marker measurement

Laser range finder type	Leica Geosystems
Precision	Standard: $\pm$ 1.5mm/Maximum: $\pm$ 2mm
Typical measuring accuracy	1mm
Measuring Range	0.3m - 100m
Wave length	635nm

Figure A.5: Computer used for marker measurement

Table A.3: Specification of computer running marker measurement program

Computer type	Thinkpad X60
OS	Windows XP Professional

Appendix B Details of First Stage of Evaluation

説明資料

「拡張現実感を用いた情報提示手法の評価」ご協力のお願い

京都大学大学院エネルギー科学研究科
エネルギー情報学分野
緊急時連絡先：********（オウ）

はじめに

この度は私達の評価にご協力いただき、誠にありがとうございます。評価に先立ち、評価に関する説明および評価中の諸注意といくつかお願いがございますので、熟読の上、ご理解とご協力をお願いいたします。

評価の目的

拡張現実感という現実環境映像の上にコンピュータで生成されたコンピュータグラフィックスを重畳表示できる技術が存在します。私達はこの技術を用いることで、原子力発電プラントでの解体作業を支援するシステムを開発しようとしています。プラントの解体作業には、大型設備を運搬する作業があります。このシステムでは運搬対象となる解体対象物（仮想的に移動）と作業現場との間の距離情報を提示することができます。本日はこの機能についての様々な表現手法を評価していただきます。

図１　評価環境

評価の中止について

- ◆ 評価の途中であっても、参加者の意思でいつでも中止することができます。
- ◆ 途中で中止しても、参加者に不利益が生じることはありません。

データの取り扱いについて

- ◆ この評価で得られたデータは、研究用としてのみ用いられます。
- ◆ 評価の結果を論文などで発表する場合は、参加者の氏名や、個人が特定される情報が公開されることはありません。
- ◆ 参加者の住所氏名などの個人情報は、評価データとは切り離して扱われます。また、個人情報は、流出することのないよう厳密に管理され、研究上の必要性が消失した場合には、すみやかに廃棄します。

本日の流れ

本日の流れを図２に示します。

評価の概要を説明させていただいた後、同意書にサインしていただきます。その後、評価部屋の中で３種類の提示手法デザインを体験して頂き、アンケートに記入していただきます。アンケートでは各回答に対して、そのように回答して頂いた理由を口頭でお尋ねいたします。その際、内容を録音させていただきたく、ご理解をお願い致します。

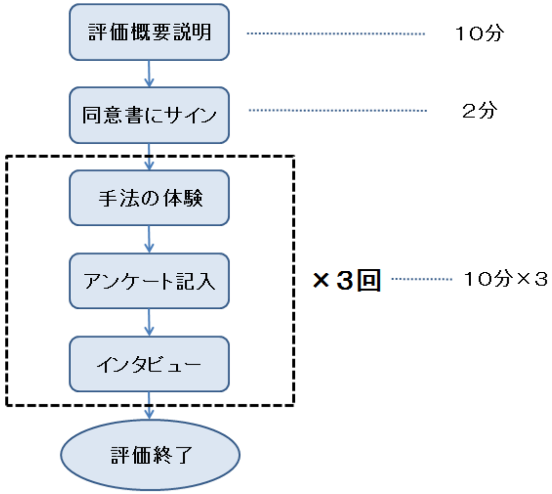


図２　本日の流れ

この評価に関する問い合わせ

◆ 評価開始後あるいは終了後、あなたに万一不利益が生じたとあなたが判断されたときは、その内容を下記に直接連絡してください。

◆ 評価内容や結果について、ご不明な点や詳しく知りたいことがございましたら、下記に連絡してください。

問い合わせ先
京都大学大学院エネルギー科学研究科
エネルギー社会・環境科学専攻
エネルギー情報学分野
〒606-8501　京都市左京区吉田本町
電話：075-753-5613
Mail：shimoda@energy.kyoto-u.ac.jp

同意書に関して

◆ 説明を受けた上で評価に協力して頂ける方には、書類に確認の署名をして頂いています。これは、参加者の方に評価の内容を説明し、同意を頂いた上で評価をするという手続きを、私たちが間違いなく確実に行うためのものです。署名を頂いたことにより、なんら拘束を受けることはありませんので、ご協力をお願い申し上げます。

◆ 同意書はこの書類の２ページ先になります。また、同意書の内容は次ページの同意書と書かれた紙面と同様になります。説明した内容の確認となりますので、同意書を書かれたページを含む本書類は、評価終了時にお持ち帰り下さい。

実施責任者　　　下田　宏

京都大学大学院エネルギー科学研究科
エネルギー社会・環境科学専攻　下田 宏　殿

同　意　書（控え）

私は、「拡張現実感を用いた情報提示手法の評価」について、目的・方法・予測される問題等について説明者より説明文書を用いて十分な説明を受け、以下の項目を理解しました。

☐ 研究の目的、方法そしてあらゆる危険性とそれに対する対応について。
☐ 私は自らの自由意志でいつでも評価を中止することができること。
☐ 私はいかなる時点において評価の参加の拒否をしても何ら不利益を被らないこと。
☐ 記録された個人情報は、外部に漏洩しないよう厳密に管理され、再評価または事故が生じたときの連絡以外の目的には使用されないこと。
☐ 私は、万一不利益をこうむった場合に京都大学大学院エネルギー科学研究科に対して申し立てを行うことができること。

そこで自らの自由意志により、上記評価の参加者として協力することを同意します。

日付　　　　　年　　月　　日

住所＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿

電話番号＿＿＿＿＿＿＿＿＿＿＿＿＿＿

ご署名＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿

評価責任者　：　京都大学大学院 エネルギー科学研究科
エネルギー社会・環境科学専攻
教授　下田 宏

※この書類は、参加者が受けた評価説明の内容と、署名をした同意書の文面を、参加者側が確認するためのものです。評価終了後、お持ち帰り下さい。

Appendix C Questionnaire in Transparent Model and Pointing Line Method

手法１

評価の流れ

運搬対象となる解体対象物と実環境の間での距離を提示する際の吹き出しの<u>直線</u>などのデザインを評価していただきます。

図１には評価の流れを示しています。

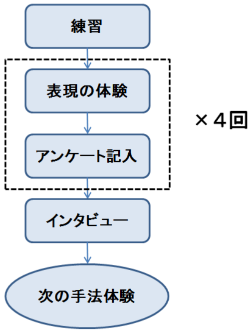


図１　評価の流れ

図２は吹き出しを使用した表現方法の画面例です。

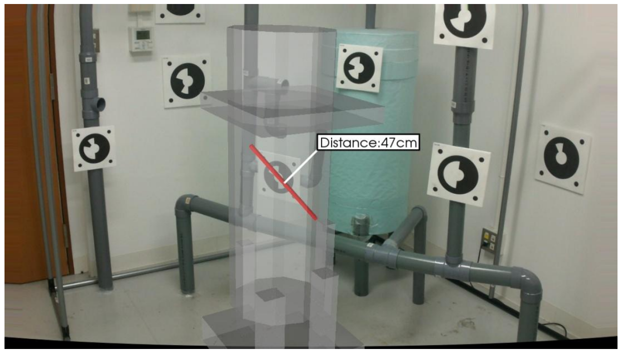


図２　手法１の画面例

図３には画面内の各領域の説明を示します。画面の背景には現実環境が表示され、その上に解体対象物となる仮想物体を表示しています。"Distance:47cm"という吹き出しは解体対象物と実環境の間の距離です。

ここでは

①　解体対象物と実環境の間の距離
②　解体対象物上の箇所
③　実環境上の箇所

の三つのことを理解していただくことがシステム利用の目的となります。

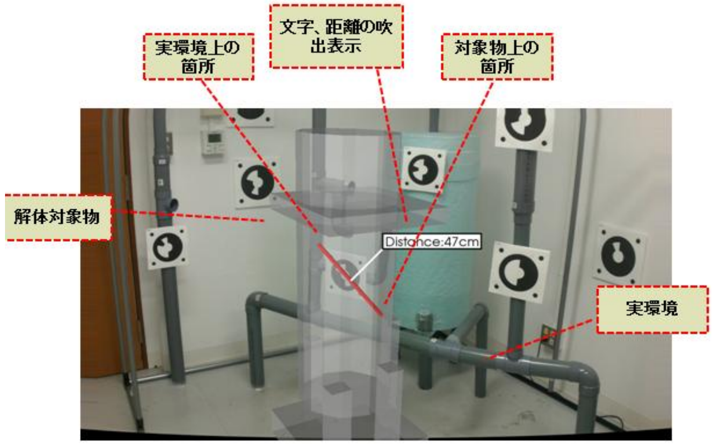


図３　評価システム画面の説明

手法１アンケート

- ここではアンケートの記入例を説明します。

　実環境の上にシステムが提示した二箇所（実環境上の箇所、解体対象物上の箇所）を理解して頂き、その箇所を写真の上に×印で記入して頂きます。
　図１はシステムが示している実環境上の箇所に×印を描いた例です。

図１　実環境上の箇所の記入例

　図２はシステムが示している解体対象物上の箇所に×印を描いた例です。

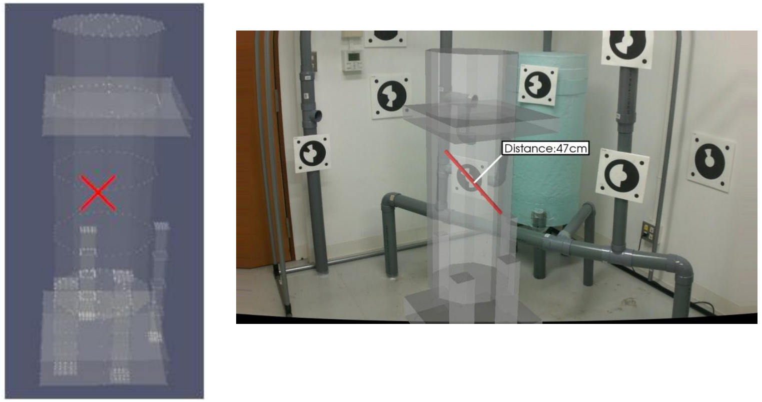


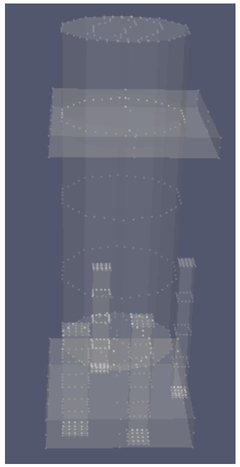
図２　解体対象物上の箇所の記入例

練習

- 以下の図に回答を描いてください。

1)　実環境上の箇所に×印を描いてください。

2)　解体対象物上の箇所に×印を描いてください。



以下の項目について、次の７段階評価に最も近い数字に〇をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
情報提示の文字の大きさは適切である。

全くそう思わない 1 ― 4 ― 7 非常にそう思う

3）練習

1. 解体対象物上の箇所を容易に理解できる。

全くそう思わない 1 ― 4 ― 7 非常にそう思う

2. 実環境上の箇所を容易に理解できる。

全くそう思わない 1 ― 4 ― 7 非常にそう思う

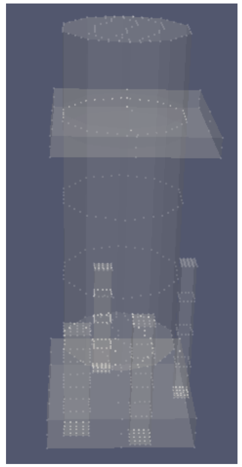
3. 手法に対する意見や不明点がありましたら、ご記入ください。

手法 1.1（透明度高い/直線細い）

● 以下の図に回答を描いてください。

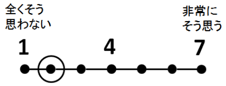
4） 実環境上の箇所に×印を描いてください。

5） 解体対象物上の箇所に×印を描いてください。



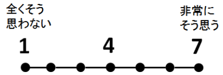
以下の項目について、次の７段階評価に最も近い数字に〇をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
情報提示の文字の大きさは適切である。

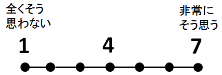


6) 手法 1.1

4. 解体対象物上の箇所を容易に理解できる。



5. 実環境上の箇所を容易に理解できる。



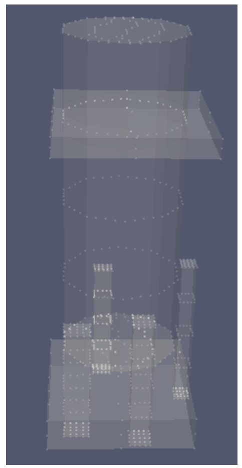
6. 手法に対する意見や不明点がありましたら、ご記入ください。

手法 1.2（透明度高い/直線太い）

● 以下の図に回答を描いてください。

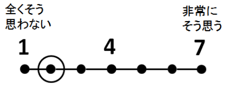
7) 実環境上の箇所に×印を描いてください。

8) 解体対象物上の箇所に×印を描いてください。



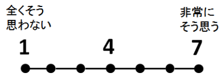
以下の項目について、次の７段階評価に最も近い数字に〇をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
情報提示の文字の大きさは適切である。

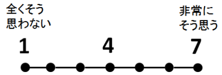


9）手法 1.2

7.　解体対象物上の箇所を容易に理解できる。



8.　実環境上の箇所を容易に理解できる。



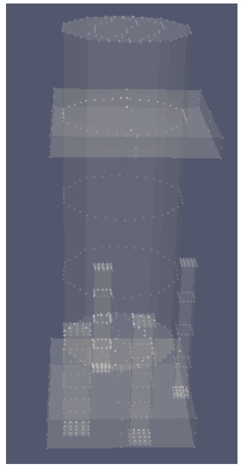
9.　手法に対する意見や不明点がありましたら、ご記入ください。

手法 1.3（透明度低い/直線細い）

● 以下の図に回答を描いてください。

10）実環境上の箇所に×印を描いてください。

11）解体対象物上の箇所に×印を描いてください。



以下の項目について、次の７段階評価に最も近い数字に〇をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
情報提示の文字の大きさは適切である。　全くそう思わない 1 ② 3 4 5 6 7 非常にそう思う

12)手法 1.3

10. 解体対象物上の箇所を容易に理解できる。　全くそう思わない 1 2 3 4 5 6 7 非常にそう思う

11. 実環境上の箇所を容易に理解できる。　全くそう思わない 1 2 3 4 5 6 7 非常にそう思う

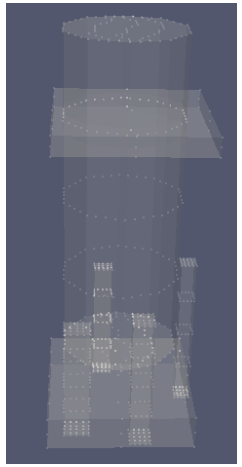
12. 手法に対する意見や不明点がありましたら、ご記入ください。

手法 1.4（透明度低い/直線太い）

- 以下の図に回答を描いてください。

13) 実環境上の箇所に×印を描いてください。

14) 解体対象物上の箇所に×印を描いてください。



以下の項目について、次の７段階評価に最も近い数字に○をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
情報提示の文字の大きさは適切である。

全くそう思わない　非常にそう思う
1　4　7

15)手法 1. 4

13. 解体対象物上の箇所を容易に理解できる。

全くそう思わない　非常にそう思う
1　4　7

14. 実環境上の箇所を容易に理解できる。

全くそう思わない　非常にそう思う
1　4　7

15. 手法に対する意見や不明点がありましたら、ご記入ください。

16)吹き出しの位置は適切である。

全くそう思わない　非常にそう思う
1　4　7

17)手法の比較

16. どちらの手法で提示した解体対象物と実環境との位置関係は分かりやすいですか。

A) 手法 1.1（透明度高い/直線細い）
B) 手法 1.2（透明度高い/直線太い）
C) 手法 1.3（透明度低い/直線細い）
D) 手法 1.4（透明度低い/直線太い）
E) 上記以外

理由

Appendix D Questionnaire in Grids Model Method

手法２

評価の流れ

解体対象物と実環境の間の距離を提示する<u>グリッド</u>のデザインを評価していただきます。

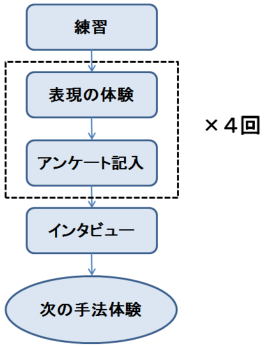


図１　評価の流れ

図２はグリッドモデルを使用した表現方法の画面例です。

図２　手法２の画面例

図３には画面内の各領域の説明を示します。グリッドと呼ばれる立方体を使って、距離情報を提示しています。赤色と紫色のグリッドはシステムが示そうとしている箇所です。緑色のグリッドも表示されますが、システムが表示しようとしている箇所の周辺の位置を示しています。

ここでは

①　解体対象物と実環境の間の距離
②　解体対象物上の箇所
③　実環境上の箇所

の三つのことを理解していただくことがシステム利用の目的となります。

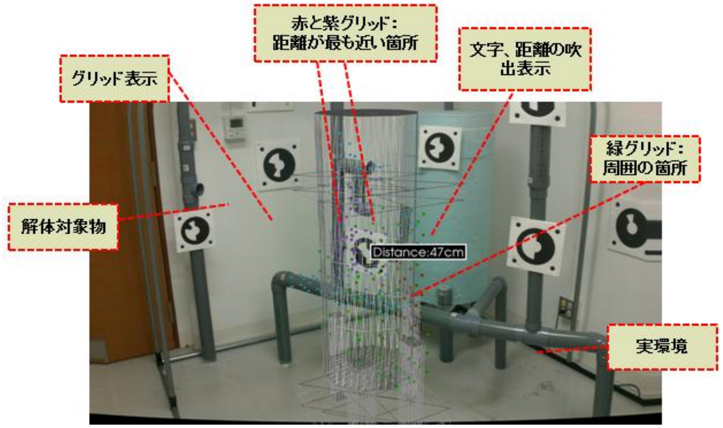


図３　評価システム画面の説明

評価２アンケート

● ここではアンケートの記入例を説明します。

実環境の上にシステムが提示した二箇所（実環境上の箇所、解体対象物上の箇所）を理解して頂き、その箇所を写真の上に×印で記入して頂きます。

図１はシステムが示している実環境上の箇所に×印を描いた例です。

図１　実環境上の箇所の記入例

図２はシステムが示している解体対象物上の箇所に×印を描いた例です。

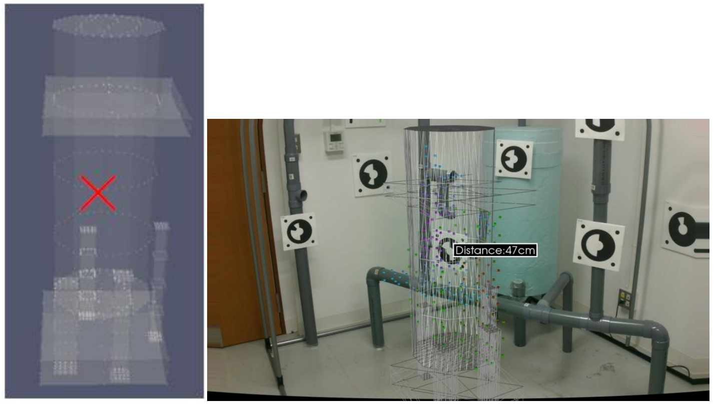


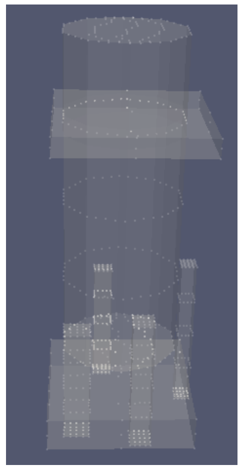
図２　解体対象物上の箇所の記入例

練習

● 以下の図に回答を描いてください。

1)　実環境上の箇所に×印を描いてください。

2)　解体対象物上の箇所に×印を描いてください。



以下の項目について、次の７段階評価に最も近い数字に○をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
グリッドサイズの大きさは適切である。

全くそう思わない 1 4 7 非常にそう思う

3）練習

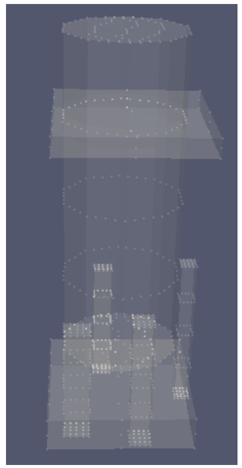
1. 赤色と紫色グリッドのサイズの大きさは適切である。
   全くそう思わない 1 4 7 非常にそう思う
2. 赤色と紫色グリッドのサイズ変化のスピードは適切である。
   全くそう思わない 1 4 7 非常にそう思う
3. 解体対象物上の箇所を容易に理解できる。
   全くそう思わない 1 4 7 非常にそう思う
4. 実環境上の箇所を容易に理解できる。
   全くそう思わない 1 4 7 非常にそう思う
5. 手法に対する意見や不明点がありましたら、ご記入ください。

手法 2.1（グリッドサイズ大/変化遅い）

- 以下の図に回答を描いてください。

4) 実環境上の箇所に×印を描いてください。

5) 解体対象物上の箇所に×印を描いてください。



以下の項目について、次の７段階評価に最も近い数字に〇をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
グリッドサイズの大きさは適切である。　全くそう思わない 1 ― 4 ― 7 非常にそう思う

6) 手法 2. 1

6. <u>赤色と紫色グリッド</u>のサイズの大きさは適切である。　全くそう思わない 1 ― 4 ― 7 非常にそう思う

7. <u>赤色と紫色グリッド</u>のサイズ変化のスピードは適切である。　全くそう思わない 1 ― 4 ― 7 非常にそう思う

8. <u>解体対象物上</u>の箇所を容易に理解できる。　全くそう思わない 1 ― 4 ― 7 非常にそう思う

9. <u>実環境上</u>の箇所を容易に理解できる。　全くそう思わない 1 ― 4 ― 7 非常にそう思う

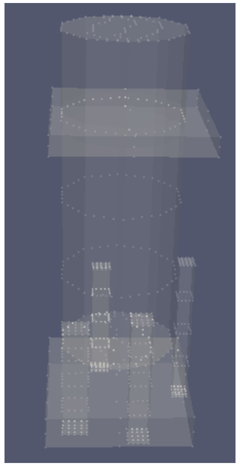
10. 手法に対する意見や不明点がありましたら、ご記入ください。

<u>手法 2. 2（グリッドサイズ大/変化速い）</u>

● 以下の図に回答を描いてください。

7) 実環境上の箇所に×印を描いてください。

8) 解体対象物上の箇所に×印を描いてください。



以下の項目について、次の７段階評価に最も近い数字に〇をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
グリッドサイズの大きさは適切である。　全くそう思わない 1 ・ ② ・ ・ 4 ・ ・ 7 非常にそう思う

9）手法 2.2

11. 赤色と紫色グリッドのサイズの大きさは適切である。　全くそう思わない 1 ・ ・ ・ 4 ・ ・ 7 非常にそう思う

12. 赤色と紫色グリッドのサイズ変化のスピードは適切である。　全くそう思わない 1 ・ ・ ・ 4 ・ ・ 7 非常にそう思う

13. 解体対象物上の箇所を容易に理解できる。　全くそう思わない 1 ・ ・ ・ 4 ・ ・ 7 非常にそう思う

14. 実環境上の箇所を容易に理解できる。　全くそう思わない 1 ・ ・ ・ 4 ・ ・ 7 非常にそう思う

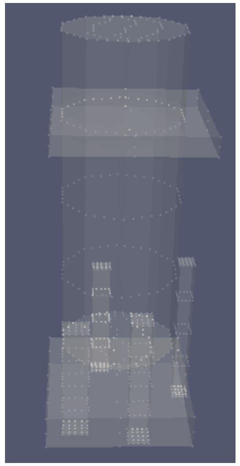
15. 手法に対する意見や不明点がありましたら、ご記入ください。

手法 2.3（グリッドサイズ小/変化遅い）

- 以下の図に回答を描いてください。

10）実環境上の箇所に×印を描いてください。

11）解体対象物上の箇所に×印を描いてください。



以下の項目について、次の７段階評価に最も近い数字に〇をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
グリッドサイズの大きさは適切である。

全くそう思わない　1　4　7　非常にそう思う

12)手法 2. 3

16. 赤色と紫色グリッドのサイズの大きさは適切である。

全くそう思わない　1　4　7　非常にそう思う

17. 赤色と紫色グリッドのサイズ変化のスピードは適切である。

全くそう思わない　1　4　7　非常にそう思う

18. 解体対象物上の箇所を容易に理解できる。

全くそう思わない　1　4　7　非常にそう思う

19. 実環境上の箇所を容易に理解できる。

全くそう思わない　1　4　7　非常にそう思う

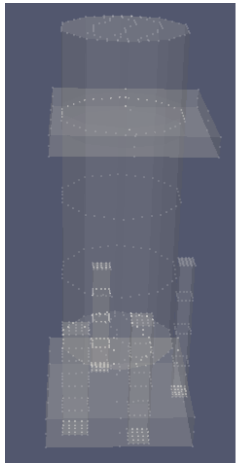
20. 手法に対する意見や不明点がありましたら、ご記入ください。

手法 2. 4（グリッドサイズ小/変化速い）

- 以下の図に回答を描いてください。

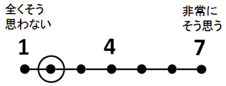
13) 実環境上の箇所に×印を描いてください。

14) 解体対象物上の箇所に×印を描いてください。



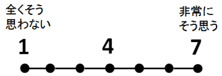
以下の項目について、次の７段階評価に最も近い数字に〇をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
グリッドサイズの大きさは適切である。

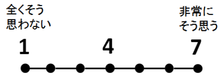


15)手法 2. 4

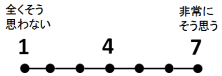
21. <u>赤色と紫色グリッド</u>のサイズの大きさは適切である。



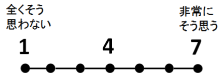
22. <u>赤色と紫色グリッド</u>のサイズ変化のスピードは適切である。



23. <u>解体対象物上</u>の箇所を容易に理解できる。

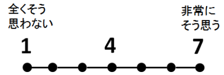


24. <u>実環境上</u>の箇所を容易に理解できる。



25. 手法に対する意見や不明点がありましたら、ご記入ください。

16)表示している<u>グリッドの色</u>は適切である。



17)手法の比較

26. どちらの手法で提示した解体対象物と実環境との位置関係は分かりやすいですか。

A) 手法 2.1（グリッドサイズ大/変化遅い）
B) 手法 2.2（グリッドサイズ大/変化速い）
C) 手法 2.3（グリッドサイズ小/変化遅い）
D) 手法 2.4（グリッドサイズ小/変化速い）
E) 上記以外

理由

Appendix E Questionnaire in Model Rotation and Shift Method

手法３

評価の流れ

運搬対象となる解体対象物と実環境の間での距離を提示するために、作業と関係なく解体対象物を**強制移動**させる手法を評価していただきます。

図１には評価の流れを示しています。

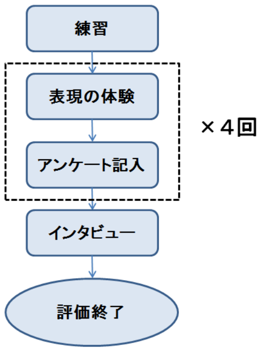


図１　評価の流れ

図２は評価中使用するシステム上の画面例です。

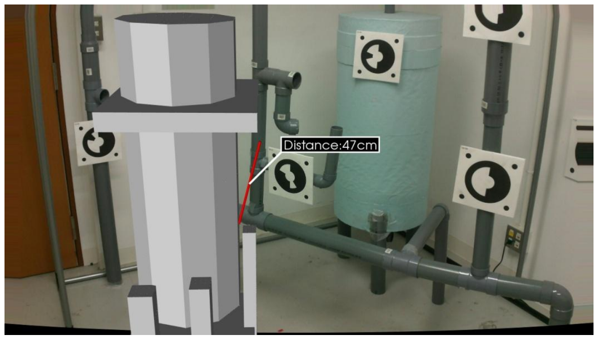


図２　手法３の画面例

図３には画面内の各領域の説明を示します。この手法はシステムが示そうとしている箇所が解体対象物の陰にならないように強制的に移動させるものです。

ここでは

①　解体対象物と実環境の間の距離

②　解体対象物上の箇所

③　実環境上の箇所

の三つのことを理解していただくことがシステム利用の目的となります。

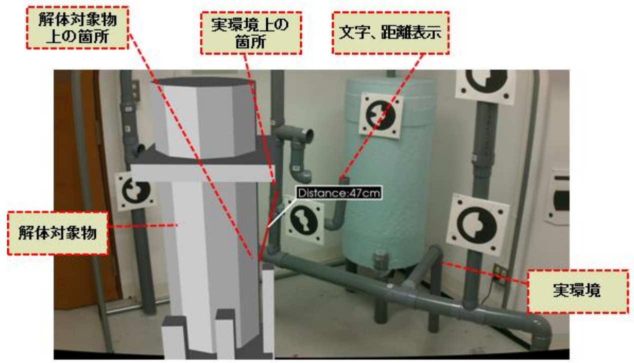


図３　評価システム画面の説明

評価３アンケート

● ここではアンケートの記入例を説明します。

実環境の上にシステムが提示した二箇所（実環境上の箇所、解体対象物上の箇所）に理解して頂き、その箇所を写真の上に×印で記入して頂きます。

図１はシステムが示している実環境上の箇所に×印を描いた例です。

図１　実環境上の箇所の記入例

図２はシステムが示している解体対象物上の箇所に×印を描いた例です。

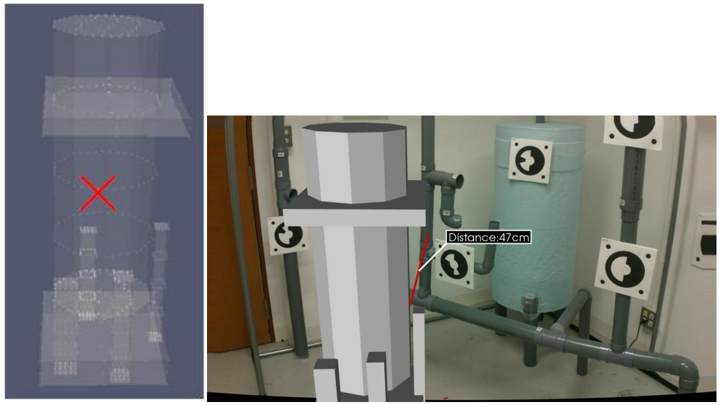


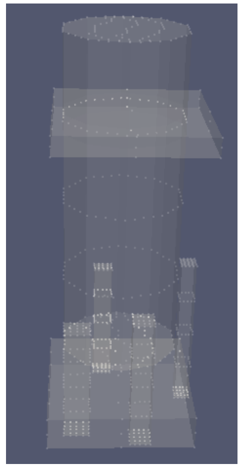
図２　解体対象物上の箇所の記入例

練習

● 以下の図に回答を描いてください。

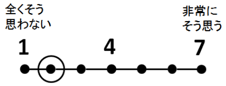
1)　実環境上の箇所に×印を描いてください。

2)　解体対象物上の箇所に×印を描いてください。



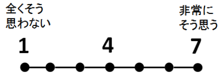
以下の項目について、次の７段階評価に最も近い数字に○をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
回転のスピードは適切である。

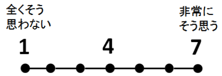


3）練習

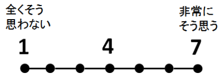
1. 解体対象物の<u>回転スピード</u>は適切である。



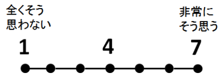
2. 解体対象物の<u>平行移動距離</u>は適切である。



3. <u>解体対象物上</u>の箇所を容易に理解できる。



4. <u>実環境上</u>の箇所を容易に理解できる。



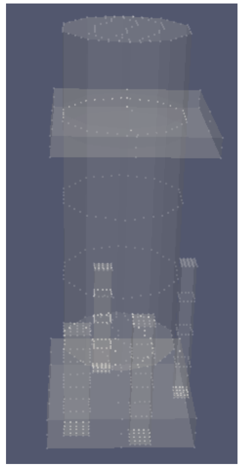
5. 手法に対する意見や不明点がありましたら、ご記入ください。

<u>手法 3.1（回転スピード遅い/平行移動距離少ない）</u>

- 以下の図に回答を描いてください。

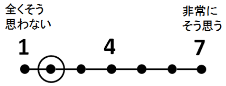
4）実環境上の箇所に×印を描いてください。

5）解体対象物上の箇所に×印を描いてください。



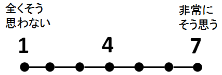
以下の項目について、次の７段階評価に最も近い数字に〇をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
回転のスピードは適切である。

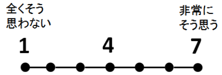


6）手法 3.1

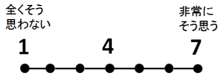
6.　解体対象物の<u>回転スピード</u>は適切である。



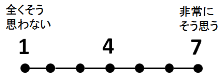
7.　解体対象物の<u>平行移動距離</u>は適切である。



8.　<u>解体対象物上</u>の箇所を容易に理解できる。



9.　<u>実環境上</u>の箇所を容易に理解できる。



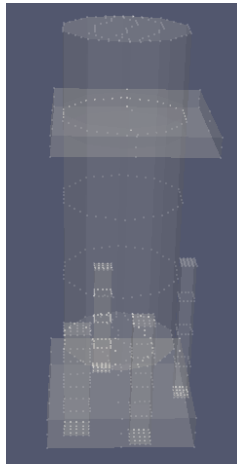
10. 手法に対する意見や不明点がありましたら、ご記入ください。

<u>手法 3.2（回転スピード遅い/平行移動距離多い）</u>

● 以下の図に回答を描いてください。

7）　実環境上の箇所に×印を描いてください。

8）　解体対象物上の箇所に×印を描いてください。



以下の項目について、次の７段階評価に最も近い数字に〇をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
回転のスピードは適切である。　全くそう思わない 1 ― ② ― 3 ― 4 ― 5 ― 6 ― 7 非常にそう思う

9）手法 3.2

11. 解体対象物の<u>回転スピード</u>は適切である。　全くそう思わない 1 ― 2 ― 3 ― 4 ― 5 ― 6 ― 7 非常にそう思う

12. 解体対象物の<u>平行移動距離</u>は適切である。　全くそう思わない 1 ― 2 ― 3 ― 4 ― 5 ― 6 ― 7 非常にそう思う

13. <u>解体対象物上</u>の箇所を容易に理解できる。　全くそう思わない 1 ― 2 ― 3 ― 4 ― 5 ― 6 ― 7 非常にそう思う

14. <u>実環境上</u>の箇所を容易に理解できる。　全くそう思わない 1 ― 2 ― 3 ― 4 ― 5 ― 6 ― 7 非常にそう思う

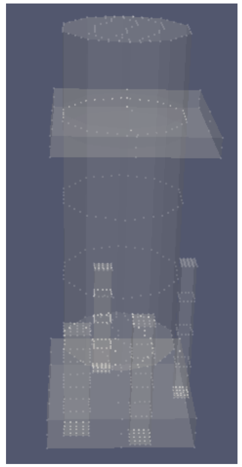
15. 手法に対する意見や不明点がありましたら、ご記入ください。

<u>手法 3.3（回転スピード速い/平行移動距離少ない）</u>

● 以下の図に回答を描いてください。

10）実環境上の箇所に×印を描いてください。

11）解体対象物上の箇所に×印を描いてください。



以下の項目について、次の７段階評価に最も近い数字に〇をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
回転のスピードは適切である。　全くそう思わない 1　4　7 非常にそう思う

12)手法 3.3

16. 解体対象物の<u>回転スピード</u>は適切である。　全くそう思わない 1　4　7 非常にそう思う

17. 解体対象物の<u>平行移動距離</u>は適切である。　全くそう思わない 1　4　7 非常にそう思う

18. <u>解体対象物上</u>の箇所を容易に理解できる。　全くそう思わない 1　4　7 非常にそう思う

19. <u>実環境上</u>の箇所を容易に理解できる。　全くそう思わない 1　4　7 非常にそう思う

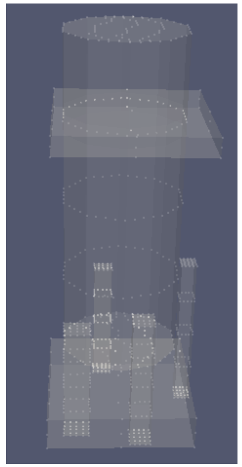
20. 手法に対する意見や不明点がありましたら、ご記入ください。

<u>手法 3.4（回転スピード速い/平行移動距離多い）</u>

- 以下の図に回答を描いてください。

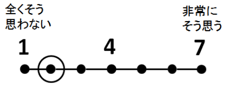
13) 実環境上の箇所に×印を描いてください。

14) 解体対象物上の箇所に×印を描いてください。



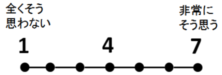
以下の項目について、次の 7 段階評価に最も近い数字に〇をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
回転のスピードは適切である。

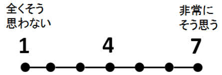


15)手法 3. 4

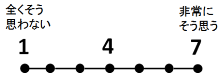
21. 解体対象物の回転スピードは適切である。



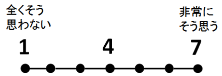
22. 解体対象物の平行移動距離は適切である。



23. 解体対象物上の箇所を容易に理解できる。



24. 実環境上の箇所を容易に理解できる。



25. 手法に対する意見や不明点がありましたら、ご記入ください。

16)手法の比較

26. どの提示法が比較的に良いですか。
A) 手法 3.1（回転スピード遅い/平行移動距離少ない）
B) 手法 3.2（回転スピード遅い/平行移動距離多い）
C) 手法 3.3（回転スピード速い/平行移動距離少ない）
D) 手法 3.4（回転スピード速い/平行移動距離多い）
E) 上記以外

理由

Appendix F Questionnaire in The Comparison Evaluation

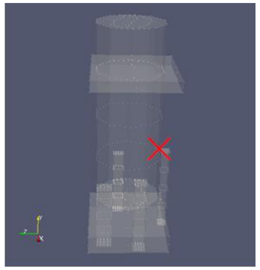
● ここではアンケートの記入例を説明します。

実環境の上にシステムが提示した二箇所（実環境上の箇所、解体対象物上の箇所）を理解して頂き、その箇所を写真の上に×印で記入して頂きます。

図１はシステムが示している実環境上の箇所に×印を描いた例です。

図１　実環境上の箇所の記入例

図２はシステムが示している解体対象物上の箇所に×印を描いた例です。



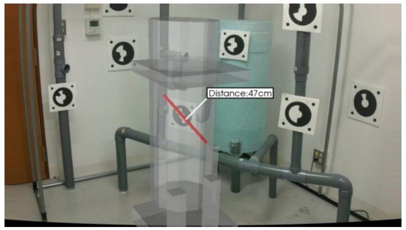


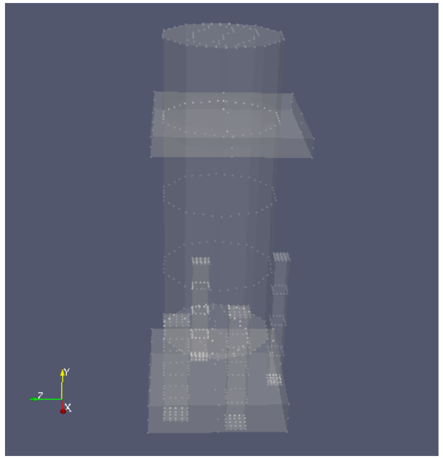
図２　解体対象物上の箇所の記入例

手法１（座標１）

● 以下の図に回答を描いてください。

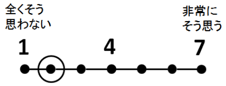
1)　実環境上の箇所に×印を描いてください。

2)　解体対象物上の箇所に×印を描いてください。



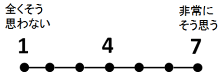
以下の項目について、次の 7 段階評価に最も近い数字に○をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
情報提示の文字の大きさは適切である。

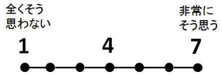


3）手法 1（座標 1）

1. <u>実環境上</u>の箇所を容易に理解できる。



2. <u>解体対象物上</u>の箇所を容易に理解できる。

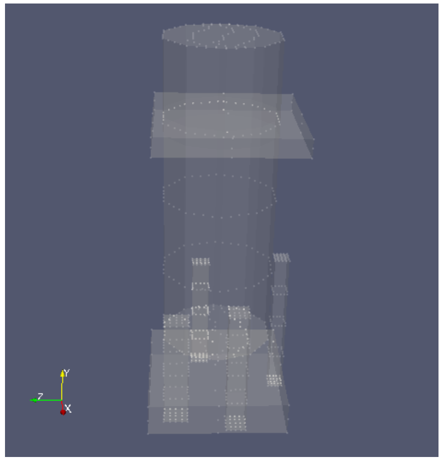


<u>手法 1（座標 2）</u>

- 以下の図に回答を描いてください。

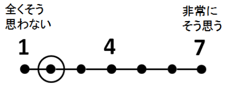
4）実環境上の箇所に×印を描いてください。

5）解体対象物上の箇所に×印を描いてください。



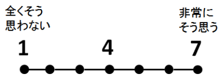
以下の項目について、次の７段階評価に最も近い数字に〇をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
情報提示の文字の大きさは適切である。

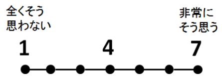


6）手法 1（座標 2）

3. 実環境上の箇所を容易に理解できる。



4. 解体対象物上の箇所を容易に理解できる。

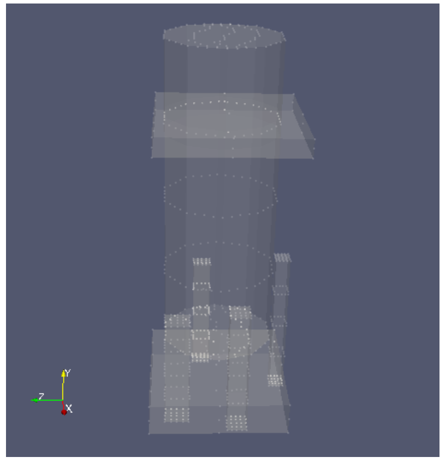


手法 1（座標 3）

● 以下の図に回答を描いてください。

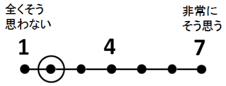
7）実環境上の箇所に×印を描いてください。

8）解体対象物上の箇所に×印を描いてください。



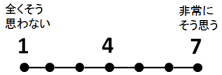
以下の項目について、次の７段階評価に最も近い数字に○をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
情報提示の文字の大きさは適切である。

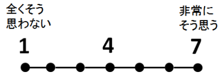


9）手法 1（座標 3）

5. 実環境上の箇所を容易に理解できる。



6. 解体対象物上の箇所を容易に理解できる。

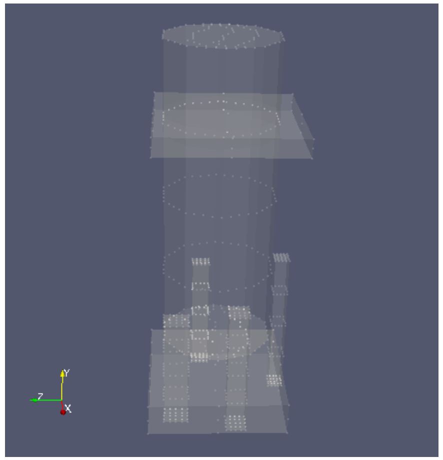


手法 2（座標 1）

- 以下の図に回答を描いてください。

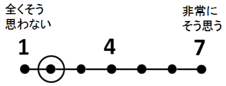
10）実環境上の箇所に×印を描いてください。

11）解体対象物上の箇所に×印を描いてください。



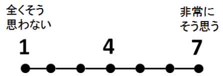
以下の項目について、次の７段階評価に最も近い数字に○をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
情報提示の文字の大きさは適切である。

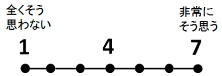


12)手法 2（座標 1）

7.　実環境上の箇所を容易に理解できる。



8.　解体対象物上の箇所を容易に理解できる。

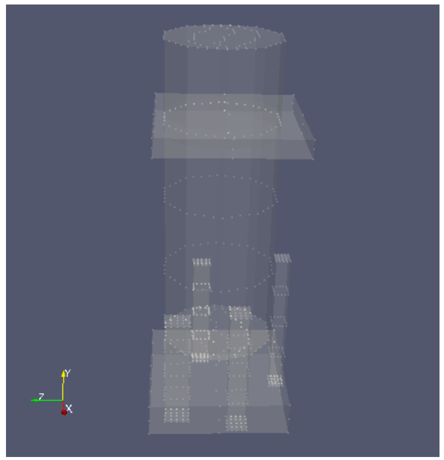


手法 2（座標 2）

● 以下の図に回答を描いてください。

13) 実環境上の箇所に×印を描いてください。

14) 解体対象物上の箇所に×印を描いてください。

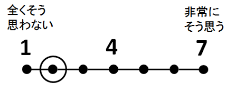


以下の項目について、次の７段階評価に最も近い数字に〇をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。

1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

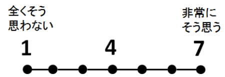
記入例：

情報提示の文字の大きさは適切である。

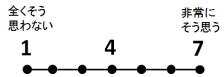


15)手法 2（座標 2）

9.　実環境上の箇所を容易に理解できる。



10. 解体対象物上の箇所を容易に理解できる。

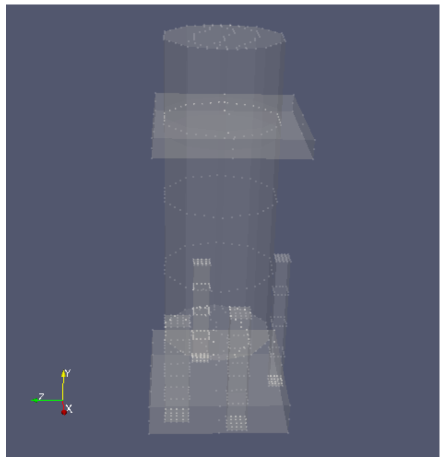


手法 2（座標 3）

● 以下の図に回答を描いてください。

16) 実環境上の箇所に×印を描いてください。

17) 解体対象物上の箇所に×印を描いてください。



以下の項目について、次の７段階評価に最も近い数字に○をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
情報提示の文字の大きさは適切である。

全くそう思わない　1　4　7　非常にそう思う

18)手法 2（座標 3）

11. 実環境上の箇所を容易に理解できる。

全くそう思わない　1　4　7　非常にそう思う

12. 解体対象物上の箇所を容易に理解できる。

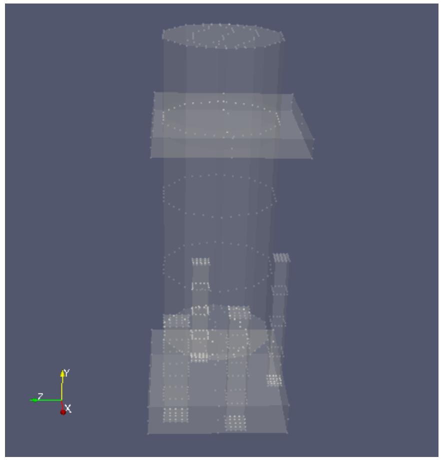
全くそう思わない　1　4　7　非常にそう思う

手法 3（座標 1）

- 以下の図に回答を描いてください。

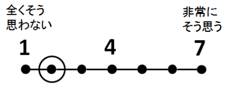
19) 実環境上の箇所に×印を描いてください。

20) 解体対象物上の箇所に×印を描いてください。



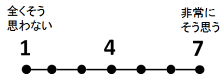
以下の項目について、次の７段階評価に最も近い数字に〇をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
情報提示の文字の大きさは適切である。

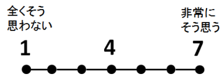


21)手法 3（座標 1）

13. 実環境上の箇所を容易に理解できる。



14. 解体対象物上の箇所を容易に理解できる。

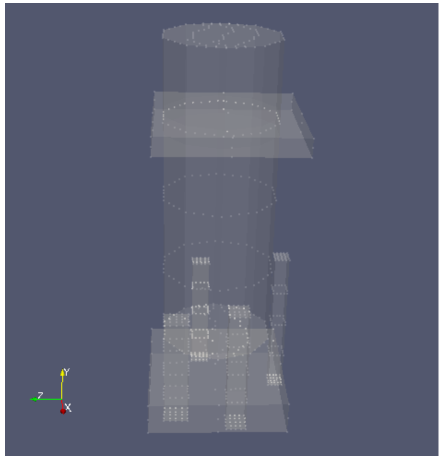


手法 3（座標 2）

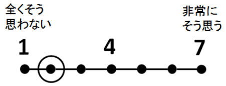
● 以下の図に回答を描いてください。

22) 実環境上の箇所に×印を描いてください。

23) 解体対象物上の箇所に×印を描いてください。

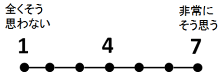


以下の項目について、次の７段階評価に最も近い数字に○をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。
記入例：
情報提示の文字の大きさは適切である。

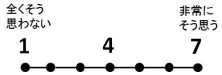


24)手法 3（座標 2）

15. <u>実環境上</u>の箇所を容易に理解できる。



16. <u>解体対象物上</u>の箇所を容易に理解できる。

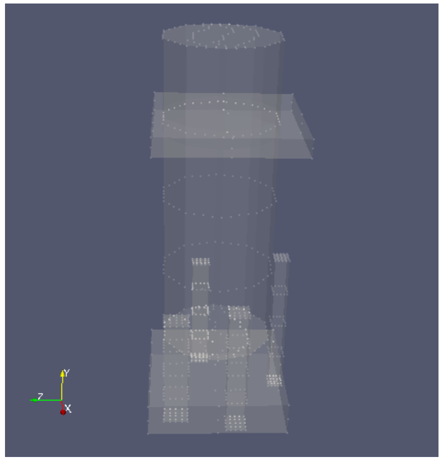


<u>手法 3（座標 3）</u>

● 以下の図に回答を描いてください。

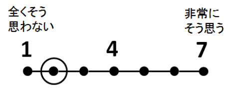
25) 実環境上の箇所に×印を描いてください。

26) 解体対象物上の箇所に×印を描いてください。



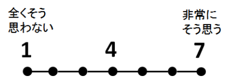
以下の項目について、次の７段階評価に最も近い数字に〇をつけてお答えください。アンケートに記入して頂いた後、回答の理由を口頭でお伺いします。
1 全くそう思わない、2 そう思わない、3 あまりそう思わない、4 どちらでもいえない、5 ややそう思う、6 そう思う、7 非常にそう思う。

記入例：
情報提示の文字の大きさは適切である。

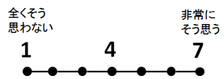


27)手法 3（座標 3）

17. <u>実環境上</u>の箇所を容易に理解できる。



18. <u>解体対象物上</u>の箇所を容易に理解できる。



28)手法の比較

19. どちらの手法で提示した解体対象物と実環境との位置関係は分かりやすいですか。

A）手法 1
B）手法 2
C）手法 3

理由