Depth Sensing & Photogrammetry

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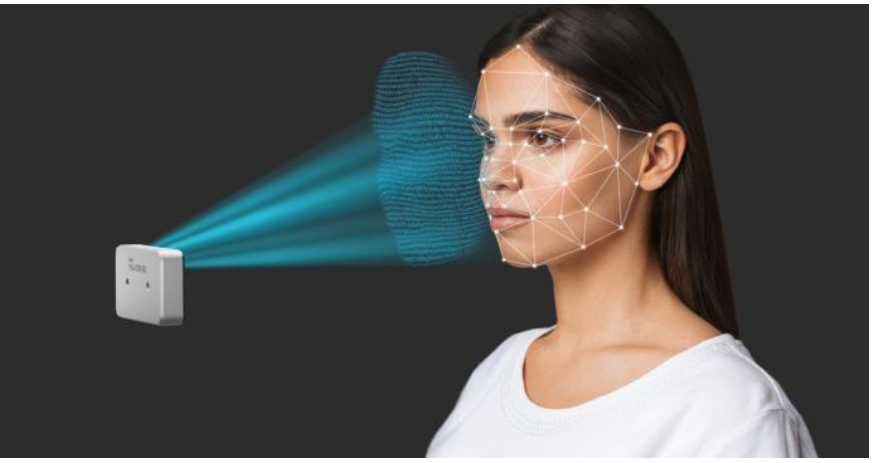
3D Depth Sensing: Definition

Camera technology that records the distance of objects within a scene. Broad Applications:

- Capture the 3D form of things (objects in room)
- Measure the distance between objects in a scene
- Self-driving cars, motion-tracking of hands, bodies
- Navigation tools for the blind
- Facial recognition



https://www.intelrealsense.com/facial-authentication/

3D Depth Sensing

Microsoft Kinect: Licensed from PrimeSense (2010)

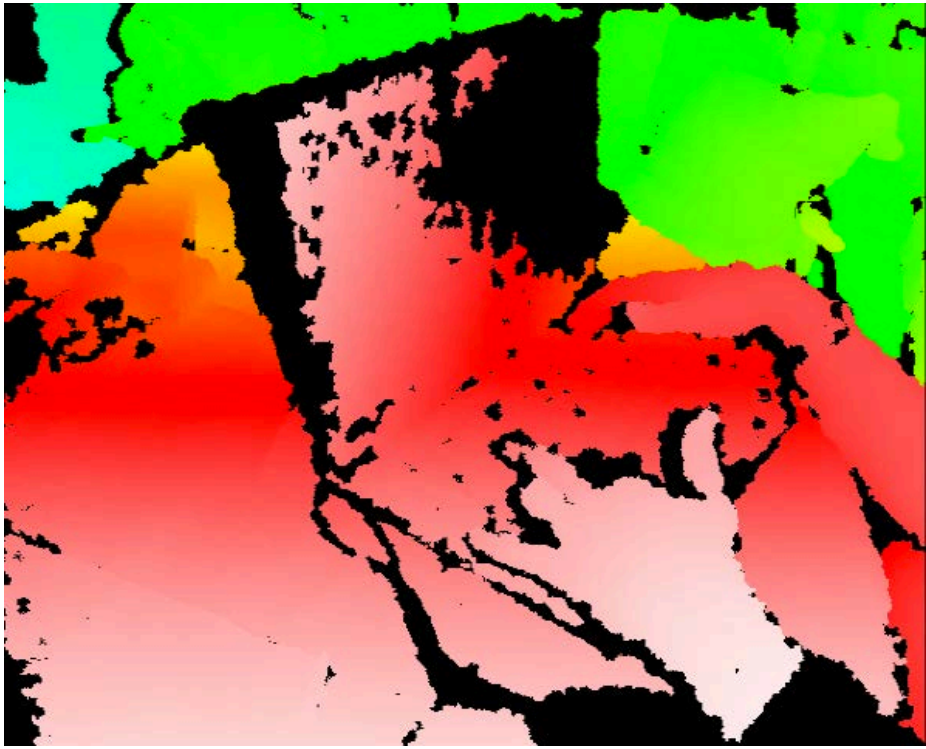
Motion sensing input device (infrared projection/detector)

Analyses projected pattern to measure depth (structured light)

Realtime gesture recognition, body skeletal detection (up to 4 people). Natural user interface

Apple acquired PrimeSense in 2013. Integrated features into iphone

Depth Sensing



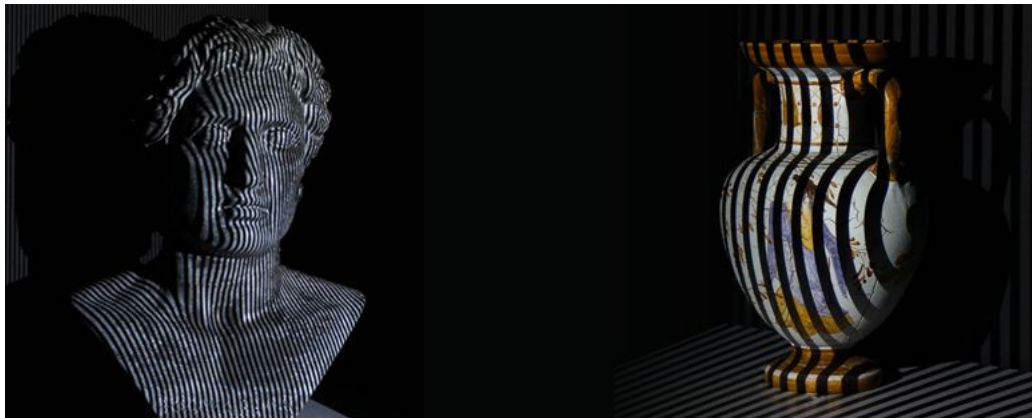
1st version: Near-infrared pattern projected across the space in front of the Kinect, while an infrared sensor captured the reflected light pattern

Next version "time-of-flight": infrared projector on the Kinect sends out modulated infrared light which is then captured by the sensor. Infrared light reflecting off closer objects will have a shorter time of flight than those more distant.

https://en.wikipedia.org/wiki/Kinect#/media/File:Kinect2-deepmap.png

Structured light refers to a known light pattern that is projected onto an object or scene with a projector and is recorded by a minimum of one camera.

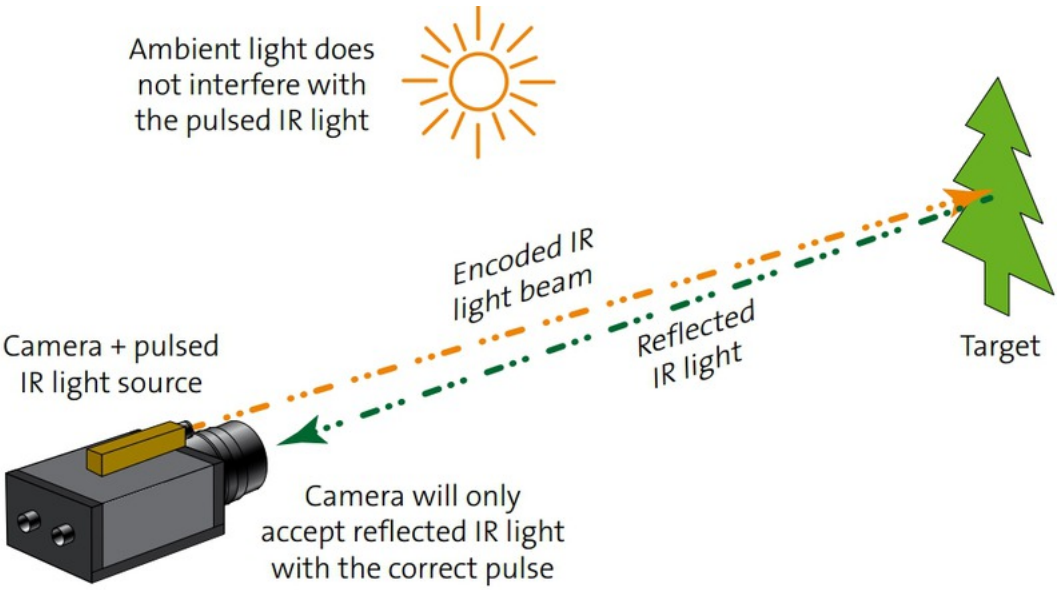
- Cameras placed at known angles to the projector pick up the distorted pattern (usually camera and projector are combined in a single device).
- By calculating the difference between the projected pattern and the distorted pattern observed by the camera, the depth of the scene can be reconstructed and presented as depth map.



3D Depth Sensing: Time of Flight

Time of flight (**ToF**) is the measurement of the time taken by an object, particle or wave (be it acoustic, electromagnetic, etc.) to travel a distance through a medium (air or water or…)

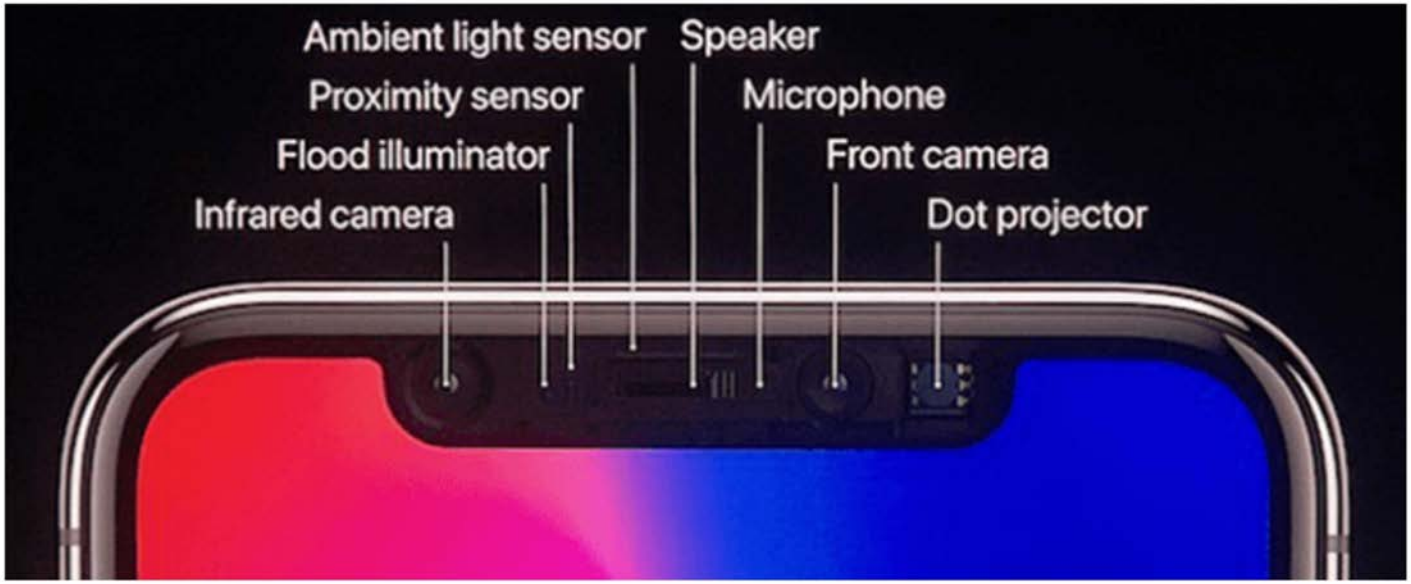
- This information can then be used to measure velocity or path length, or as a way to learn about the particle or medium's properties (such as composition or flow rate).
- The light is usually emitted by LED or laser in the infrared spectrum.



Depth Sensing

What is the TrueDepth camera system?

The iPhone X launched a completely redesigned front camera system. Apple calls this system the TrueDepth camera. What does the TrueDepth camera do? Where is the TrueDepth camera?



Apple's TrueDepth camera system replaces the front facing camera on the iPhone X and later. In addition to a 7 megapixel (MP) camera for photos, the system features several components dedicated to capturing 3D information for Face ID authentication and Animoji.

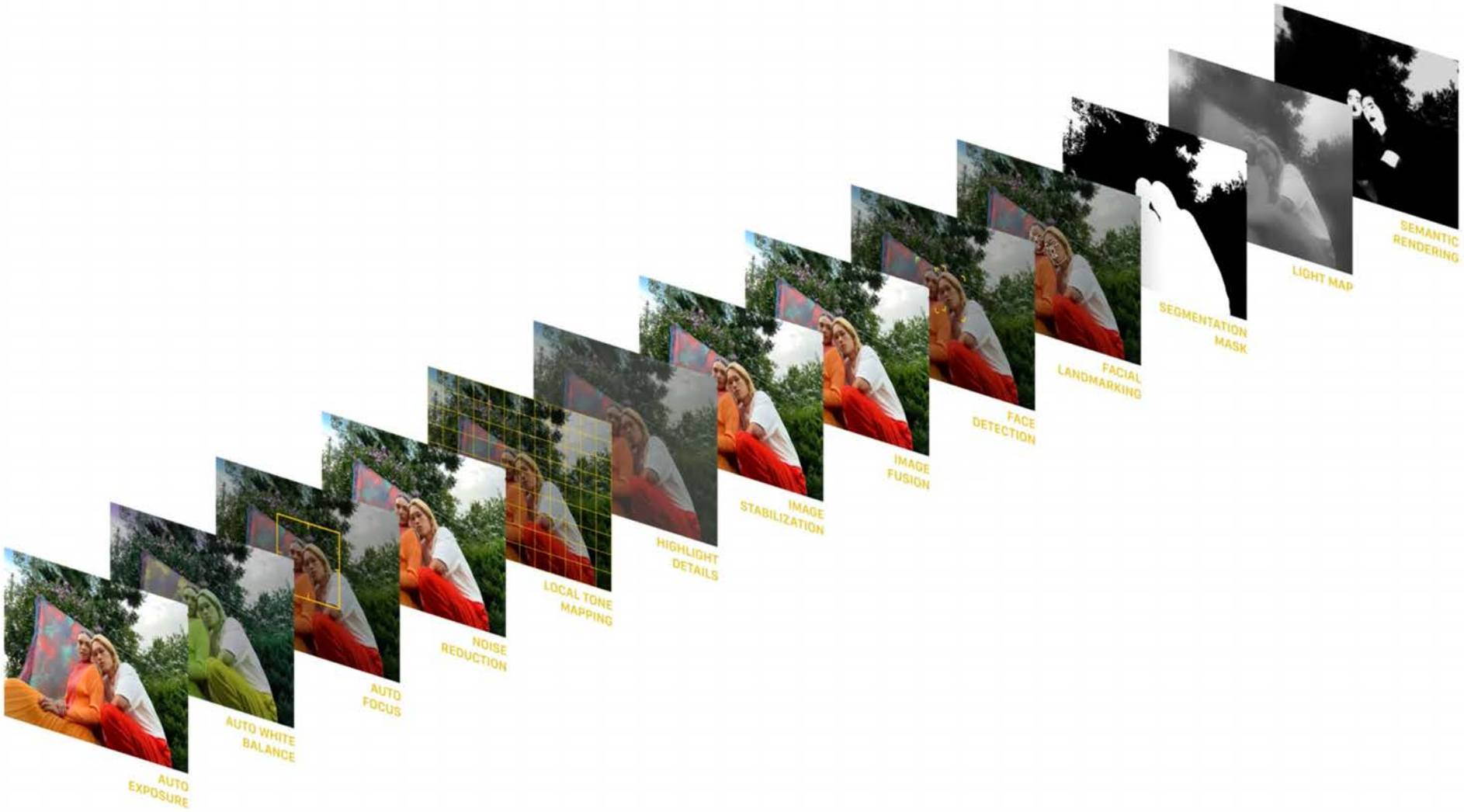
A dot projector throws over 30,000 dots onto the user's face, which are then captured by an infrared camera. To ensure the system operates properly in the dark, a flood illuminator adds more infrared light when needed.

https://www.iphonefaq.org/archives/976228

Iphone 13

https://www.dpreview.com/files/p/articles/6780391159/iPhone13Pro-3CameraModules.jpeg

Image processing in the iphone 13



https://www.dpreview.com/files/p/articles/6780391159/iPhone13-MultiFrameImageProcessingPipeline.jpeg

Dual Photography

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(a) (b) (c) (d)

Figure 1: (a) Conventional photograph of a scene, illuminated by a projector with all its pixels turned on. (b) After measuring the light transport between the projector and the camera using structured illumination, our technique is able to synthesize a photorealistic image from the point of view of the projector. This image has the resolution of the projector and is illuminated by a light source at the position of the camera. The technique can capture subtle illumination effects such as caustics and self-shadowing. Note, for example, how the glass bottle in the primal image (a) appears as the caustic in the dual image (b) and vice-versa. Because we have determined the complete light transport between the projector and camera, it is easy to relight the dual image using a synthetic light source (c) or a light modified by a matte captured later by the same camera (d).

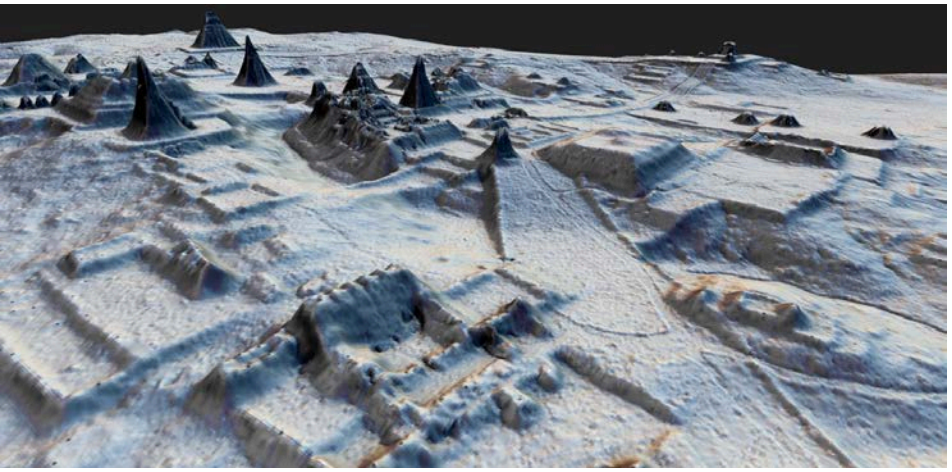
Abstract

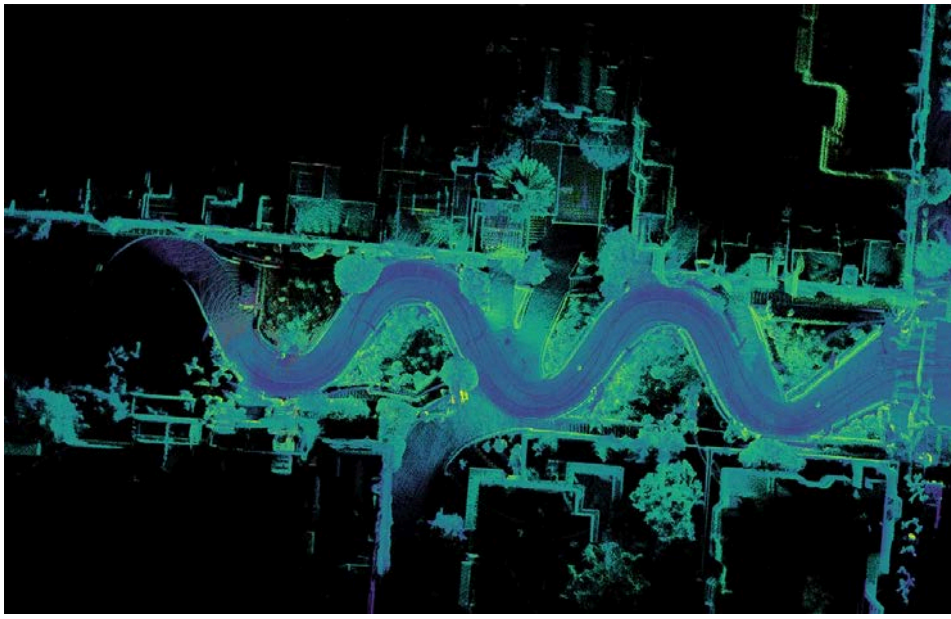
We present a novel photographic technique called dual photography, which exploits Helmholtz reciprocity to interchange the lights and cameras in a scene. With a video projector providing structured illumination, reciprocity permits us to generate pictures from the viewpoint of the projector, even though no camera was present at that location. The technique is completely image-based, requiring no knowledge of scene geometry or surface properties, and by its nature automatically includes all transport paths, including shadows, inter-reflections and caustics. In its simplest form, the technique can be used to take photographs without a camera; we demonstrate this by capturing a photograph using a projector and

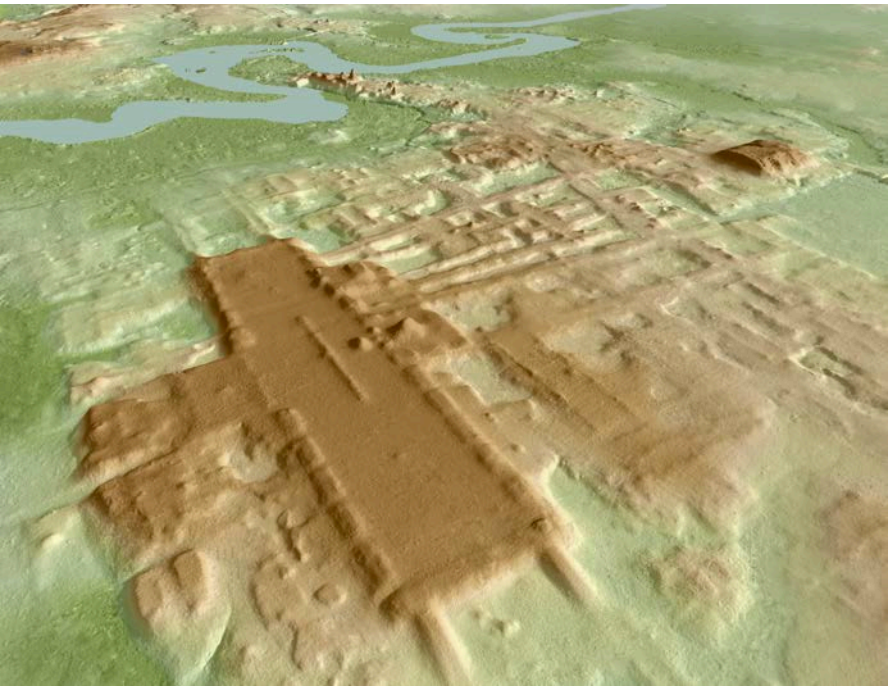
1 Introduction

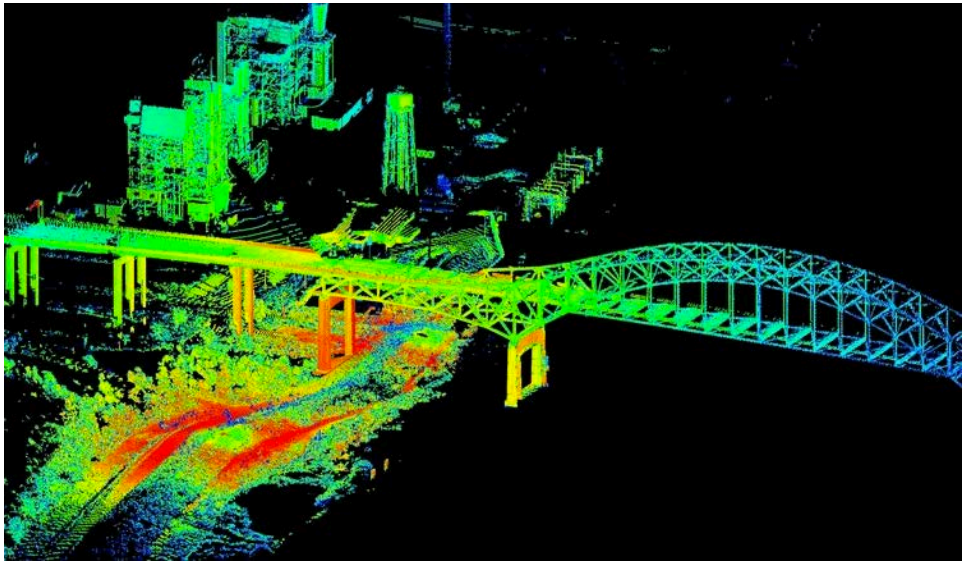
Helmholtz reciprocity, the idea that the flow of light can be effectively reversed without altering its transport properties, is exploited in many graphics applications to reduce computational complexity (e.g. in ray-tracing systems [Whitted 1980]). In the graphics literature, this reciprocity is typically summarized by an equation describing the symmetry of the radiance transfer between incoming and outgoing directions ω_i and ω_o: $f_r(\omega_i \rightarrow \omega_o) = f_r(\omega_o \rightarrow \omega_i)$, where f_r represents the BRDF of the surface. Although this general form is often attributed to Helmholtz, his original treatise on optics makes this claim only for specular interactions [1856]. Rayleigh later extended reciprocity to include non-specular reflection [1900].

Lidar: Light Detection And Ranging



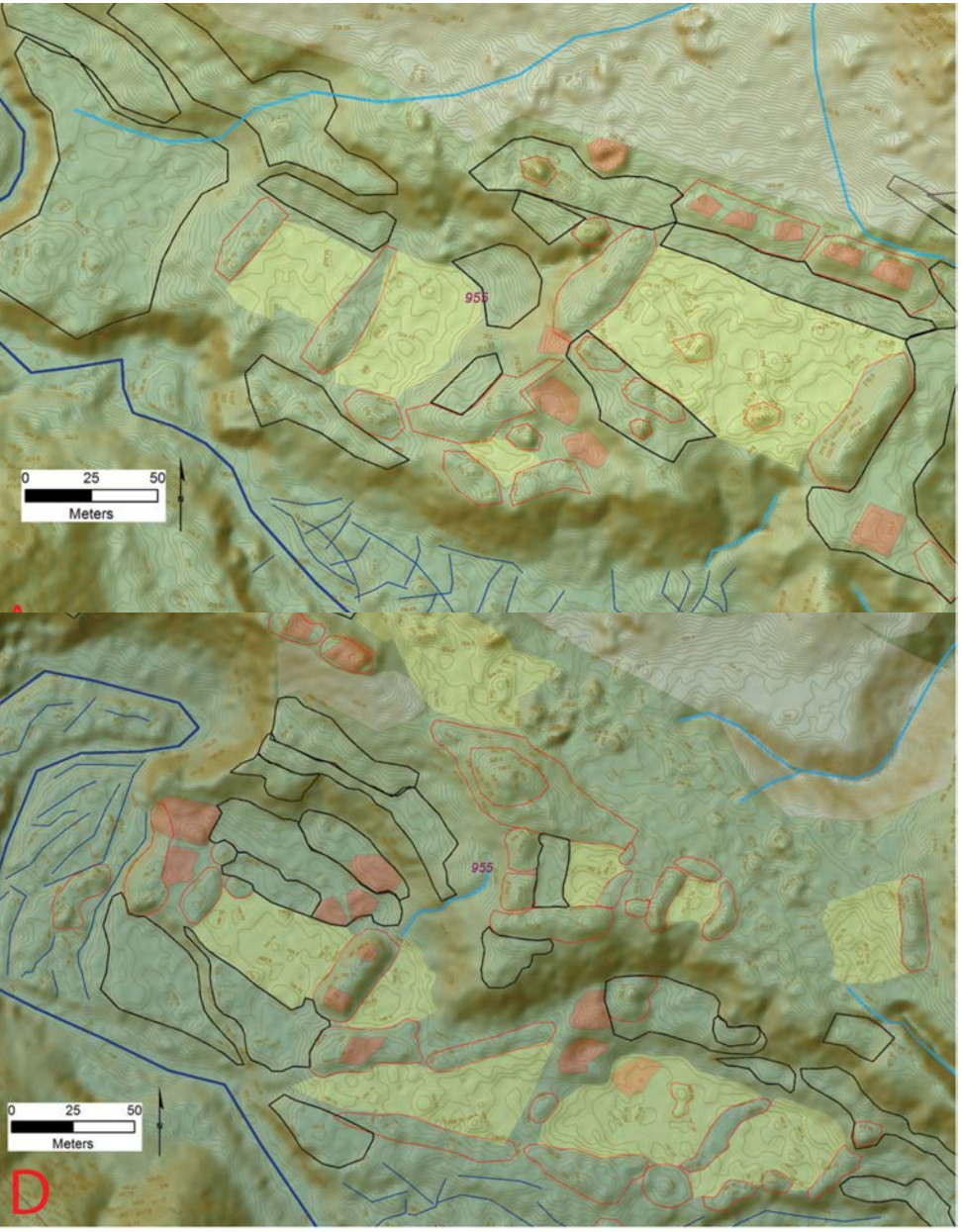






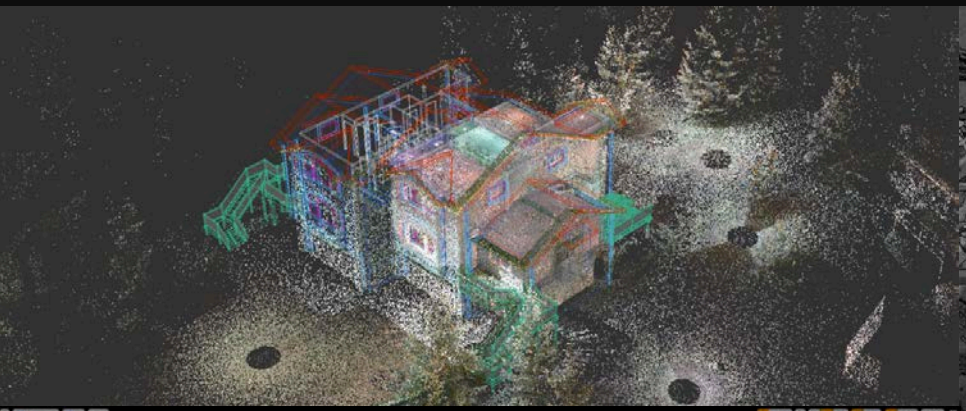
https://ouster.com/blog/lidar-mapping-with-ouster-3d-sensors/

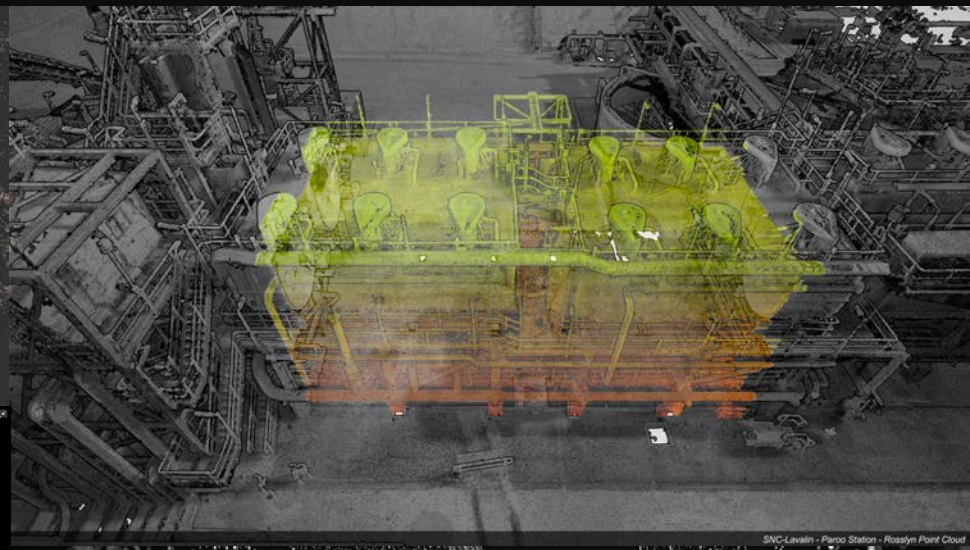
Lidar: Ancient Settlement Patterns in Mosquitia, Honduras (2016)

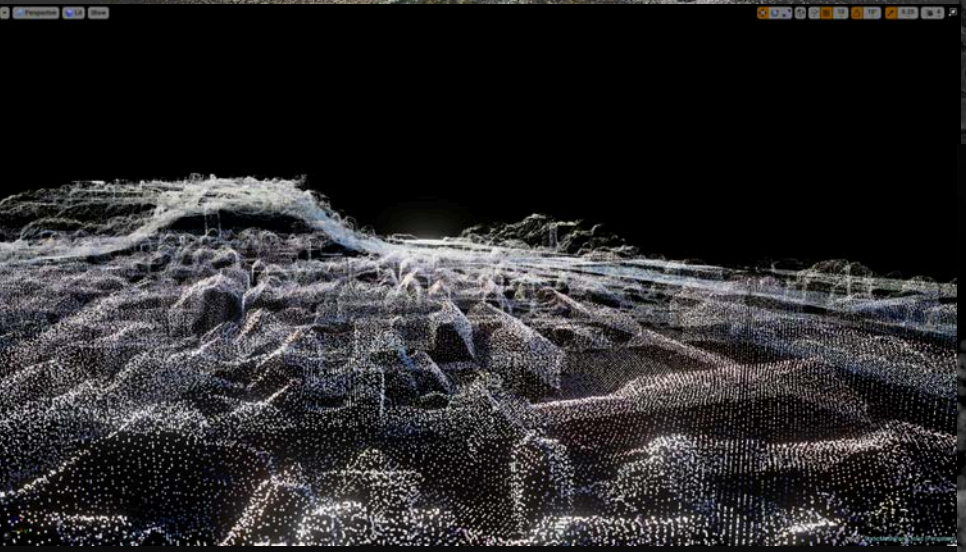


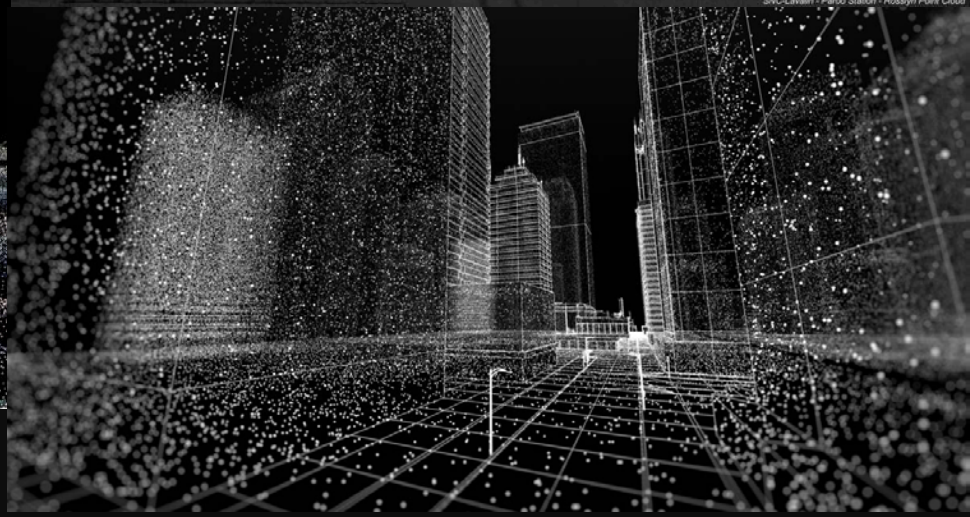
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0159890

Point Cloud



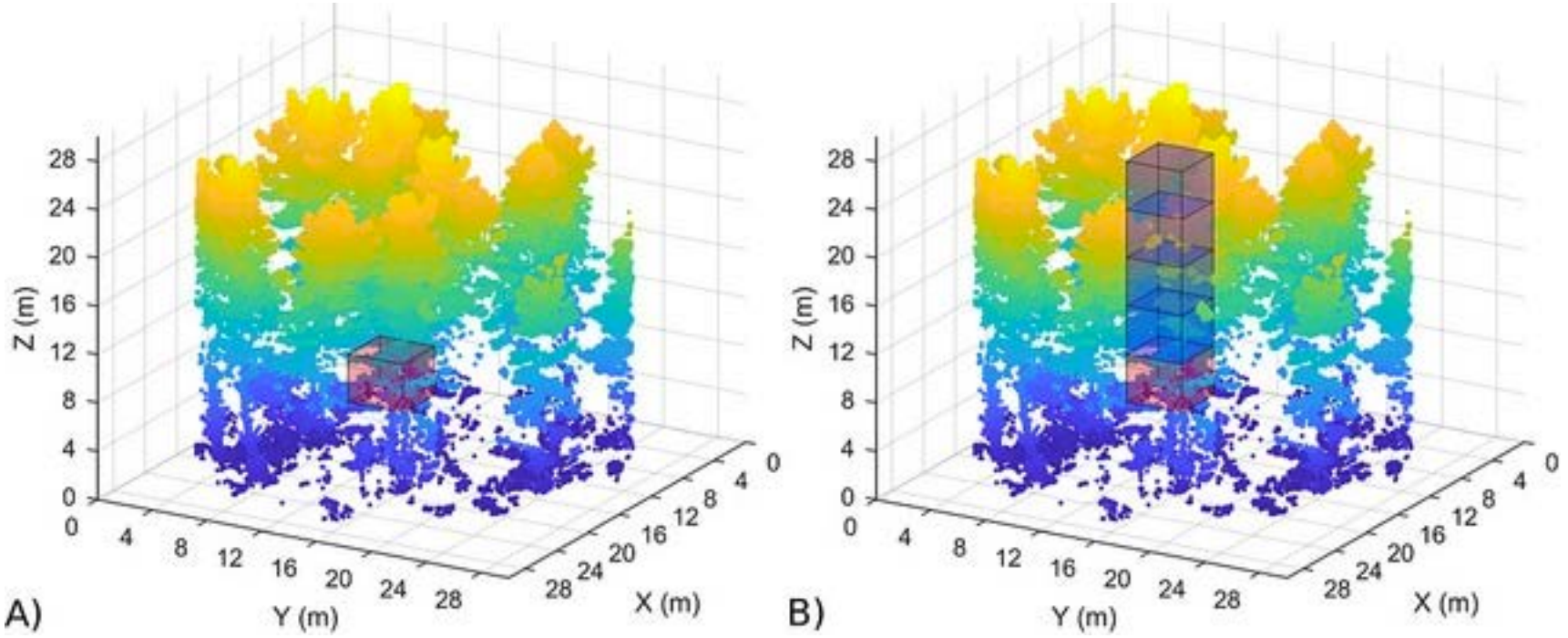






https://answers.unrealengine.com/questions/572630/view.html

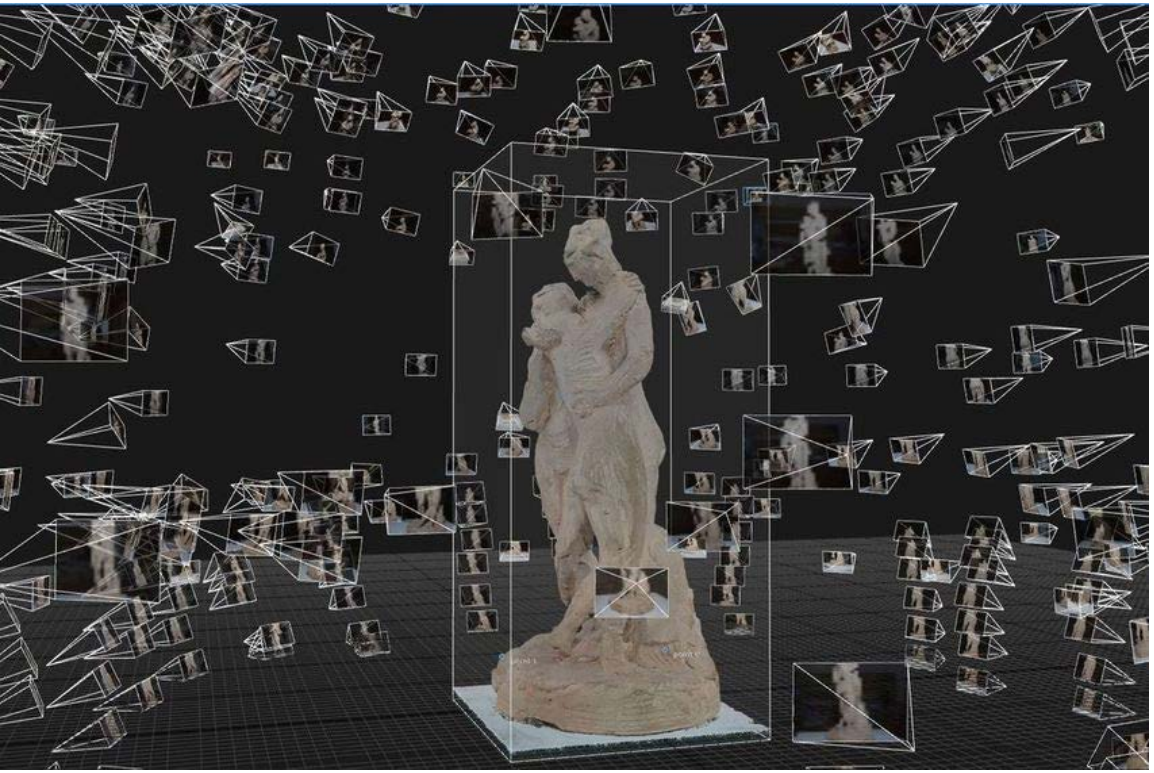
Voxel: A 3D pixel



Voxels can be thought of as 3D pixels or cubes that are formed around a 3D point cloud.

https://www.scionresearch.com/about-us/about-scion/corporate-publications/scion-connections/past-issues-list/scion-connections-issue-30,-december-2018/voxel-based-metrics-prove-more-accurate-for-forest-inventory

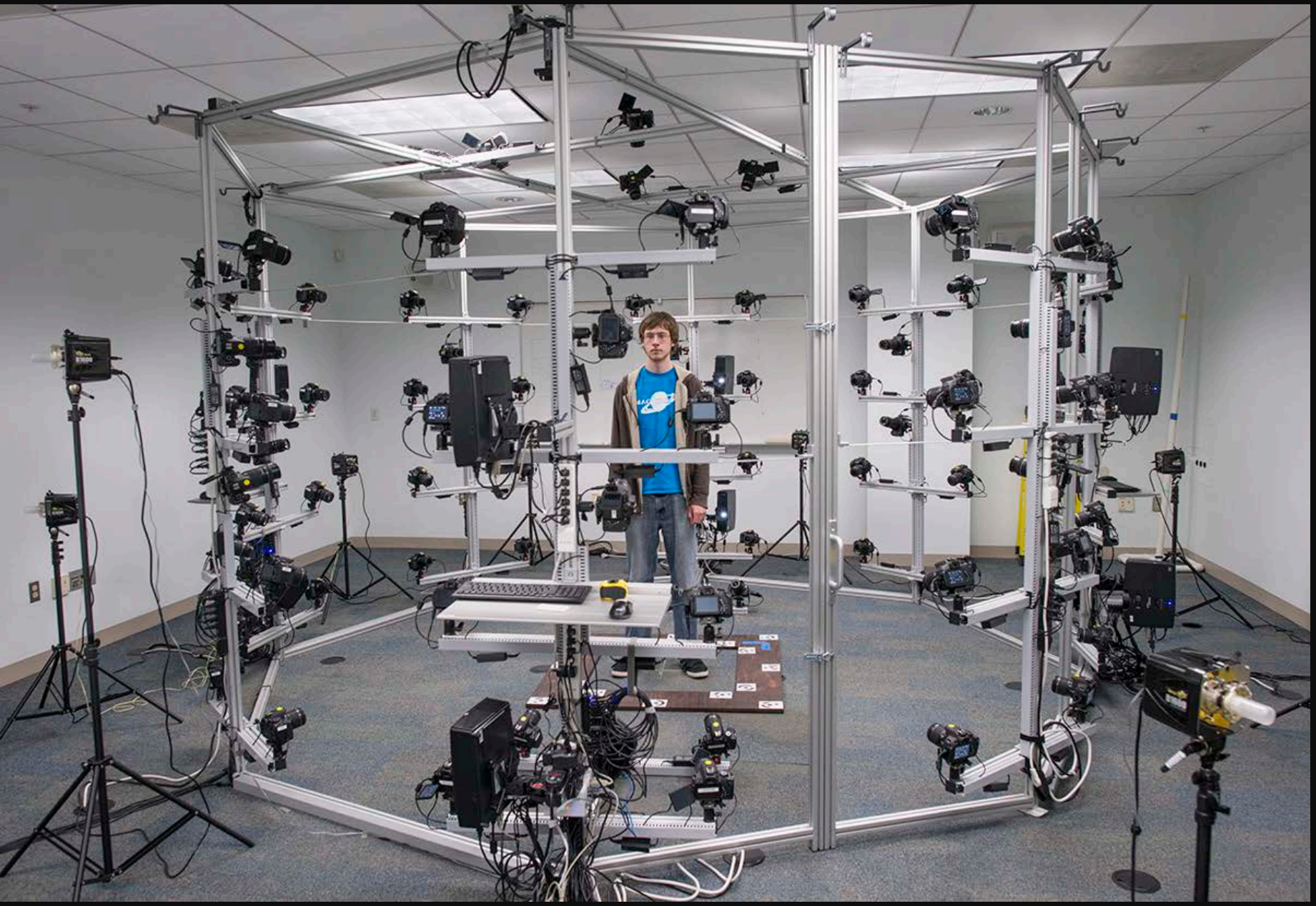
Point Cloud Photogrammetry in Cultural Heritage



Photogrammetry is a 3D recording technique that employs 2D images to create a 3D model of an object or surface. It involves taking hundreds of overlapping photographs of an object from many different angles and processing them using specialised software such as RealityCapture (RC) or Agisoft PhotoScan. The digital 3D model can be used for study or outputted as a physical object via 3D printing or CNC milling.

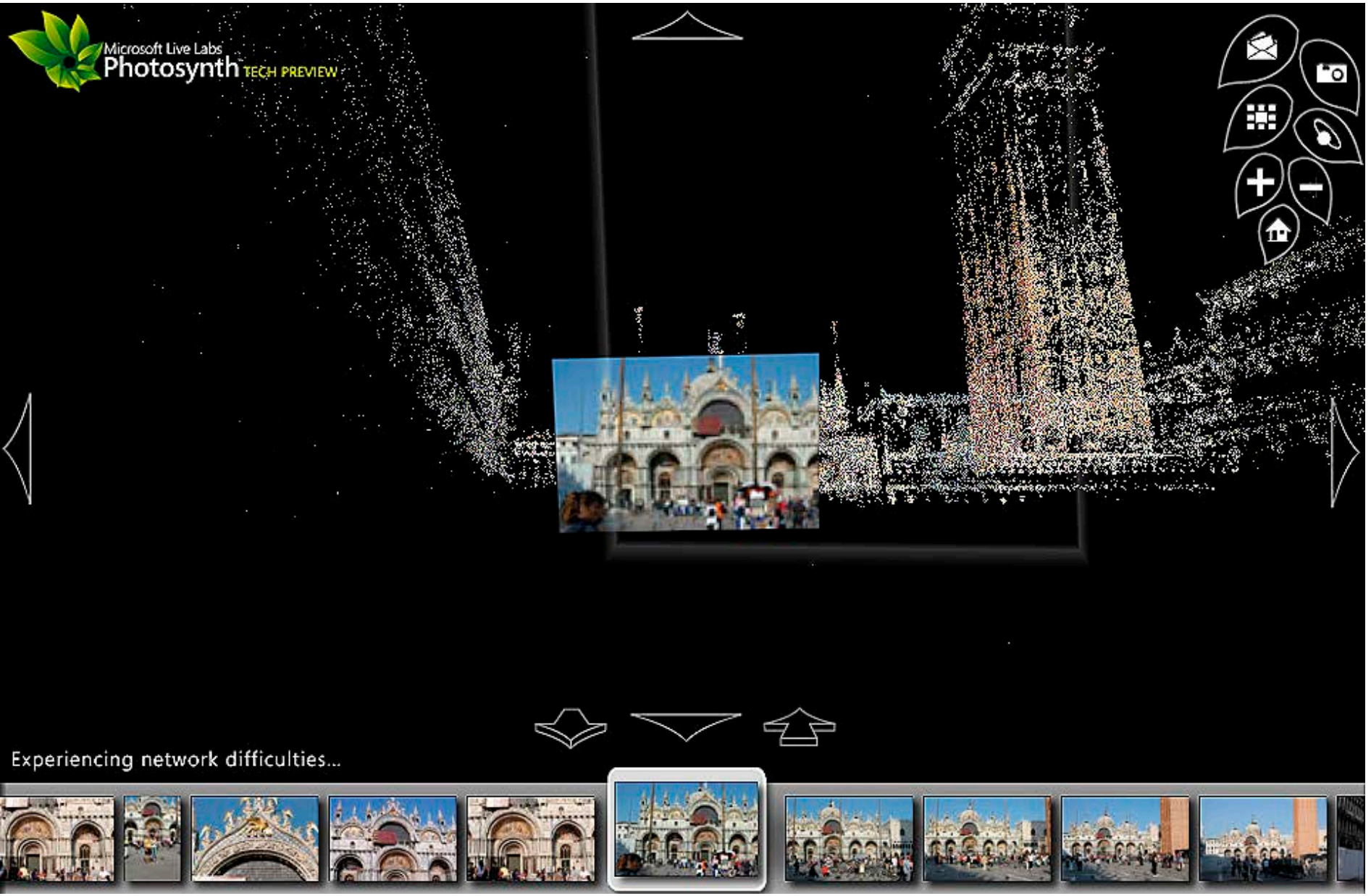
https://www.factumfoundation.org/pag_fa/1345/photogrammetry

3D Photogrammetry Scanning



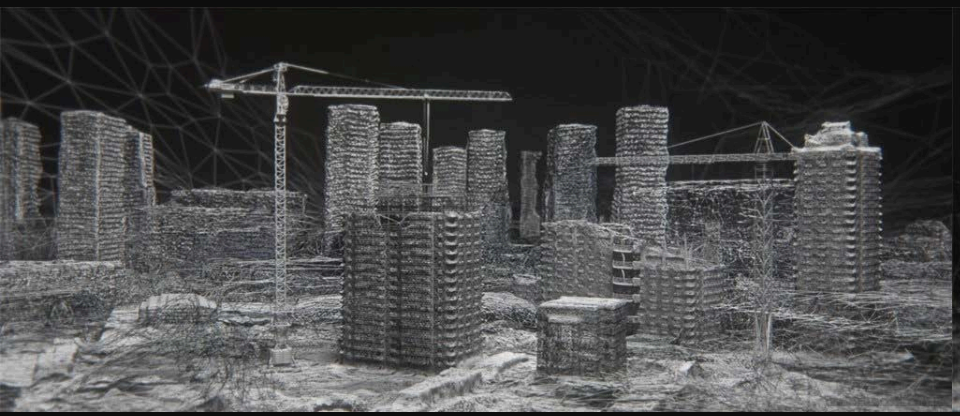
http://photogrammetry.irc.umbc.edu/

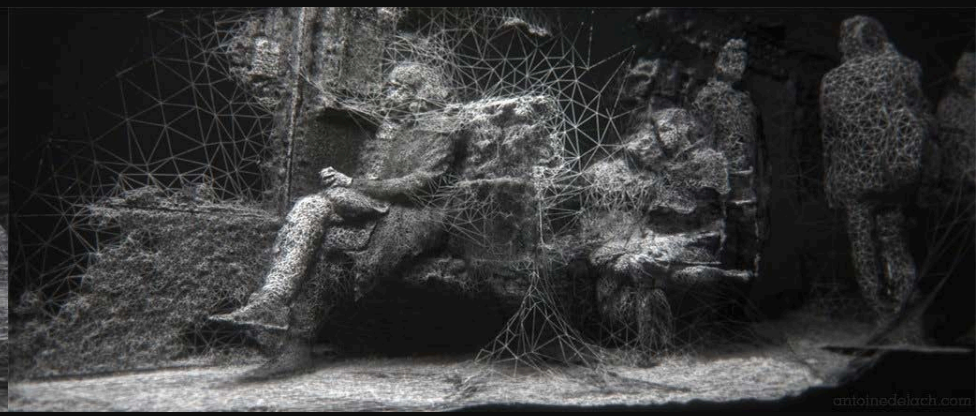
PhotoSynth (discontinued): Photos to interface with others on the Web



https://www.ted.com/talks/blaise_aguera_y_arcas_how_photosynth_can_connect_the_world_s_images

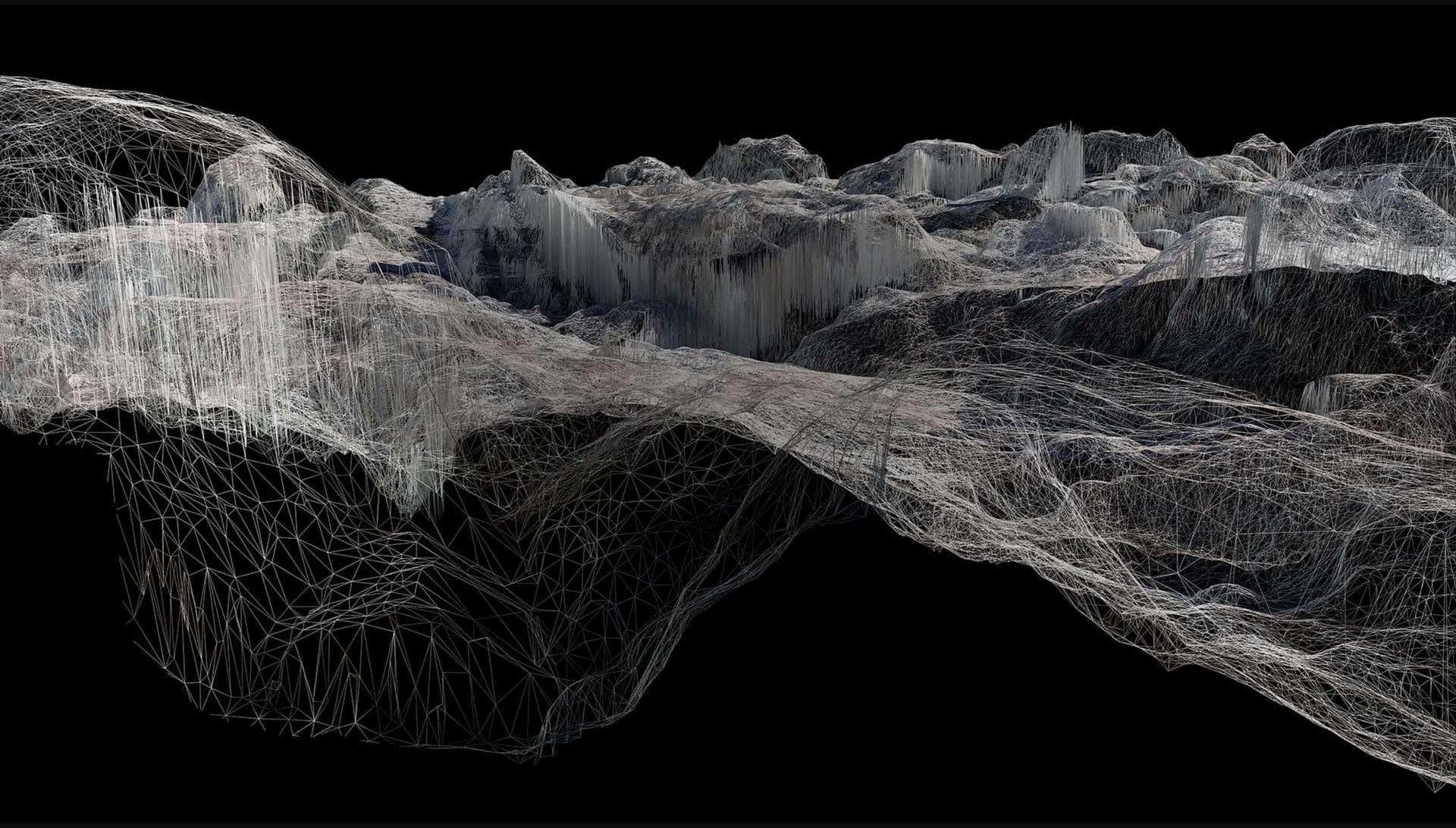
Ghost Cell





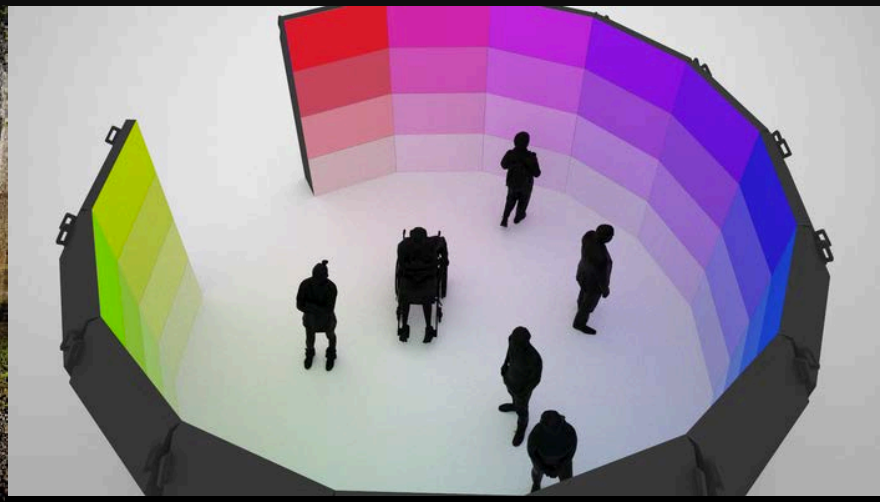
http://www.antoinedelach.com/GHOST-CEL/

“Continuous Topography”, Dan Holdsworth (2016-2018)



https://www.atlasofplaces.com/photography/continuous-topography/

Parragirls Past, Present (2017)



https://kuchelmeister.net/portfolio/parragirls-past-present/

To be continued…