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DEVELOPMENT OF A HYBRID MIXED REALITY VISUALIZATION SYSTEM FOR THE UNDERWATER OBJECTS

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Abstract. This paper presents a development of a hybrid Mixed Reality visualization system using location-based and marker-based methods. The Microsoft Hololens 2 is employed for the MR device. In open-sky environment, location-based method was used for the superimposition method. To obtain location information, GNSS (Global Navigation Satellite System) receivers are used, which can obtain highly accurate location information by network RTK positioning at open-sky environment. The system is capable of superimposed 3D models into real space accurately and automatically. Also, by allowing the switch to marker-based method, this system can be applied to non-open-sky environment. The present system is applied to the visualization of underwater objects in order to check the validity and effectiveness.

1 INTRODUCTION

In recent years, visualization technology has been used in various fields, such as entertainment and beauty [1]. In the civil engineering field, it can be used in the several stage of construction work, such as planning, design, construction, maintenance and management. In the visualization technologies, we focused on Mixed Reality (MR) [2]. This technology can visualize with both hands free, by using dedicated head mounted display such as Hololens 2. Therefore, it is safer than Augmented Reality (AR) [3] when visualizing, and more suitable for use at construction sites which are dangerous.

We have developed visualization systems using marker-based method and location-based method [4][5]. Although the marker-based method allows high accurate superimposition, it is necessary to set the marker at the precise position. Also, it is difficult to keep high accuracy of superimposition in the case of increasing distance between the marker and visualization device without recognizing the marker. On the other hand, the location-based method using Global Navigation Satellite System (GNSS) receivers allows high accurate superimposition in open-sky environment. However, as the accuracy of superimposition depends on the accuracy of location information which is acquired by GNSS receivers, it is difficult to be applied for non-open-sky environment. Thus, we investigated to develop the system which could switch the two superimposition methods and be applied to any environment.

This paper presents a hybrid MR visualization system based on the marker-based method and the location-based method. The present system is applied to the visualization for underwater parts of piers. The paper is organized as follows. Section 2 describes the development environment, Pre-processing, Main processing, and accuracy of location information acquired by the receivers. Section 3 shows the application of this system to underwater parts of piers. Section 4 presents the conclusions of this paper and future tasks.

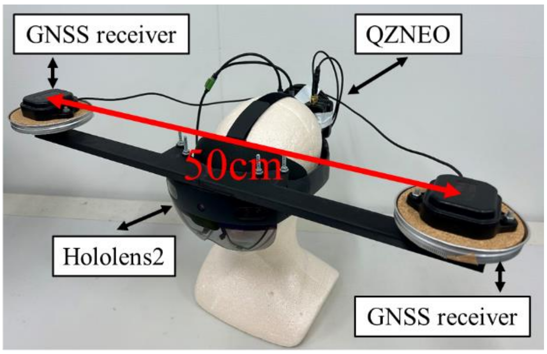
2 MR VISUALIZATION SYSTEM

2.1 Development Environment

As shown in Figure 1 (a), we used Unity as the integrated development environment and MRTK as the development toolkit. The program was written in C#. We used Hololens 2, a head-mounted computer device manufactured by Microsoft. A QZNEO made by the CORE GROUP was the GNSS receiver that was used to obtain location information. The communication protocol used to transmit position information from the GNSS receiver to Hololens 2 was UDP, which can communicate with multiple terminals simultaneously and has a higher communication speed than TCP. As shown in Figure 1 (b), the two GNSS receivers are placed at apart the top of Hololens2 for angle correction as described below.

Development software	Unity 2020.3.24f1
Development toolkit	MRTK 2.8.2
Programming language	C#
Visualization device	Hololens 2
GNSS receiver	QZNEO
Communication Protocol	UDP

(a) Software, tools and equipment



(b) Device structure

Figure 1: Development environment

2.2 Pre-process

A flowchart of this system is shown in Figure 2.

It is inputted the three-dimensional (3D) data of the model to be visualized as visualization information. As location information, it is inputted the latitude, longitude, and ellipsoidal height of the superimposed position of the model.

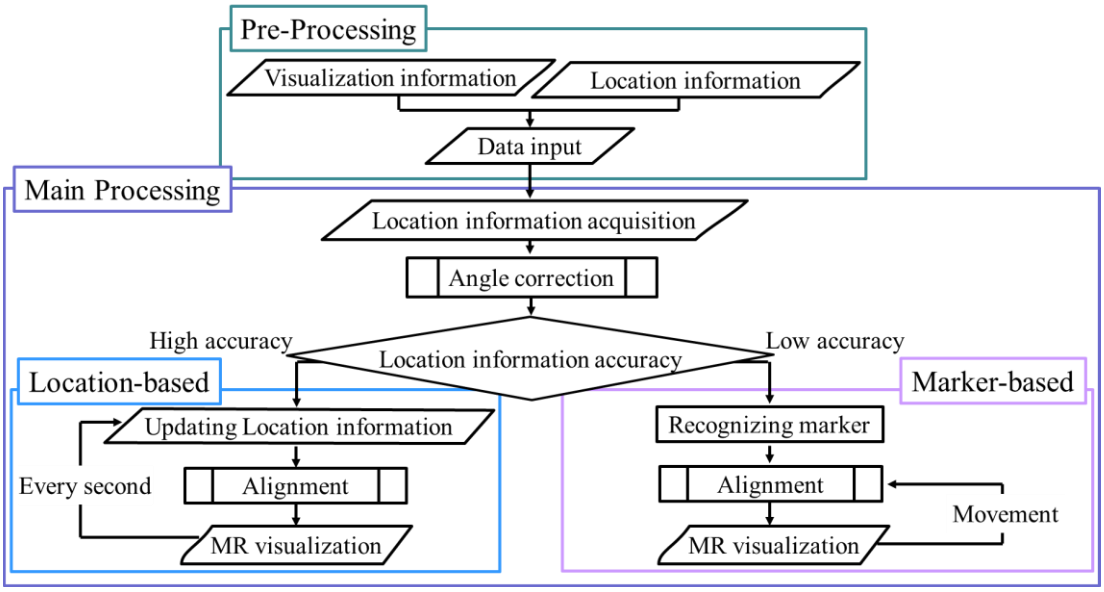


Figure 2: Flowchart

2.3 Main Process

2.3.1 Angle Correction

As shown in Figure 3 (a), when the application is launched, the system constructs a left-handed coordinate system with the *y*-axis positive for the vertical upward direction and the *z*-axis positive for the frontal direction of the device. Therefore, in order to achieve high accurate alignment with location-based method, it is necessary to perform angle correction to align the *z*-axis of the virtual space with the north of the real space and the *x*-axis with the east. As shown in Figure 3 (b), the azimuth angle in the frontal direction of the device is calculated from the difference in latitude and longitude obtained by the two GNSS receivers. Then, the coordinate system of the virtual space is rotated by the magnitude of the azimuth angle relative to the *y*-axis. As shown in Figure 3 (c), after the angle correction, the coordinate systems of the real space and the virtual space are matched and it is possible to superimpose high precision by location-based method.

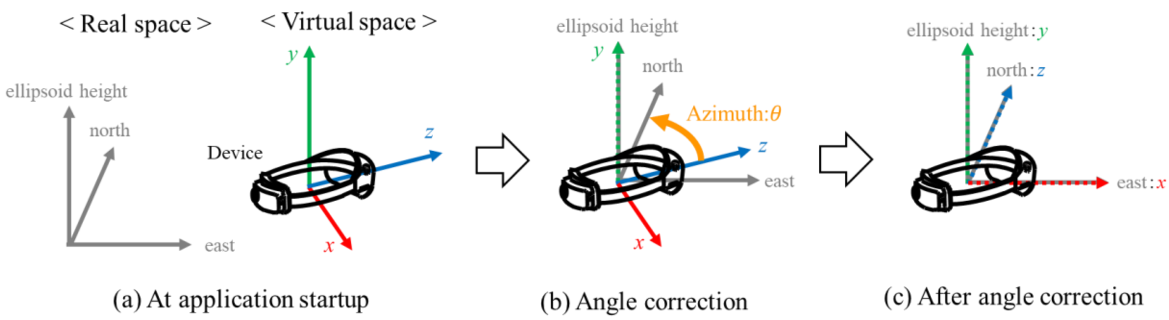


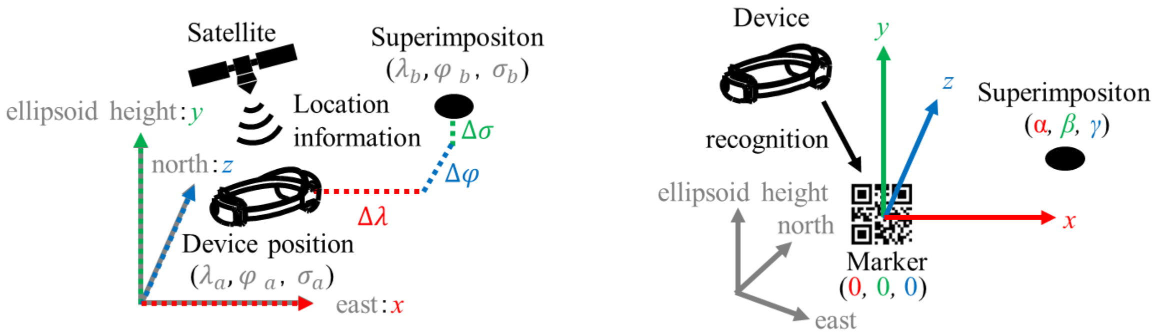
Figure 3: Angle correction

2.3.2 Alignment by Location-based Method

The visualization position is calculated from the distance between the position information of the device and the position information of the superimposed position set in the pre-processing in the coordinate system after the angle correction. Location information and the visualization position are updated every second. Therefore, superimposition is maintained with high accuracy even when the device's position changes.

2.3.3 Switching Superimposition Method

As shown in Figure 4 (a), the location-based method is difficult to apply to non-open-sky environments because its superimposition accuracy depends on the location information accuracy obtained by the GNSS receivers. Therefore, GNSS receivers are used to determine location accuracy. As shown in Table 1, this equipment shows a value 4 when location information is acquired with the highest accuracy, and a value 5 when the accuracy is reduced by one step. Thus, while the application is running, the above values can be displayed on the UI to check the location information accuracy in real time shown in Figure 5. Based on the above, when the location information accuracy decreases, namely when numerical values 5 are displayed in the UI, the system switches to a marker-based method in which the superimposition accuracy does not depend on the location information accuracy shown in Figure 4 (b), in order to maintain high precision superimposition.

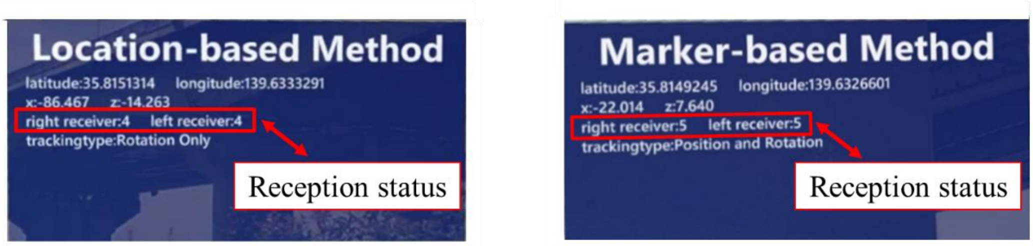


(a) Location-based method (b) Marker-based method

Figure 4: Characteristics of each superimposition method

Table 1: Definition of GNSS receiver reception status

Number	Positioning state	Estimation accuracy
0	No positioning	―
1	Single positioning	3.0 m
2	Relative positioning	40 cm
5	Float (Preliminary stage of real-time kinematic (RTK) positioning)	20 cm
4	Fixed (RTK positioning completed)	2 cm



(a) Highest accuracy (b) One step down in accuracy.

Figure 5: UI while the application is running

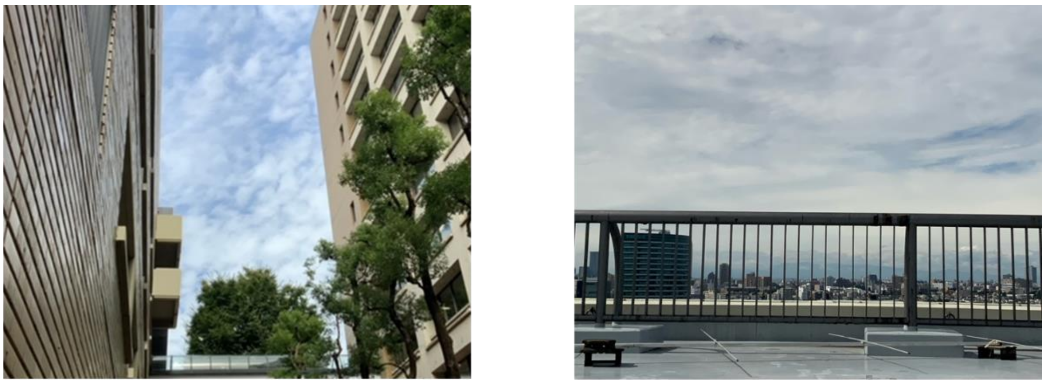
2.3.4 Alignment by Marker-based Method

In the marker-based method, when visualization device recognizes the marker, the center of the marker is used as the origin of the coordinate system in the virtual space to visualize the 3D model. This method requires that the marker is placed in precise position when visualizing. However, it is suitable for use indoors and in inner-city because it uses surrounding feature points for alignment.

2.4 Location Information Accuracy of GNSS Receiver

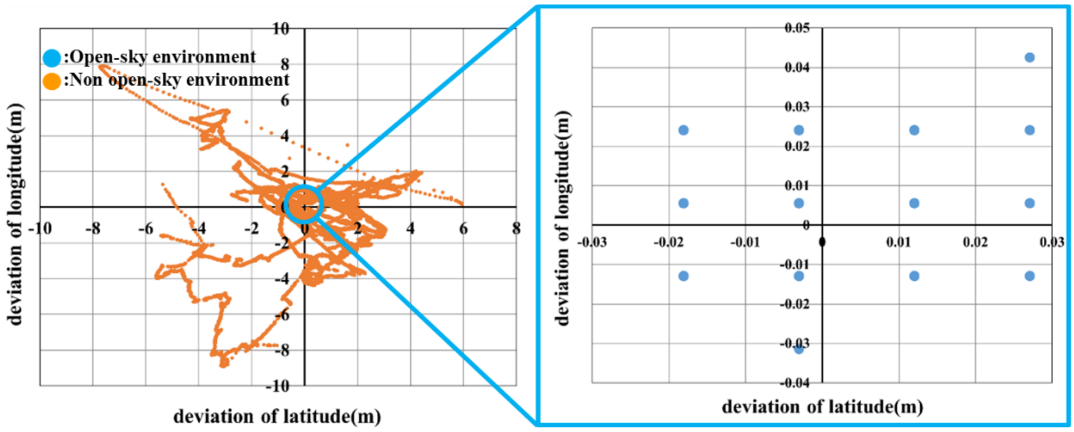
The location information accuracy of the GNSS receiver used in this system was verified in (a) Non open-sky environment and (b) Open-sky environment on the campus shown in Figure 7. The verification method was a comparison of the deviation of received location information at the two locations for 24 hours. In this verification, an open-sky environment is defined as an environment where the receivers show value 4, and a non-open-sky environment is defined as an environment where the receivers show value 5 in Table 1.

As shown in Figure 7, the range of the received position fluctuates about 15 meters in (a) Non open-sky environment, while the range of the received position fluctuates only about 5 cm in (b) Open-sky environment. Therefore, the location-based method can be used for high accurate superimposition in an open-sky environment, and if the value shows 5, it is necessary to switch to the marker-based method.



(a) Non open-sky environment (b) Open-sky environment

Figure 6: Verification environment



(a) Non open-sky environment (b) Open-sky environment

Figure 7: Verification results

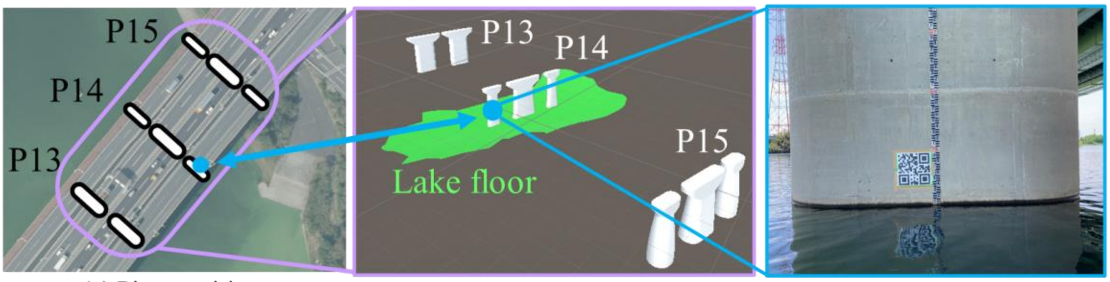
3 APPLICATION EXAMPLE

As shown in Figure 8, submerged areas at the base of piers are difficult to check due to the reflection of light on the water surface and the quality of the water. Therefore, this system can be applied to superimpose the base of piers with high accuracy to improve work efficiency during reinforcement work.

3.1 Implementation Environment

The site of application is Lake Saiko, Toda City, Saitama Prefecture shown in Figure 8, 9 (a). The visualization targets are the piers of the Sakitama Bridge and the lake floor around the piers shown in Figure 9 (b) [7]. The marker for marker-based method was attached to Pier 14 as shown in Figure 9 (c). If 3D models are superimposed without occlusion, the result of visualization will be strange. Therefore, in this application example, an Opening model is used as the visualization representation.

Figure 8: Lake Saiko



(a) Piers position (b) Visualization 3D models (c) Marker position

Figure 9: Implementation environment

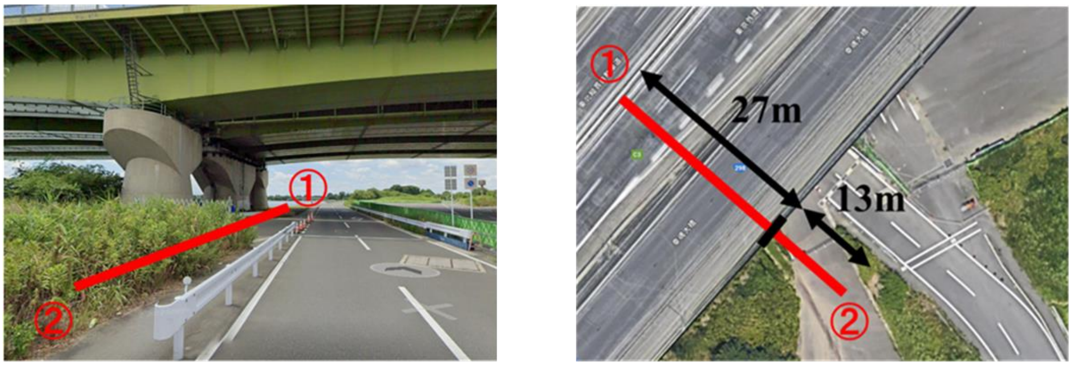


Figure 10: Verification environment

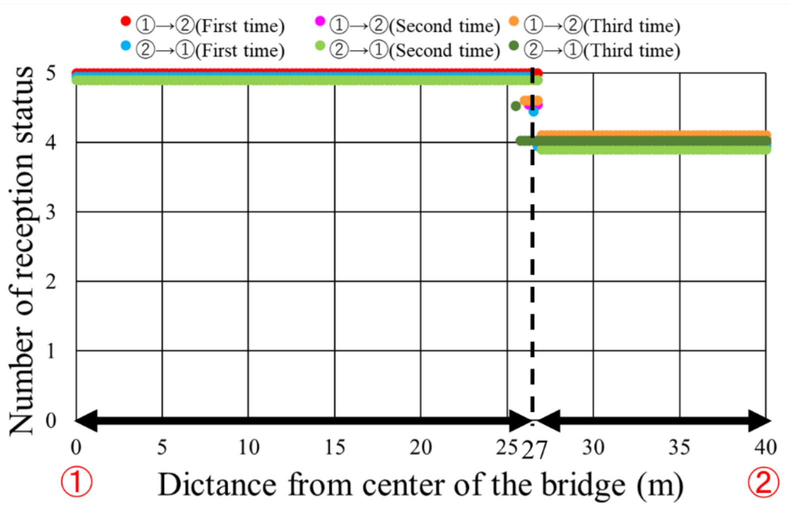


Figure 11: Verification result

As shown in Figure 10, the accuracy of the location information was verified around the implementation environment before superimposing. The reception level of the location information was checked by moving in 0.25 m increments of three times in each direction along a straight line from point ① under the center of the bridge to point ② in an open-sky environment 13 m away from the edge of the bridge. Receiving level is a number of the position information accuracy obtained by the GNSS receiver, as shown in 2.4 Location Information Accuracy of GNSS Receiver and Table 1.

Figure 11 shows that the reception level changes at 27 m from the center of the bridge. In other words, at a distance of 27 m or more from the center of the bridge where more than half of the sky above the receivers is not covered by the bridge, the location-based method can be used for high accurate superimposition as an open-sky environment. On the other hand, at locations within 27 m from the center of the bridge where more than half of the sky above receiver's sky are covered by the bridge, it is necessary to switch to the marker-based method.

3.2 Controlled by Xbox Controller

As shown in Figure 12, Microsoft Xbox controller was used to switch the superimposition method, show or hide the visualization representation, and adjust the superimposition position. The Xbox controller and the visualization device, Hololens 2, were wired connected.

Xbox Controller

① *x*-axis and *z*-axis position
② *x*-axis and *z*-axis rotation
③ up and down : *y*-axis position
left and right : *y*-axis rotation
④ Marker-based → Location-based
⑤ Location-based → Marker-based

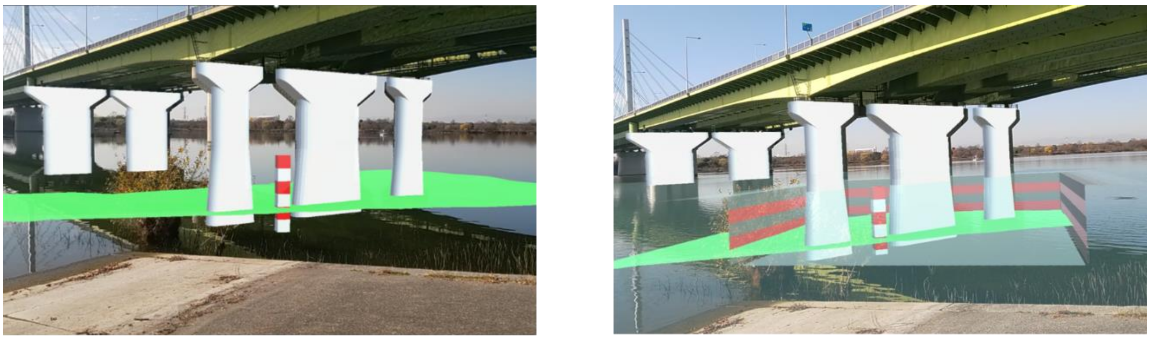
⑥ Hide UI
⑦ Display UI
A : Hide Virtual water surface
B : Display Virtual water surface
X : Hide Opening model
Y : Display Opening model

Figure 12: Operation List

3.3 Application Results

3.3.1 Confirmation from land

As shown in Figure 13, location-based method provides high accurate superimposition in the open sky environment. It can also be shown that the use of the Opening model reduces some of the strange feeling of the visualization results.

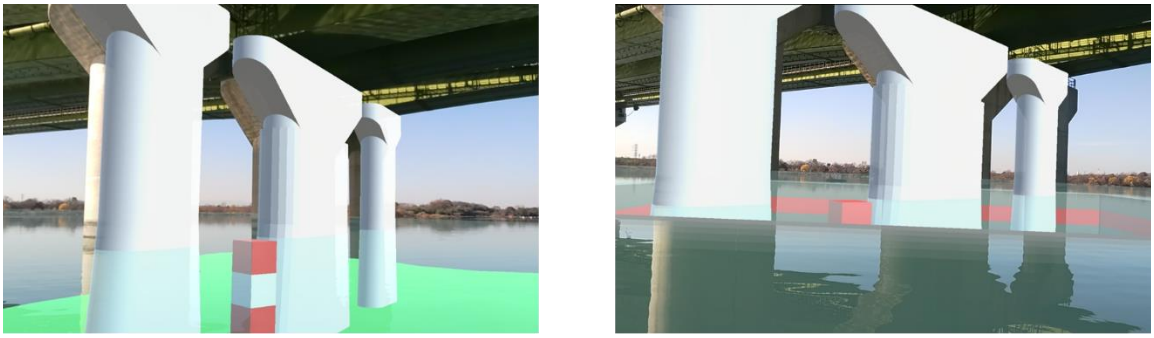


(a) Without Opening model (b) With Opening model

Figure 13: Visualization results from land

3.3.2 Confirmation on the lake

As shown in Figure 14, even on the lake, location-based method can be used for high accurate superimposition in an open-sky environment. In addition, when confirming from land, it was necessary to delete the front face of the Opening model due to the large distance from the visualization device to the piers. However, because it is possible to approach the piers by boat on the lake, it was able to reduce the strange feeling of the visualization results more compared to the visualization results from land by not deleting the front surface the Opening model.

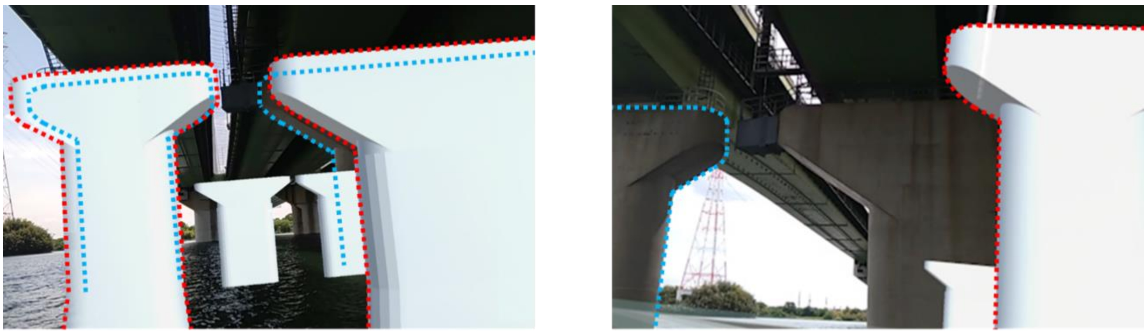


(a) Without Opening model (b) With Opening model

Figure 14: Visualization results on the lake

3.3.3 Confirmation in a non-open-sky environment

As shown in Figure 15, switching the superimposition method to the marker-based method enables more accurate superimposition compared to the superimposition results with the location-based method in non-open-sky environment.



(a) Marker-based method (b) Location-based method

: 3D models : Real piers

Figure 15: Visualization results in a non-open-sky environment

3.3.4 Switching from marker-based to location-based methods

As shown in Figure 16, high accurate superimposition is also possible when reverting back to the location-based method. Therefore, this system can be applied to any environment by switching the superimposition method at any time.

Figure 16: After switching to location-based method in open-sky environment

4 CONCLUSIONS

This paper has been presented a hybrid MR visualization system based on the marker-based method and the location-based method. The present system has been applied to the visualization for underwater parts of piers to show the validity and efficiency of the system. And the following conclusions were obtained.

- By enabling to switch between location-based and marker-based methods, high accurate superimposition is possible in any environment without being affected by the reception status of location information.
- By using an Opening model, the strange feeling of the visualization results can be reduced.

The future tasks are the application of this system to new objects and environments and the consideration of further visualization expressions.

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