Exploring Ancient Skies: Archaeoastronomy with arcAstro-VR

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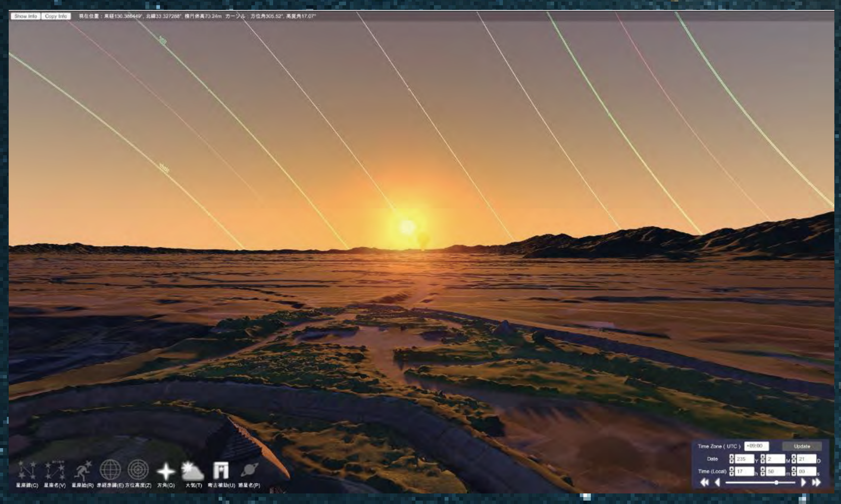
Abstract : Archaeological sites often align with celestial phenomena, providing insight into the spatial and astronomical awareness of ancient cultures. However, the celestial landscape we observe today differs from what it was in the past. Due to Earth's precession, the apparent declinations of stars shift over decades to centuries. To address this, we developed arcAstro-VR, a virtual reality system that reconstructs historical skies and archaeological landscapes in immersive 3D. Based on the open-source Stellarium software, it simulates past celestial events with high accuracy, aiding the analysis of alignments and phenomena.

The latest version (Ver0.21.2) supports Meta Quest headsets and includes features such as compass-centered mapping, dome projection, and water reflection simulation. Open-source and cross-platform, arcAstro-VR enhances archaeoastronomical studies by enabling dynamic exploration of ancient sites—demonstrated here with reconstructions of Yoshinogari in Saga Prefecture and Tsukuriyama Kofun in Okayama Prefecture in Japan.

arcAstro-VR

arcAstro-VR is an application that reconstructs archaeological remains as 3D data from actual measurements and records. Then it reproduces them in VR on a computer, along with data on topography and astronomical phenomena.

Archaeological remains surveyed using LiDAR and photogrammetry can be visualized in 3D, allowing users to freely move around in the recreated VR space and change settings to test various hypotheses.



By using arcAstro-VR, you can:

- Import your own 3D models and archaeological remains data,
- Show/hide and move 3D models, and place markers and auxiliary lines,
- Freely move around the VR space using a mouse or game controller,
- Reproduce astronomical phenomena from the period 2000 BC to 6000 AD with high precision,
- Test sunlight, shadows, and water surface reflections using the sun or moon as light sources.

* For more information, please visit https://arcastrovr.org/en/.

What's New in arcAstro-VR

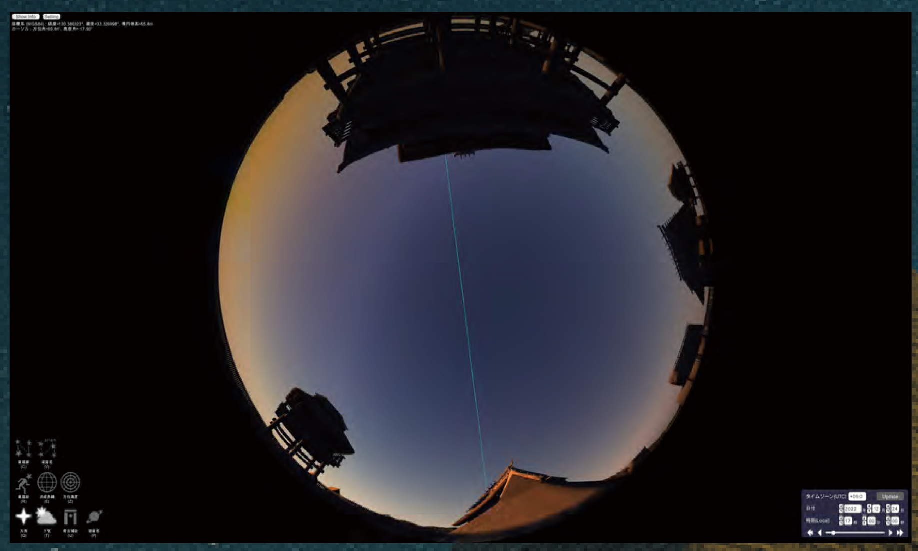
In response to user requests, arcAstro-VR has added new features deemed necessary for archaeological purposes. The latest version, 0.21.2, supports Meta Quest (Oculus Quest) and allows users to experience VR spaces through an HMD by connecting to a PC via MetaLink. Additional features include a compass map display centred on a marker that serves as the starting point of a guideline, Dome Master output for 360-degree projection onto a dome using a fisheye lens, and the ability to place a water surface anywhere to simulate reflections. arcAstro-VR is open source and licensed under the terms of the GNU General Public License, version 3, and is available for Windows (Windows 8 and later) and macOS (macOS 10.14 and later).

Compass map function

- It can display a compass map (an ortho map directly above with direction added) centred on the marker that is the starting point of the auxiliary line.

Dome Master output

- 360-degree projection on a dome using a fisheye lens is now possible (Dome Master format).
- It can also specify the angle of view and azimuth (fixed direction of travel, fixed azimuth angle, etc.).



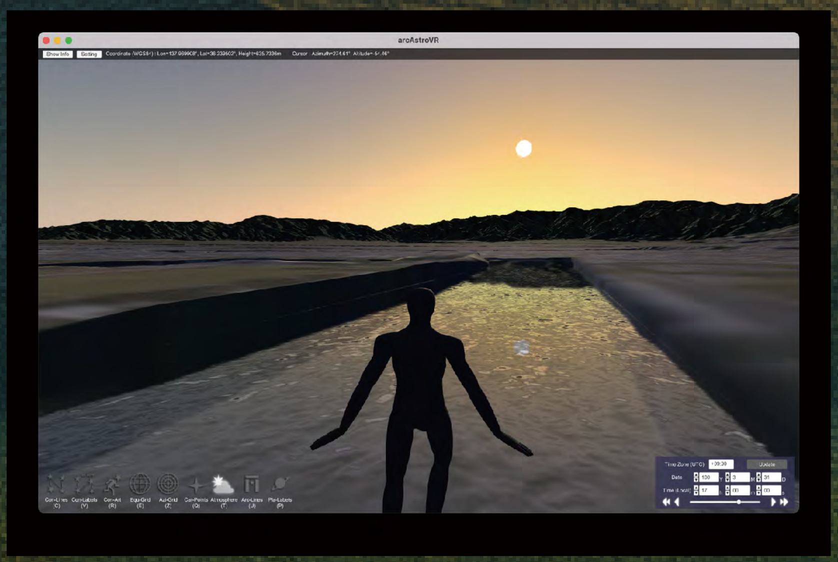
HMD compatible

- Compatible with Meta Quest (Oculus Quest).

By connecting to a PC with MetaLink, you can experience VR space through the HMD.
*Compatible with Windows only

Water expression

- Water surfaces can be placed anywhere.
- Water surface reflections can be simulated.



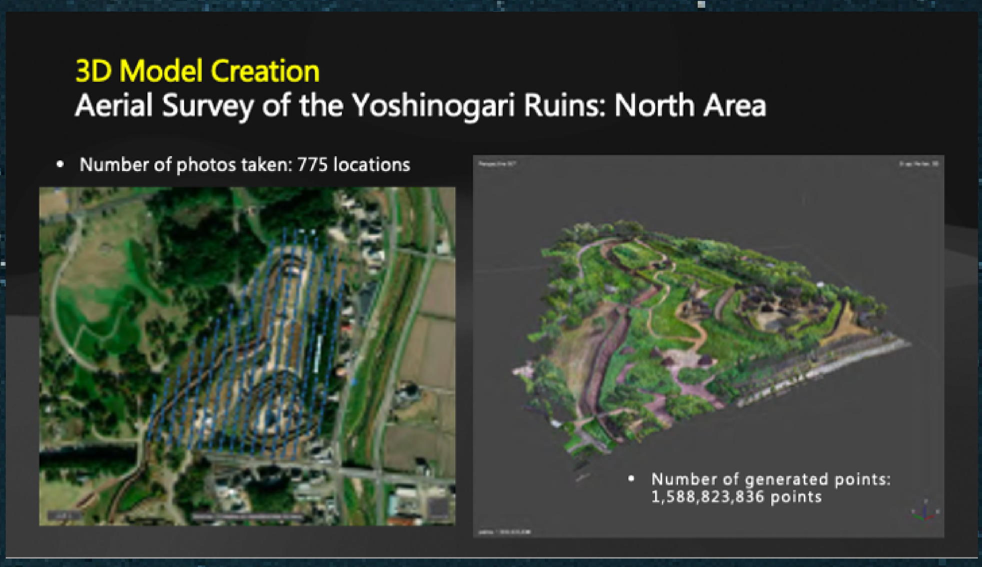
Creating 3D models

3D surveying of the Yoshinogari Ruins was conducted from 2021 to 2022, and a 3D model was created for arcAstroVR using the following steps:

1. Created a point cloud from the survey data
2. Classified the point cloud into terrain, trees, buildings, etc., and then noise-removed
3. Automatically generated a low-polygon model of the terrain based on the classified point cloud
4. Manually created low-polygon models of buildings using the classified point cloud as a reference
5. Created a normal map for the low-polygon model and then created a detailed model
6. Created a texture map for the low-polygon model
7. Outputted the 3D model

Aerial survey data processing

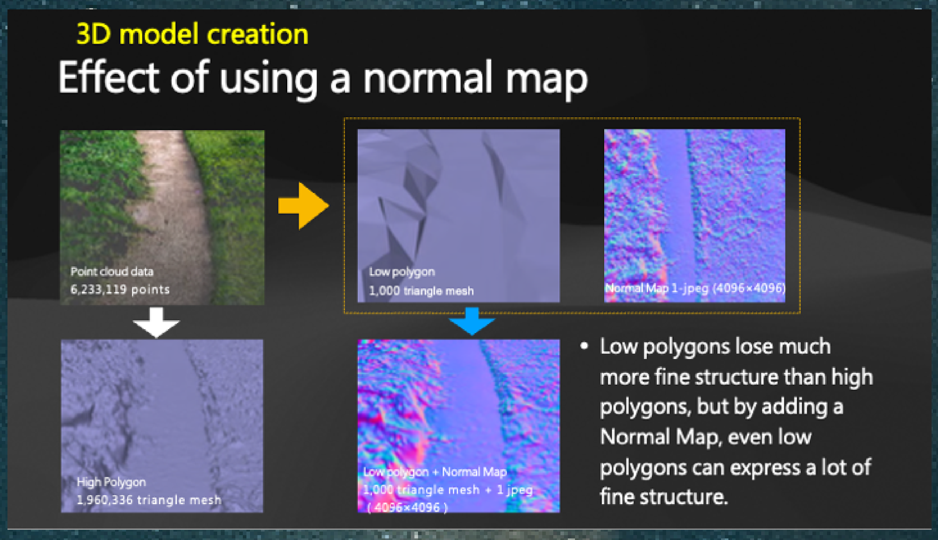
- Using Agisoft's Metashape, the point cloud is separated into terrain and buildings.
- For the terrain point cloud, Metashape's polygonization function is used to output both the highest precision (for creating a normal map) and custom precision (for the polygons actually used) with 100,000 polygons specified.



- For the building point cloud, only the highest precision polygons (for creating a normal map) are output. The low-polygon models that will actually be used will be created manually in Blender, so they are not output here.

Low-polygon and normal map

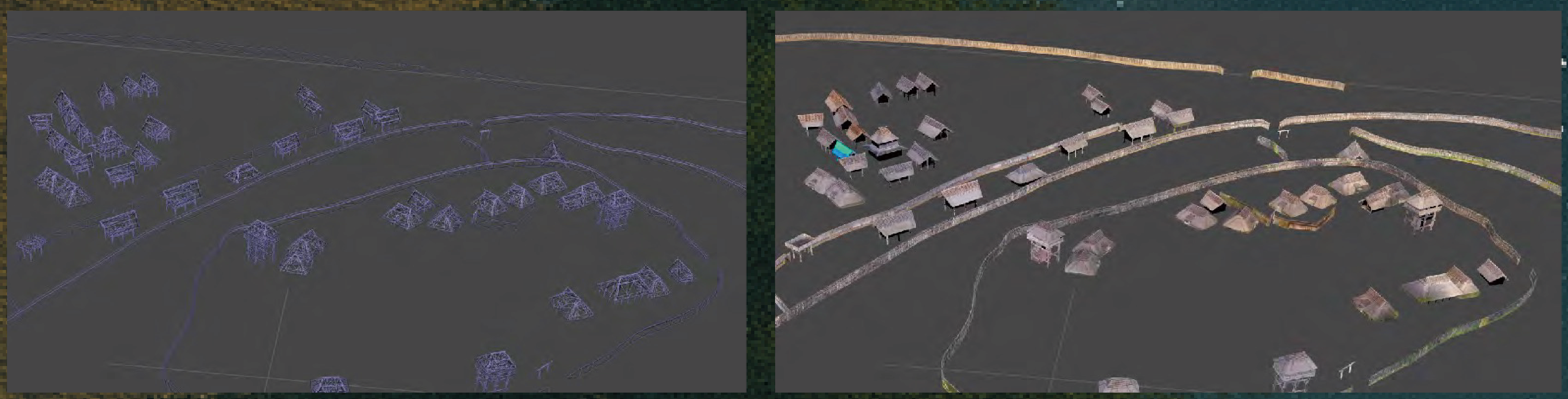
- When the number of polygons is reduced, fine structure is lost. To compensate for this, a normal map is created.



- A normal map is a type of image file (texture) that is attached to polygons, and is an image of the unevenness of the polygon's surface. By imaging polygons with fine irregularities, the number of polygons can be reduced, and the unevenness of the polygon's surface can be simulated from the normal map.
- Even for objects that appear small from a distance, all polygon data must be constructed, but texture images can be compressed according to their apparent size, without affecting accuracy.

Building modelling and texture processing

- A 3D model of a building created with CG software is loaded into Metashape, and textures and normal maps are made based on this 3D model to create a high-precision model.



- After aligning and integrating the point clouds of the building created using the 360-degree camera and the iPhone/iPad LiDAR scanner, we loaded them into CG software (using Blender) and used them as a reference for modelling.

Limitations of arcAstroVR's 3D data

- When converting the entire Yoshinogari area into 3D, the model was too heavy and barely moved at the highest polygon output. Hence, we had to devise a low-polygon approach, similar to that of a 3D game.
- Lightness is measured by low polygon count, high division, and low file size.
- For a model to run in arcAstroVR on a desktop PC (2017 iMac) with specs: GPU: Radeon Pro 580, CPU: Intel Core i7, and memory: 20GB, it is reasonable to aim for a total polygon count of no more than 2 million.

Please visit our web page : https://arcastrovr.org/en/