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VISUALIZATION OF FLOW SIMULATION BASED ON AR USING GNSS DATA

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Abstract. *This paper presents an AR visualization system for flow simulation based on the location-based AR using GNSS data. The accuracy of position data obtained by the GNSS receiving machine is investigated and the position correction method using two GNSS receiving machines is investigated. The present method is applied to the visualization of flow velocity in rivers. The validity and the efficiency of the present method is investigated by the comparison with the marker based AR.*

1 INTRODUCTION

The Information and Communications Technology (ICT) has been applied in the field of civil engineering with the recent development of it. Augmented Reality (AR) technology is no exception to this trend, and AR visualization is being used to understand the status of construction sites and for maintenance and other purposes. One of the most effective examples of AR visualization is the visualization of seafloor structures. For example, recovery operation in the seafloor area affected by a tsunami caused by an earthquake can be dangerous because of not only difficult to confirm visually, but also the drastic change from the situation at the site before the disaster.

The authors have focused on these points and have developed an AR visualization system for use at sea. Marker-based AR[1][2], one of the vision-based AR methods, is commonly used as an AR visualization method, however it is difficult to superimpose correctly because there are no reference points in the vicinity offshore or on board ships.

Therefore, in this study, we developed a GNSS-based AR visualization system that provides geographic coordinates to a 3D model of a visualization target and performs accurate superimposition using a GNSS receiver. In this paper, we apply this method to the visualization of urban river flow as a visualization case study at ground level in order to compare it with conventional marker-based AR methods.

2 AR MECHANISM

AR is a digital technology that uses digital information to project a 3D model of a visualization target into real space through a visualization device. AR is broadly classified into "vision-based AR" and "location-based AR" according to the visualization method.

2.1 Vision-based AR

Vision-based AR is a system that reads marker images or scenery captured from a camera and superimposes 3D models on them. Vision-based AR is classified into marker type and marker-less type according to the superimposition method of visualization models.

In marker-based AR, it is necessary to prepare images such as QR codes called markers in advance. By placing a marker at the location where the 3D model is to be displayed, the position where the visualized model is superimposed can be set. On the other hand, a system that analyzes the scenery captured by a camera and displays a 3D model is called marker-less AR.

2.2 Location-based AR

Location-based AR is a system that performs visualization based on location information obtained from a satellite positioning system called GNSS. The accuracy of superimposition depends on the accuracy of GNSS, and the accuracy of superimposed positions is greatly reduced indoors or in areas surrounded by high-rise buildings[3]. On the other hand, the system offers high usability in an open-sky environment where there is no obstruction to the radio waves transmitted from the GNSS in the surrounding area, such as at sea.

3 DEVICE

As shown in **fig. 1**, in this study, a device for visualization and a GNSS receiver were fixed for visualization. The devices for visualization are a Google Pixel 5a, a smartphone manufactured by Google, iPhone XS and iPad Pro manufactured by Apple. The two GNSS receivers are Cohac QZNEO manufactured by CORE , which is compatible with GPS, GLONASS, Galileo, BeiDou, QZSS, and SBAS.

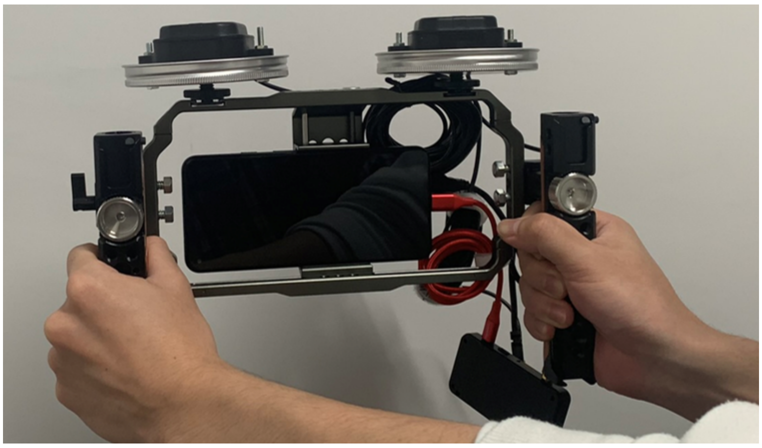

Figure 1: AR Device

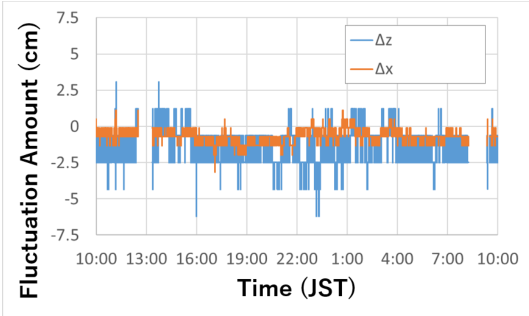

Figure 2: 24 hours measurement

● North-South direction (cm)

Maximum error (Northward)	Maximum error (Southward)	Mean of error
6.18	3.09	1.43

● East-West direction (cm)

Maximum error (Eastward)	Maximum error (Westward)	Mean of error
3.16	1.12	0.73

Table 1: Accuracy of GNSS receiver

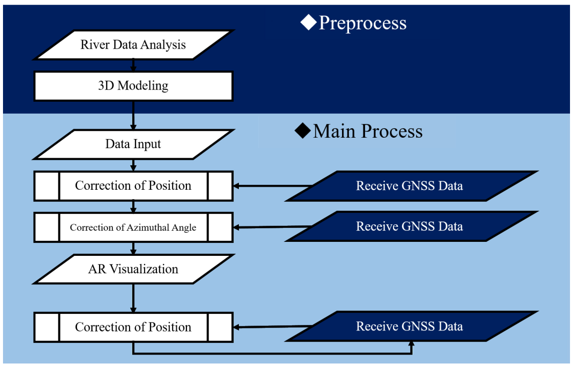

Figure 3: System Flowchart

The accuracy of the GNSS receiver was measured using a reference point. Both the x- and z-directions were within a few centimeters of error, and the use of a GNSS receiver is expected to improve the superimposition accuracy. The error results of GNSS data measured for a total of 24 hours are shown in **fig. 2** and **tab. 1**.

4 SYSTEM SUMMARY

A flowchart of the system is shown in the **fig. 3**. Each item in the flowchart is described below.

Figure 4: Visualization Studied Area

4.1 Development environment

In this study, the game engine Unity version 2020.3.24f1 was used as the general development environment to create the application for visualization. The devices used are as described in Chapter 3. As a comparison, a marker-type AR system was also built under the same development environment.

4.2 Visualization target

The visualization target is the Kanda River that flows through Tokyo, and was visualized from the Koishikawa Bridge located in Bunkyo-ku, Tokyo (**fig. 4**).

4.3 Preprocess

4.3.1 River data analysis

Water surface velocity vector data analyzed in the previous study ”Development and applicability of a visualization system based on markerless Augmented Reality for water environmental flow problems” was used[4].

4.3.2 3D modeling

A total of 100 steps from 0 to 99 seconds of the analyzed data were output as a 3D model. The 3D model was animated to represent the river flow.

4.4 Main process

4.4.1 Data input

In the data input section, the 3D model output in the pre-process was input into Unity. Note that the input model does not have the latitude and longitude information that is used to set the position information as the superimposed position. Therefore, the latitude and longitude coordinates in real space were assigned to the model origin using the Google Map function. The z axis, x axis, and y axis in Unity were set to north, east, and height, respectively.

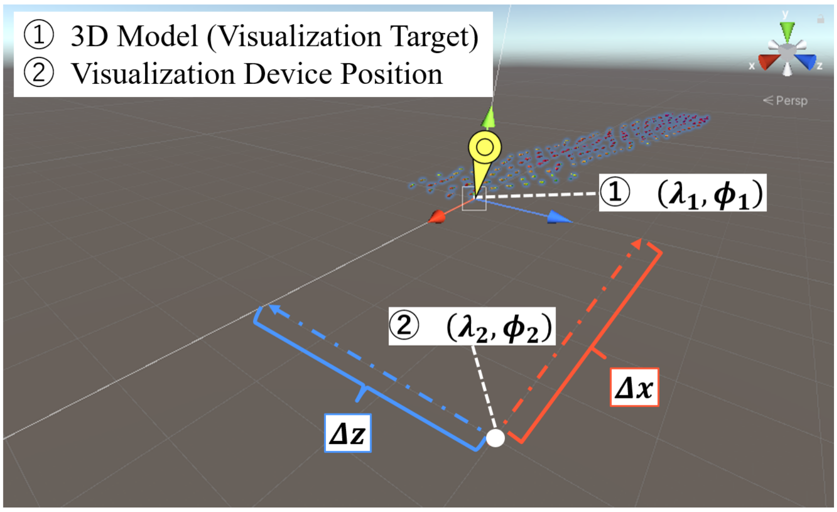

Figure 5: Correction of Position

4.4.2 Correction of position

As shown in the **fig. 5**, the relative positions of the visualization 3D model and the visualization device are set as coordinates in Unity space. In this case, as shown in the **fig. 1**, GNSS antennas are placed at equal distances from the center of the visualization device, and the average value of the values obtained from two GNSS receivers is given as the coordinates of the visualization device.

The coordinates in the Unity space are set by calculating the relative distance between the model and the device based on the latitude and longitude coordinate difference. The coordinates obtained from the GNSS receiver are updated every second, so superimposed position errors caused by movement can be corrected as needed. For position correction, the earth is assumed to be a perfect circle, and the calculation is performed using Equation (1). The λ_1 and ϕ_1 used in the equation are the latitude and longitude coordinates given to the visualization model, and λ_2 and ϕ_2 are the latitude and longitude coordinates given to the device by the GNSS receiver.

$$\begin{aligned}\Delta z &= 2\pi R\frac{(\phi_1-\phi_2)}{360}\\ \Delta x &= 2\pi r\frac{(\lambda_1-\lambda_2)}{360}\\ R &= 6,378,137\\ r &= R\sin(90-((\phi_1+\phi_2)/2))\end{aligned} \tag{1}$$

4.4.3 Correction of azimuthal angle

Unity sets the frontal direction of the visualization device to the z axis at application startup. Therefore, it is not possible to superimpose a 3D model at an accurate position simply by calculating the relative distance between the model and the device. In this report, accurate superimposition is performed by correcting the angular difference between the direction at the time of application startup and true north. The x and z axes are shown before correction, and the x' and z' axes are shown after correction.

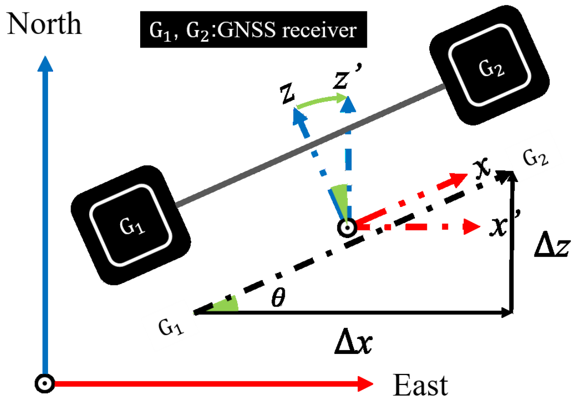

Figure 6: Correction of Azimuthal Angle

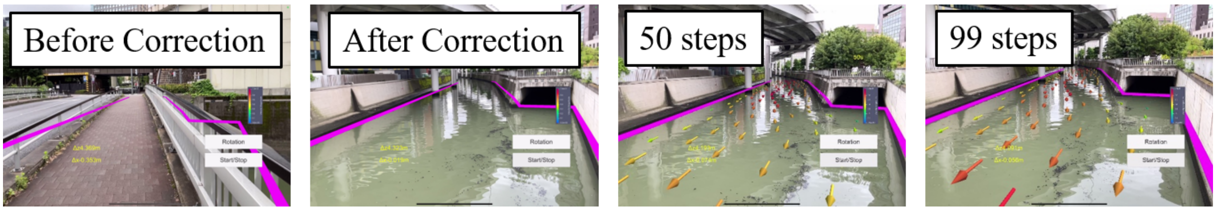

Figure 7: GNSS-based AR

The latitude and longitude information of the two GNSS receivers are used to calculate the angular corrections obtained from the relative positions. As shown in **fig. 6**, the distance between the two GNSS receivers calculated using the latitude and longitude differences is denoted as Δx and Δz, respectively, and the angular corrections are calculated using Equation (2).

$$\theta = \sin^{-1}(\Delta z/\Delta x) \tag{2}$$

4.4.4 AR visualization

Visualization is started by executing the procedure described in the previous section. In addition, in the user interface, in addition to the angle correction, the text displaying the number of visualization steps and the distance between the visualization position and the device, and the buttons for controlling the start and stop of the animation are created.

5 APPLICATION EXAMPLE

The **fig. 7** shows the result of GNSS type AR visualization. The superimposed location was under an elevated road, and there were concerns about the accuracy of GNSS data reception, but the data was received without problems. It was also confirmed that changes in the river flow could be visualized with good accuracy along the width of the river.

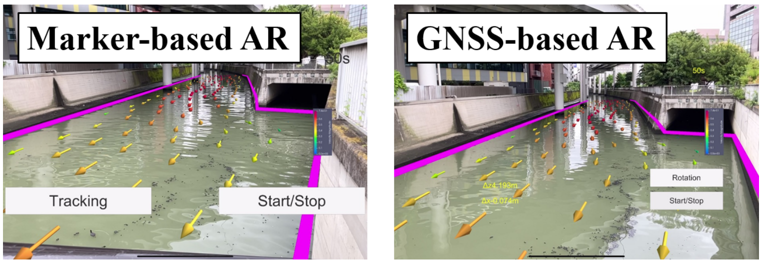

Figure 8: Comparison of superimposed results

5.1 Comparison of superimposed results

Comparison of visualization results between GNSS-based AR and marker-based AR is shown in the **fig. 8**. GNSS superimposition can maintain the same level of accuracy as marker superimposition, and a simple system can be constructed. The disadvantage is that the device must be activated vertically to start visualization.

6 CONCLUSION

In this study, we developed a GNSS-based AR visualization system that performs accurate superimposition using a GNSS receiver. In this paper, we applied this method to the visualization of urban river flow as a case study of visualization on the ground in order to compare it with conventional marker-based AR methods. The results showed that GNSS-based AR did not require marker installation, and the superimposition accuracy was equivalent to that of marker superimposition. For the future work, we will study the possibility of automating angle correction.

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