

# Application of mixed reality technology in geotechnical industry

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## Abstract

Over the past decade virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies have been applied to the construction industry. The 3D geological models are also used to visualize the ground information for revealing the risk of geology in the geotechnical industry, and new approaches using VR/AR/MR technology are useful in understanding the relationship between the ground and structures. In this paper, examples of the application of MR technology will be introduced to further clarify how this technology changed the geotechnical industry.

*Key words:* 3D geological model, BIM/CIM, risk communication, mixed reality, HoloLens 2

## 1. Introduction

With the acceleration of the use of BIM/CIM (Building/ Construction Information Modeling, Management) in the construction industry have been, three-dimensional (3D) geological models are used as the BIM/CIM models in the geotechnical industry. 3D geological models are expected to visualize the ground information such as the risks of geology affecting seriously construction structures and to support the risk assessment process which is very meaningful to the design/construction phases. In this paper, an example of the use of 3D geological model and mixed reality (MR) technology as communication tools in risk assessment is introduced.

## 2. Mixed Reality Technology and HoloLens 2

In recent years, virtual reality (VR), augmented reality (AR), and mixed reality (MR) have brought about drastic changes in many industries, most notably in the entertainment industry, film, video game, retail, etc. Mixed reality (MR) is the merging of real and virtual worlds to produce new environments and visualizations, where physical and digital objects co-exist and interact in real time. Mixed reality does not exclusively take place in either the physical world or virtual world but is a hybrid of augmented reality and virtual reality. In addition, all such real-and-virtual combined environments and human-machine interactions generated by computer technology and wearables are collectively called extended reality (XR) including VR/AR/MR and the areas interpolated among them.

HoloLens 2 (Fig. 1(a)) is an HMD (head-mounted display) developed by Microsoft Corporation in the United States and is an MR device that can display a 3D model in a hologram (Fig. 1(b)). HoloLens 2 allows you to freely enlarge, reduce, and rotate the hologram with your fingers, and you can also move it by touching it. It is equipped with an infrared LiDAR scanner that can perform spatial mapping of the real world up to 5 to 10 m away. This allows the hologram displayed by HoloLens 2 to be superimposed at an accurate position in the real space.

In the construction field, the introduction of HoloLens 2 was being promoted in advance by displaying a full-scale BIM model of piping, mechanical equipment, and steel skeleton of a building, etc. in a hologram. The designed equipment layout in the building is visualized and the constructed layout is examined. In addition, tools and services that support the inspection process of buildings by displaying the inspection points of the building in the hologram have been put into practical use. In this way, work efficiency is improved. By using HoloLens 2, remote assistance services in which skilled technicians provide remote support to young technicians who are working at the site through a video conference system are also being provided.

## 3. Hologram of the 3D geological model

Confirmation of the 3D geological models, for example, the 3D geological model of an erosion control dam (Fig.2), which is a BIM / CIM model in the geology/soil field, is usually performed on 3D model viewer software that can review 3D models. The 3D geological model was created by the AEC collection (Autodesk) [2] and GEORAMA, a 3D-geological modelling software provided by

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HoloLens 2



b) Hologram of a 3D object in real space (Microsoft Corporation 2022 [1])

**Figure 1: HoloLens 2 and hologram generated by HoloLens 2**

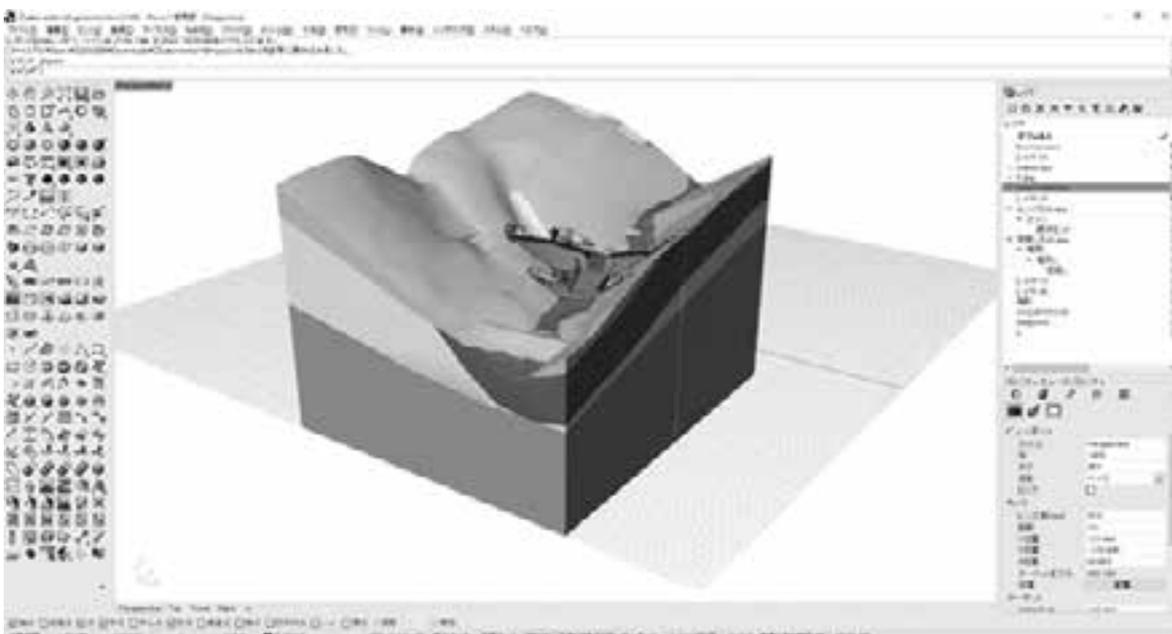
ITOCHU Techno-Solutions Corporation (CTC) [3]. And then the 3D models were imported into Rhinoceros, a 3D-CAD software developed by Robert McNeel & Associates [4], and holographically displayed by HoloLens 2. To display holograms with HoloLens 2, we used an add-on software for Rhinoceros named Fologram which was developed by Fologram Pty Ltd [5]. Figure 3 shows an example of a 3D geological model of an erosion control dam with a hologram display on HoloLens 2. By utilizing MR technology, now 3D geological models can be displayed right before our eyes, and actively the actively viewing and interacting of all or each layer in real space can be done (Fig.4). Moreover, the 3D geological model can be viewed from different angles for many viewers at the same time. These are the advantages of using MR, which are impossible with 3D model viewer software.

Although the 3D model (BIM/CIM) is displayed as a full-

scale (1: 1 scale) hologram for a relatively large model such as a 3D geological model in general, by using the scale function of Fologram, the displayed hologram can be scaled down to any size. Therefore, it is possible to display the created 3D geological model on the desk in the conference room. In the case of a scaled-down hologram, to intuitively grasp the true size of the 3D model, a guide ruler such as a 3D scale bar that shows the actual size of the model should be added to the 3D models. Since HoloLens 2 does not have a device for acquiring position information like GPS, the hologram is aligned using a marker (QR code).

#### 4. Hologram of 3D rockfall source models

Dangerous slopes with rockfall sources are spots where many unstable rocks and floating rocks exist, and most of them are steep slopes with a slope of  $60^\circ$  or more [6]. In many cases, the approach to the inspection point of the outcrops of the rockfall source is a difficult and dangerous

**Figure 2: 3D geological model imported in Rhinoceros**

task for investigators. But by utilizing MR technology, it is possible to realistically reproduce the situation at the site as a hologram without going to the site. As a result, engineers and experts can see the rockfall source situations as they are on-site and get a realistic recognition of the site situation. Through such advanced communication methods, they can share information, discuss disaster risks, and create various ideas for countermeasures.

The 3D rockfall source model was created with photogrammetry software that requires 50 or more digital photographs of the rockfall source from all directions. The created 3D rockfall source model was then opened and displayed with Rhinoceros, after that the hologram of the 3D rockfall source model was displayed on HoloLens 2 using Fologram in real scale in real space (Fig. 5).

The advantages of displaying a hologram of a 3D rockfall source model are as follows.

(1) It is possible to safely check the rockfall source situation and its danger without going to the site in the case of unstable and risky rockfall sources.

(2) Since the hologram of the 3D rockfall source model allows you to check the detailed situation while walking around the hologram as in the field. In this way, it can easily check the opening cracks on the slope with the hologram.

(3) Advanced communication can be conducted. For example, a skilled technician or expert wearing HoloLens 2 and observing the hologram of the 3D rockfall model can share his/her viewpoint while streaming the hologram through the PC screen.

On the other hand, the problems related to the hologram display of the 3D rockfall source model are as follows.

To create a 3D rockfall source model, it is necessary to take many photographs of the rockfall source from all angles. If some parts of the rockfall source model cannot be photographed or that can only be taken from a limited angle, the data is insufficient to convert to a 3D model. As a result, the model quality is inferior.

When a realistic and too detailed 3D rockfall source model is created, it takes much time to display the hologram on HoloLens 2 because the mesh data is too large.

While such issues are recognized, it can be said that the benefit of being able to safely confirm dangerous sites of the rockfall sources is extremely great.

## 5. Summary

In this paper, we introduced the hologram display of the 3D geological and 3D rockfall source models by utilizing MR technology and HoloLens 2. The hologram display makes it easier and more intuitively to understand the geological composition in the 3D geological model. In the case of the hologram of the 3D rockfall source model, it allows an experience of the situation of the

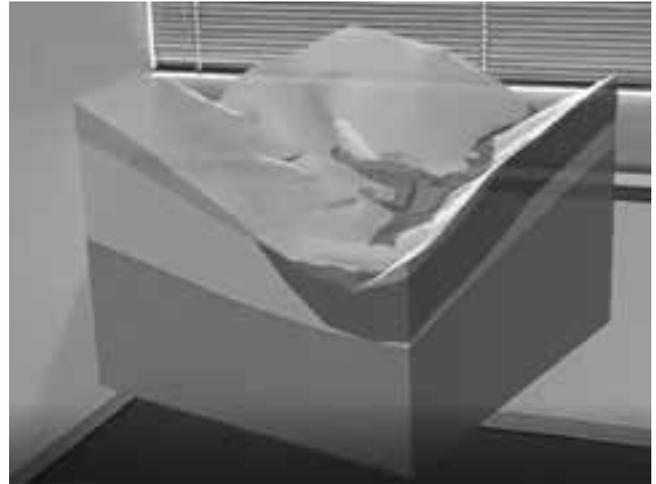


Figure 3: Hologram of a 3D geological model displayed in real space (1/1,000 scale)

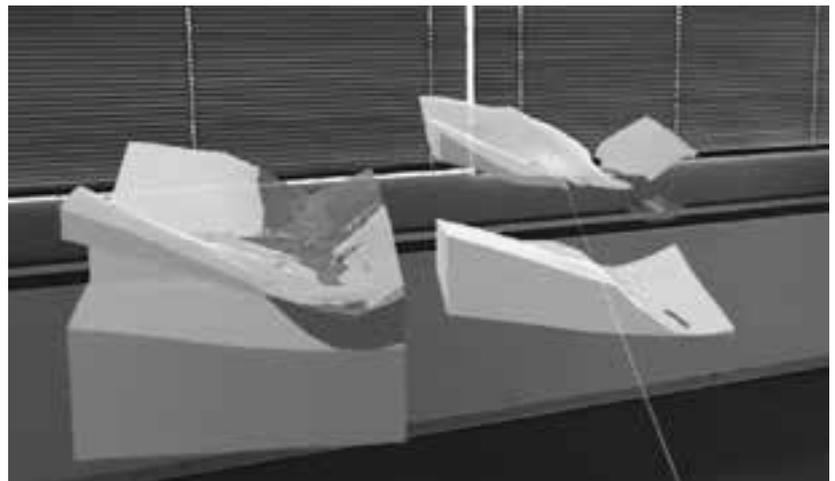


Figure 4: User interacting with the hologram of the geological model displayed in real space



Figure 5: Hologram of a 3D rockfall source model displayed indoors

rockfall source in a realistic manner.

However, HoloLens 2 itself has the following problems:

(1) Since the device itself does not have position information like GPS, it is not easy to align the BIM/CIM model of slopes with the position in real space.

(2) It takes time to load the 3D data with a large file size to display the hologram with HoloLens 2.

(3) The device itself is not dust-proof or drip-proof, and the system is likely to go down under conditions where the temperature is 30° C or higher.

Regarding the solutions for the above-stated issues, for (1), it is possible to perform accurate alignment by combining

it with the position correction technology of the quasi-zenith satellite "MICHIBIKI" [7], which is operated by JAXA [8]. Regarding (2), the 3D model should be optimized to reduce the size as much as possible before being displayed with HoloLens 2. For the issue stated in (3), we expect that next-generation devices developed in the future can withstand use under harsh conditions such as in the civil engineering and construction site. Some cooling equipment for HoloLens 2 was also introduced and we hope that these accessories will be developed further to help HoloLens 2 work better in multiple types of environments./.

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## Development of static P-Y curves from experimental measurements...

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- Optimization p-multiplier process produces closed fit between the predicted shafts responses and the collected measurements.

- Nonlinear characteristic of bending stiffness is important and significantly impacts the predicted shaft responses in terms of lateral displacements and bending moments, as well as the predicted p-y models.

- Linear and nonlinear methodologies of applying bending stiffness to the computational program show the substantial differences in both shapes and magnitudes of predicted shaft responses and the significant differences of predicted p-y models.

- By using nonlinear bending stiffness considered the cracking of concrete section and the methodology to derive p-y models implemented in the computational program, the experimental p-y curves can be established reasonably and practicably.

- The p-y curves derived from experimental measurements are compared to the conventional p-y curves. The comparisons are useful for perspective on how the test data align with models commonly assumed in practice.

The proposed approach is limited to the static p-y curves for onshore long flexible drilled shafts, not for the case of cyclic loading or for short rigid pile or for offshore conditions. Further readings should refer to API RP 2A-WSD, 22nd Edition, November 2014 and DNVGL-RP-C212, 2019 Edition, September 2019./.

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