

# **Holographic mixed reality: an enhanced technology for visualizing and evaluating complex 3D geologic data**

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**ABSTRACT:** Rock mass characterization involves field data collection, processing, and analysis of the measurement results. Software packages facilitate creation of 3D models as well as the representation of rock mass parameters and resulting block arrays. The computer-generated imagery is traditionally illustrated as static perspective pseudo 3D screenshots, 2D maps or numerical tables and diagrams.

Mixed reality greatly improves data visualization within an immersive and interactive 3D holographic environment enabling interaction with scaled holograms at the actual field dimension. The holograms are inspected individually or via remote collaboration within shared virtual spaces. The physical outcrop together with quantitative aspects of the rock mass structure is portrayed, enhancing communication and understanding of actual field attributes.

This paper presents case examples of mixed reality holographic models based on photogrammetry, terrestrial and hand-held LiDAR devices. The benefits and potential applications of mixed reality in engineering geology and rock mass characterization are summarized.

*Keywords: Mixed reality, digitalization, rock mass characterization, hologram.*

## **1 INTRODUCTION**

The use of LiDAR and unmanned aerial vehicles (UAVs) in the geosciences and engineering disciplines require the transformation of vast amounts of 3D data into tangible information (Janeras et al. 2022). Although the collected data is 3D, georeferenced and often of very high resolution, the derived models are traditionally decimated and represented in 2D (e.g. maps, plans, cross sections, outcrop drawings, structural plots and graphs). With extended reality (XR) technology, geodata can now be represented and visualized in a truly 3D immersive environment. XR is a collective term including virtual reality (VR), augmented reality (AR), and mixed reality (MR). AR and MR represent virtual information that is directly registered to the physical 3D environment, and offer real time user interaction (Schmalstieg & Höllerer 2016). Unlike 2D representations of 3D data, such as computer monitors or other planar screens, head mounted displays (HMDs) such as Microsoft's HoloLens 2 can project holographic imagery in true 3D space, while also maintaining reference to

the physical environment through simultaneous spatial mapping (Wang et al. 2020). Virtual objects can be manipulated as if they were real objects via integrated hand tracking and gesture recognition. The HMD user experiences perspective and scaled model observations with interactive and intuitive data query functions. The model and interpretive data are visualized in a common framework with layers and hypertexts that provide rapid situational awareness yet low cognitive load for the observer (Anderson 2020).

This paper presents the benefits and potential applications of MR technology in the field of engineering geology with emphasis on rock mass characterization. With selected case examples, the technology, steps, workflow for model creation and inspection are elaborated. The use cases embrace collaborative office-based sessions as well as potential worksite applications.

## 2 DATA COLLECTION, MODEL CREATION AND HOLOGRAPHIC PROCESSING

Depending on the scale of interest and desired resolution, a number of different technologies are available for collecting field measurements as 3D point clouds. For the cases presented herein, a Riegl LMS-Z620 terrestrial laser scanner (TLS) with integrated camera and Leica GNSS GS15 RTK rover was utilized for acquisitions at a range of approximately 800m, while, close range (up to 7m) LiDAR acquisitions were made with an iPad Pro (3<sup>rd</sup> generation). Close range SfM based photogrammetry was also performed using a Nikon D80 camera. The Riegl point cloud was produced with the software RiScan and the iPad Pro point cloud was produced with the 3D Scanner App<sup>TM</sup>. Photogrammetric processing was performed using Agisoft Metashape. In each case, georeferenced true color point clouds are obtained. In MR applications, true color information is considered essential for creating photorealistic textured models.

The case examples enumerated below include: (1) the Ricobayo Dam site in Zamora, Spain; (2) the Mölltaler Glacier in Carinthia, Austria; and (3) the Feldkofel area, also in Carinthia, Austria. All study areas are characterized by blocky rock masses having negligible vegetative cover. For 3D holographic MR visualizations with the Microsoft HoloLens 2, the cloud-based collaborative applications Ada Viewer by Clirio Technologies Inc. and Trimble Connect MR (TCMR) were used.

Integrating 3D models into HoloLens 2 often requires decimation of raw data. As an example, the maximum number of polygons should be limited to approximately 250,000 (Boghosian et al. 2019 and Kaspar & Kieffer 2023). Scalability also needs to be considered. The Unity game engine based HoloLens 2 apps only supports 3D meshes and bitmaps for rendering. The data originating from the different platforms are processed with respect to the desired output and are later merged into a common data environment. The model resolution should also satisfy specific project needs.

Figure 1 illustrates the workflow associated with data extraction and model preparation for use with HoloLens 2. For both LiDAR and photogrammetric data, the first step involves point cloud generation and image acquisition in the field. The office-based operations include mesh generation, texture building, decimating, georeferencing and conversion to a 3D file format, but also inputting structural data and geotechnical design details. This added data is inserted into the base models in order to convey relevant site-specific information in a holistic, 3D framework.

For editing, processing and optimizing LiDAR and photogrammetric data, the open source freeware programs CloudCompare (Girardeau-Montaut 2022), MeshLab (Cignoni et al. 2008), and Blender are utilized. The commercial software Agisoft Metashape was used to generate select models. The ShapeMetriX<sup>3D</sup> software is used for reconstructing outcrop models from overlapping digital photographs and for quantifying rock mass parameters such as joint orientations, spacing, persistence and location.

Joint set extraction from LiDAR point clouds follows the methods described in Boulch and Marlet (2016), Dewez et al. (2016), and Liu et al. (2021). In order to store the color information representing the joint sets in the point cloud, the scalar field colors are transferred to RGB color values before exporting. The RGB colors stored in the point data serves as source for colorizing the final triangulated mesh during the screened Poisson surface reconstruction (Kazhdan & Hoppe 2013). In practice it has proven best to create UV mapped textures rather than storing the color information directly in the faces of the mesh for seamless rendering on the HoloLens 2. In this process, the texture is a separate raster file wrapped around the 3D object. Large models are decimated using the quadric

edge collapse decimation algorithm (Garland & Heckbert 1994). For visualizing LiDAR data without triangulating a watertight mesh, each vertex point is replaced by a predefined 3D base object using Blender's DupliVerts operation. Blender and MeshLab use 3D Cartesian coordinate systems (X = East, Y = North, positive Z = up) and are consistent with UTM units. ShapeMetriX<sup>3D</sup> models are exported as Virtual Reality Modeling Language (VRML) files and then processed for HoloLens 2 rendering.

Once the exported structural entities are converted to a digital asset exchange format (.dae), they are assigned to a layer in SketchUp and additional attributes or hypertext labels are updated. The resulting .skp-file is uploaded to the cloud. For models imported to the Ada Viewer, the files are converted to OBJ-files.

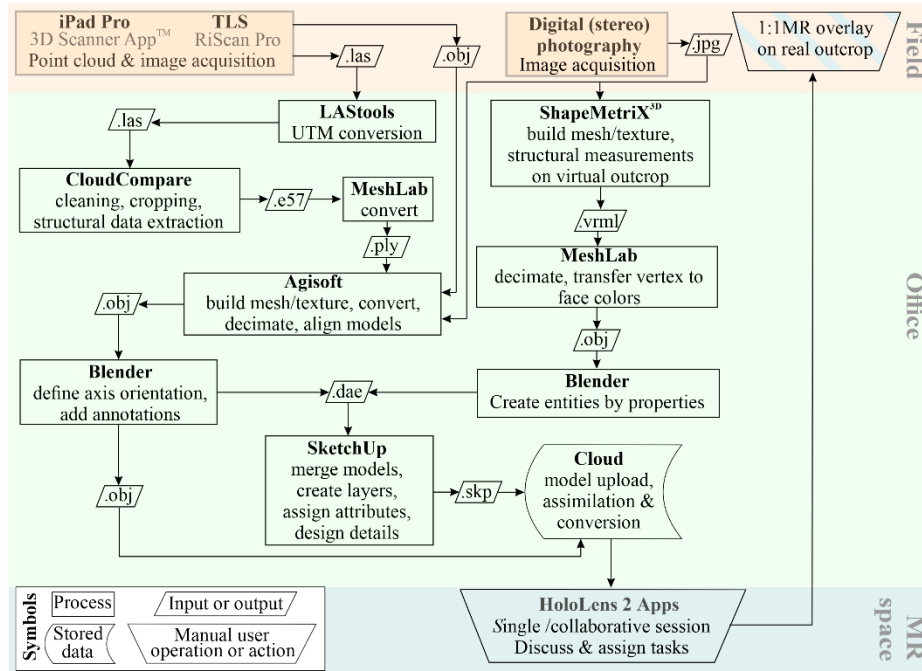


Figure 1. Workflow for data collection, processing, analysis and rendering for HoloLens 2 applications.

### 3 CASE EXAMPLES

#### 3.1 Digital twins and modeled data

The model of a road outcrop at the Ricobayo Dam site consists of the true color, texturized mesh of the outcrop and the vertex/face colored mesh of the structural map showing the joint sets. The fitted planes representing the joint sets are exported as color coded polygons and are assigned to a layer. The polygons contain attribute data such as joint orientations which can be retrieved by query functions within the TCMR app (Figure 2a). The visibility of the layers can individually be controlled in the layer manager tab. With the 1:1 scaled model, the digital twin of the site is virtually revisited and inspected using interactive measuring tools. With the virtual pointer, distance measurements are performed in the higher (physically inaccessible) areas directly on the holographic model by defining start and endpoints. By walking behind the virtual rock face, the alignment of rock anchors extending into the rock mass is checked and a clash between two anchors is identified (Figure 2b). Supplementary data include the stereographic plots of the joint sets (equatorial and polar) and the associated 3D lower hemisphere model (Karabinos 2020) and anchor installations in the rock wall. With the 1:1 scaled hologram placed over the real outcrop in the field, MR overlays can be used to perform collaborative peer review and independent expert assessment. The relative position of any attendees of the collaborative session is represented as an avatar, whose gaze projects directly onto the correct model position (Figure 2c).



Figure 2. Model of roadcut outcrop at the Ricobayo Dam site as viewed with HoloLens 2. (a) Physical measurements (distance and orientation) retrieved from a 1:1 scaled model, (b) immersive view from behind the rock face identifying the clash of two rock anchors, (c) and downscaled tabletop size model for remote collaboration, showing an avatar and its gaze.

HSV color coded joint orientation representations of an outcrop from the Feldkofel area in Austria (Liu & Kaufmann 2015) together with 3D block shapes are visualized in Figure 3. Viewed with the HoloLens 2, the model provides an immersive example of kinematic removability in the context of block theory (Goodman & Shi 1985). In the example shown, the subset of potential key blocks (red) and safe removable blocks (green) are shown. With the virtual removal of the lowermost potential key block, the bordering safe removable blocks themselves become potential key blocks by virtue of a retrogressive block failure process. This illustrates the principle of block theory in a far more convincing way than can be represented in a 2D drawing: if the potentially dangerous blocks are found prior to movement and their stability is assured, then no block movements will occur anywhere (Goodman & Shi 1985).

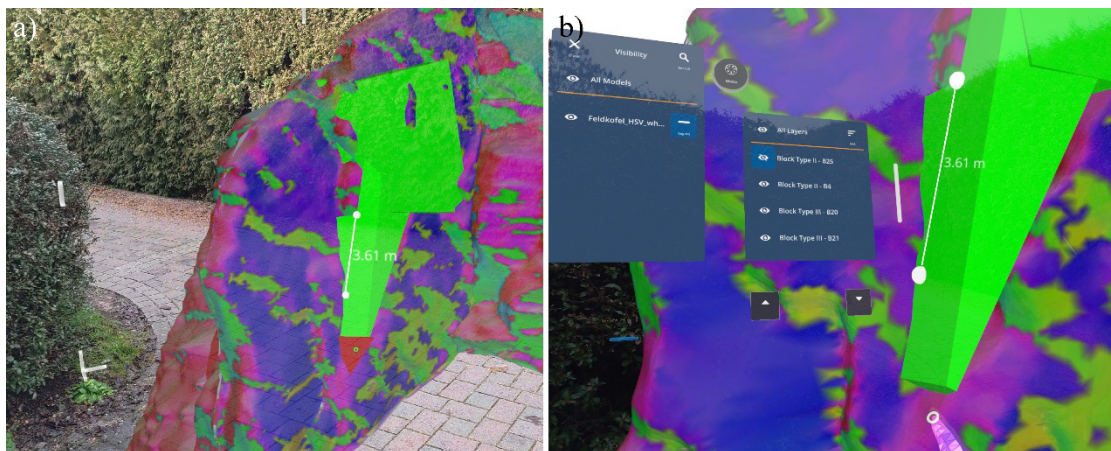


Figure 3. Potential key block (red) and safe removable blocks (green) in an HSV colored outcrop. (a) Potential key block occurs at the base, and (b) if removed, renders the green blocks as potential key blocks through a retrogressive block failure process. Block dimensions are measured directly in the model.



### 3.2 Holographic model creation via iPad or iPhone

The recent integration of LiDAR (together with high resolution digital photography) in smart phones and tablets (e.g. iPad and iPhone) greatly facilitate the workflow for creating 3D models (Torkan et al. 2022). Although limits on mesh size, range and precise georeferencing restrain the assortment of applications, the created models can be highly suitable for visualizing with the HoloLens 2. As an example, Figure 4 depicts a holographic projection of an outcrop along the Mölltaler Glacier road at a 1:1 scale. The virtual outcrop (Figure 4a) is processed to represent the joint orientations in the HSV framework (Figure 4b). Actual locations of joint orientation measurements in the field by traditional contact-based measurements on the real outcrop using a geological compass and virtual compass measurements from CloudCompare are highlighted in the 3D model. By retrieving the orientation data at these locations using a query function, the real and virtual joint orientation measurements can easily be compared (Figure 4b). Revisiting the field site in its actual size supplemented with structural data plots linked to the actual 3D model, offers the viewer a fast situational awareness.

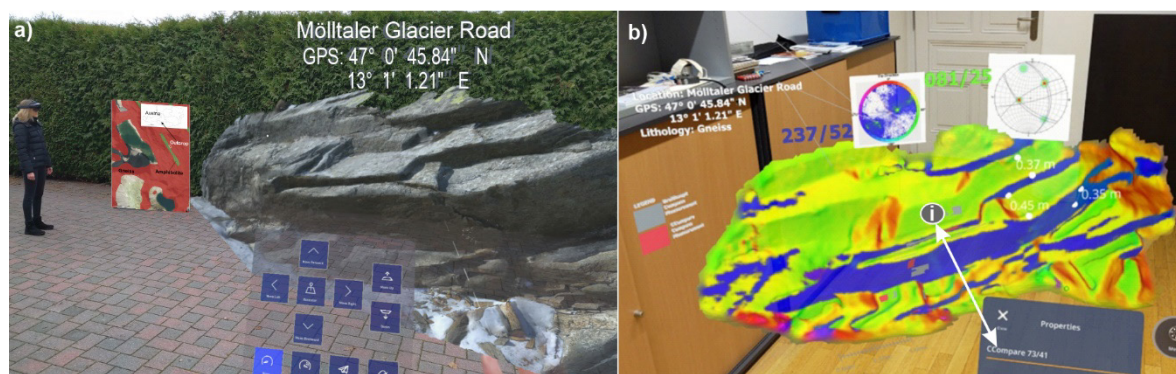


Figure 4. Holographic outcrop projection rendered from the iPad Pro. (a) 1:1 scaled, true color textured outcrop model, together with an embedded geologic map of the field area and hypertexts providing additional information for enhancing collaborative viewing. (b) HSV colored, tabletop model of the outcrop visualized in TCMR showing joint set orientations obtained by real and virtual methods.

## 4 SUMMARY AND CONCLUSION

MR is an unparalleled technology for representing complex geological data in a fully immersive 3D environment. The holographic models are georeferenced, scalable and of sufficient resolution to permit meaningful quantitative measurements and interpretations. Viewed with the HoloLens 2, the models convey complex 3D data in an intuitive way that is considered far superior to sliced and rotated models as traditionally viewed with a 2D computer monitor. The collaborative capabilities greatly facilitate data understanding by multiple participants independent of their location, while also facilitating technical peer review and expert input. With modern smart phones and tablets, the entry cost and workflow for creating close range models is not prohibitive, and a wide range of HMDs are available for data visualization.

MR is also highly effective for communicating complex 3D spatial data to non-experts, stakeholders (Janeras et al. 2022) or for educational and training purposes (Kalkofen et al. 2020). MR applications will surely find increasing applications and utilization in rock mechanics and engineering geology. In particular, the visualization of fully scalable BIM data represents an attractive use case. Potential future applications also include the use of HoloLens 2 as a direct close-range digital field mapping device (Onsel et al. 2019).

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