Developing 3D River Level Forecast Visualization with VR Technology

(Research period: FY 2020–2022)

MOROOKA Yoshimasa (Ph.D. in Engineering), Senior Researcher, TSUCHIYA Shuichi (Ph.D. in Engineering), Senior Researcher, TAKESHITA Tetsuya (Ph.D. in Engineering), Head, Water Cycle Division, River Department

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1. Introduction

In recent years, flood disasters caused by torrential rains have occurred frequently throughout Japan. This has underscored the importance of providing timely flood forecast information, enabling the swift implementation of flood control measures and evacuations. In response to this situation, the NILIM developed a national flood forecasting model known as the Flood Risk Line. This model has been operational at the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) since 2019. Meanwhile, a study conducted by the Cabinet Office's "Review Meeting on Evacuation Behaviors After the Series of Torrential Rain Disasters Since July 2021" highlighted that inadequate communication about the urgency and realistic threat of an imminent disaster is impeding appropriate evacuation measures.

For this reason, NILIM has developed a three-dimensional (3D) display technology utilizing virtual reality (VR) technology, referred to as the *VR display*. This technology is integrated into the Flood Risk Line system as an additional function with the aim of conveying the urgency and realistic threat of disasters in a more easily understandable manner. The following section details the features of the VR display.

2. Development of VR display technology for river level forecast communication

(1) Validating the validity and feasibility of the VR display

During the technology development process, we conducted a survey of existing studies and case examples and found that utilizing VR technology to display river level forecast information could enhance evacuation behavior. Furthermore, regarding the 3D topographic data and background images crucial for the VR display, we confirmed that 3D topographical and urban models will be accessible through the 3D administrative maps, which are to be developed for all first-class water systems by the end of FY 2025, and the Project PLATEAU led by the MLIT.

(2) Development environment and selection of target rivers

When selecting the development environment for the VR display of river level forecasts, we emphasized the following three key factors and chose Unity, a gaming engine known for its easy 3D information processing and rich visual effects:

i) Operability: Prioritizing the speed of information display.

ii) Effects: Focusing on visual effects that effectively convey a sense of urgency and realistic threat.

iii) Accessibility: Ensuring compatibility with various devices and operating systems. We developed a system that enables users to access and interact with information through web browsers on both computers and smartphones. This was achieved by converting the Unity-developed environment into WebGL format.

We chose the Yamakuni River, a first-class water system, as our target river because we secured cooperation from the river administration office. During the system development for the Yamakuni River, there were no existing 3D administrative maps or urban models available. We thus captured photographic images using ground cameras and drones.

(3) Investigating methods to enhance operability

Improving operability posed a challenge because of the extensive 3D terrain data that needed to be processed. To address this, we created the 3D terrain mesh by reducing the number of polygons from around 10 million to approx. 30,000 per 30 km². This reduction was achieved through retopology (rearranging surfaces based on shape) as illustrated in Figure 1. Areas with complex shapes had increased polygon count, while areas with minimal shape changes had fewer polygons.

As a result, the data size (in bytes) was reduced to approximately 1/500 of the case where the 3D terrain mesh was directly generated from LP data. This reduction significantly enhanced both data transmission and display efficiency. Additionally, the time needed to draw each distance marker per screen was reduced from approximately 1 minute to around 0.1 seconds.

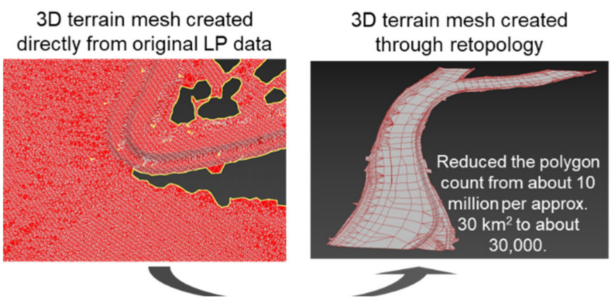

Figure 1. Retopology (reattaching a surface according to shape)

These enhancements have made it feasible to display river level forecast information in VR at a practical level.

(4) Creating 3D water surface model and adding effects

We added effects to enhance the realism of flooding threats, such as changes in water surface turbidity corresponding to water levels, the swaying of water caused by varying flow velocity and water spray, cloudy skies, and dynamic rainfall that changes based on measured and predicted rainfall data. Moreover, the water level at which evacuation decisions are made, as well as the flooding hazard level, are overlaid on the 3D model of the levee slope surface. This addition enhances the realism of the flooding threat.

(5) Creating VR operational screens

Figure 2 shows the operational screen displaying the VR images of river level forecasting information that we have created. This operational screen enables users to adjust and zoom their viewpoint. Users can also switch between current and projected times, distance markers, and the left and right banks. We are currently enhancing the display screen to support longer forecast times, extending up to 36 hours ahead for the flood risk line. Additionally, in collaboration with the Yamakuni River Office, we held discussions with disaster preparedness staff from local governments and river cooperative groups along the river. We received feedback, including the suggestion to include a sign indicating how much the water level can rise before reaching the flooding danger level, and incorporated these suggestions to enhance the display screen.

3. Observation on the VR display of river level forecasting information

(1) Benefits apart from communicating urgency and realism in disaster threats.

Figure 3 shows a comparison between an image taken from a CCTV camera at night (midnight, September 19, 2022) and a VR display at the same time when Typhoon Nanmadol (Typhoon #14) approached Kyushu near the 26.8 KP of the Yamakuni River in 2022. The VR display makes it visually easier to check the river level at night. Other advantages confirmed with the VR display include its ability to project forecasts up to six hours in advance, unlike CCTV cameras that can only show the current status. Additionally, the VR display can switch to showing areas where cameras have not been installed yet.

(2) Challenges in forecasting accuracy and communicating information during disasters

While we are working to enhance the accuracy of flood risk line forecasts by assimilating observed data, concerns persist regarding the potential impact on residents in the event of a significant disparity between forecasted information and actual conditions. This arises from the VR display of uncertain forecast information and the possibility of server downtime caused by access overload during a disaster.

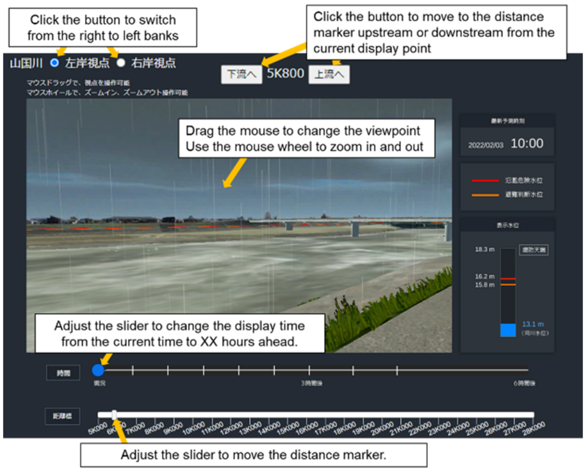

Figure 2. Operational screen for VR display we developed

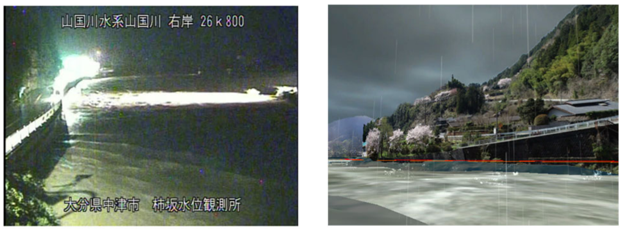

Figure 3. Comparison of CCTV and VR images at the same time at night (near the 26.8 KP of the Yamakuni River) (Left: CCTV camera image, Right: VR display image)

In addressing these challenges, we are improving the accuracy of flood risk line forecasts. At the same time, we are considering strategies, such as limiting VR displays to areas where a specific level of forecast accuracy is confirmed, such as near water level stations. Furthermore, we are contemplating the addition of a feature that allows the creation of trimmed videos with reduced data volume and limited duration.

4. Future outlook

The findings of this study will be published in 2023 as specifications for additional features of the flood risk line forecasting system. Furthermore, local governments along the Yamakuni River have requested the installation of VR displays at their Disaster Preparedness Offices. A trial operation is scheduled to start during the 2023 flooding season.

☞For more information:

1) Webpage of Water Cycle Division: Example of 3D Display of River Level Forecast using Virtual Reality (VR) Technology (under development)
https://www.nilim.go.jp/lab/feg/index.htm