Automated 3D model reconstruction from photographs

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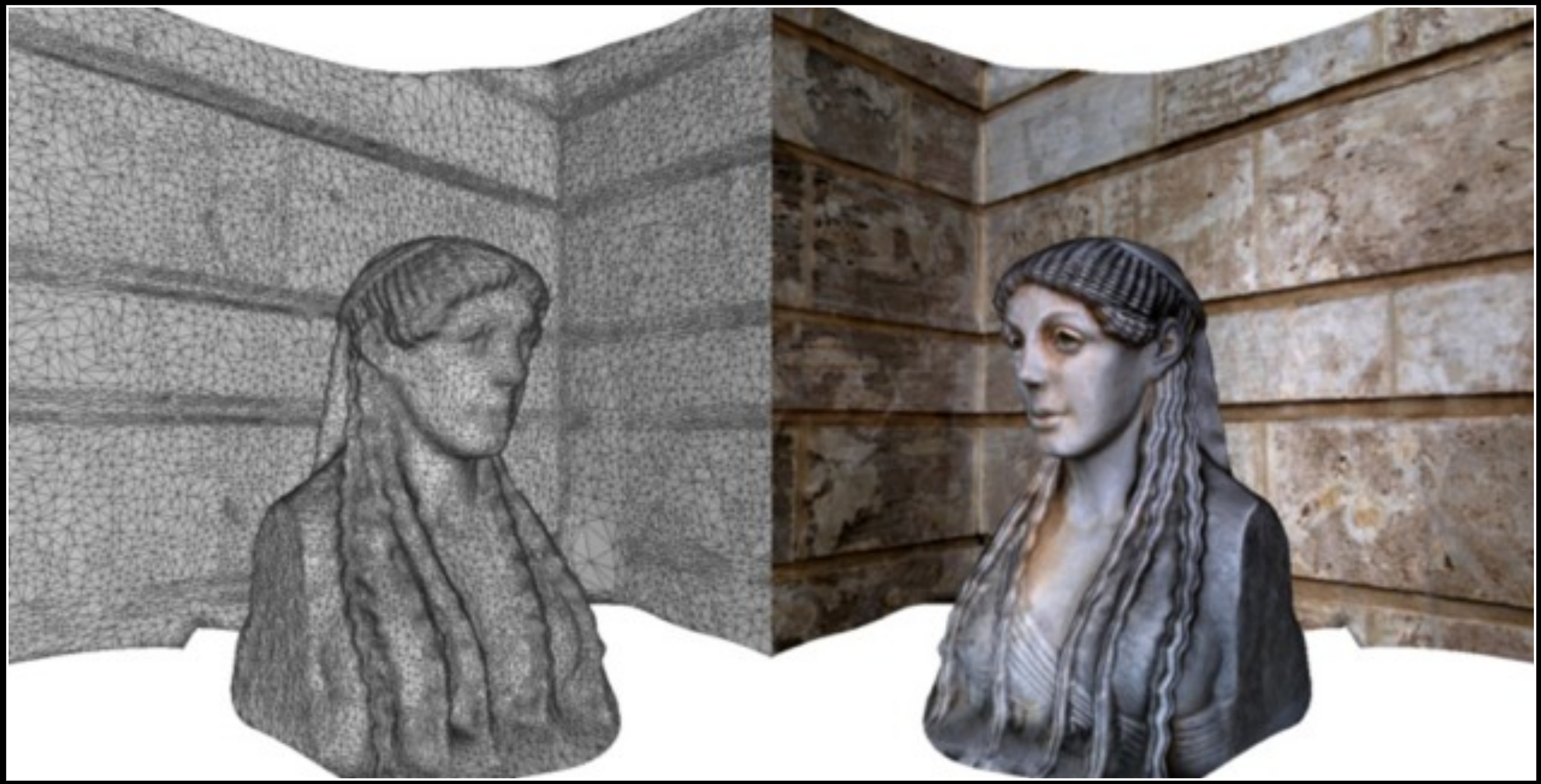


Outline

- Introduction, Outcomes, Motivation
- Software
- Photography
- Case study 1: 2.5D
- Geometry processing
- Case study 2: 3D
- Other related topics
- Limitations and challenges
- Case study 3: Worked example, grinding stone
- Additional applications
- Further reading, references, and discussion
- Experiments / workshop

These slides will be made available online so no need to take notes.

Outcomes

- Familiarity with the state of the technology.
- Knowing what questions to ask.
- Understand the terminology.
- Familiarity with the software and tools.
- Some expectations of the limitations.
- Knowledge of a range of applications/research the technology is being applied to.

3D reconstruction from (ad hoc) photographs

- Goal: Automatically construct 3D geometry and texture based solely upon a number of photographs.
- Similar to traditional photogrammetry but employs different algorithms.
- Creating richer objects (compared to photographs) for recordings in archaeology and heritage.
- Create geometric models suitable for analysis, eg: in geology or geoscience.
- Wish to avoid any in-scene markers required by some solutions.
Often impractical (access) or not allowed (heritage).
- Want to target automated approaches as much as possible.
[Current site surveys recorded 100’s of objects].

Motivation : Virtual worlds, Serious gaming

- Creating 3D assets for virtual environments, serious games.
- Removes the need for time consuming 3D modelling.
- Removes the interpretation that can occur if one models real objects with organic forms.

Movie

Beacon Island

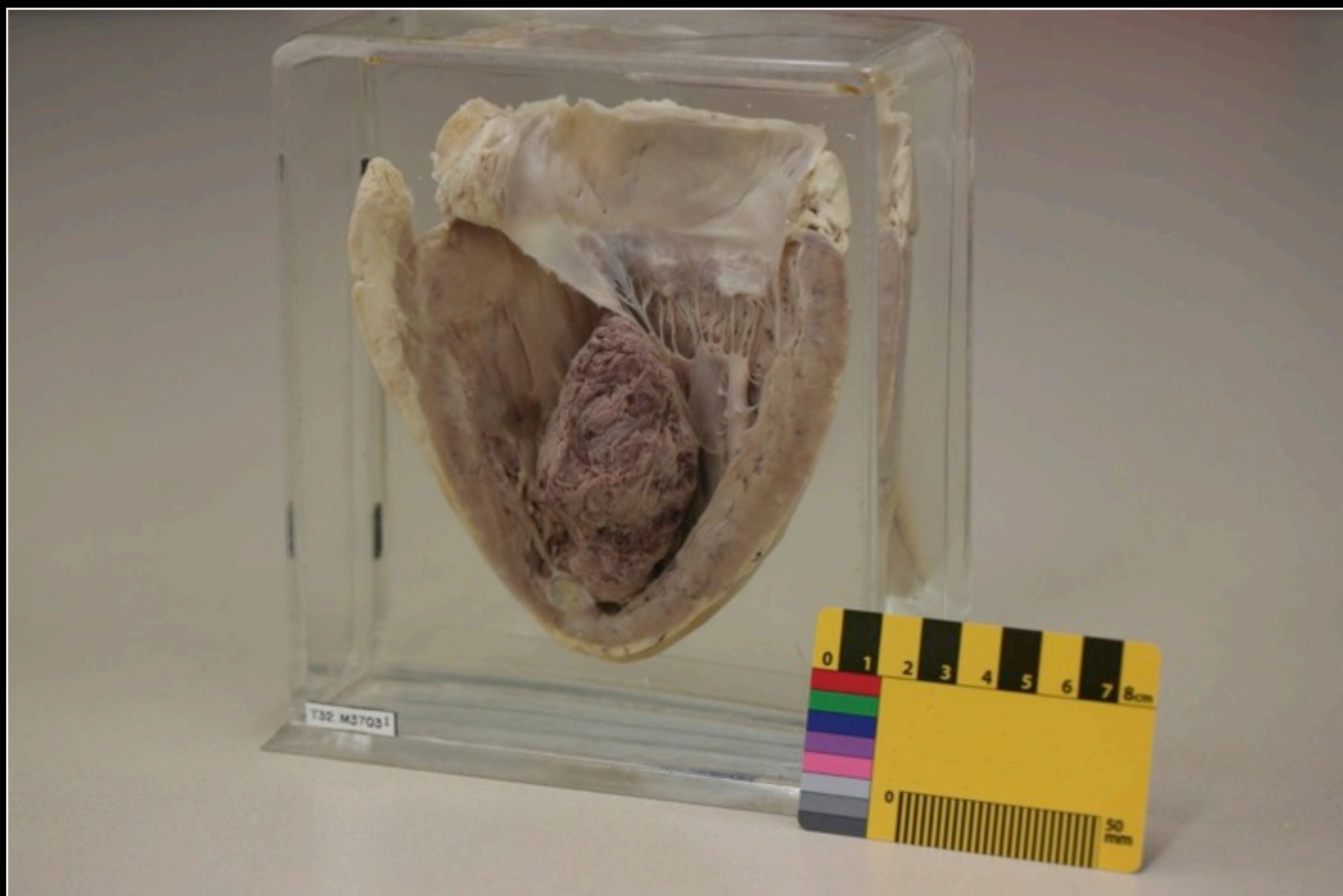
Motivation: Assets for virtual heritage

Movie

Beacon Island

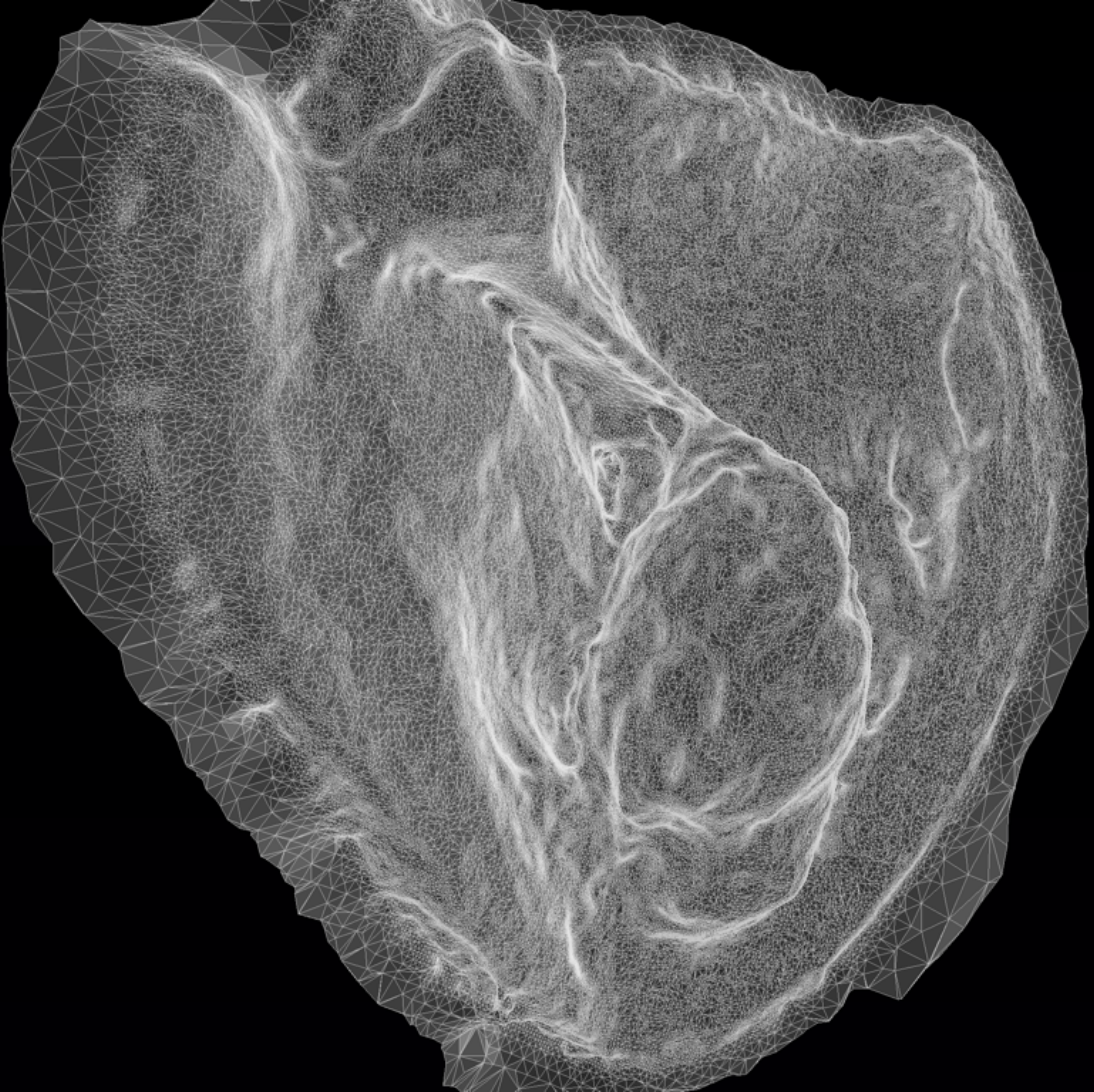
Motivation : Research

- Medical applications.
- Non intrusive capture can have advantages.
- Capture of 3D objects for forensic analysis.



Pathology, QE II

Movie



Motivation : Geology

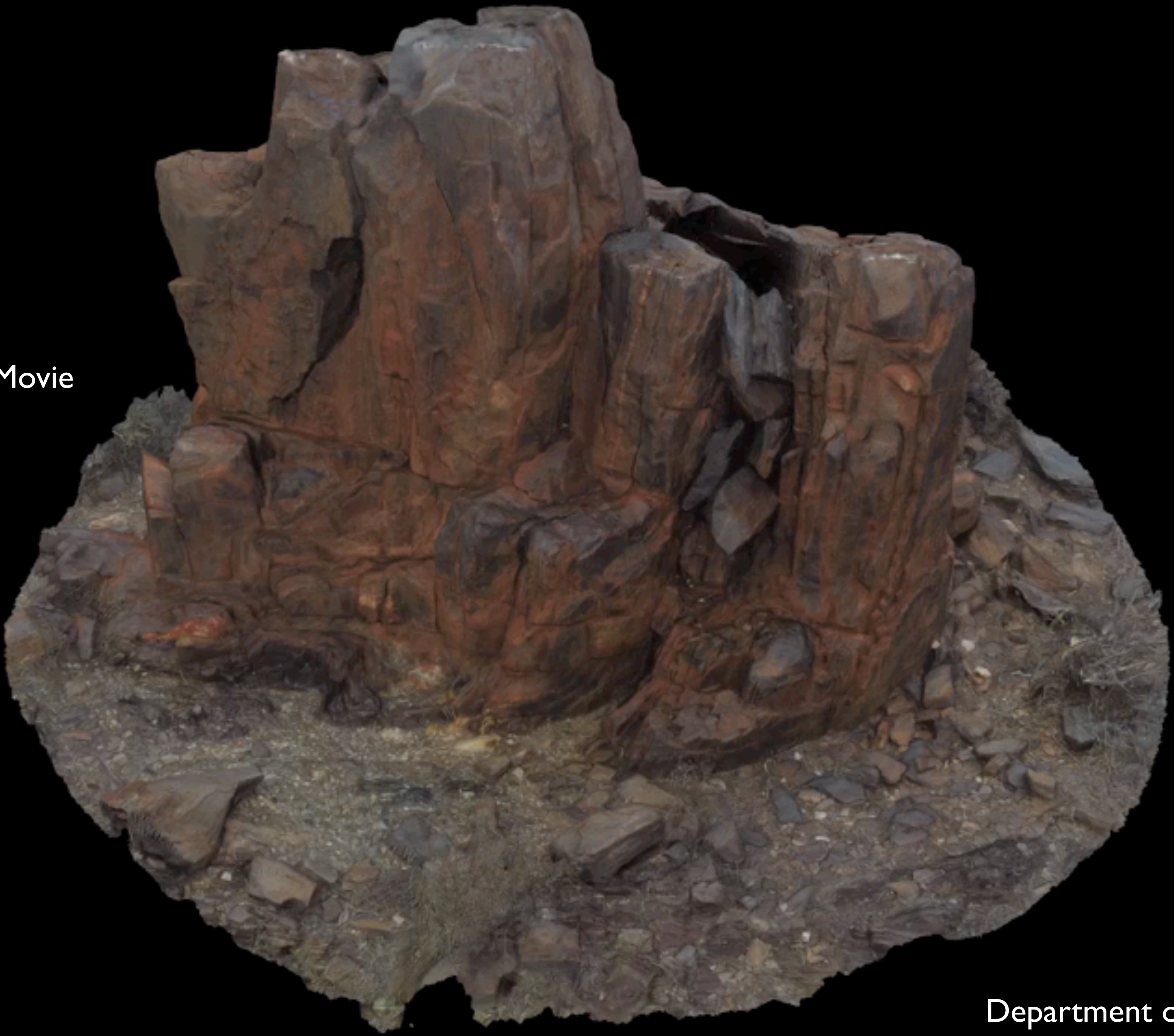
- Aim to apply analysis techniques to the surface.
- Fault line detection, bulk properties, etc.

Movie

Motivation : Geoscience

- Capturing geological structures for analysis.
- Often in difficult terrain.

Movie

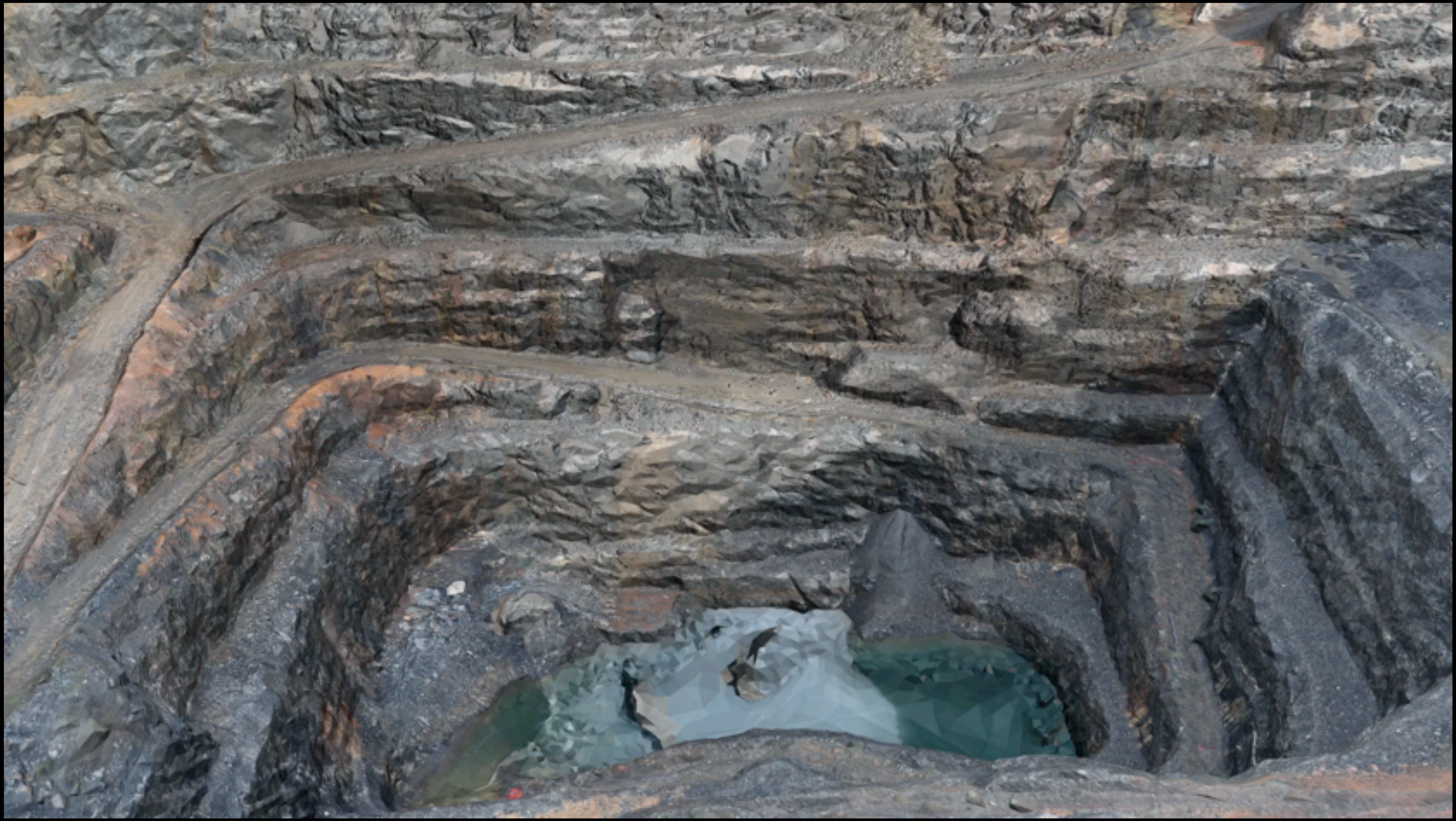


Department of Mines and Petroleum

Motivation : Mining

- Capture rock volume removed in mining operations.
- Advantages from a safety perspective, don't have to close down operations to allow surveyors on site.

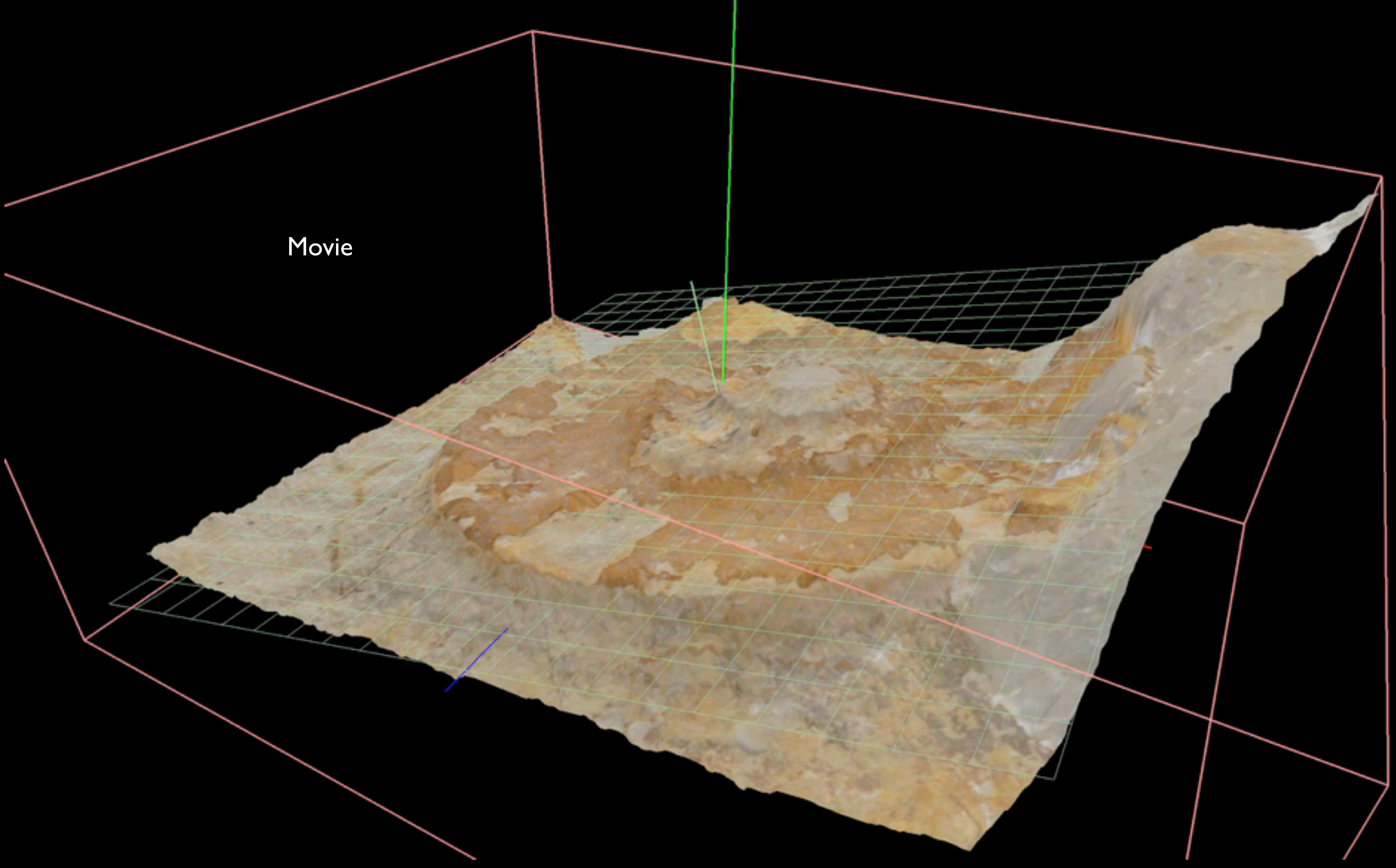
Movie



Centre for Exploration Targeting, UWA

Motivation : Fossil

- Non-destructive capture.
- Ability to perform structural analysis, derive metrics.



Motivation: Artefacts in cultural heritage

Movie

Ngintaka, South Australia Museum

Motivation: Heritage preservation

Movie

Dragon Gardens, Hong Kong

History

- Photogrammetry is the general term for deriving geometric knowledge from a series of images.
- Initially largely used for aerial surveys, deriving landscape models.
  Generally stereoscopic, that is, just two photographs.
- More recently the domain of machine vision, for example: deriving a 3D model of a robots environment.
- Big step forward was the development of SfM algorithms: structure from motion.
  This generally solves the camera parameters and generation of a 3D point cloud.
- Most common implementation is called Bundler: “bundle adjustment algorithm allows the reconstruction of the 3D geometry of the scene by optimizing the 3D location of key points, the location/orientation of the camera, and its intrinsic parameters”.

Other technologies

- In some areas it is starting to replace technologies such as laser scanning. LIDAR - light detection and ranging.
  - particularly so for capture of object in difficult locations
  - only requires modest investment

- Another technology are so called depth cameras
  - Primesense (eg: Kinect)
  - Structured light techniques (eg: Artec Scanner)

- Both in theory can give more accurate results. Subject to debate.

- Both also have limitations around lighting conditions and range.

- Future: Light field cameras (plenoptic camera).
  - Captures an array of images from a grid of positions

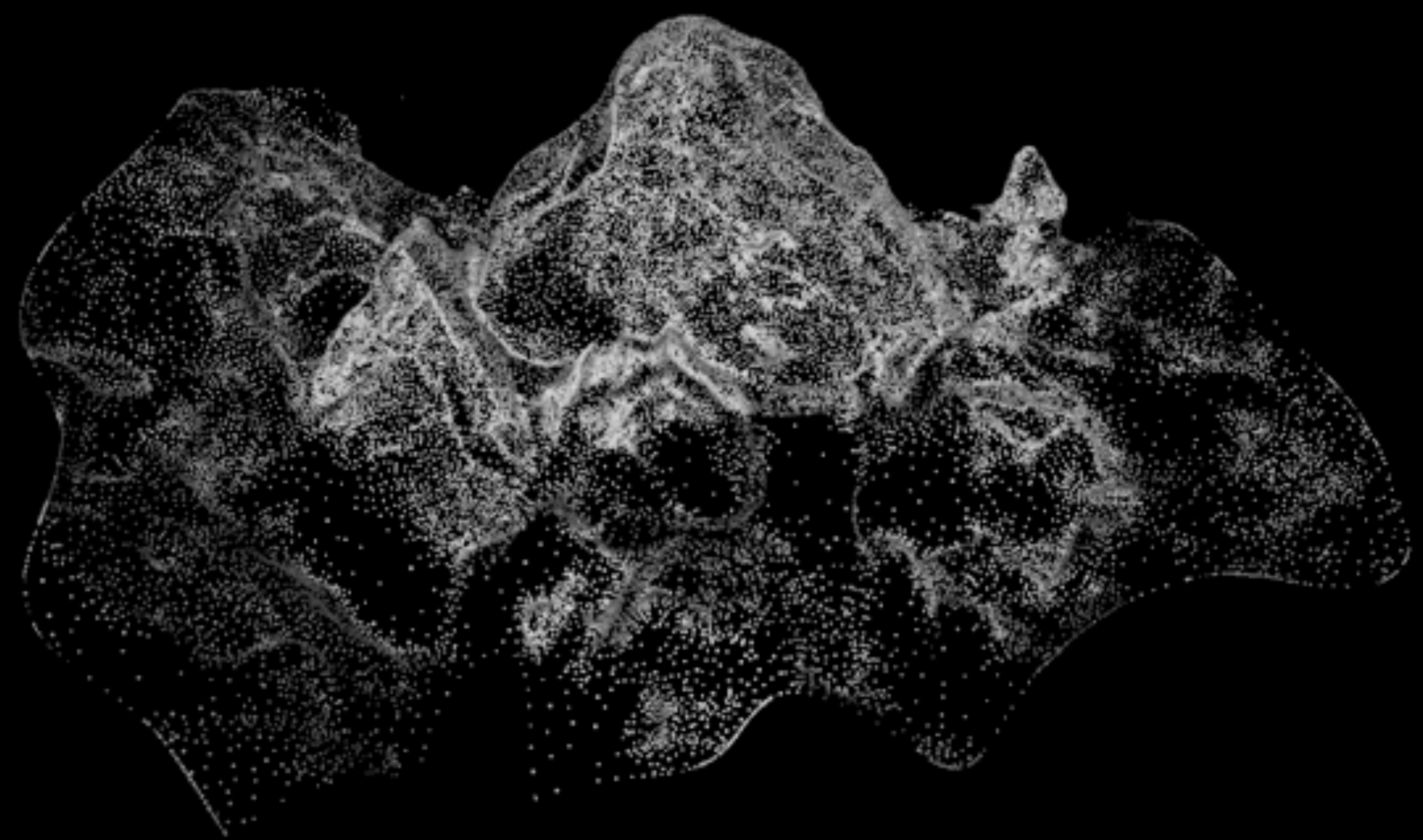
LIDAR

Structured light

Software

- Processing pipeline from a number of opensource projects
- SiroVision
- PhotoScan
- PhotoSynth
- PhotoModeller / Scanner
- 123D Catch
- Visual SfM (Structure from Motion)

- Apero (not yet evaluated)
- AdamTech solution (not yet evaluated)
- iWitness Pro (not yet evaluated)



Movie

Software : Pipeline components

- Perform lens calibration (only done once, can be optional)
- Read images, correct for lens, and compute feature points between them (eg: SIFT - scale invariant feature transform)
- Compute camera positions and other intrinsic camera parameters (eg: Bundler, SfM - Structure from Motion, http://phototour.cs.washington.edu/bundler/)
- Create sparse 3D point cloud, called “bundle adjustment” (eg: PMVS - Patch-based Multi-view Stereo, http://www.di.ens.fr/pmvs/)
- Create dense point cloud (eg: CMVS - Clustering Views for Multi-view Stereo, http://www.di.ens.fr/cmvs/)
- Form mesh from dense point cloud (eg: ball pivoting, Poisson Surface Reconstruction, Marching Cubes)
- Reproject images from camera positions to derive texture segments
- Optionally simplify mesh (eg: quadratic edge collapse decimation) and fill holes
- Export in some suitable format (eg: OBJ files with textures)

Software : Typical pipeline

SIFT for key point extraction between images

↓

SfM software package Bundler to generate a sparse 3D point cloud

↓

PMVS2 (Patch-based Multiview Stereo software) to reconstruct the model of the imaged scene as dense point cloud

↓

Convert point cloud to mesh

↓

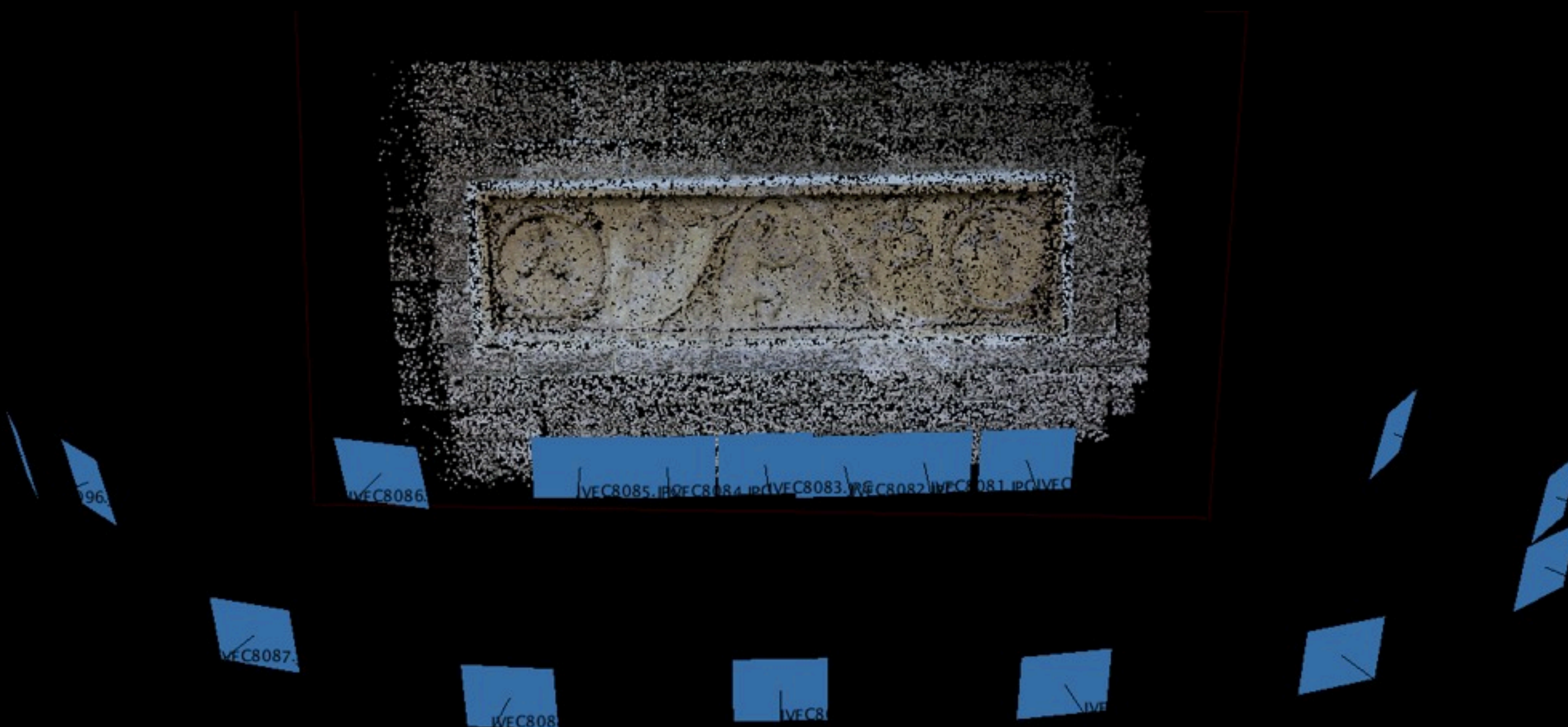
Re-project textures

Software: Pipeline - Photographs

- Don’t take two photos from the same position.
- Obviously can’t reconstruct what is not photographed.
- In general, more is better. Can always analyse just a subset of the images.

Software: Pipeline - Sparse point cloud

- Find matching points between photographs, feature point detection.
  SIFT - scale invariant feature transform
- Compute camera positions and other intrinsic camera parameters.
  Bundler, SfM - Structure from Motion

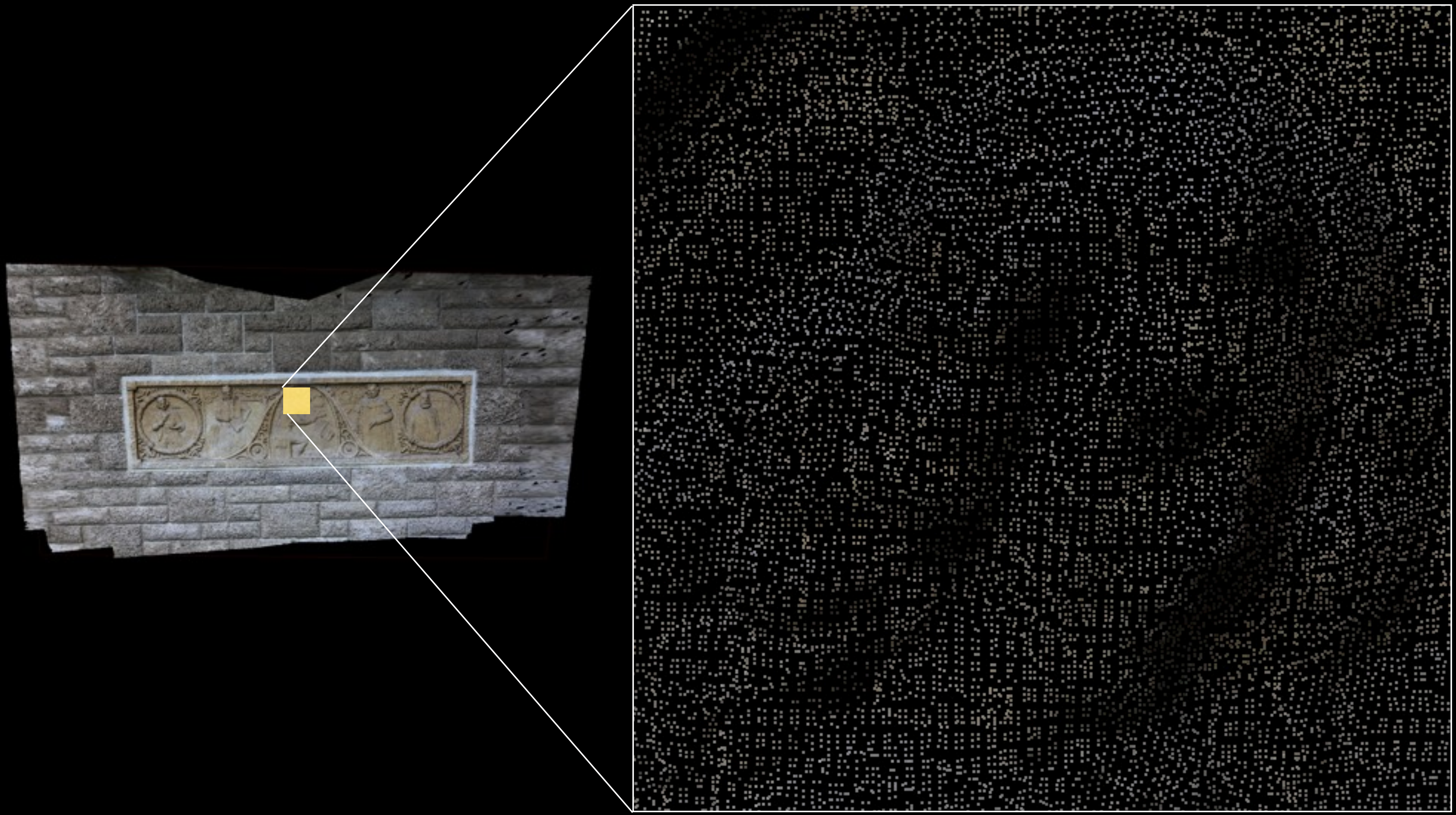


Software: Pipeline - Dense point cloud

- CMVS - Clustering Views for Multi-view Stereo.

UWA Geography Building

Software: Pipeline - Dense point cloud



Software: Pipeline - Mesh generation

- Various algorithms: Ball pivoting, Poisson Surface Reconstruction, Marching Cubes.
- Optionally simplify mesh (eg: quadratic edge collapse decimation) and fill holes.

Software: Pipeline - Texture mesh

- Re-project photographs from derived camera positions onto mesh.

UWA Geography Building

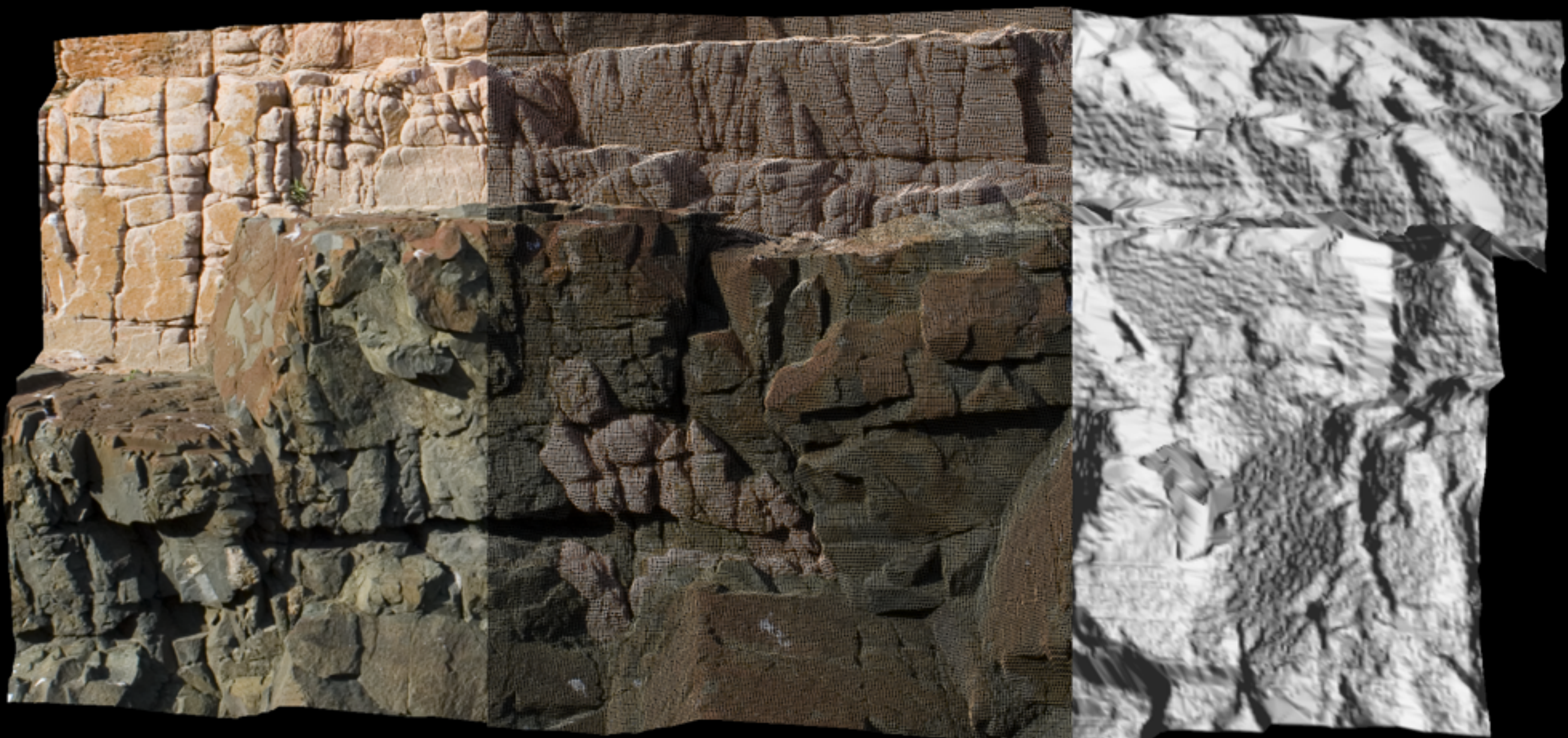
Software: Pipeline - Export

Movie

UWA Geography Building

Software : Sirovision

- Captured from 2 images only, stereo pairs but with wide base line separation.
- With in-scene markers and calibrated lens claims 3 to 5cm accuracy at 100m distance.
- Targeted mining industry, developed by CSIRO.

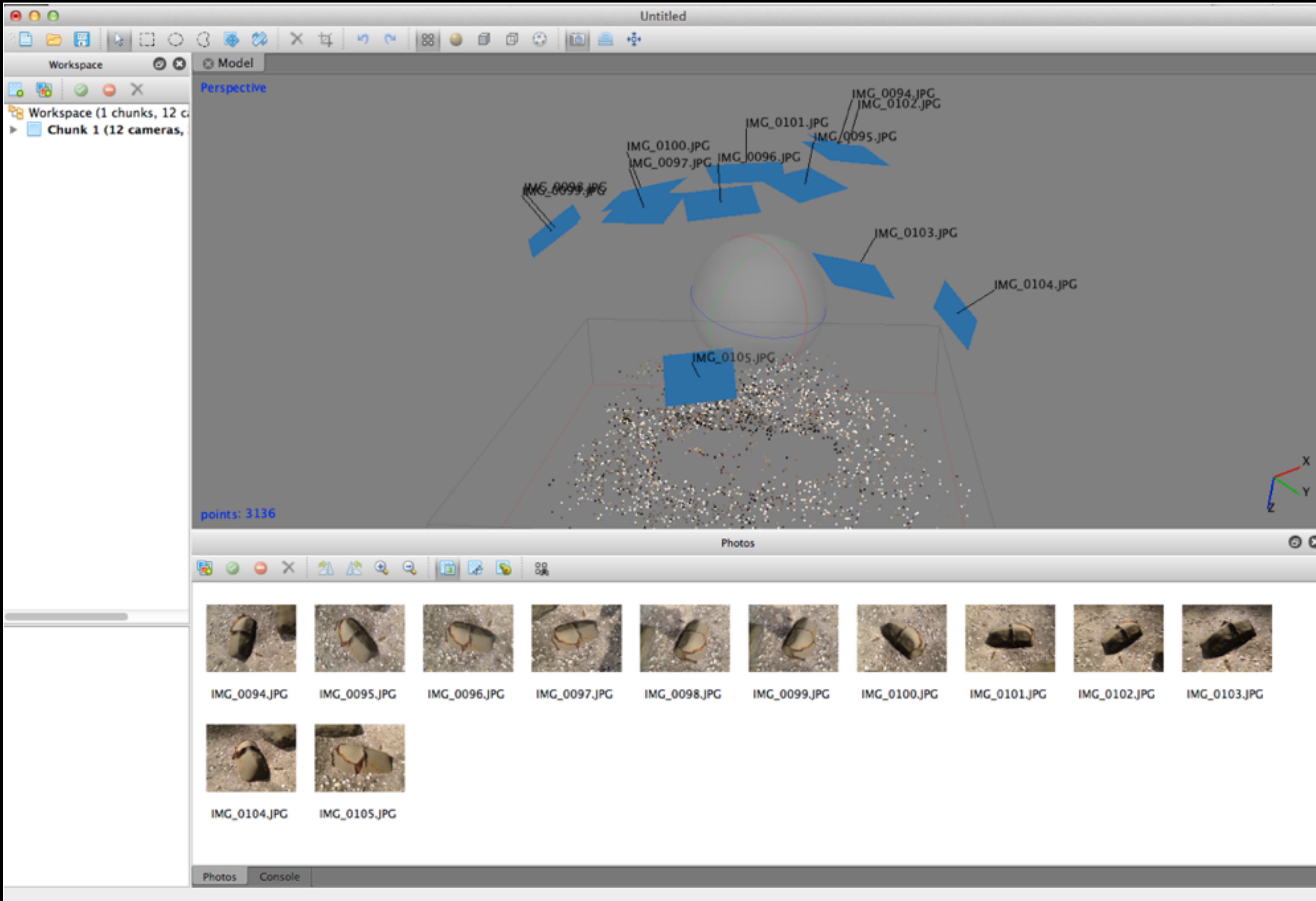


Textured Mesh Surface

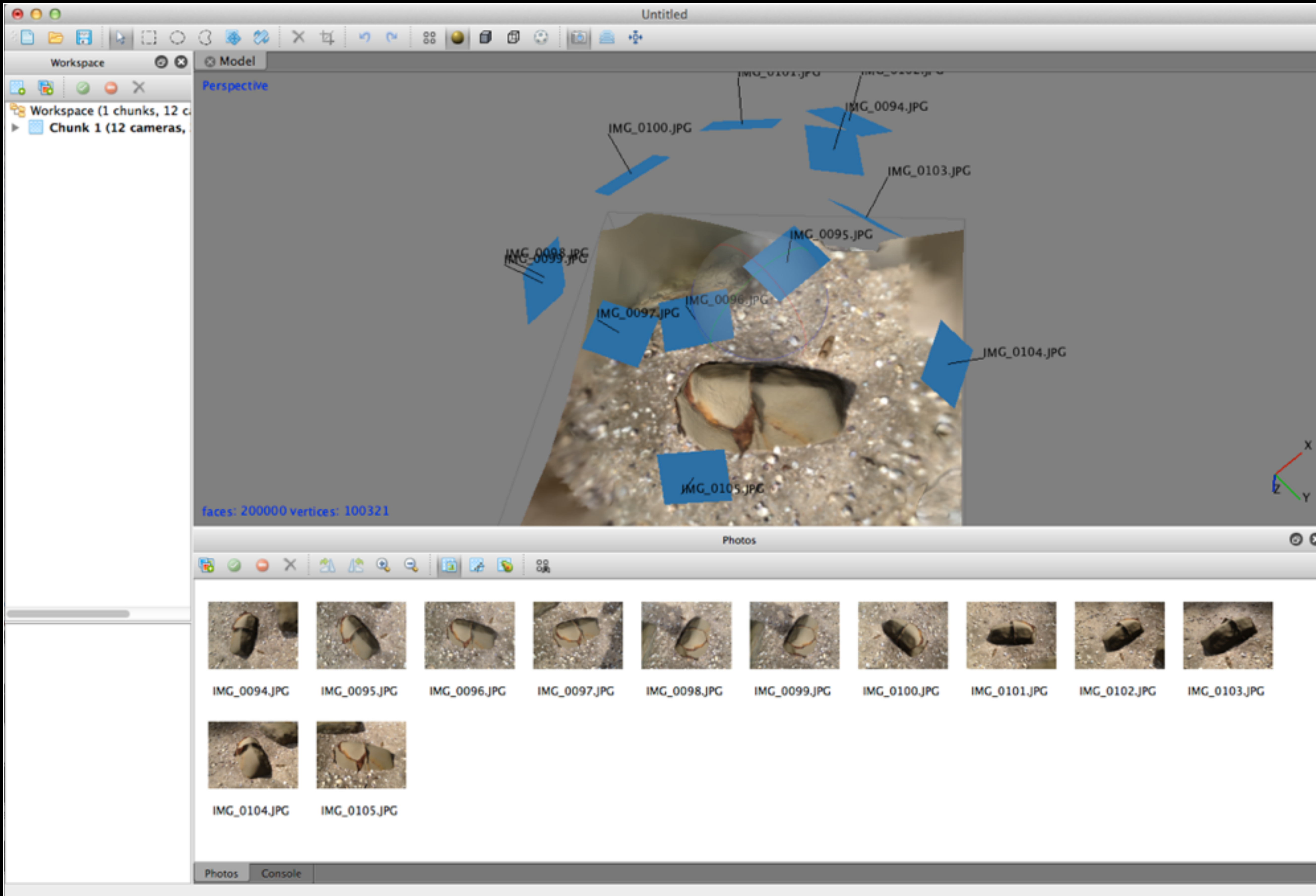
Software : PhotoScan

- From AgiSoft.
- http://www.agisoft.ru/products/photoscan.
- A series of individual steps (pipeline) one follows.
- Good mixture between low level control and automation.
  Generally "just works" but can tuned for problematic cases.
- Available for Mac and MSWindows.
- Two versions, standard is quite affordable, "Pro" version largely for georeferencing and other features important for the geology community.
- Under rapid development ... regularly improving.
- Very stable.

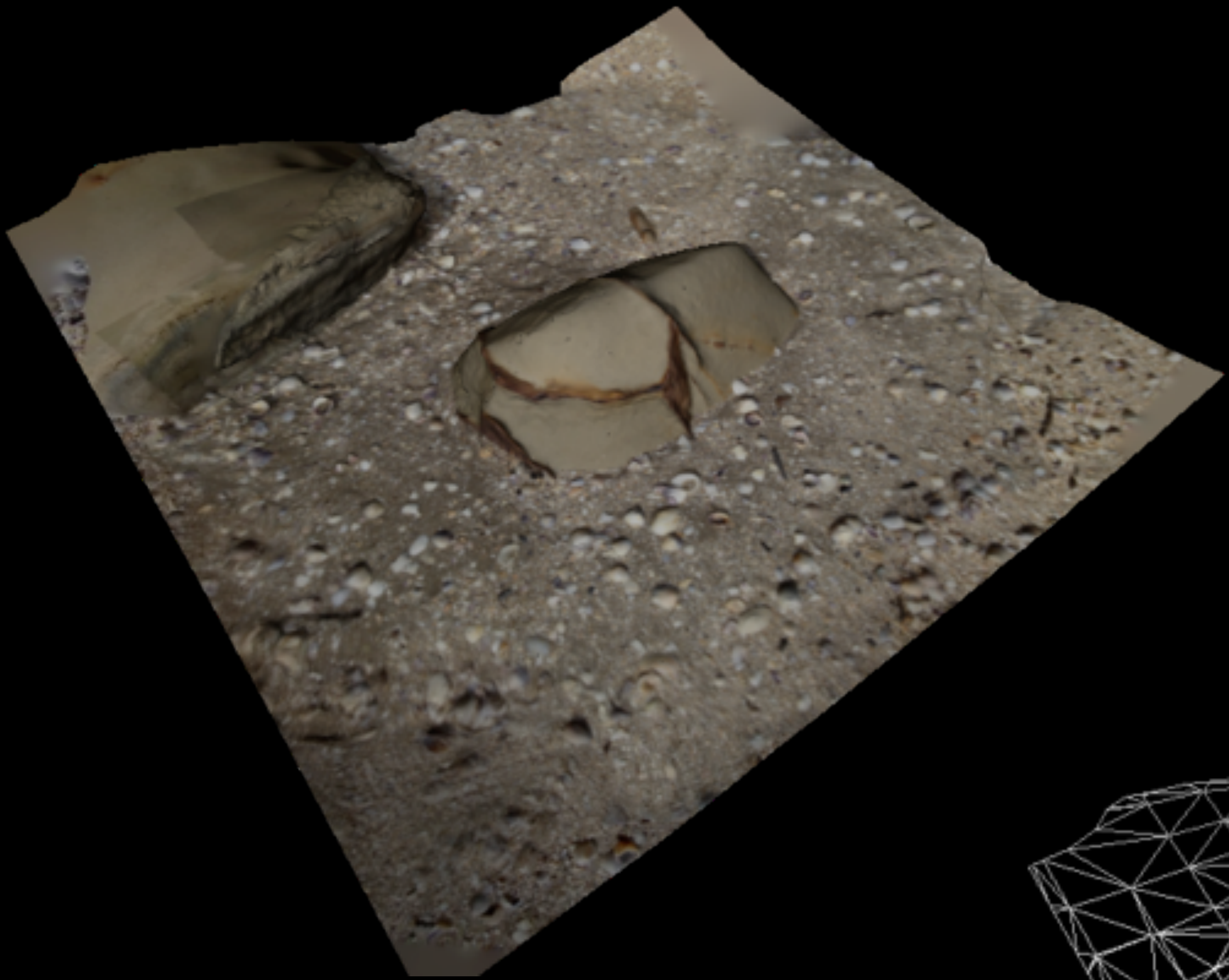
Software : PhotoScan

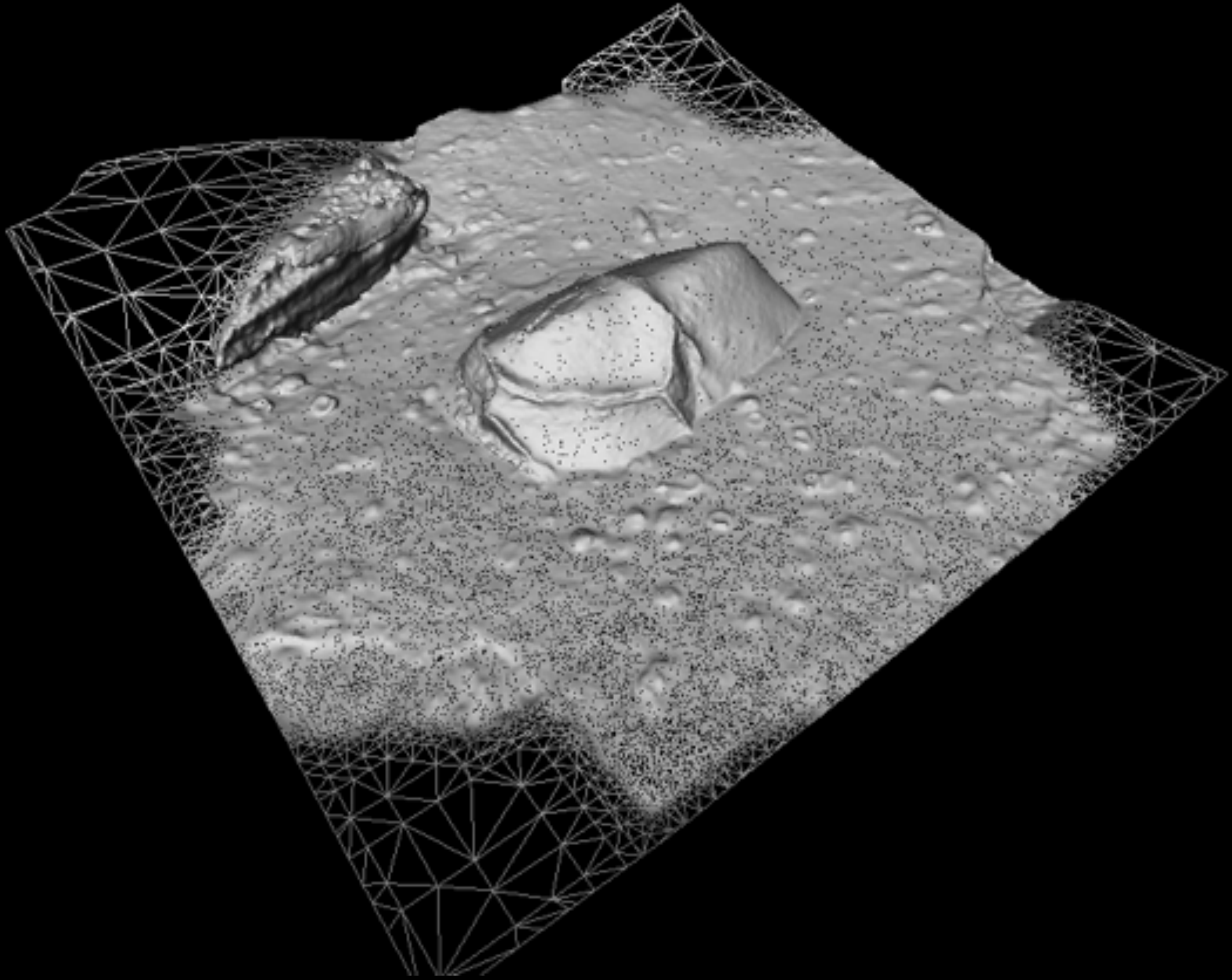


Software : PhotoScan



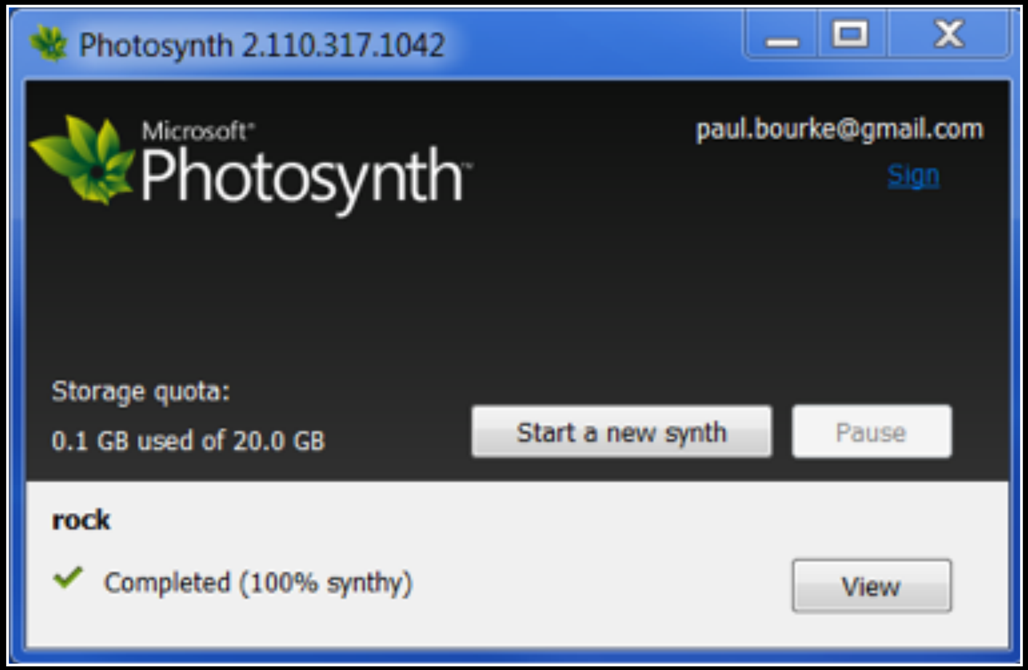
Software : PhotoScan

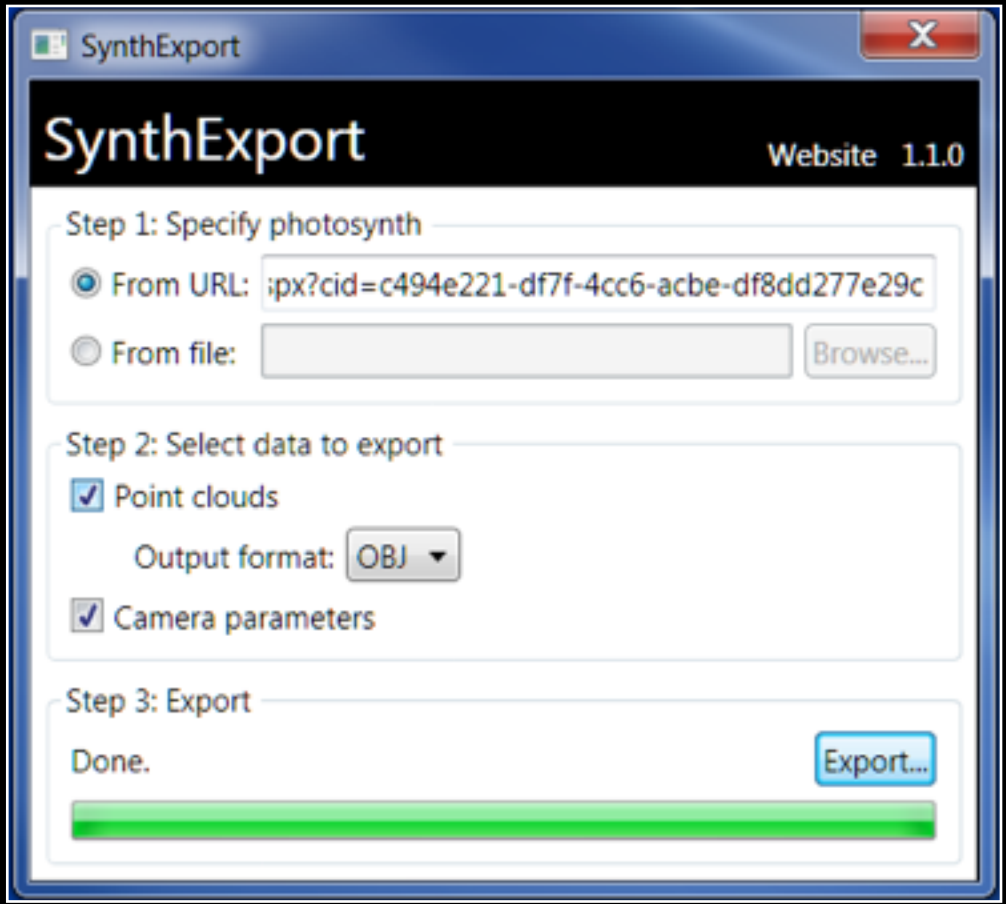




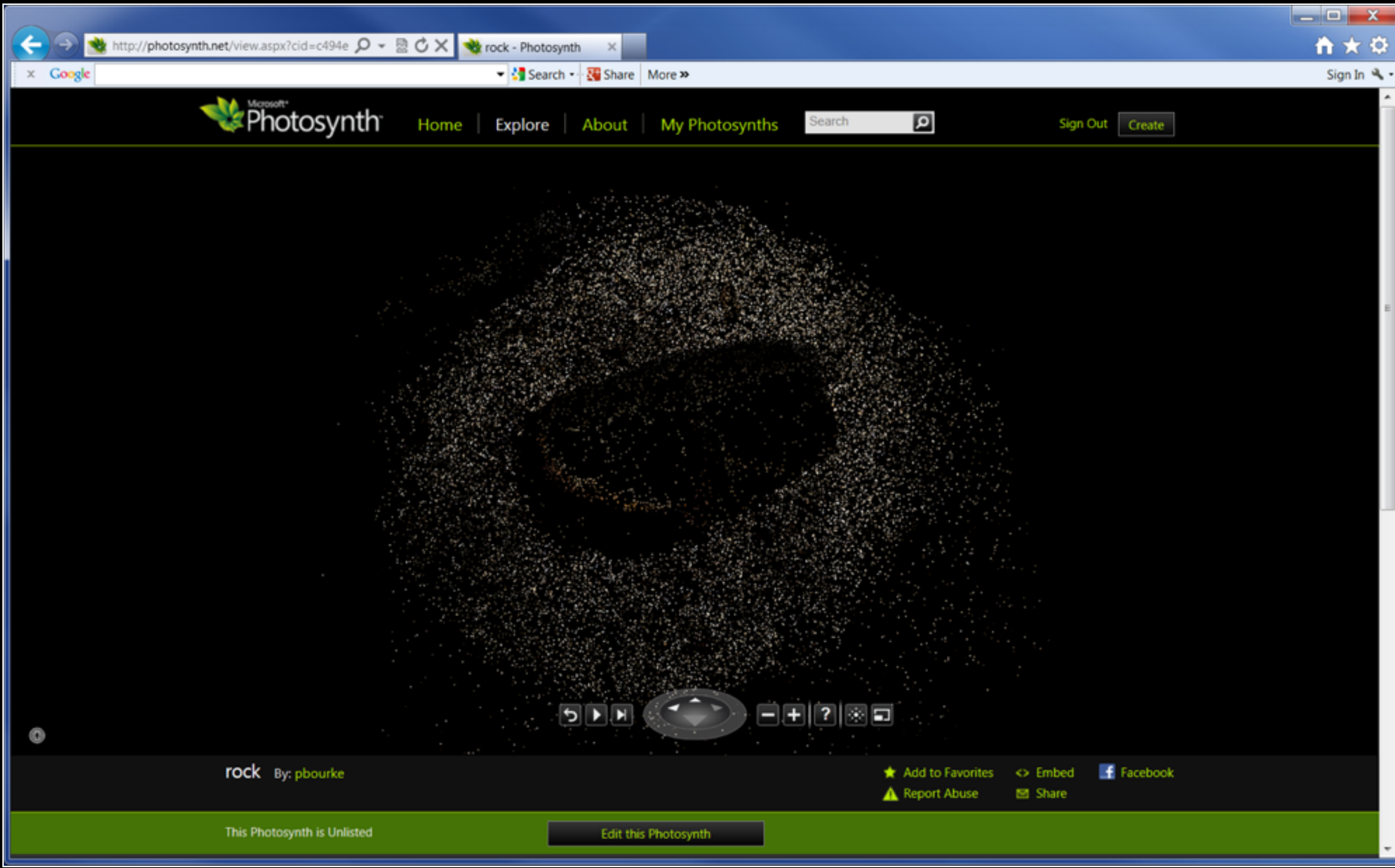
Software : PhotoSynth

- Microsoft, MSWindows only (obviously)
http://photosynth.net
- Based upon Bundler. GUI front end, computed remotely.
- Provides a “image effect” based upon reconstructed surface
- Can be useful for identifying image sets for other pipelines
- Not possible to extract the mesh/texture data from within the online software
- Synth Export
http://synthexport.codeplex.com/
Provides point cloud and camera parameter export. Would need to reconstruct mesh by other means.
- Not a leading edge tool any more.

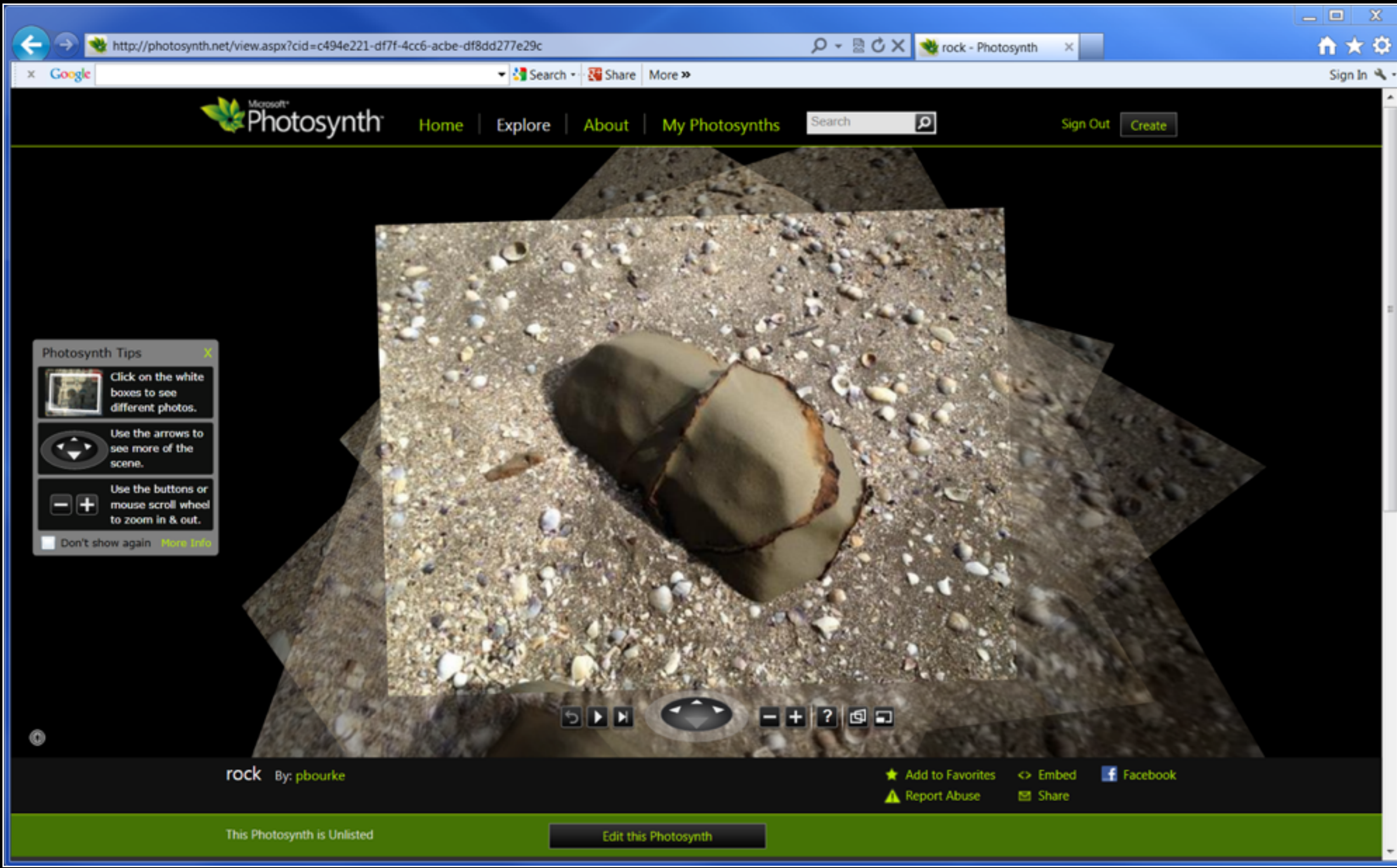




Software : PhotoSynth



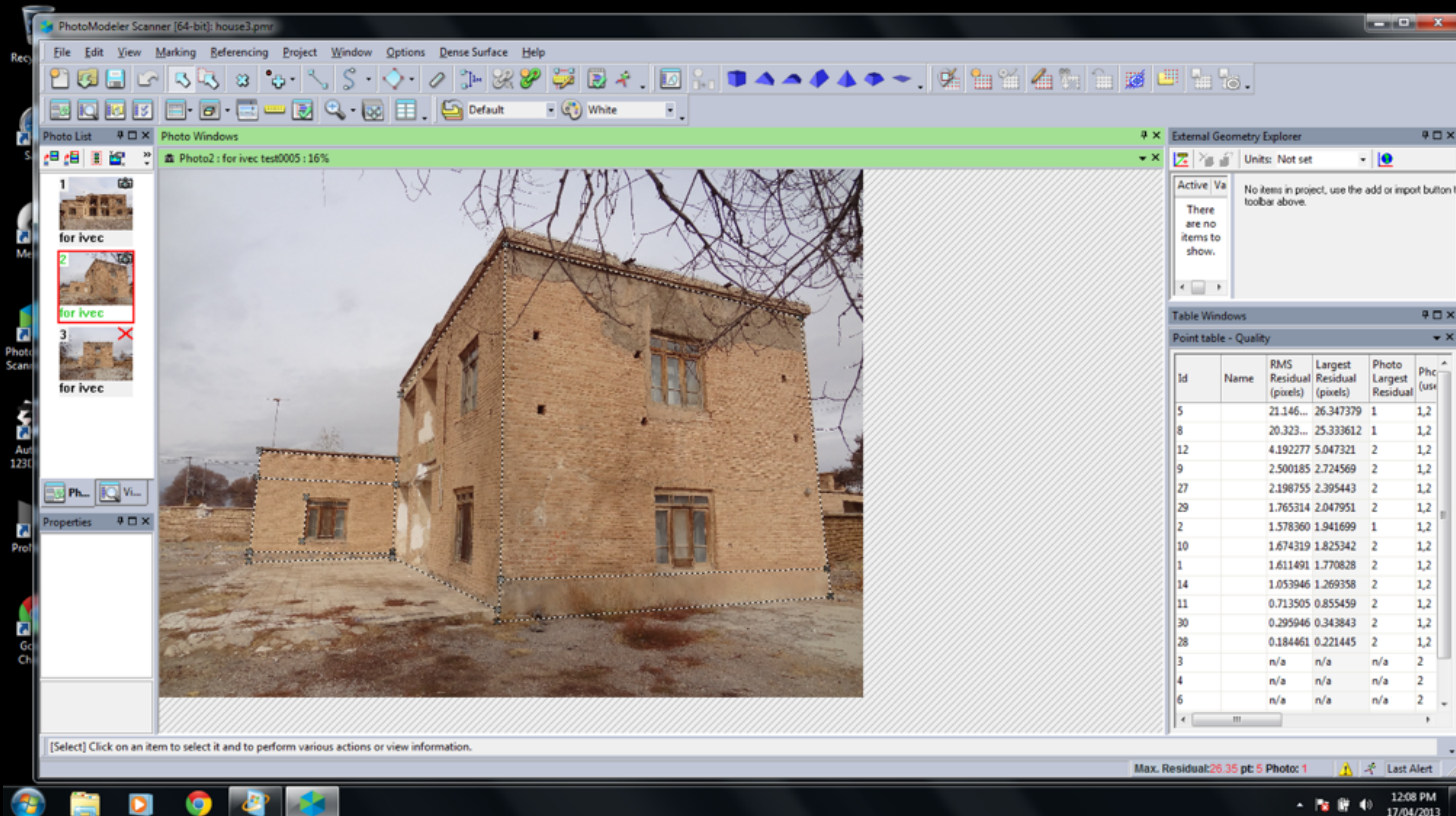
Software : PhotoSynth



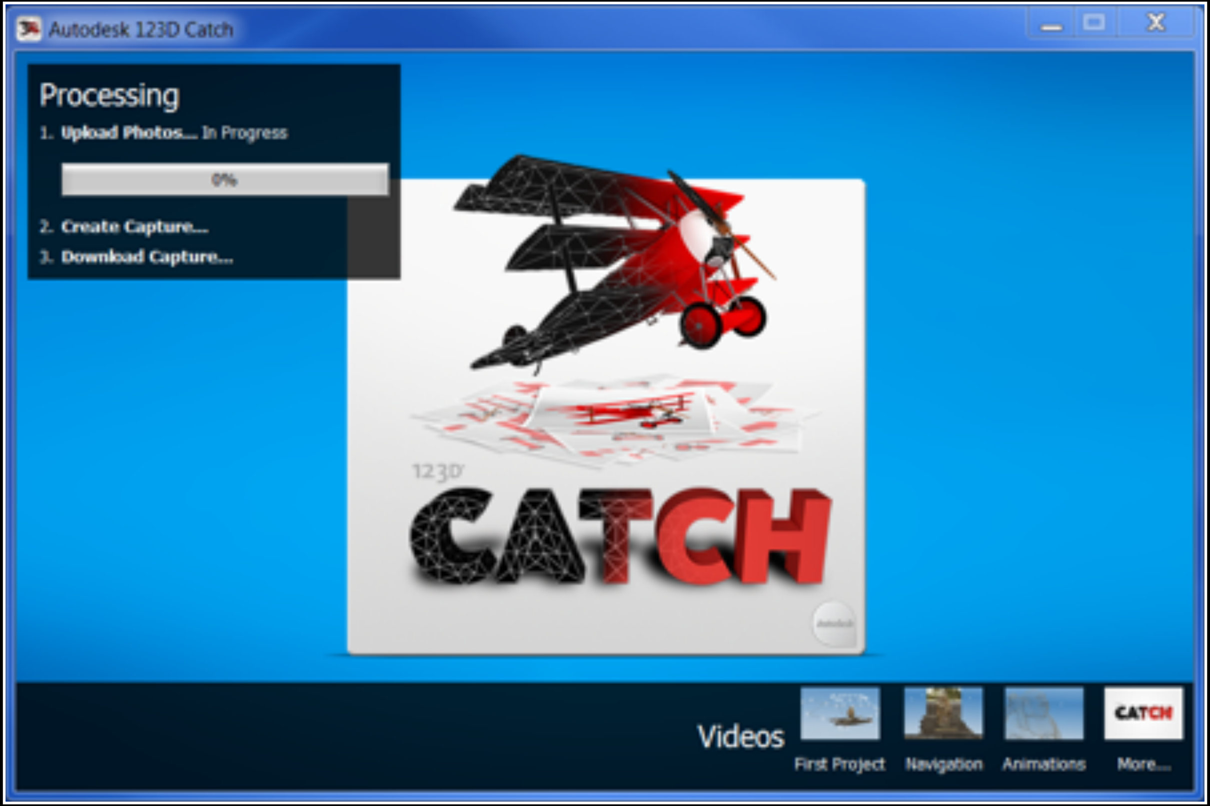
Software : PhotoModeller

- From EOS systems
- http://www.photomodeler.com/
- Comes in two flavours, the standard package is for human driven extraction of rectangular objects such as building facades
- PhotoModeller Scanner is for more organic shapes
- Claims to be capable of very accurate results, generally has a more rigorous procedure.
- Generally seems to require more manual interaction
- MSWindows only

Software : PhotoModeller

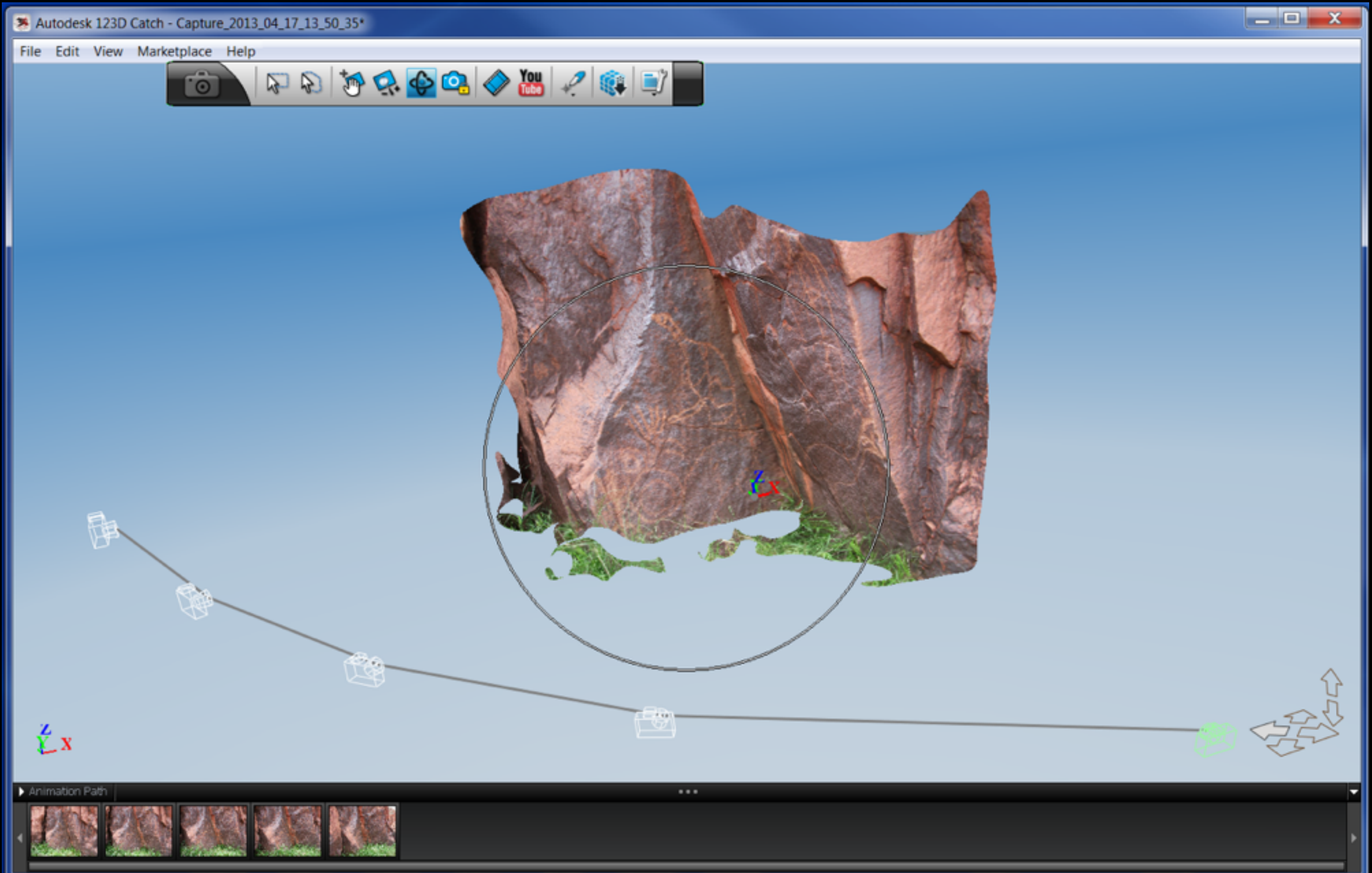


Software : 123D Catch

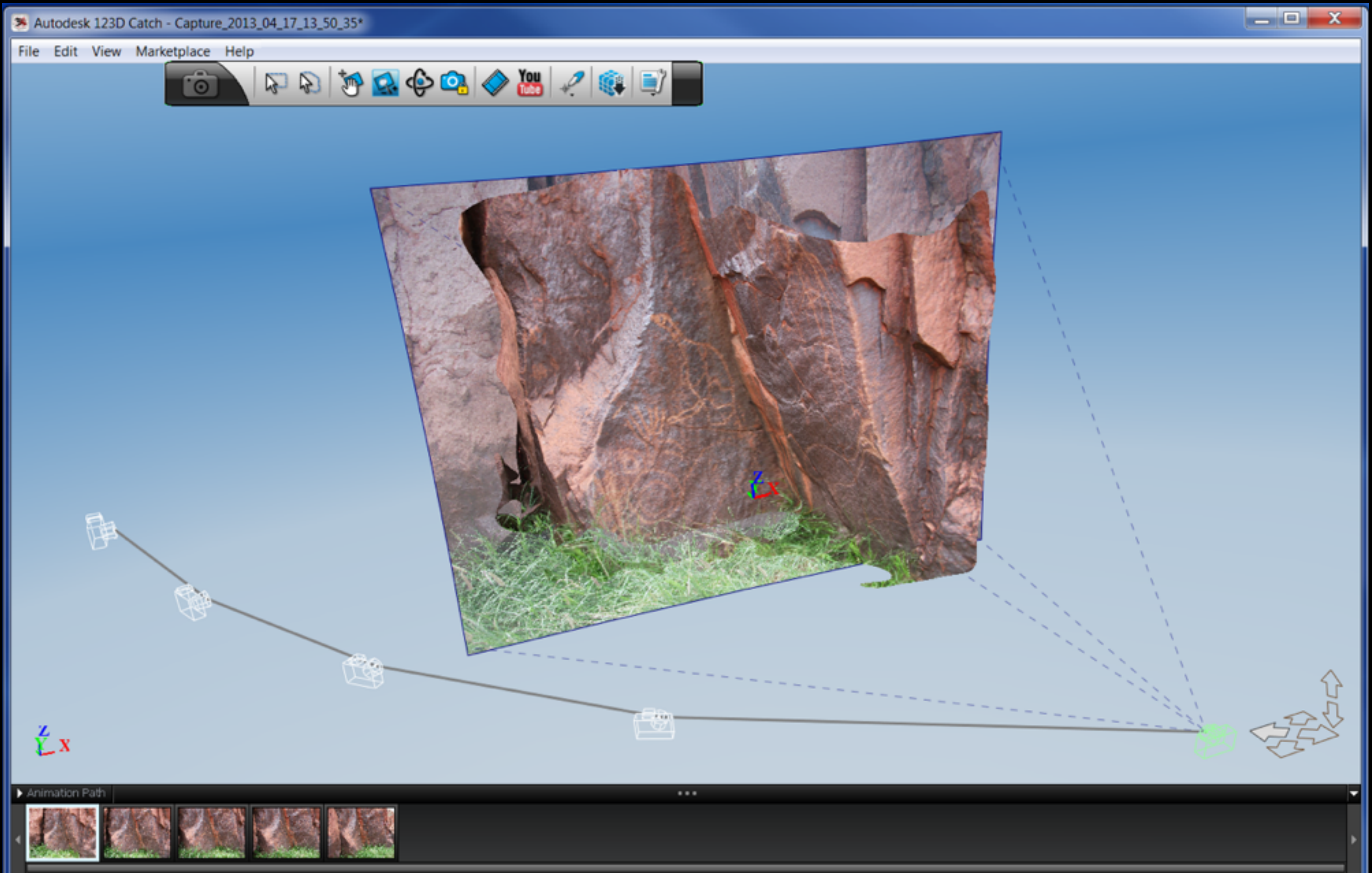


- From AutoDesk
- Free
- Cloud based so requires an internet connection
- High rate of success but no option to change algorithm parameters if things don’t work
- Does not provide access to intermediate data, such as the point cloud
- No option for camera calibration
- MSWindows only GUI
- No longer a leading edge solution

Software : 123D Catch



Software : 123D Catch



Software : Visual SfM - Bundler

- From the University of Washington
- An open source distribution of Bundler (MSWindows, Mac, Linux)
- Includes a GPU accelerated implementation
- Matches images, derives camera attributes, and computes a point cloud
- Dense point cloud and mesh generation needs to be performed elsewhere
- http://www.cs.washington.edu/homes/ccwu/vsfm/

- Bundler on Mac OS X called easyBundler
- http://openendedgroup.com/field/ReconstructionDistribution

Software : Distinguishing features

- Degree of human guidedness and interaction required
  Our goal is for largely automated processes

- Requirement or opportunity for camera calibration
  Should result in higher accuracy, questionable for a single fixed focal lens

- Sensitivity to the order the photographs are presented

- The number of photographs and resolution that can be handled

- Degree to which one needs to become an “expert”, learning the tricks to get good results
  - There are a potentially a large number of variables
  - Trade off between simplicity and control
  - 123D Catch is at one end of the scale, PhotoModeller Scanner at the other end

- Ability to create high resolution textures, larger than 4Kx4K, or multiple textures

Photography : Lenses

- Preferred: fixed focal length lens, also referred to as a “prime lens”.
  - Depends on the software, but generally recommended
- Generally have some minimum focus distance and small aperture
- EXIF: generally software reads EXIF data from images to determine focal length, sensor size, ...
- Most “point and click” cameras have a fixed focal lenses because they require no moving parts, don’t require electronics (not drawing extra power)
- We use Canon 5D MK11 and 111 with fixed focal lenses, and point-and-click cameras

Sigma 28mm, Canon mount

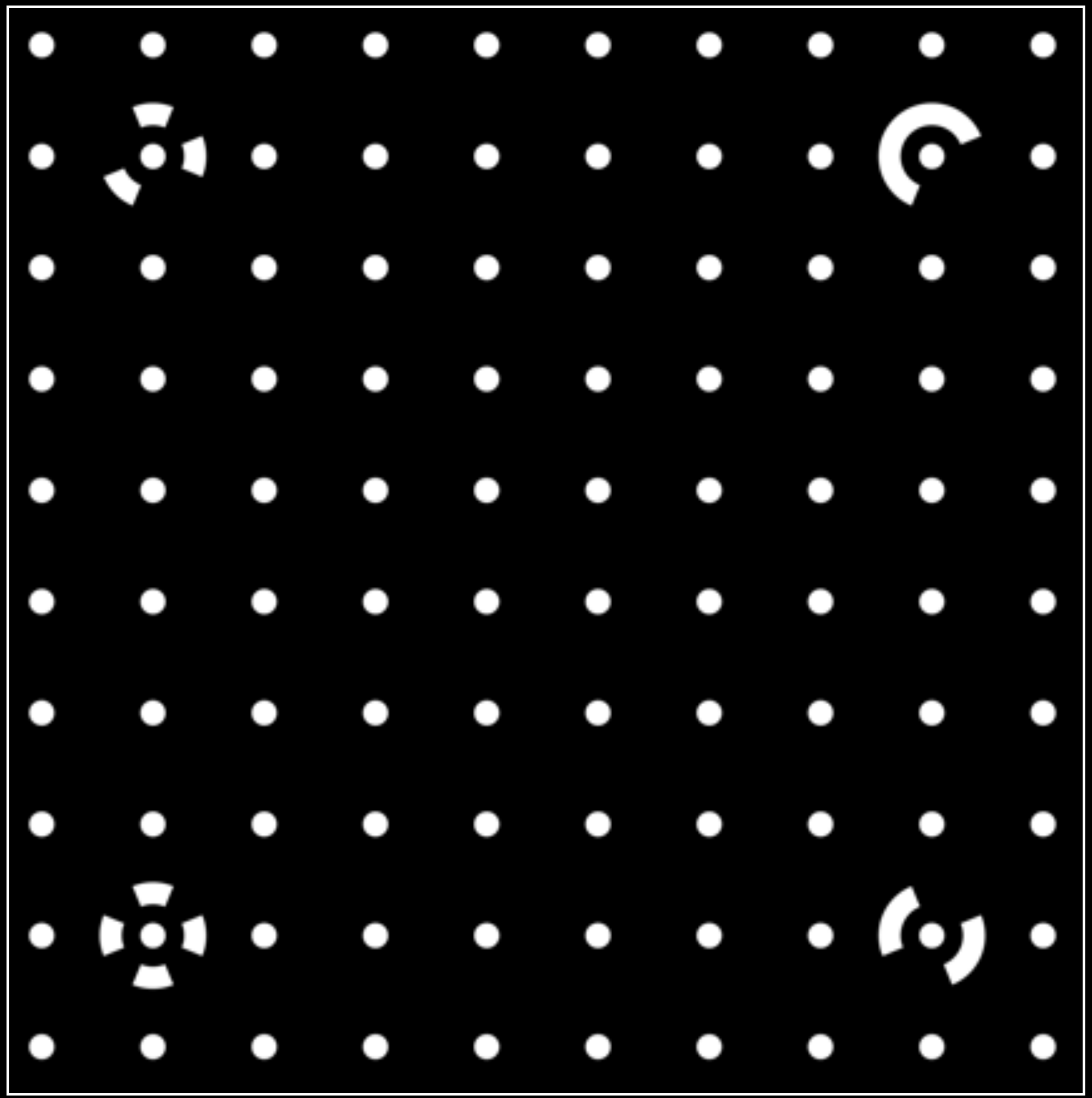
Sigma 50mm, Canon mount

Photography : shooting guide

- Obviously one cannot reconstruct what one does not capture
- Aim for plenty of overlap between photographs (Can always remove images)
- For 2.5D surfaces as few as 2 shots are required, more generally 6
- For 3D objects typically 20 or more. ~ 10 degree steps
  Repeat at one or more levels if the object is concave vertically
- For extended objects and overlapping photographs perhaps hundreds.
  1/3 to1/2 image overlap ideal
- Generally works better for the images to be captured in order moving around the object (may no longer be the case for latest algorithms)
- Generally no point capturing multiple images from the same position!
  The opposite of panoramic photography for example
- Camera orientation typically doesn’t matter, this is solved for when computing camera parameters in the Bundle processing
- Calibration: Most of the packages that include accuracy metrics will assume a camera calibration

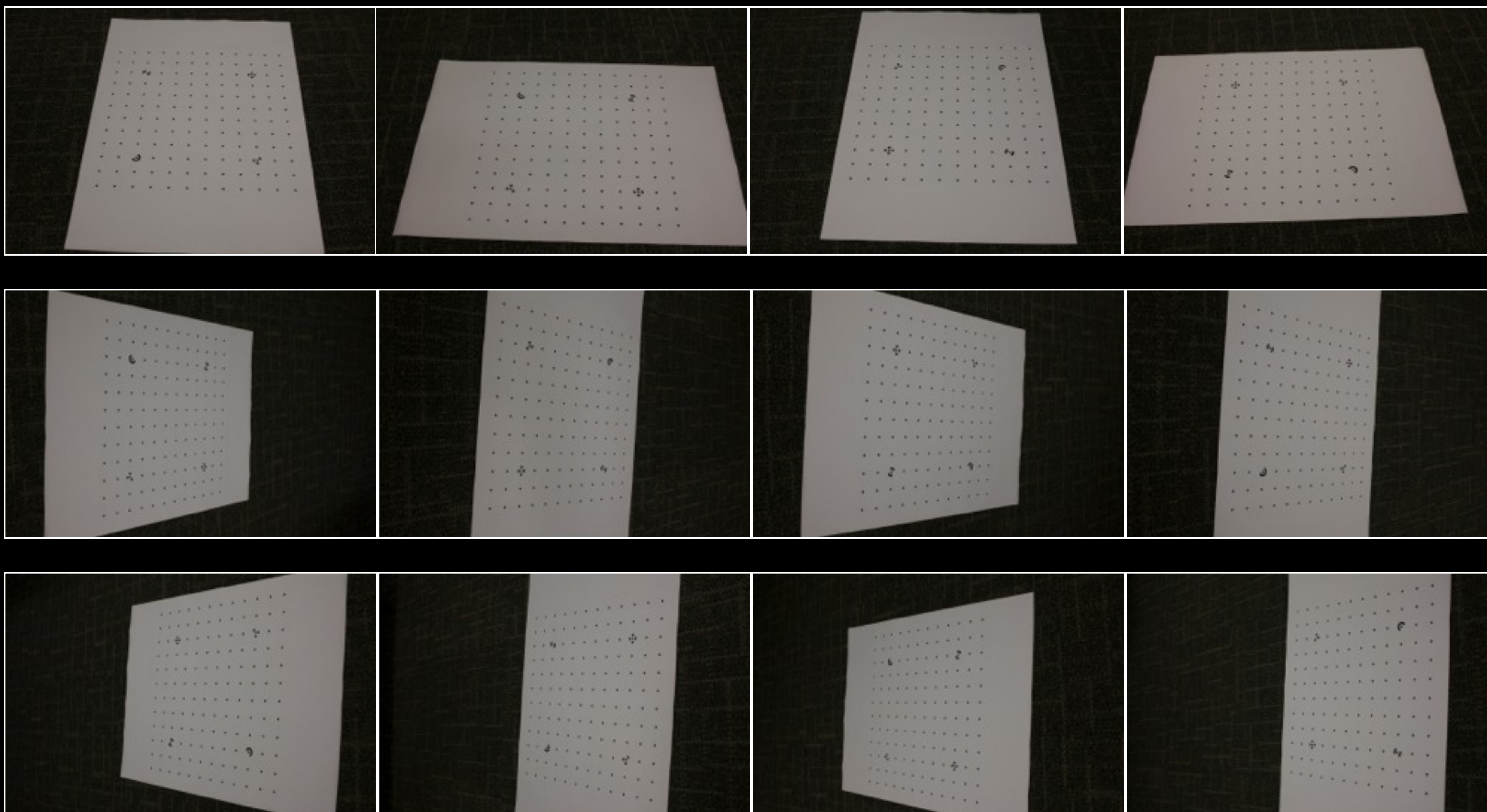
Photography : Camera calibration

- Camera/lens characteristics derived from Bundle process
  Can perform on idealised patterns beforehand
- Different procedures depending on the software
- Calibration pattern used by PhotoModeller shown here: printed A1 sheet

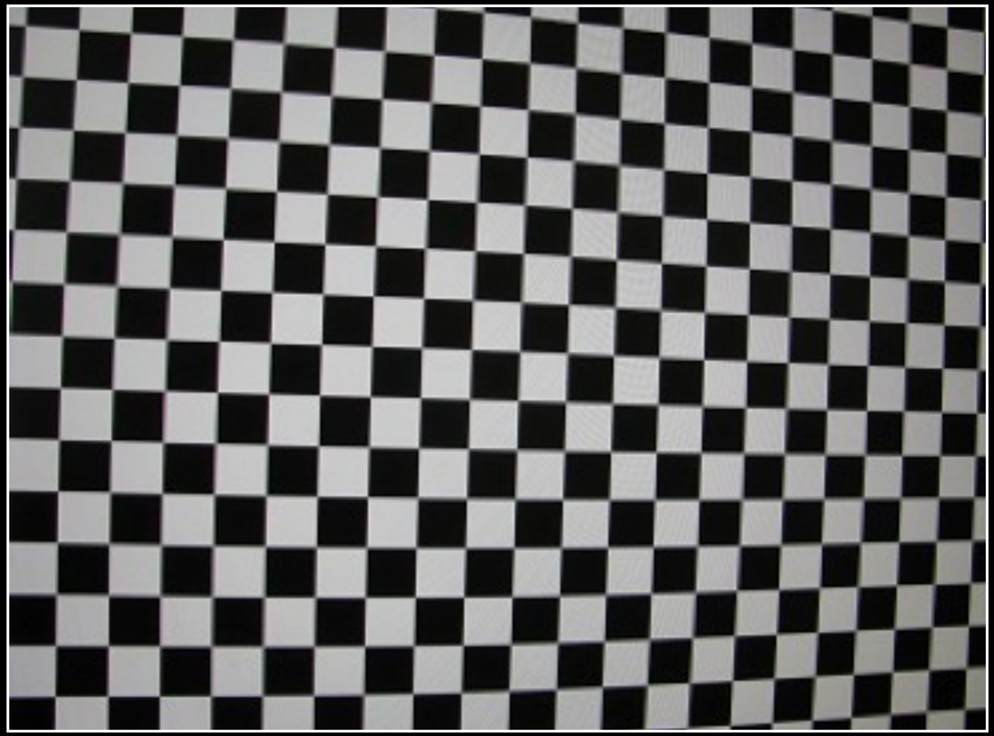


Photography : Camera calibration

- 4 photographs captured (one from each direction)
- Repeated with the camera in three orientations (rotated 90, 0, -90)



Camera calibration : Photoscan



- Estimates
  - focal length in both directions
  - principle point components in both directions
  - radial and tangential distortion coefficients
- fx, fy,   cx, cy,   K1,K2,K3,   P1,P2
- Produces a display on screen to photograph from different directions.
- Generally doesn’t for for focal length, reads from EXIF.

EXIF focal length: 50
fx = 8026.46 +- 1.5152
fy = 8027.75 +- 1.42957
cx = 2877.05 +- 1.13418
cy = 1906.64 +- 0.814478
skew = -0.806401 +- 0.151285
k1 = -0.176187 +- 0.00377854
k2 = 0.285354 +- 0.0770751
k3 = 0.300547 +- 0.619451
p1 = 0.000219219 +- 2.64764e-05
p2 = -0.000172641 +- 3.58682e-05

Camera calibration : Photoscan

Untitled

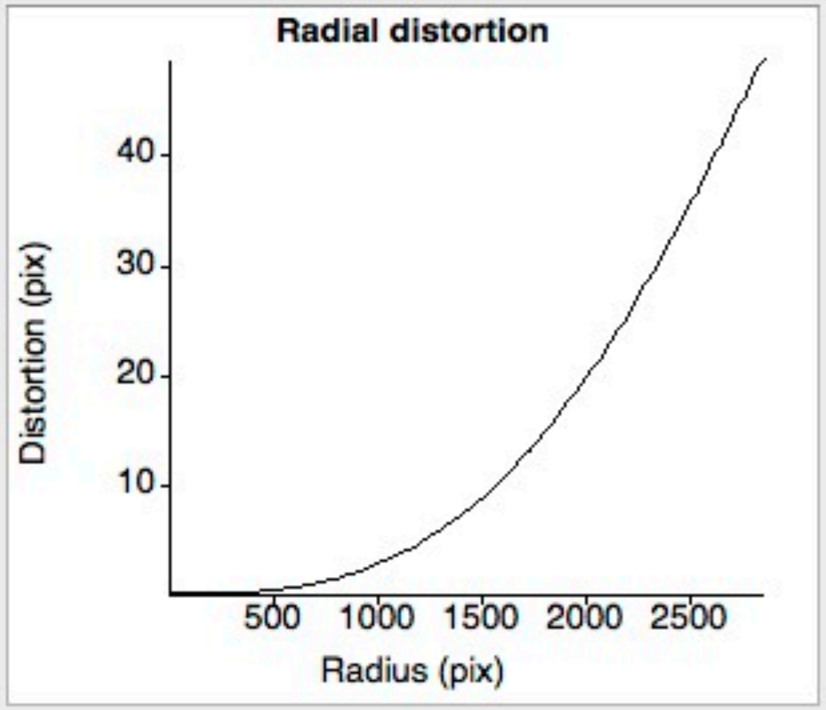
Photos

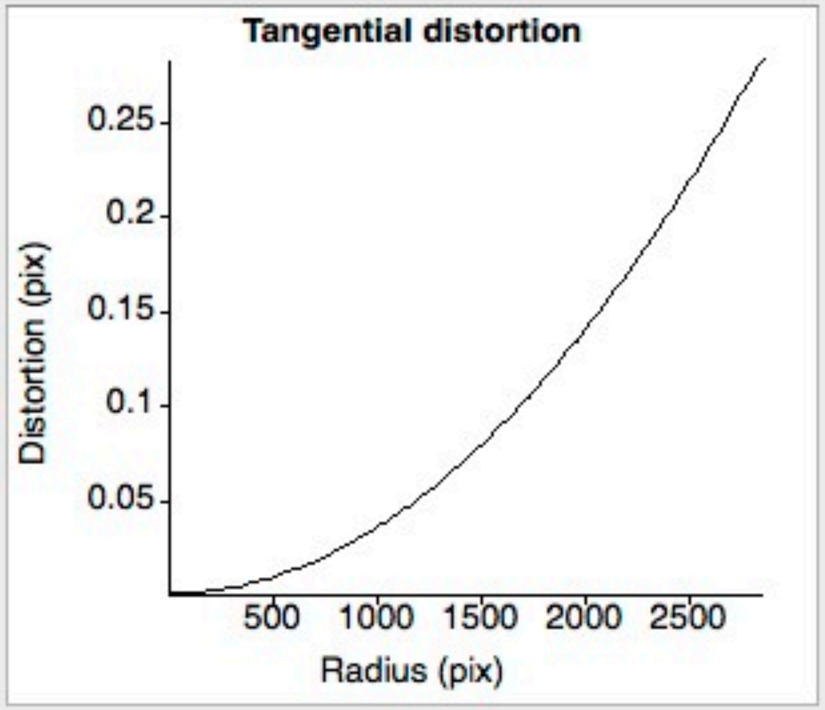
File	Size	Points
f 50		
IVEC1859.JPG	5760x3840	1434
IVEC1860.JPG	5760x3840	1320
IVEC1861.JPG	5760x3840	1208
IVEC1862.JPG	5760x3840	986
IVEC1863.JPG	5760x3840	978
IVEC1864.JPG	5760x3840	1191
IVEC1865.JPG	5760x3840	953

Report

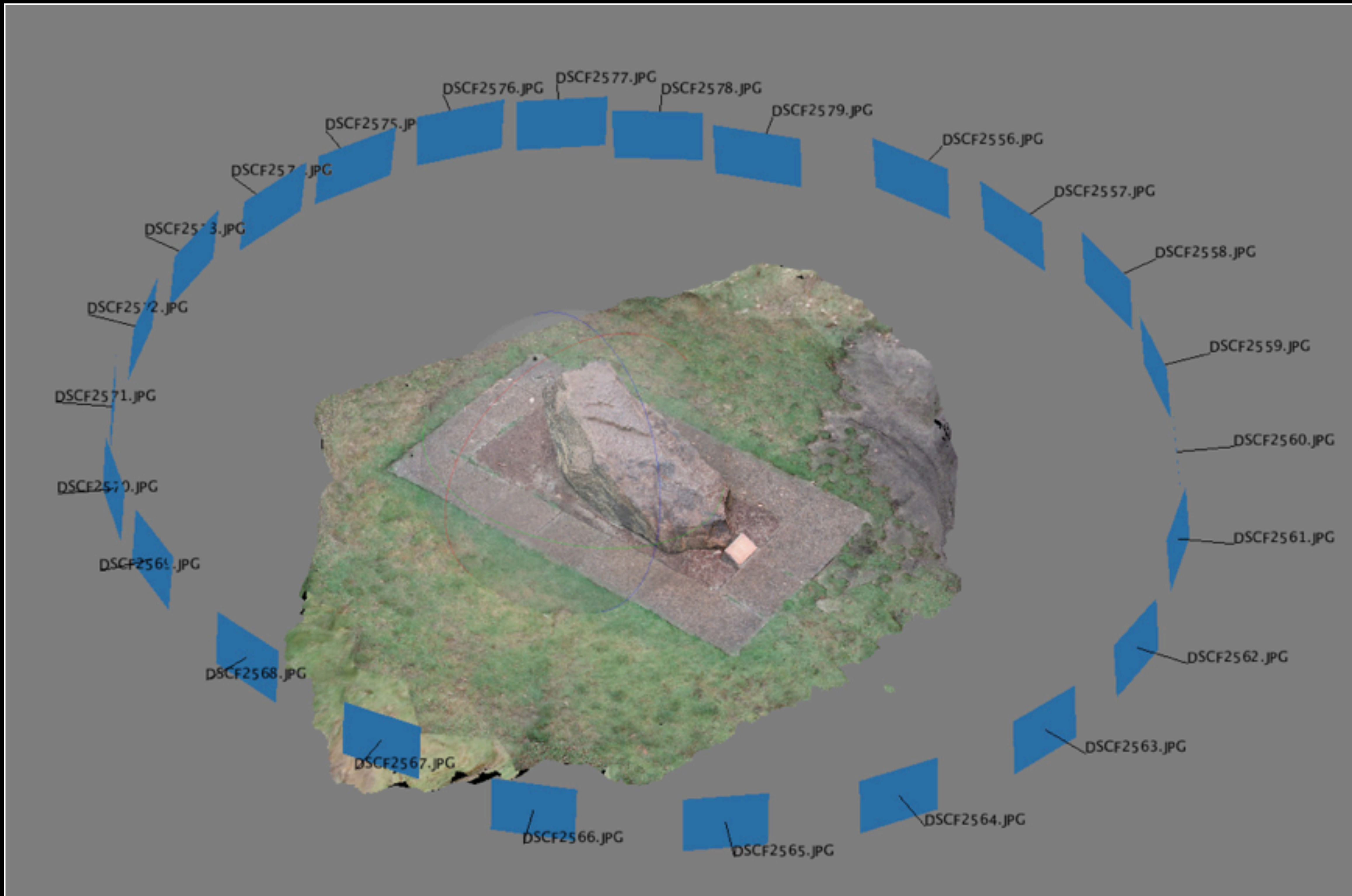
EXIF focal length: 50

Parameter	Value	Std Error
Image width	5760	
Image height	3840	
Focal length (x)	8026.46	1.5152
Focal length (y)	8027.75	1.42957
Principal point (x)	2877.05	1.13418
Principal point (y)	1906.64	0.814478
Skew	-0.806401	0.151285
Radial K1	-0.176187	0.00377854
Radial K2	0.285354	0.0770751
Radial K3	0.300547	0.619451
Radial K4	-1.09108	2.89591
Tangential P1	0.000219219	2.64764e-05
Tangential P2	-0.000172641	3.58682e-05

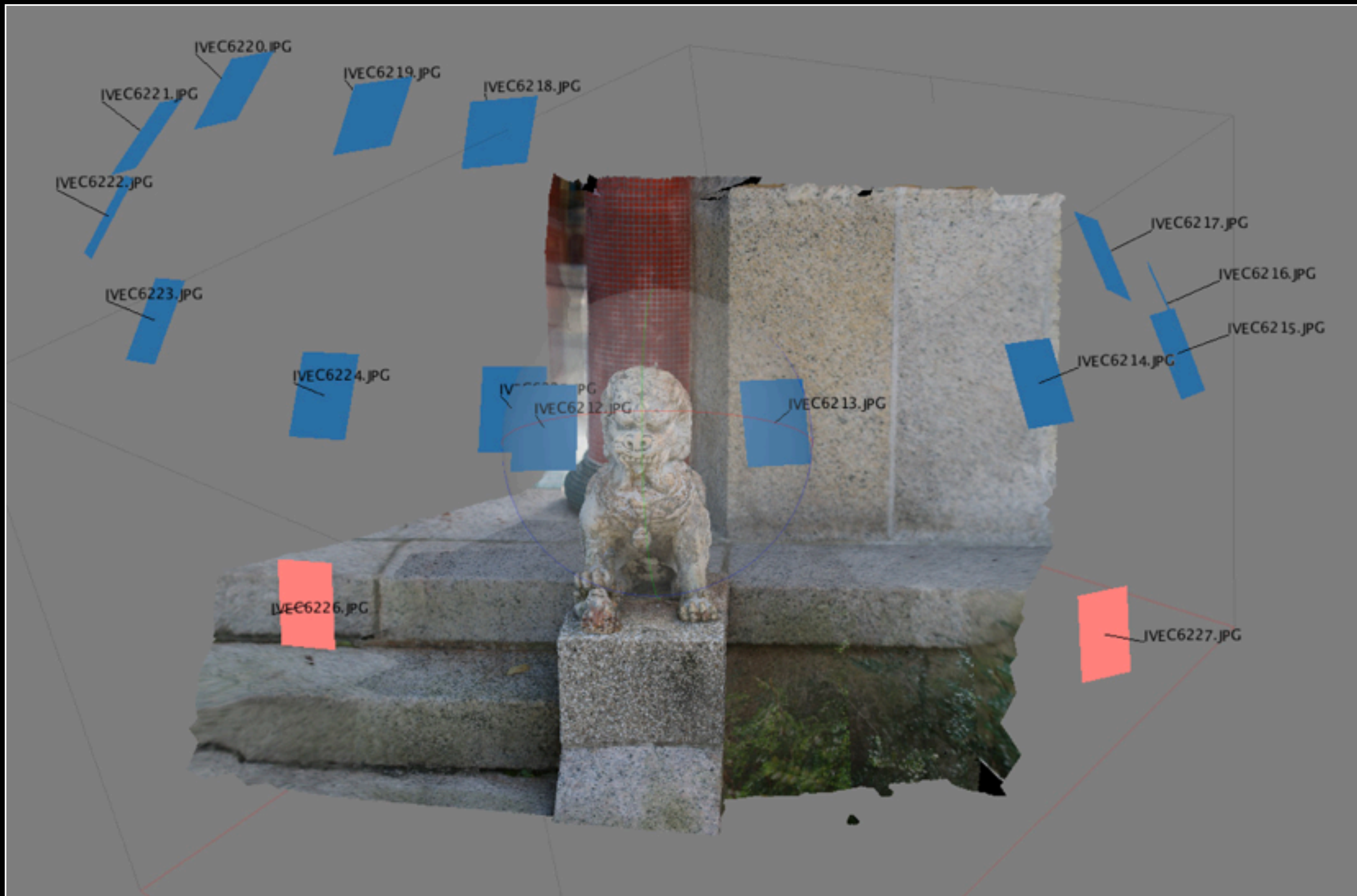




Photography : shooting guide

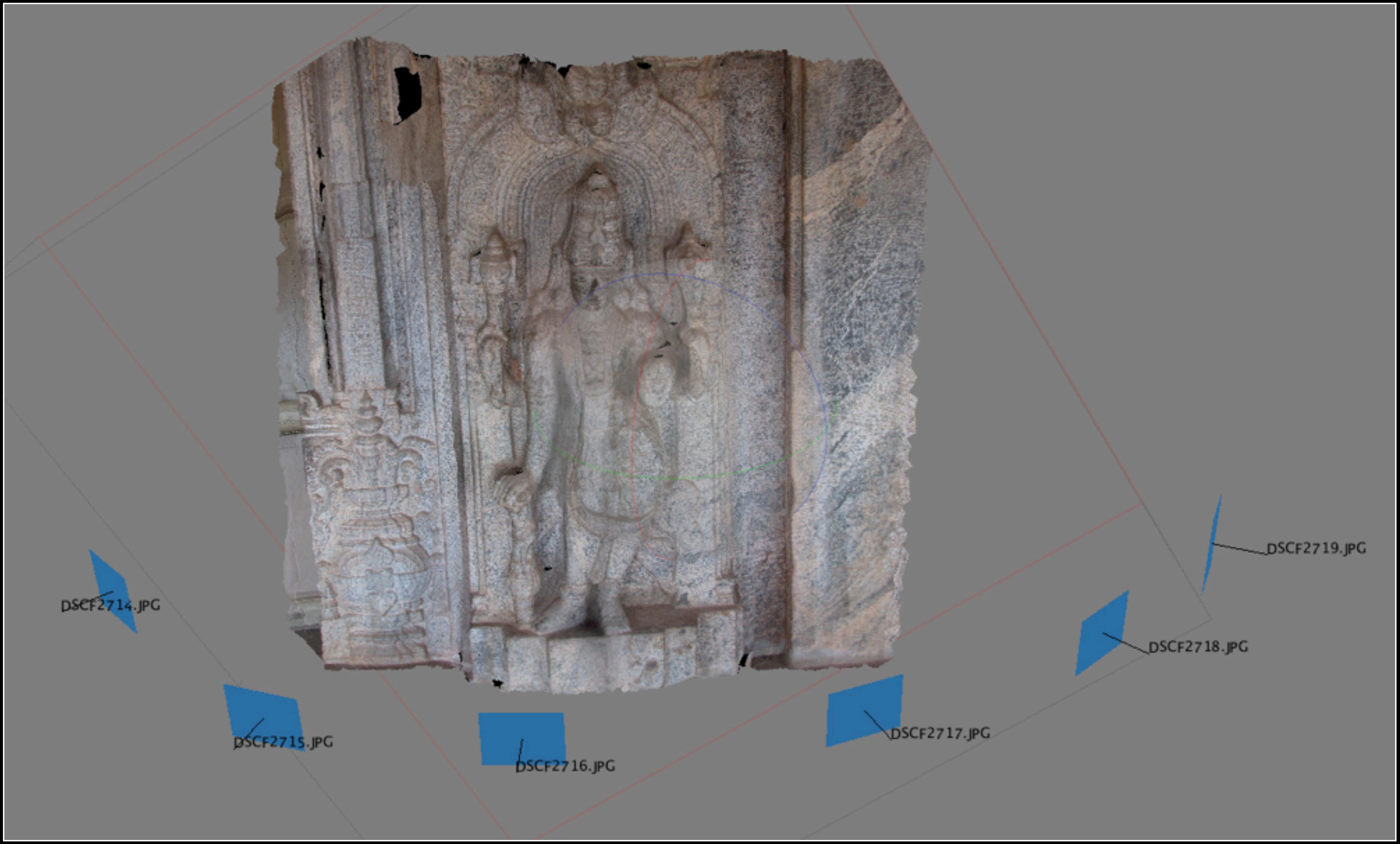


Photography : shooting guide



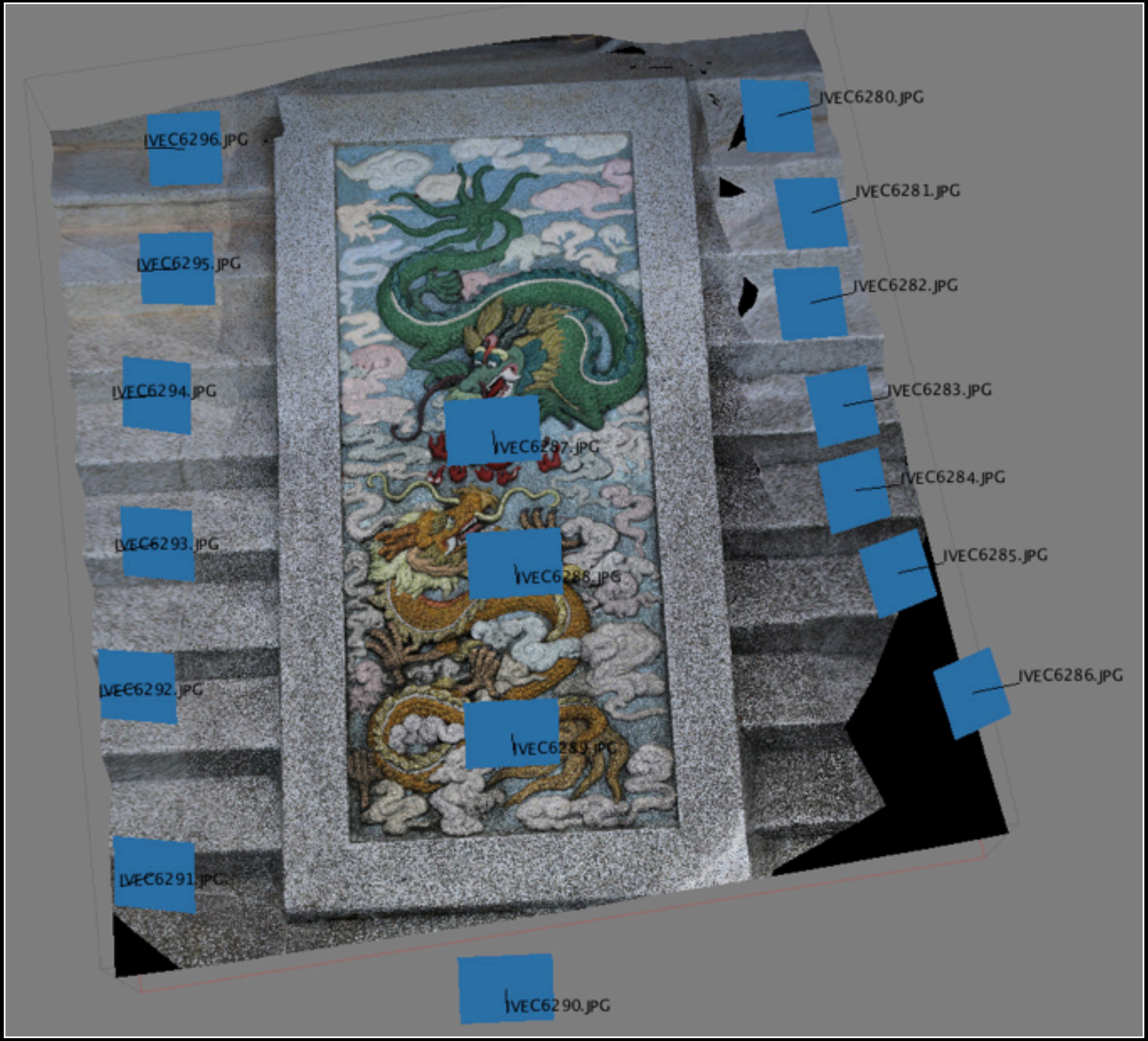
Dragon Gardens, Hong Kong

Photography : shooting guide



Manipal, India

Photography : shooting guide



Dragon Gardens, Hong Kong

Photography : 2.5D example

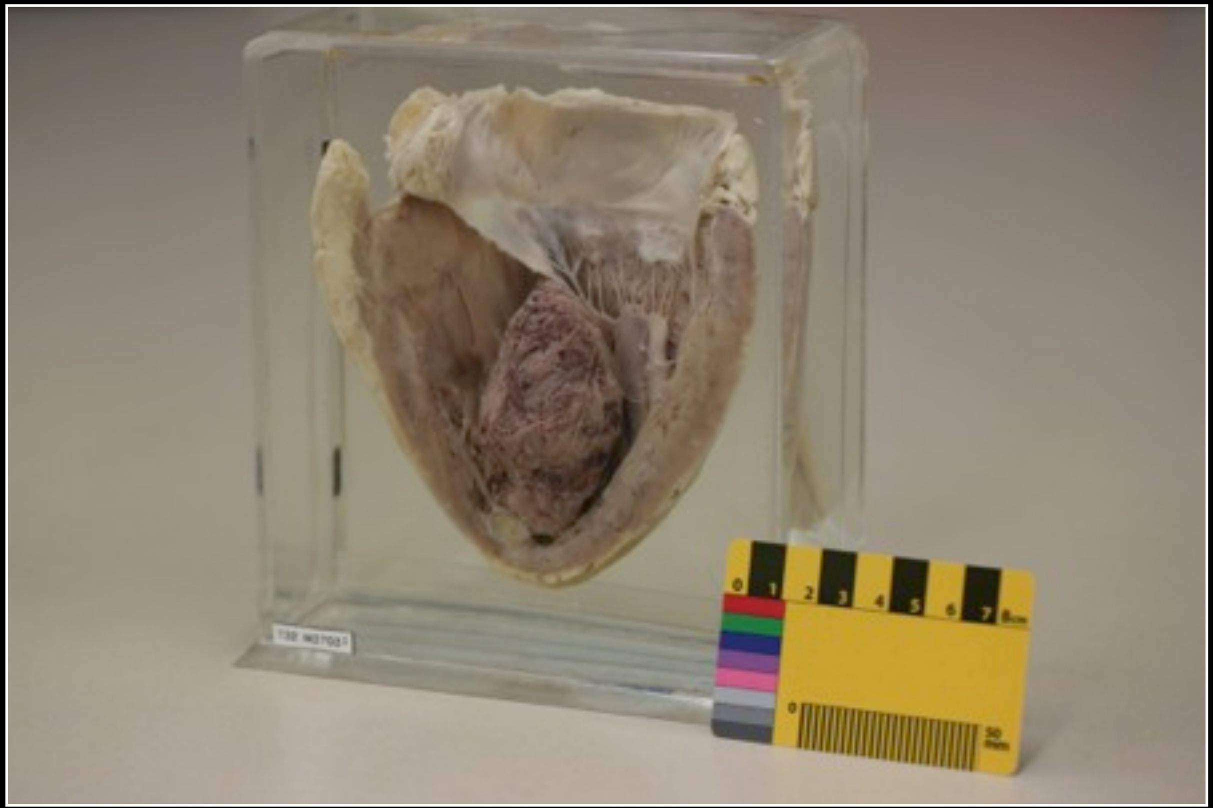
Terrenganu, Malaysia

Photography : 360 degree

UWA

Photogaphy : Linear reference objects

- Assists processing if there is a linear reference object in the scene.
- They need not be part of the final reconstruction if slightly outside the object of interest.



Case study 1 : Motifs, Indian Temple

- A relatively low number of photographs are required for 2.5D surfaces
- Degree of concavity determines the number of photographs required
  Can't reconstruct what cannot be seen
- Facades and engravings (low concavity) can require as few as 3 to 6 images
- 20cm high engraving on doors
- Photographs can be orientated at any angle
- Each object takes perhaps 15 sec to capture,
  10 minutes (on average) to process
- This example uses an iPhone

Case study 1 : Motifs, Indian Temple

Chaturmukha, India

Case study 1 : Motifs, Indian Temple

Movie

Chaturmukha, India

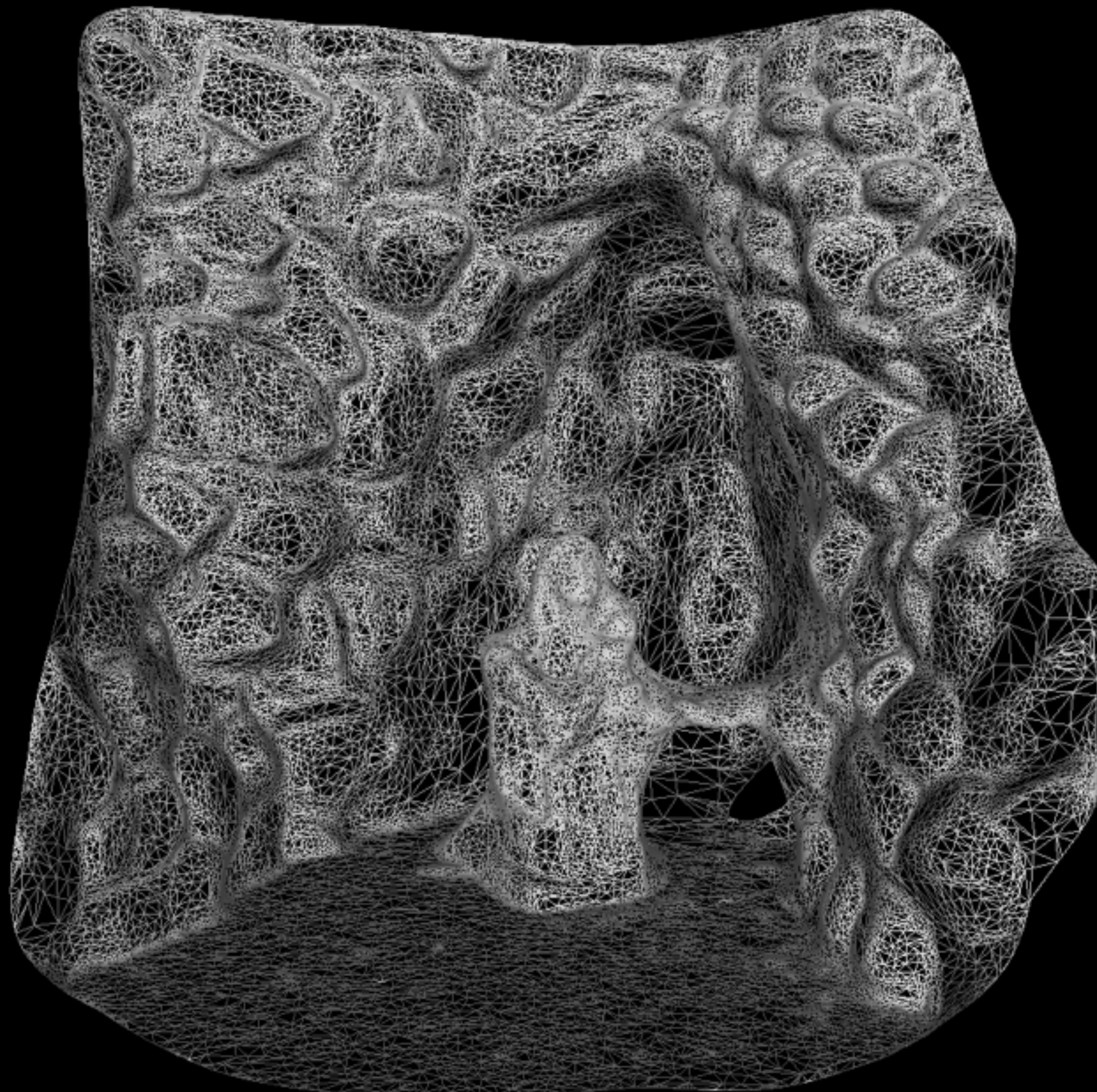
Geometry processing

- Generally dealing with unstructured meshes

- Mesh simplification
- Mesh thickening
- Hole closing
- Removing shrapnel
- Per vertex editing

- Meshlab
- Blender

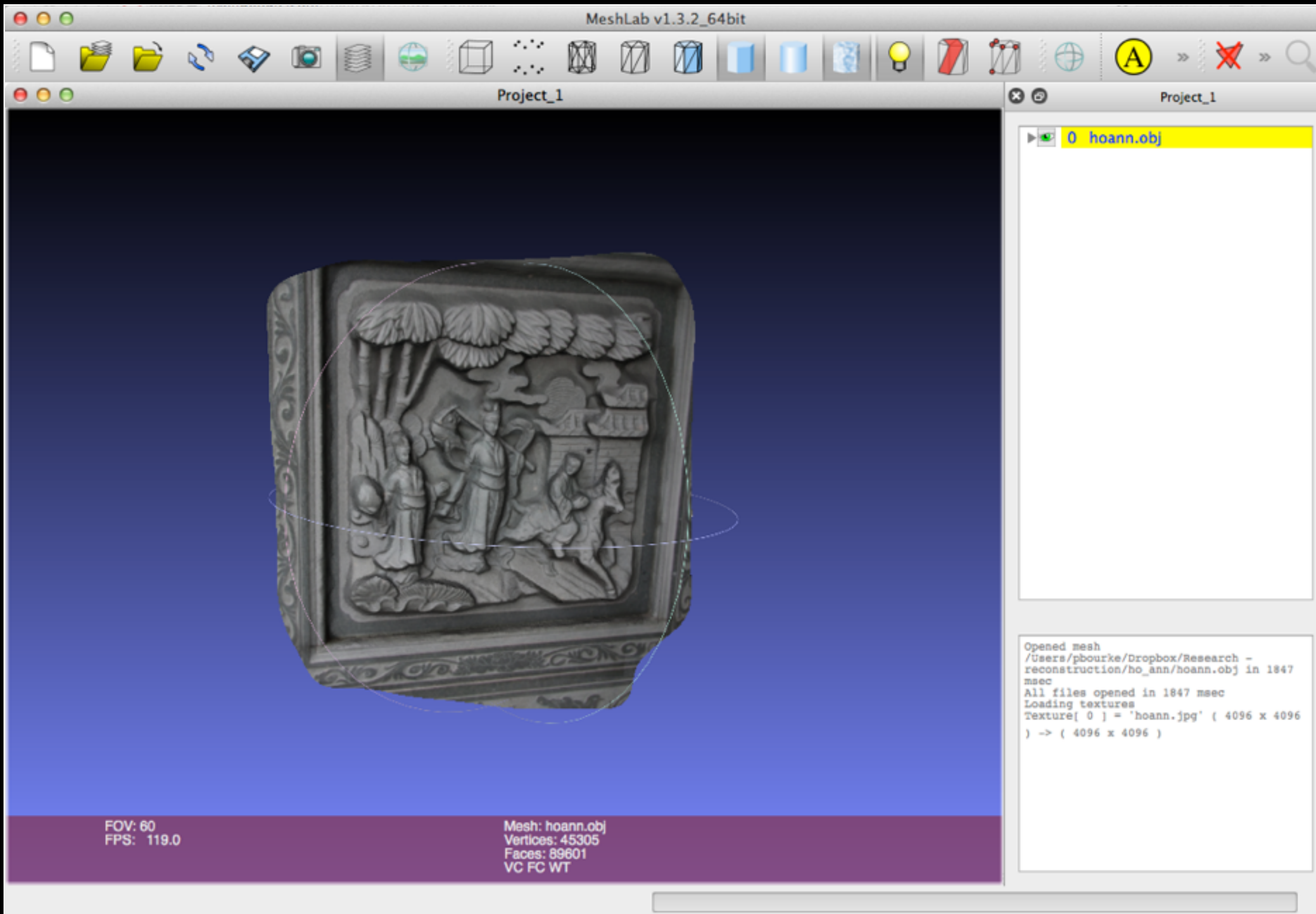
- File formats



Geometry processing : MeshLab

- There are a number of packages that can be used to manipulate the resulting textured mesh files
- Meshlab is the free package of choice
- It is cross platform with a high degree of compatibility
- Very general tool for dealing with textured meshes
- Has a large collection of algorithms and is extensible
- Unfortunately not all algorithms are “reliable”
- In cases where raw Bundler is used to create a point cloud, Meshlab can be used to construct the mesh using one of a number of algorithms
  - Ball pivot (my general choice)
  - Marching Cubes
  - Poisson surface reconstruction

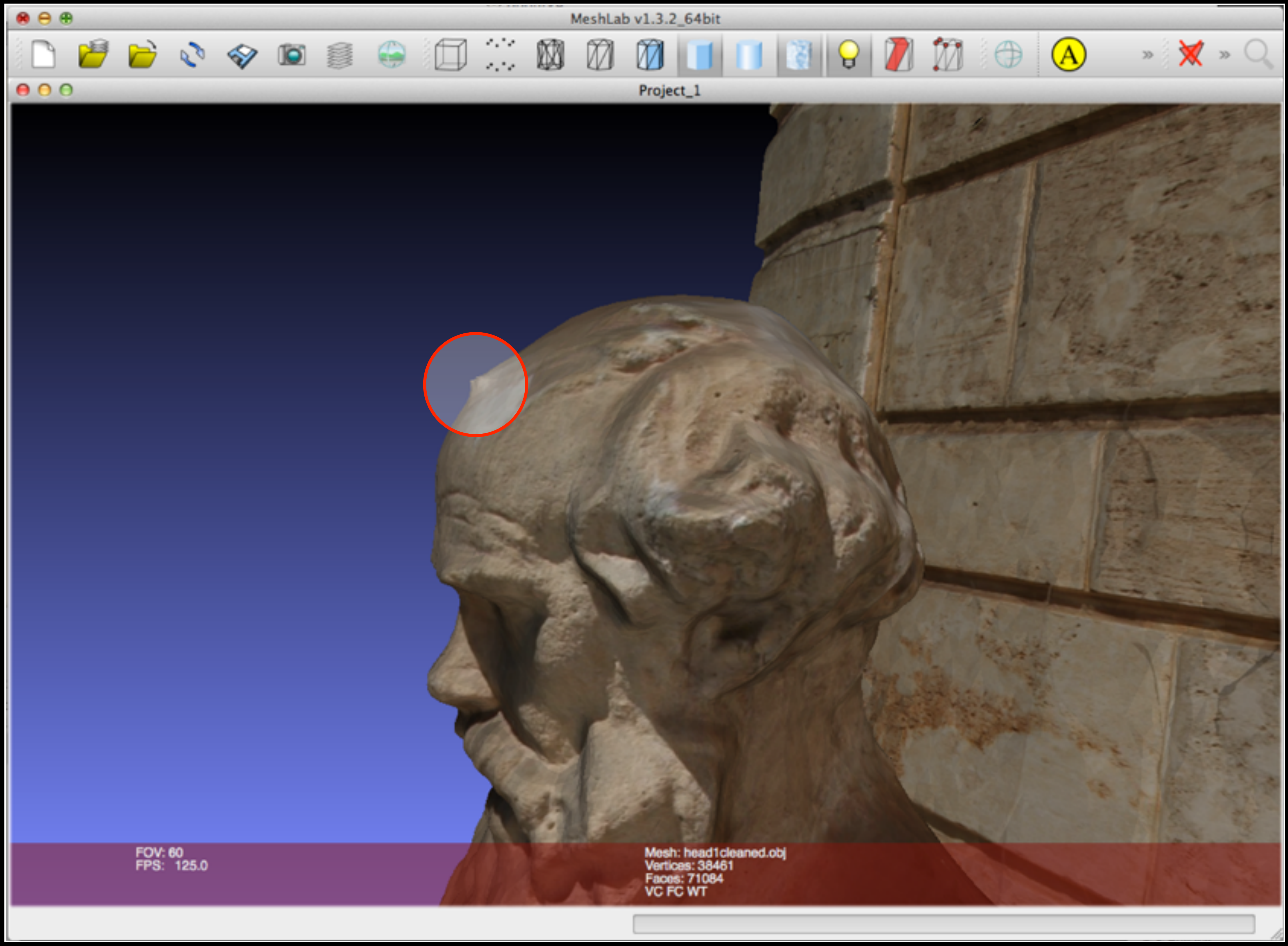
Geometry processing : MeshLab



Geometry processing : Blender

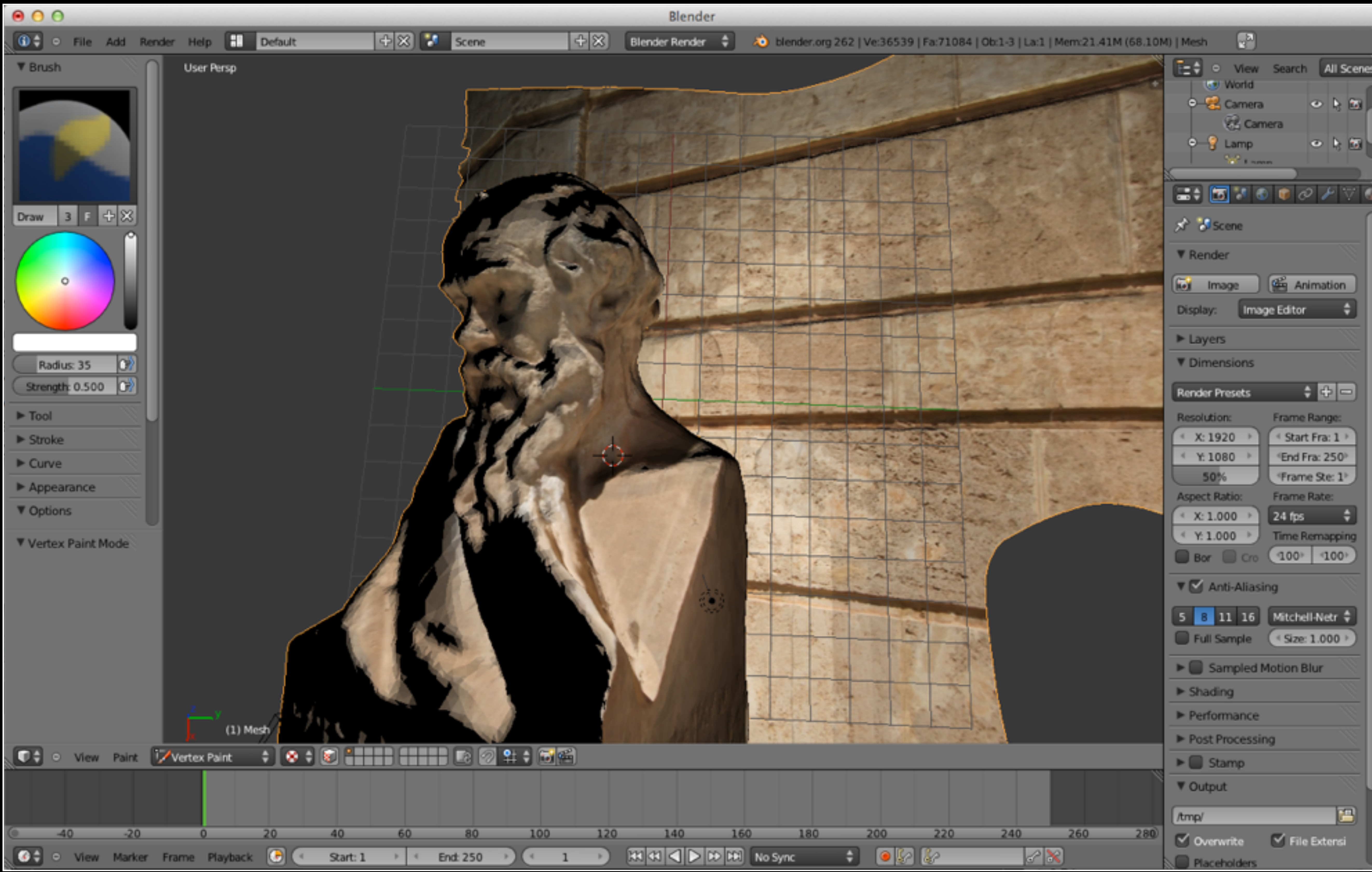
- Largely used for per vertex editing
- “Big hammer to crack a small nut”, takes some time to learn the interface
- For example, not uncommon to get single vertex “spikes”
- Contains it’s own mesh simplification and thickening algorithms
- Also used to export in a myriad of additional formats
  For example fbx for Unity3D, not available in MeshLab

Geometry processing : Blender



Socrates, UWA

Geometry processing : Blender

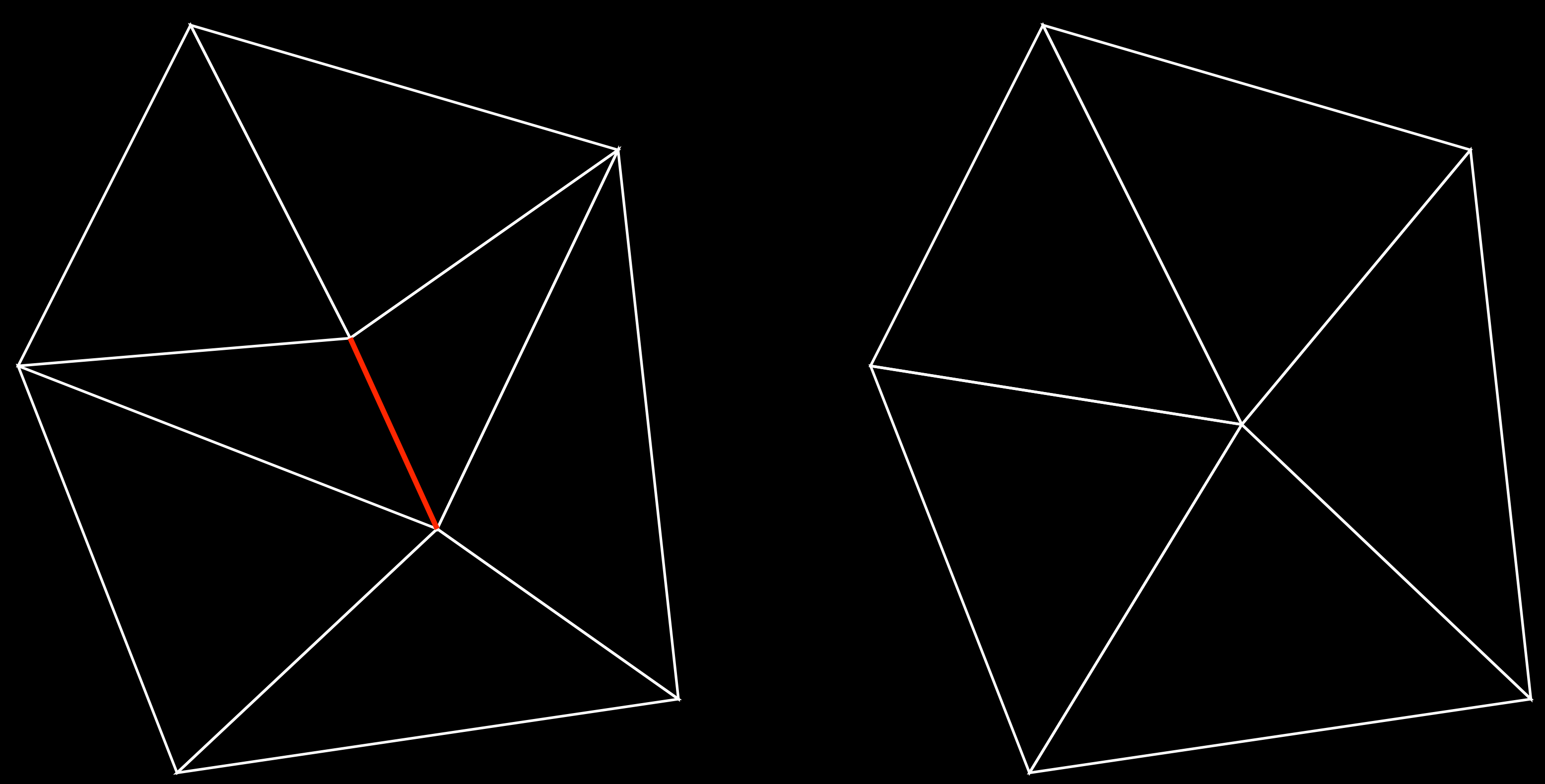


Geometry processing : Mesh simplification

- Meshes directly from the reconstruction (generated from the dense point cloud) are generally inefficient. Often need to reduce them for realtime applications and/or web based delivery
- Also used to create multiple levels of details (LOD) for gaming and other realtime applications
- The goal is easy to understand: remove mesh density where it will make minimal impact on the mesh appearance. For example, don't need high mesh density in regions of low curvature
- Most common class of algorithm is referred to as "edge collapse", replace an edge with a vertex
- A texture and geometry approximation ... need to estimate new texture coordinate at new vertices
- Need to preserve the boundary
- This has been a common topic in computer graphics research and is still a huge topic in computer graphics, see Siggraph over the last few years

Geometry processing : Mesh simplification

- Most edge collapse algorithms involve replacing an edge with a vertex
  - How to choose the edges to remove is the “trick”
  - Where to locate the new vertex so as to minimise the effect on the surface
  - How to estimate the new texture coordinate
- Number of triangles reduces by 2 on each iteration
- Can calculate the deviation of the surface for any particular edge collapse
  Choose edges with smallest deviations



Red edge removed, results in two fewer triangles

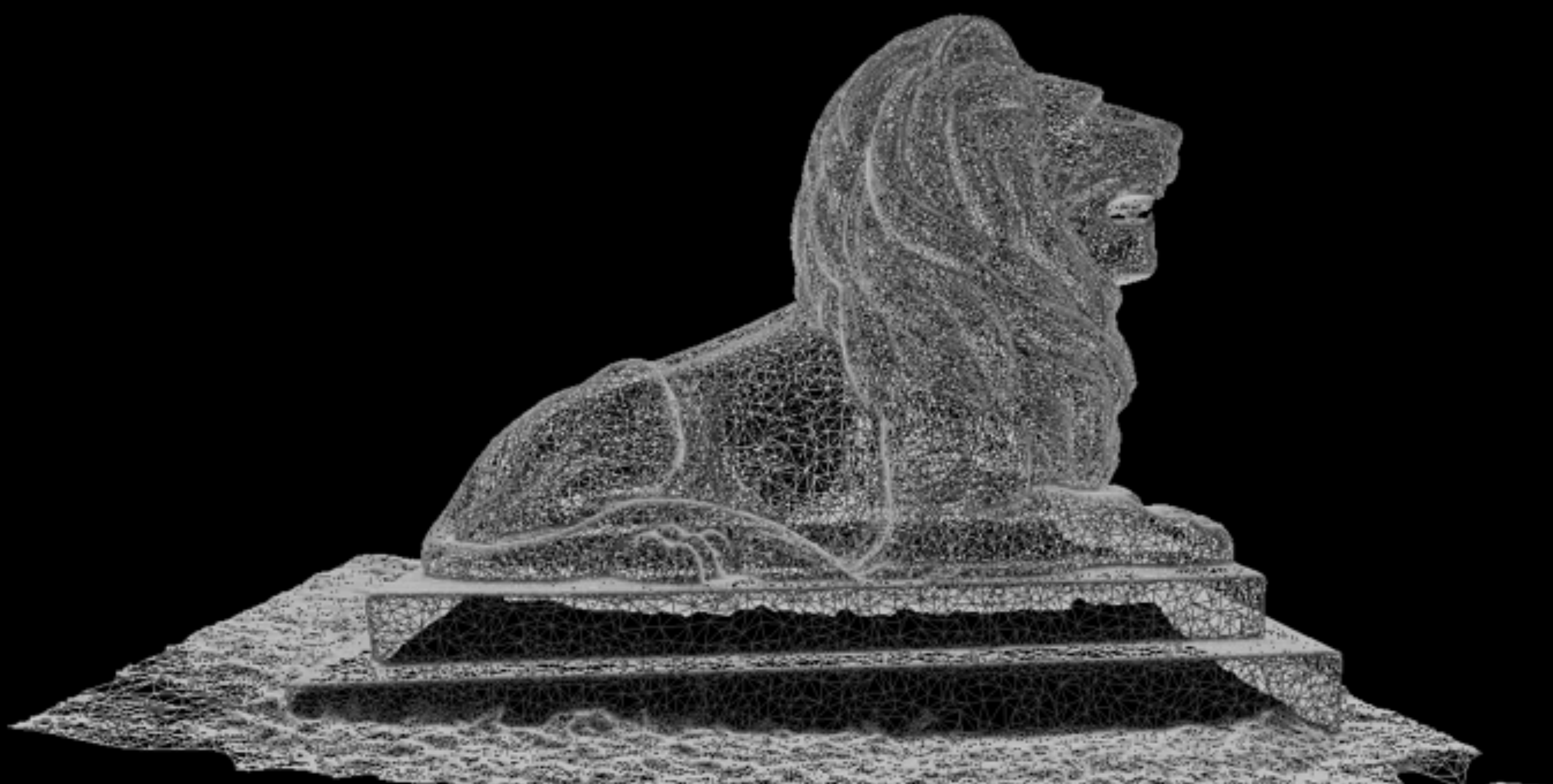
Geometry processing : Mesh simplification

1,000,000 triangles

100,00 triangles

Geometry processing : Mesh simplification

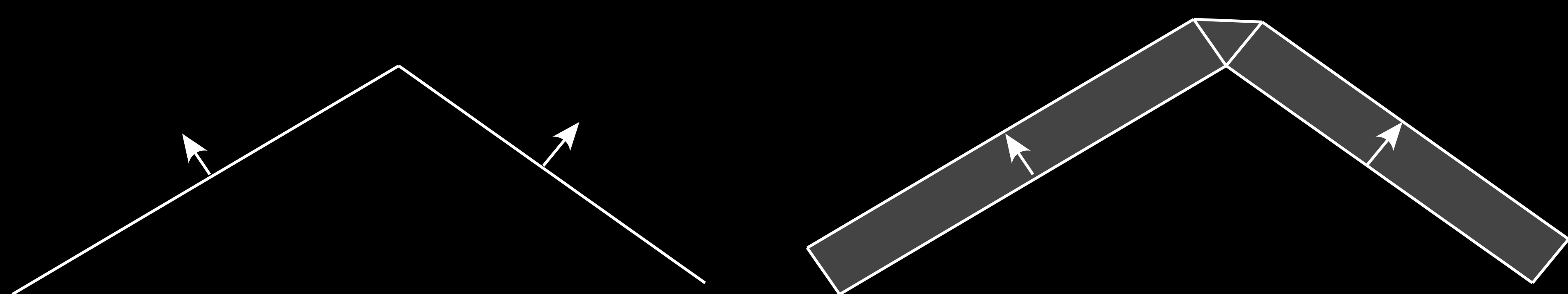
1,000,000 triangles



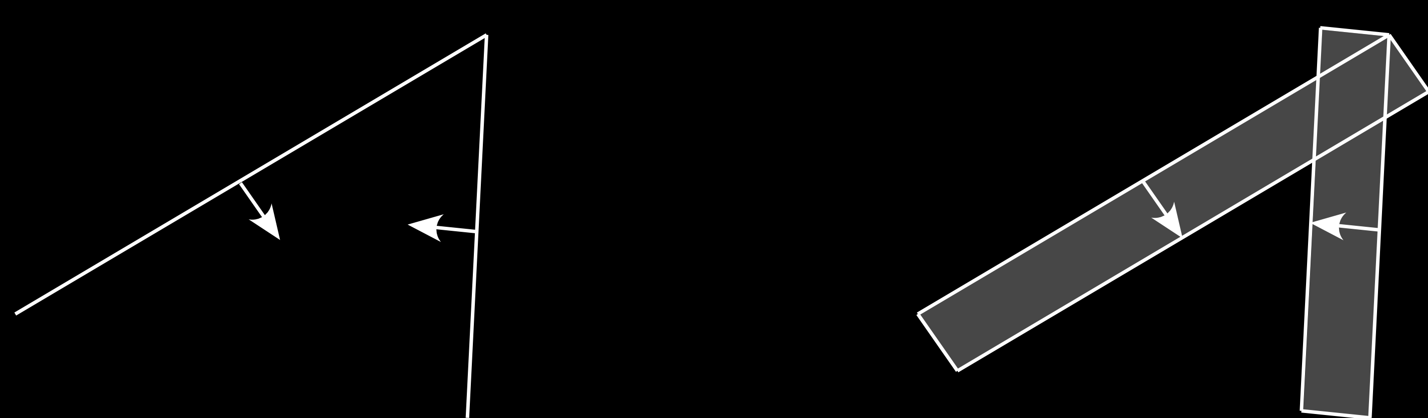
100,00 triangles

Geometry processing : Mesh thickening

- Cases exist where one does not want idealised "infinitely thin" surfaces
- Double sided rendering in realtime APIs is not quite the same visual effect as physical thickness
- Required to create physical models, see rapid prototyping later
- Perhaps the most common algorithm is known as "rolling ball"



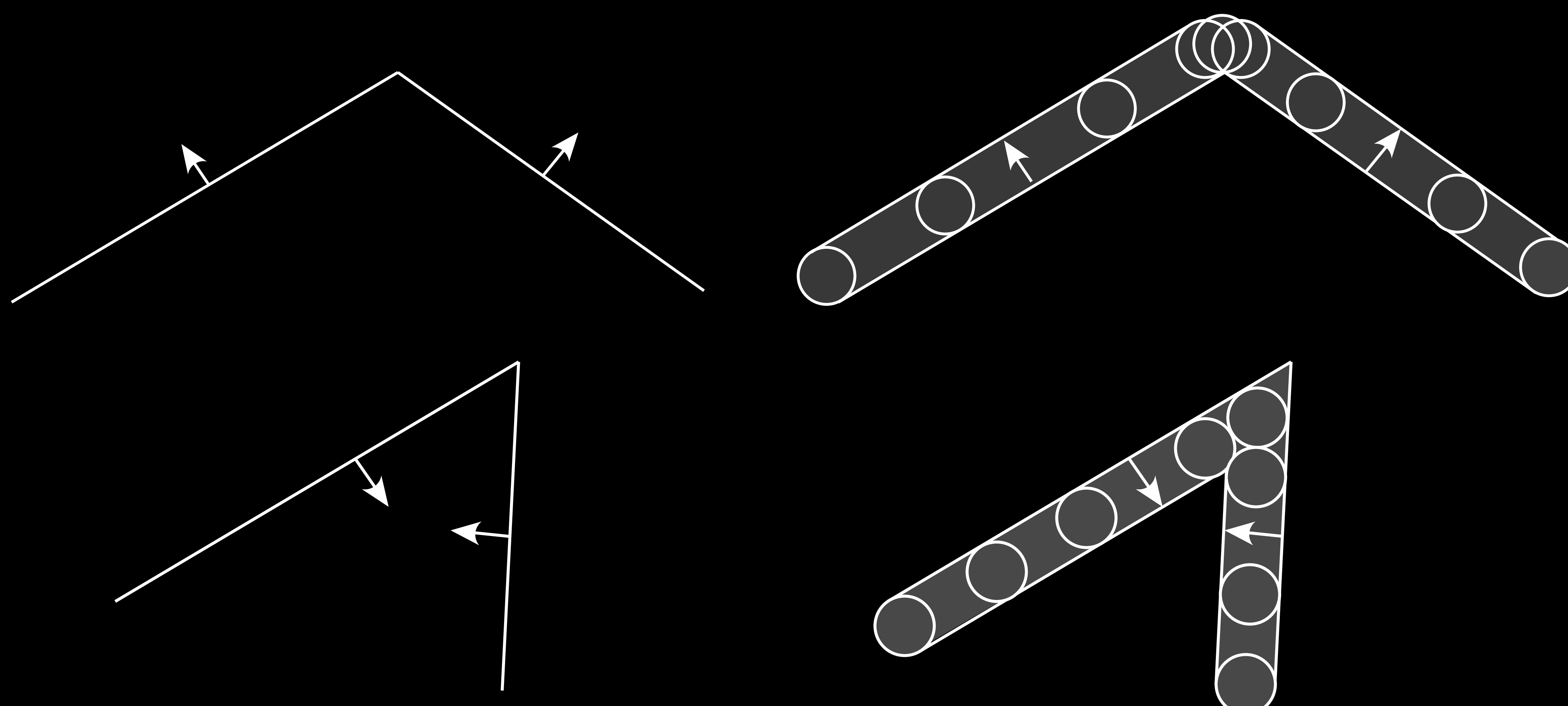
Thin joints arise at regions of high curvature



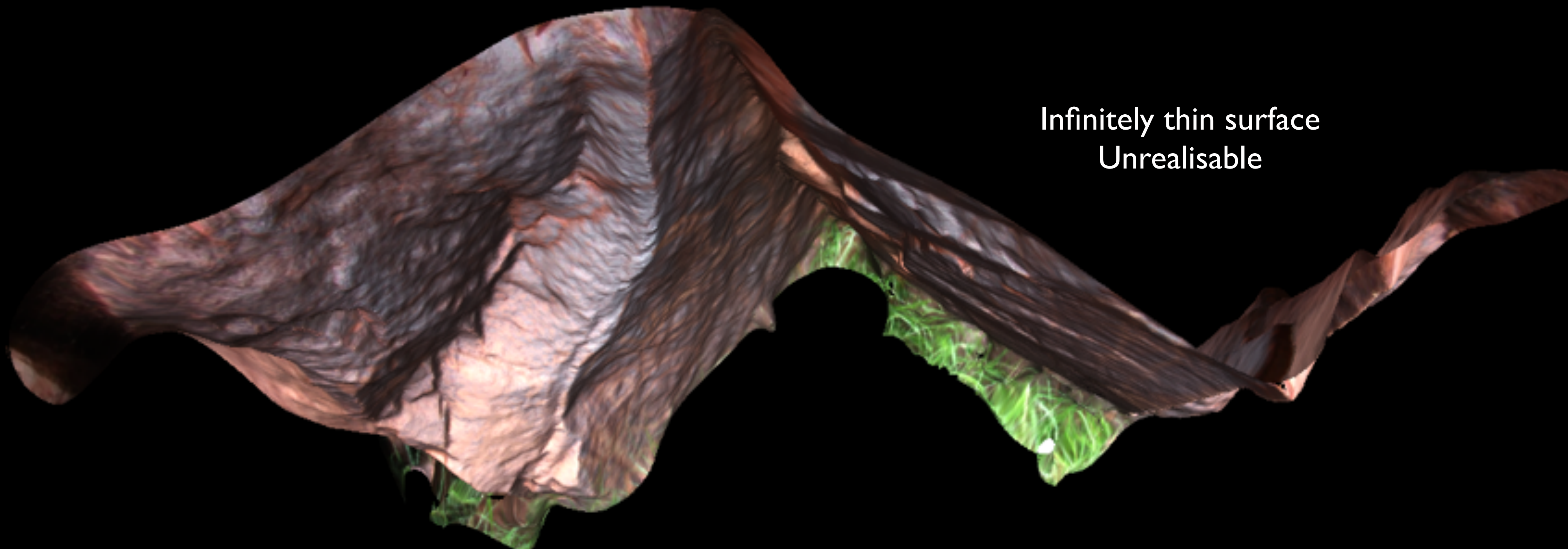
Get "poke-through" with sharp concave interiors

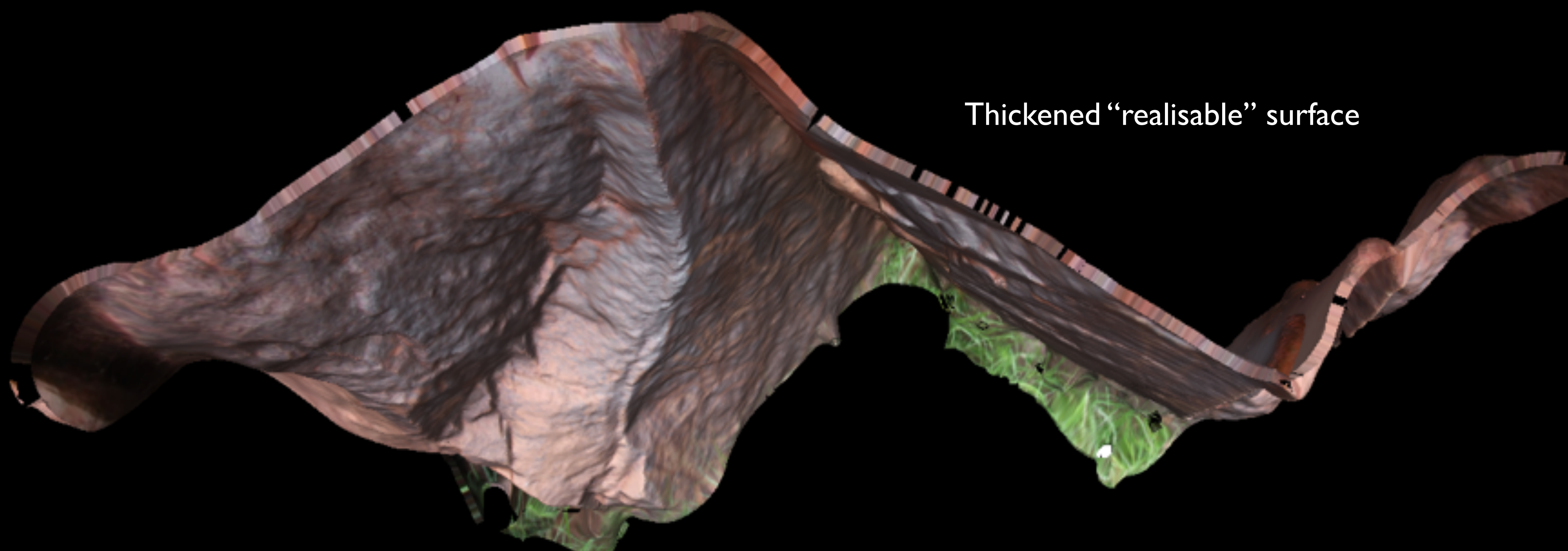
Geometry processing : Mesh thickening

- Solution is called “rolling ball” thickening.
- Imagine a ball rolling across the surface, form an external mesh along the ball path.
- Implemented in Blender as a modifier called “solidify”.



Geometry processing : Mesh thickening

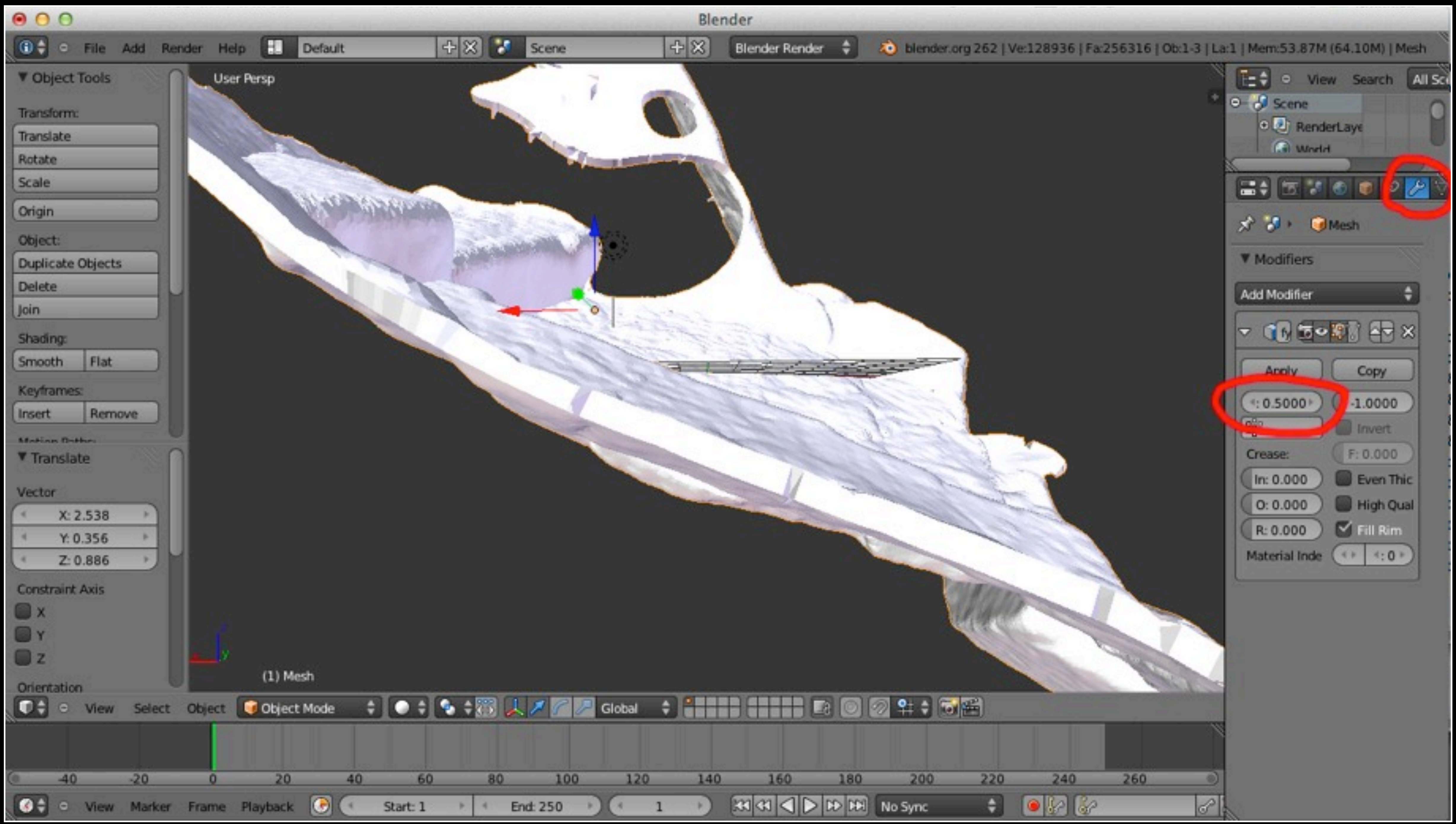




Geometry processing : Mesh thickening

- “Solidify” modifier in Blender.

- Modifiers are elegant since they don’t permanently affect the geometry, can change later.



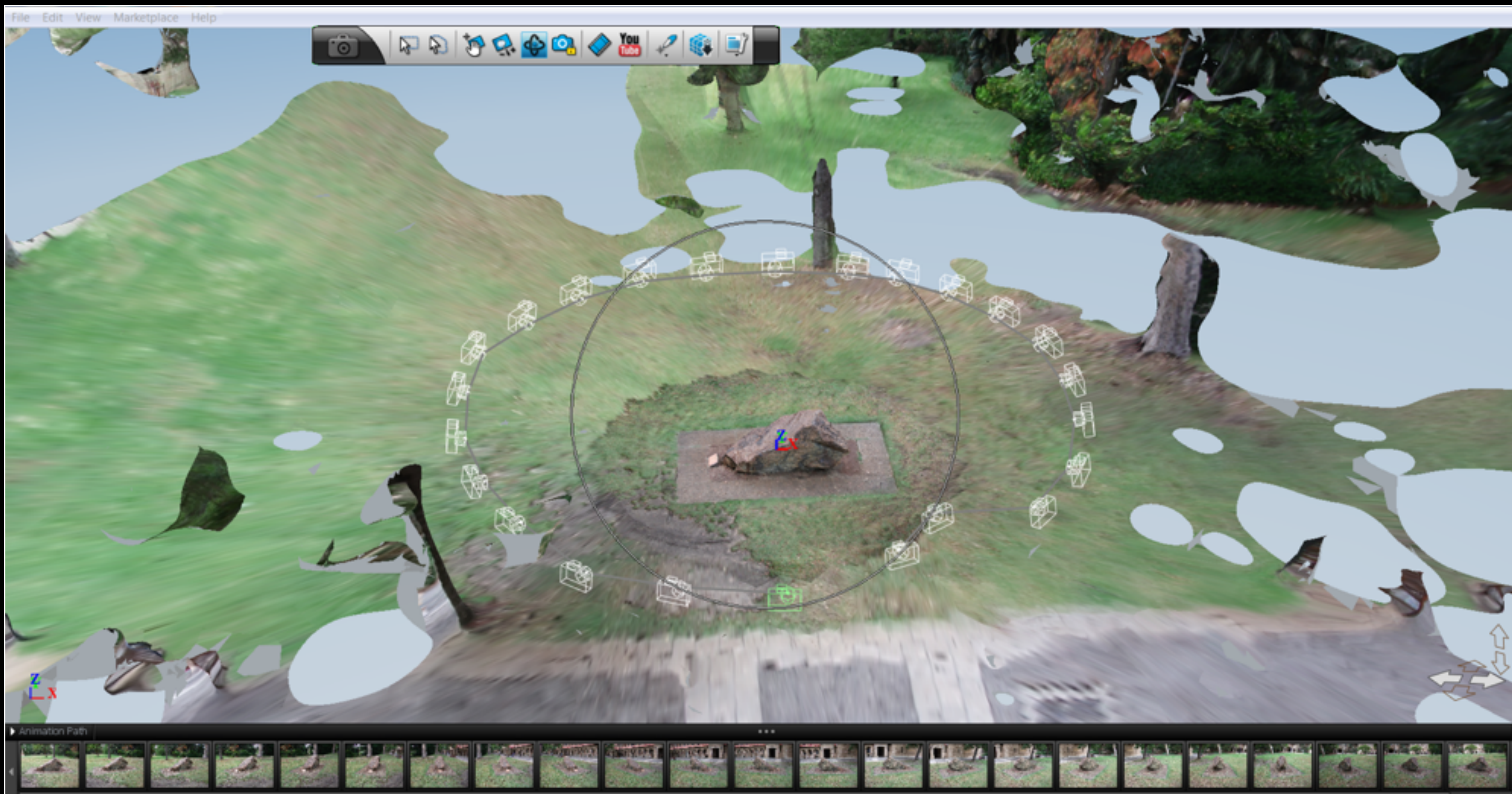
Geometry processing : Removing shrapnel and hole closing

- Very common for there to be extraneous geometry
- Remove reconstructed parts of the scene that are not of interest
- Not uncommon for meshes to contain small holes, may be closed automatically by some reconstruction packages

- Typically use MeshLab for hole closing
- Also supported in some reconstruction packages, for example: PhotoScan
- Don't usually contain texture information, holes usually due to regions not visible in any photograph

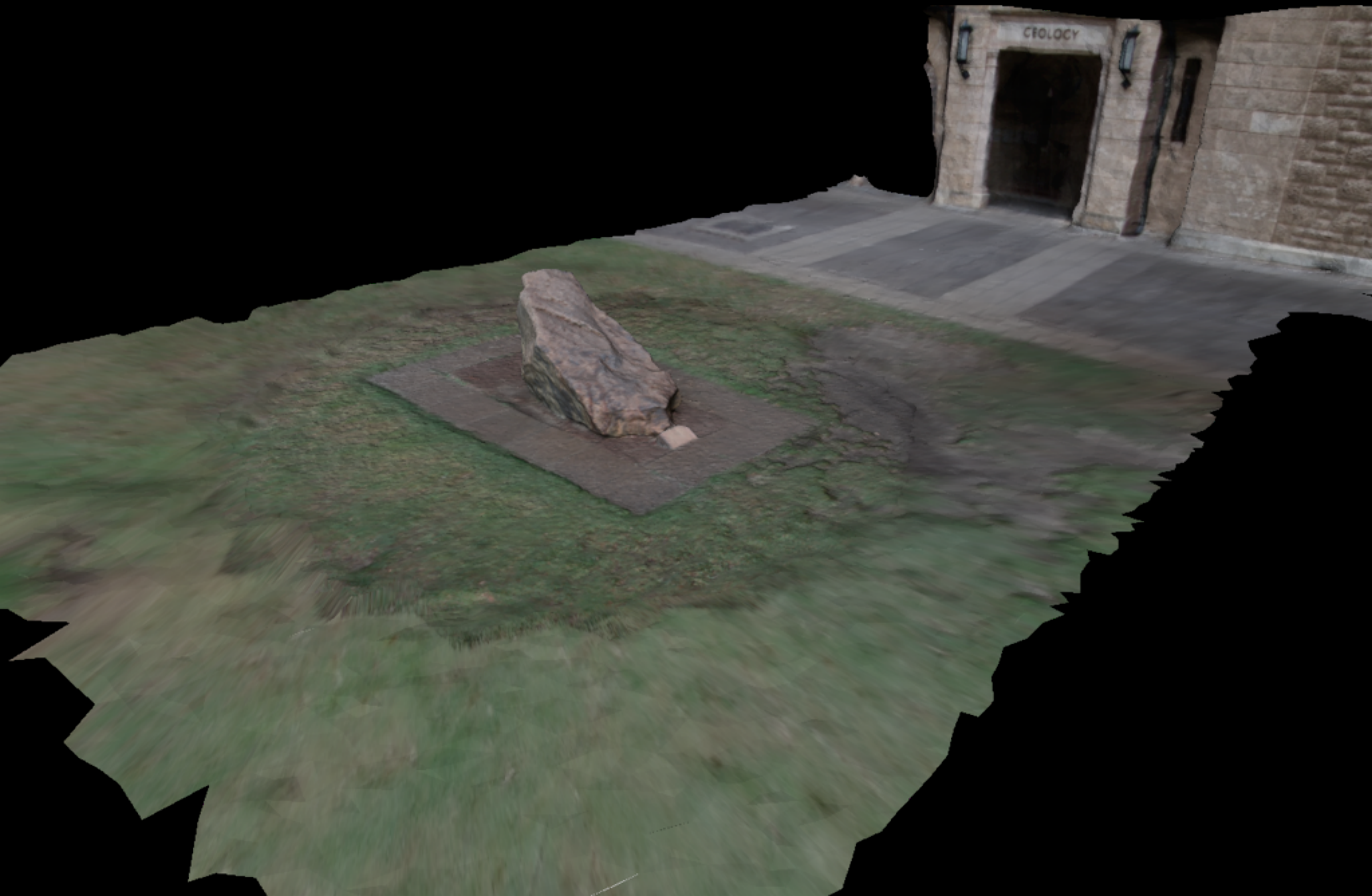
Geometry processing : Removing shrapnel and hole closing

Geometry processing : Removing shrapnel and hole closing



Geometry processing : Removing shrapnel and hole closing

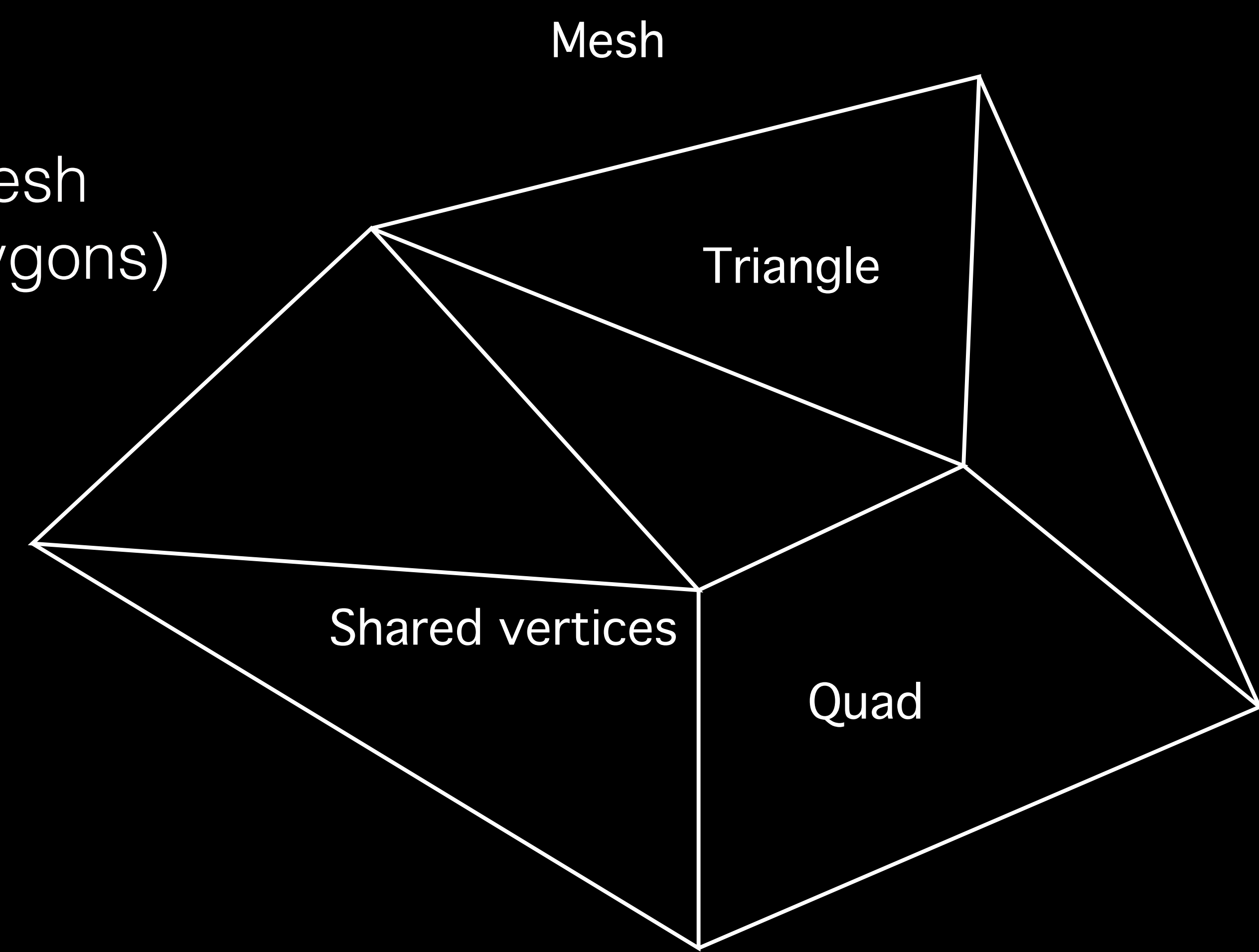
Geometry processing : Removing shrapnel and hole closing



Geometry processing : File formats

- Requirements: unstructured triangular mesh
  - mesh (vertices - edges - triangles - polygons)
  - texture coordinates
  - image based textures

- Common options
  - 3ds (3DStudioMax)
  - vrml, x3d
  - obj (Wavefront)
  - dae (collada)



- Pretty much standardised on obj, desirable characteristics
  - text only so human readable
  - relatively easy to parse by software for post processing or custom utilities
  - well supported by commercial 3D applications (import/export)
  - shared vertices so no chance of numerical holes
  - supports multiple texture materials and images

- [Poorly formed obj files by 123D Catch]

Geometry processing : File formats

- Anatomy of an OBJ file. Consists of 3 parts
  - vertex, face, normals, texture coordinates
  - materials file
  - texture image files

```
mtllib ./stone.obj.mtl

v 7.980470 5.627900 3.764240
v 8.476580 2.132000 3.392570
v 8.514860 2.182000 3.396990
  :
  :
vn -0.502475 -1.595313 -2.429116
vn 1.770880 -2.076491 -5.336680
vn -0.718451 -4.758880 -3.222428
  :
  :
vt 0.214445 0.283779
vt 0.213670 0.287044
vt 0.211291 0.287318
  :
  :
usemtl material_0
f 5439/4403/5439 5416/4380/5416 7144/6002/7144
f 5048/4013/5048 6581/5437/6581 5436/4400/5436
f 5435/4399/5435 5049/4014/5049 5436/4400/5436
  :
  :
```

vertices

normals

texture coordinates

triangles

vertex index

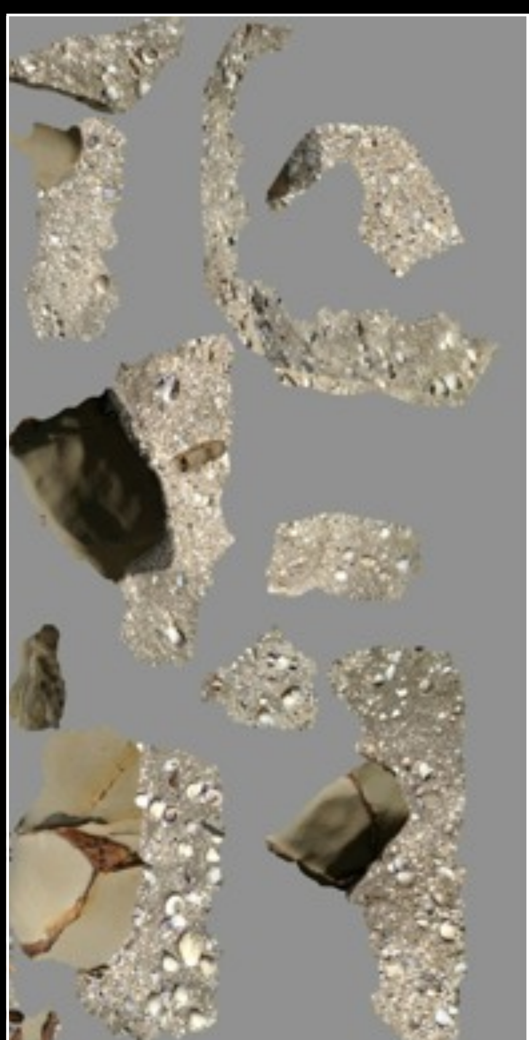
normal index

texture coordinate index

filename

material name

```
newmtl material_0
Ka 0.2 0.2 0.2
Kd 0.752941 0.752941 0.752941
Ks 1.000000 1.000000 1.000000
Tr 1.000000
illum 2
Ns 0.000000
map_Kd stone_tex_0.jpg
```



Case study 2 : Diotima (UWA)

- Require significantly more images ... a 360 objects
- 16 images in this case, a relatively low number for a full 3D object
- Some algorithms perform better if the images are captured in sequence with the best matches at the start of the bundle adjustment
- Depends on whether the software does a compare between all images
- Diffuse lighting conditions so no strong shadows, see later on limitations
- “Bald” spot because no photographs from above, see later on limitations on access

Case study 2 : Diotima

Case study 2 : Diotima

Movie

Diotima (Mistress of Pericles)
16 images

Other topics

- Resolution: real vs apparent
- Resolution: Geometric vs texture
- Relighting
- Rendering
- Annotation
- Texture editing

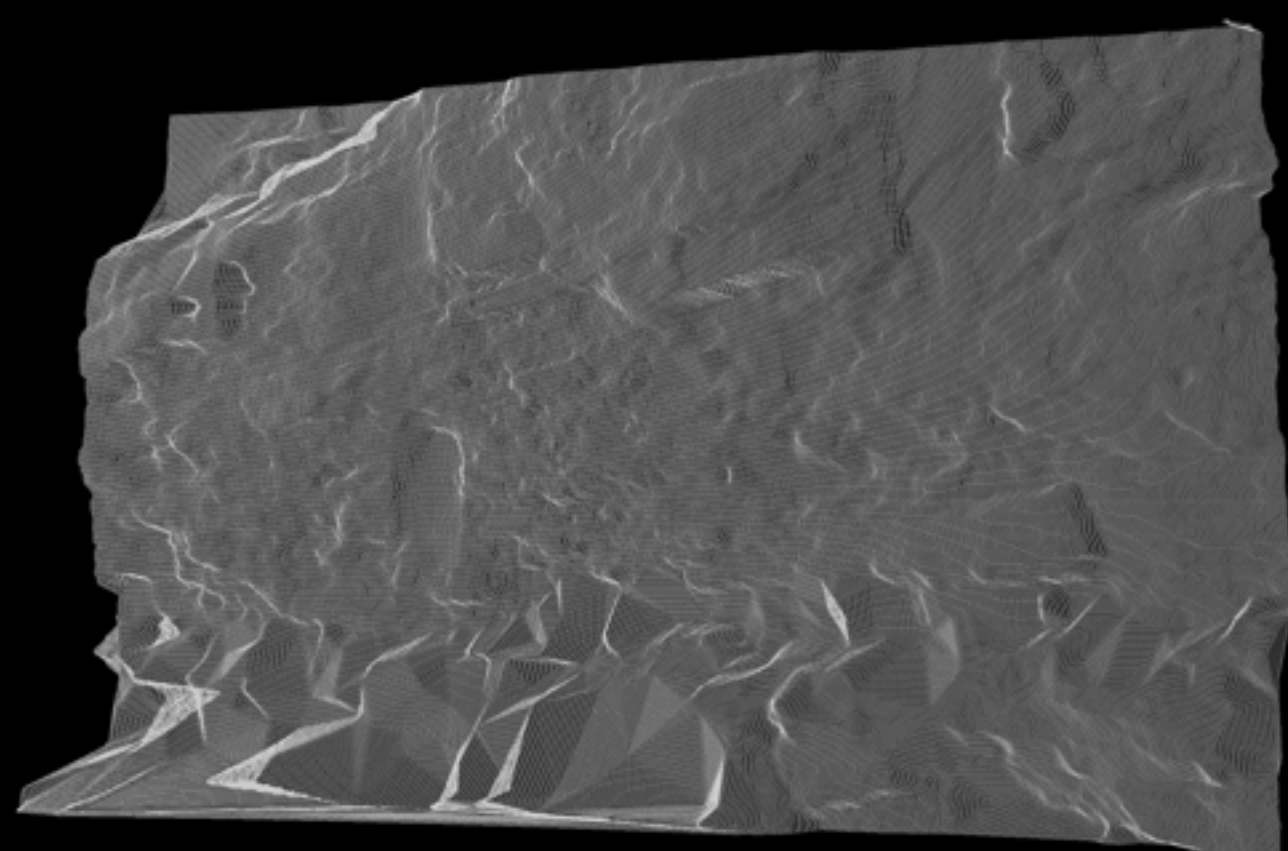
Other topics : resolution

- Actual mesh resolution vs apparent mesh resolution
- Texture resolution rather than geometric resolution
- Requirements vary depending on the end application
  - Realtime environments require low geometric complexity and high texture detail
  - Analysis generally requires high geometric detail
  - Digital record wants high geometric and texture detail

	Geometric resolution	Texture resolution
Gaming	Low	High
Analysis	High	Don't care
Education	Medium	High
Archive/heritage	High	High
Online	Low/Average	Low/average

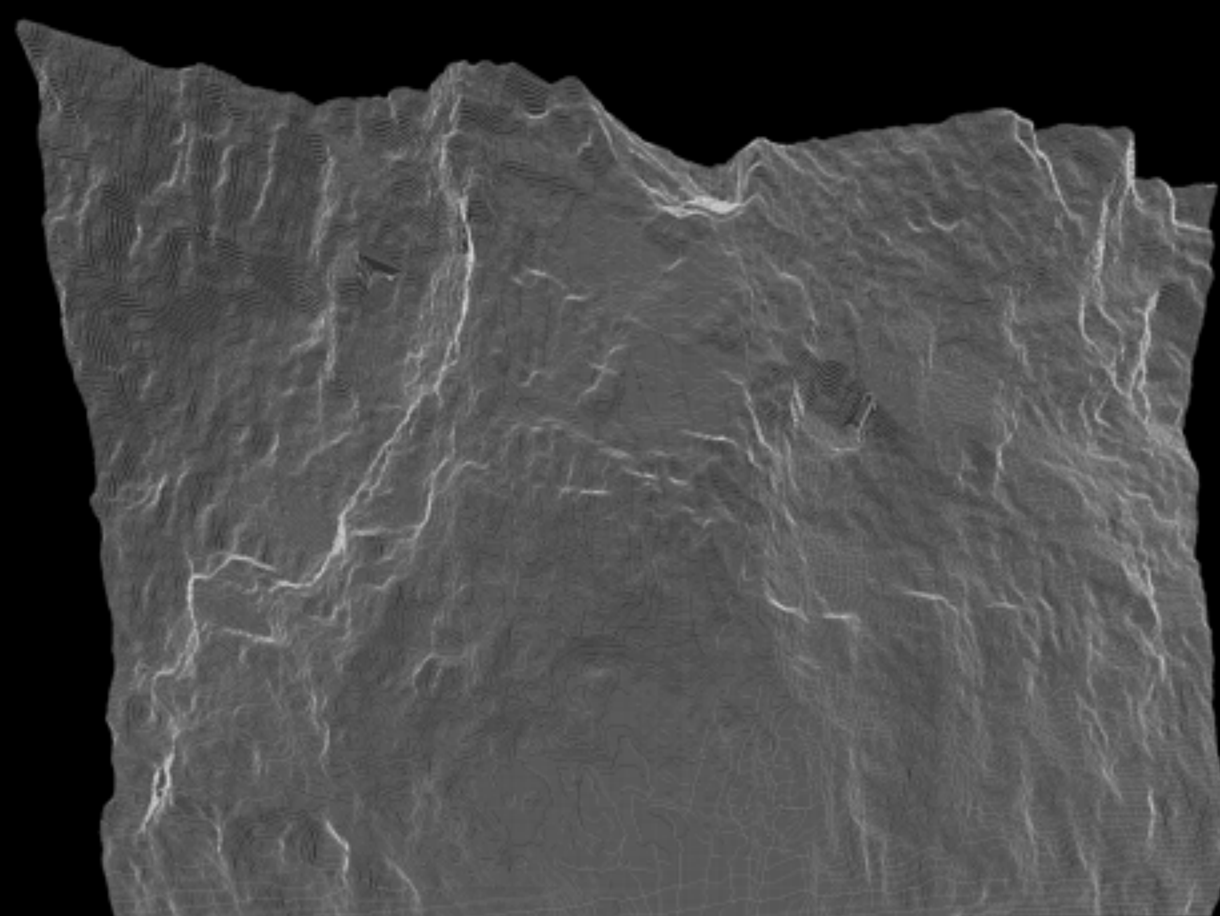
Other topics : resolution

Apparent high resolution

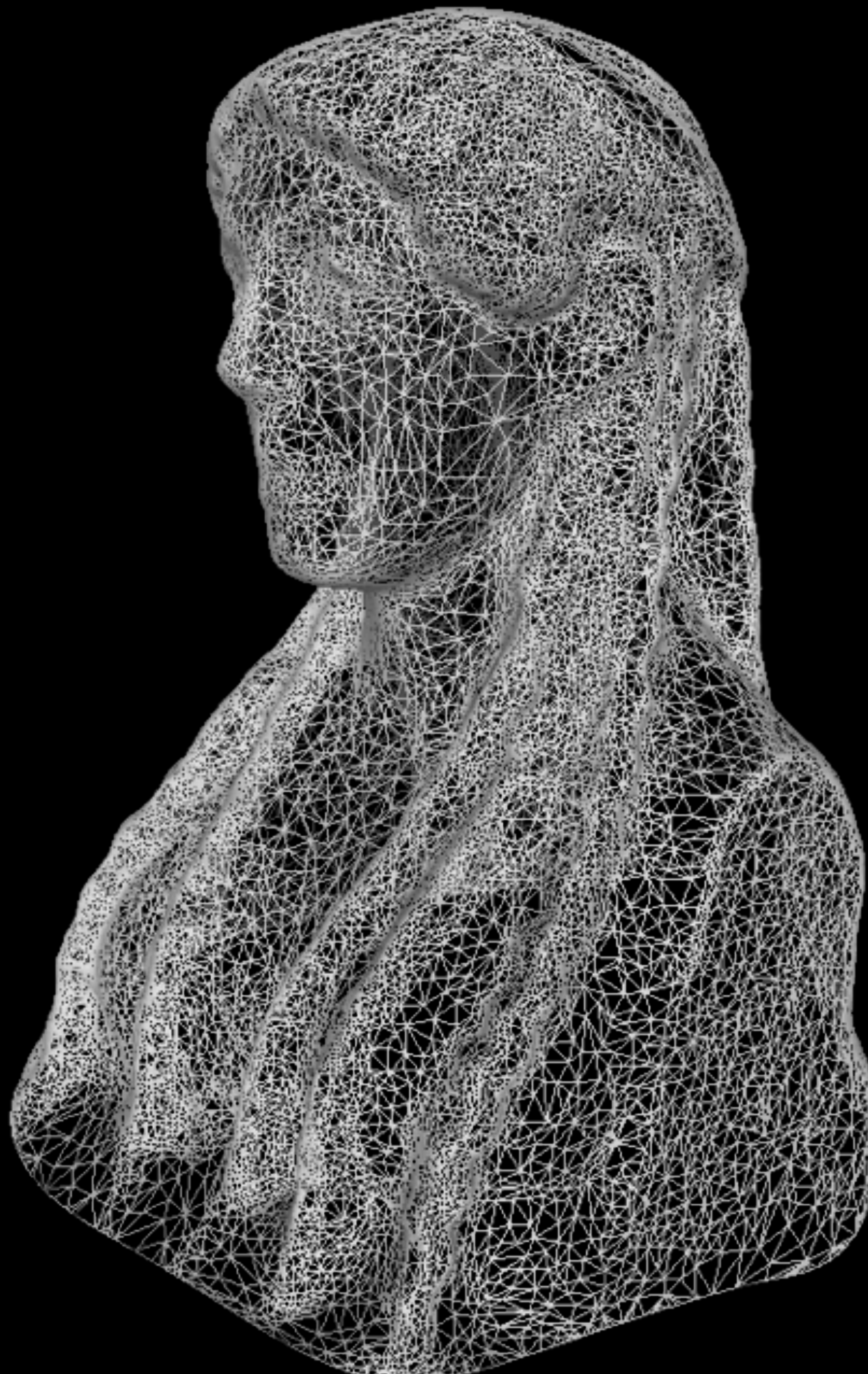


Very low resolution geometry

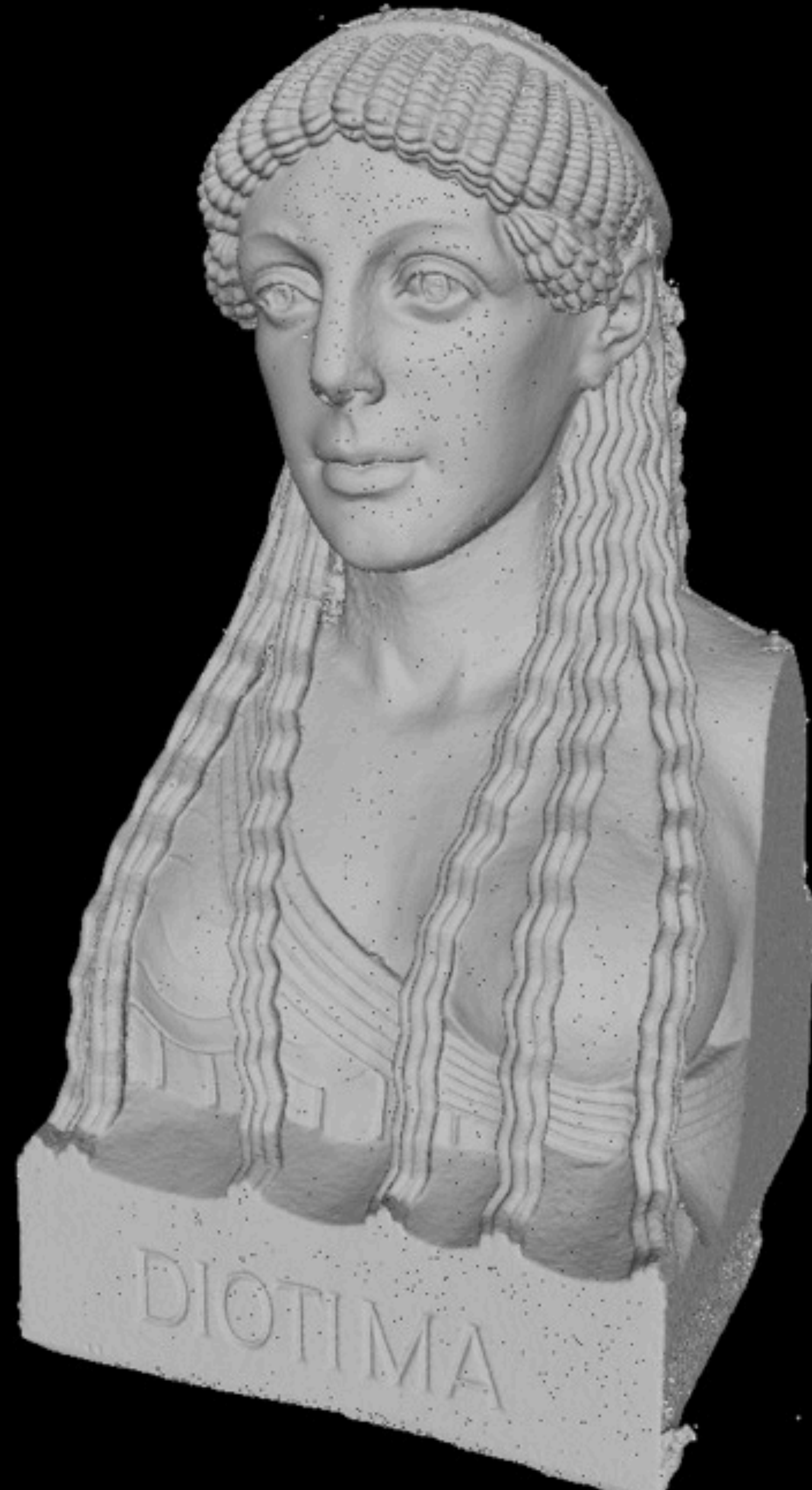
Other topics : resolution



Other topics : resolution



Other topics : resolution



Other topics : Relighting

- We have a 3D model, can “relight” it
  For example: cast shadows, adjust diffuse/specular shading
- Obviously works best with diffuse lit models
- See later for baked on texture limitations
- Interesting in the archaeology context since it is well known that some features are “revealed” in different lighting conditions
- Cannot replicate effects of dyes but can replicate effects due to shading/shadowing of fine details

Other topics : Relighting

Movie

Terrenganu, Malaysia

Other topics : Relighting

Movie

Other topics : Rendering

Movie

Other topics : Analysis

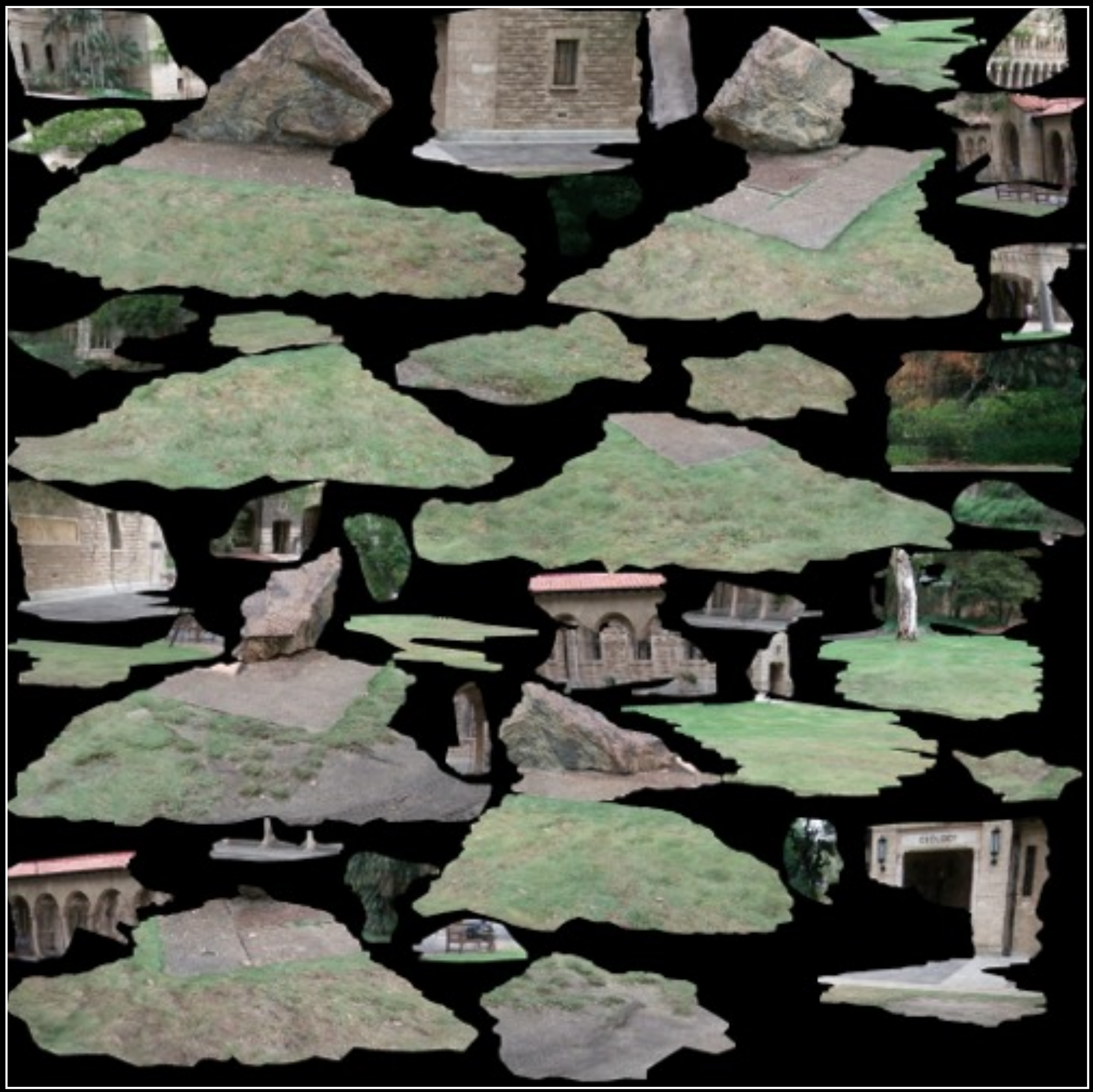
Movie

1000 Buddha temple, Manipal, India

Other topics : Annotating

- Textures from the reconstruction algorithms are often “interesting”
- Exact form of the texture depends to some extent on the software being used
  Can often identify the software based upon the appearance of the texture maps
- They are derived from re-projection of the image from the derived camera position onto the reconstructed mesh, hence potentially very high quality (perceived resolution)
- Can generally still be drawn on, treated as an image for image processing in PhotoShop, etc.

Other topics : Annotating



Texture map 1

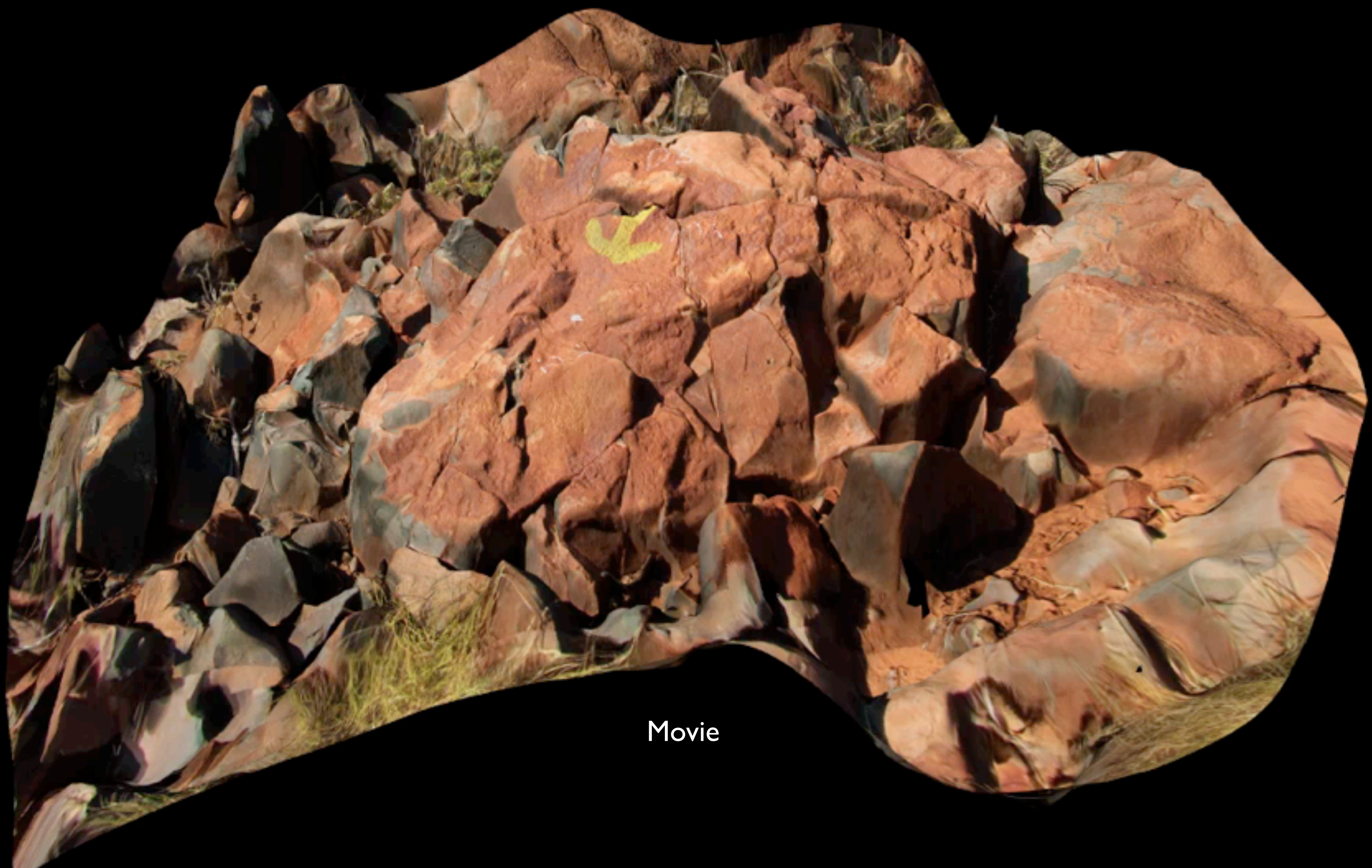
Texture map 2

Other topics : Annotating

Textured mesh

Other topics : Annotating

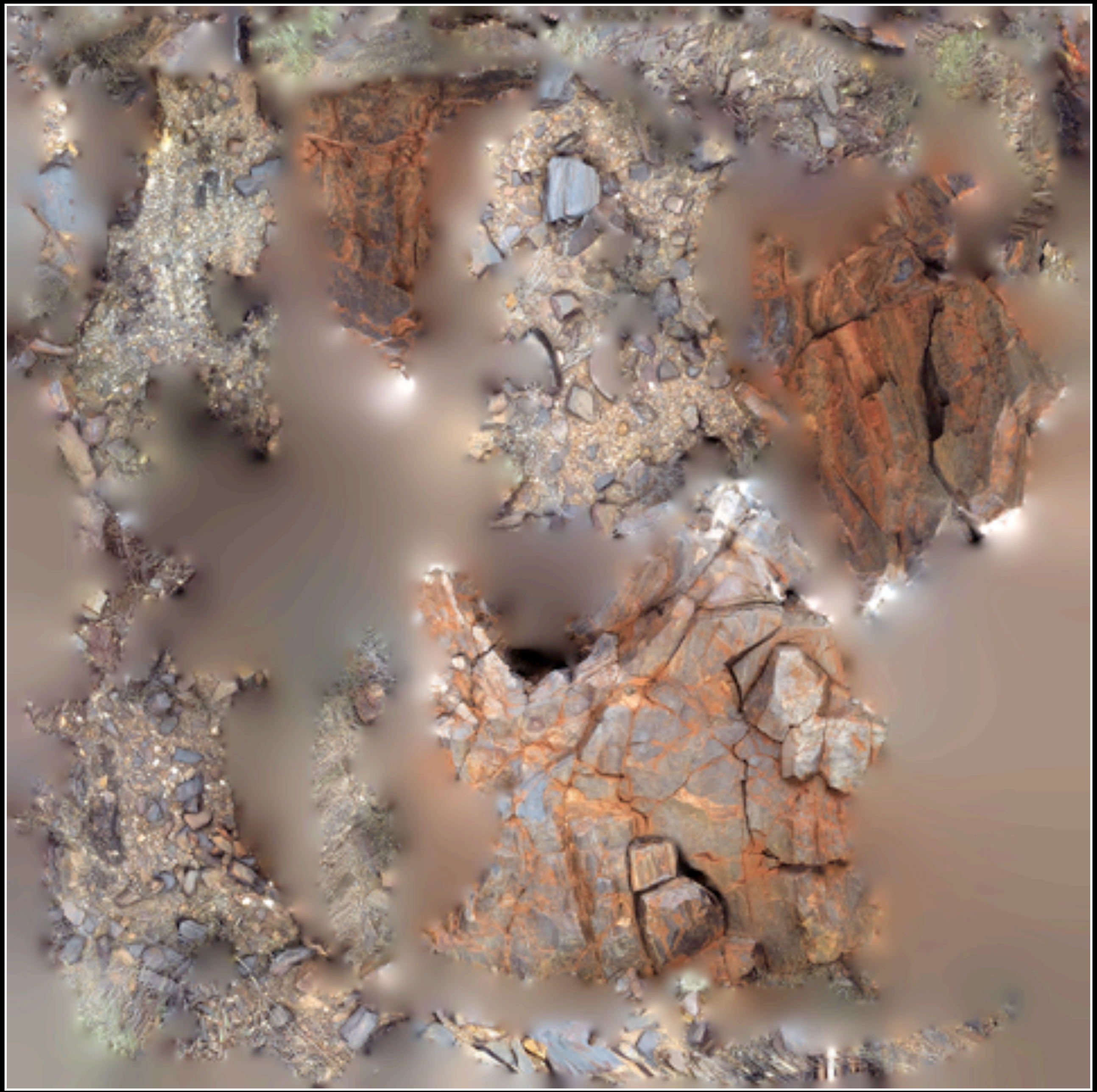
Other topics : Annotating



Movie

Other topics : texture editing

- Some texture mapping modes are easier to edit than others
- Can be difficult for per camera reprojected textures (left)
- Easier for orthographic texture maps (right), but not always a supported option.



Other topics : texture editing

- Can obviously do colour correction/grading on the texture post reconstruction.

Limitations and Challenges

- Occluders - Problematic
- Movement in the scene
- Thin structures
- Baked on shadows
- Lighting changes during capture
- Access to ideal vantage points
- Online and database access
- High level queries for geometric
- Reflective surfaces

Limitations : Occluders

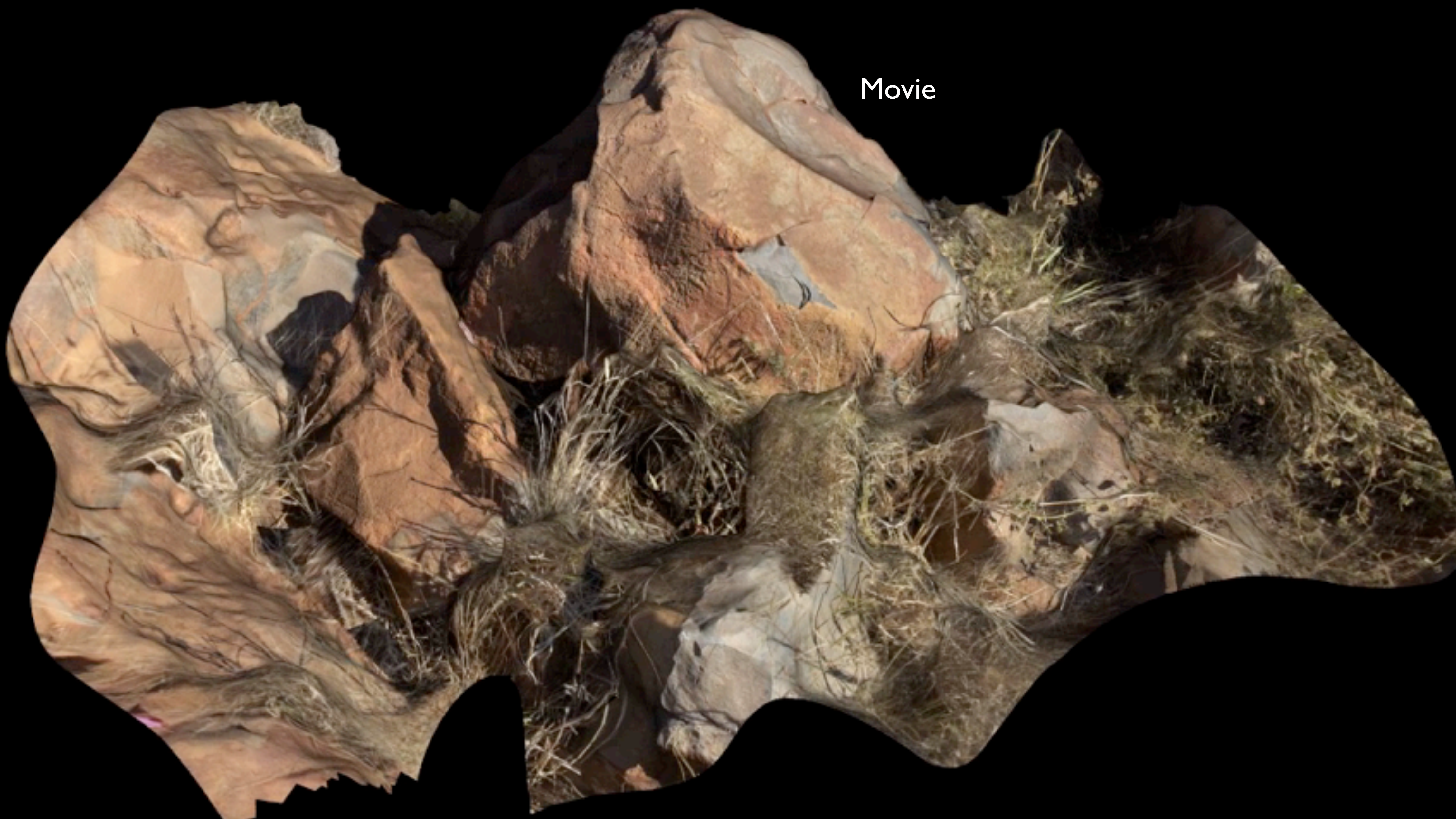
- Algorithms seem to be generally poor at handling foreground occluders
- For example: columns in front of a building
- Reason: a small change ins camera position results in a large difference in visible objects
- Capturing the backdrop behind an object
  - Often better, assuming possible, to capture them separately

Limitations : Occluders

St Lawrence, Manipal, India

Limitations : Movement

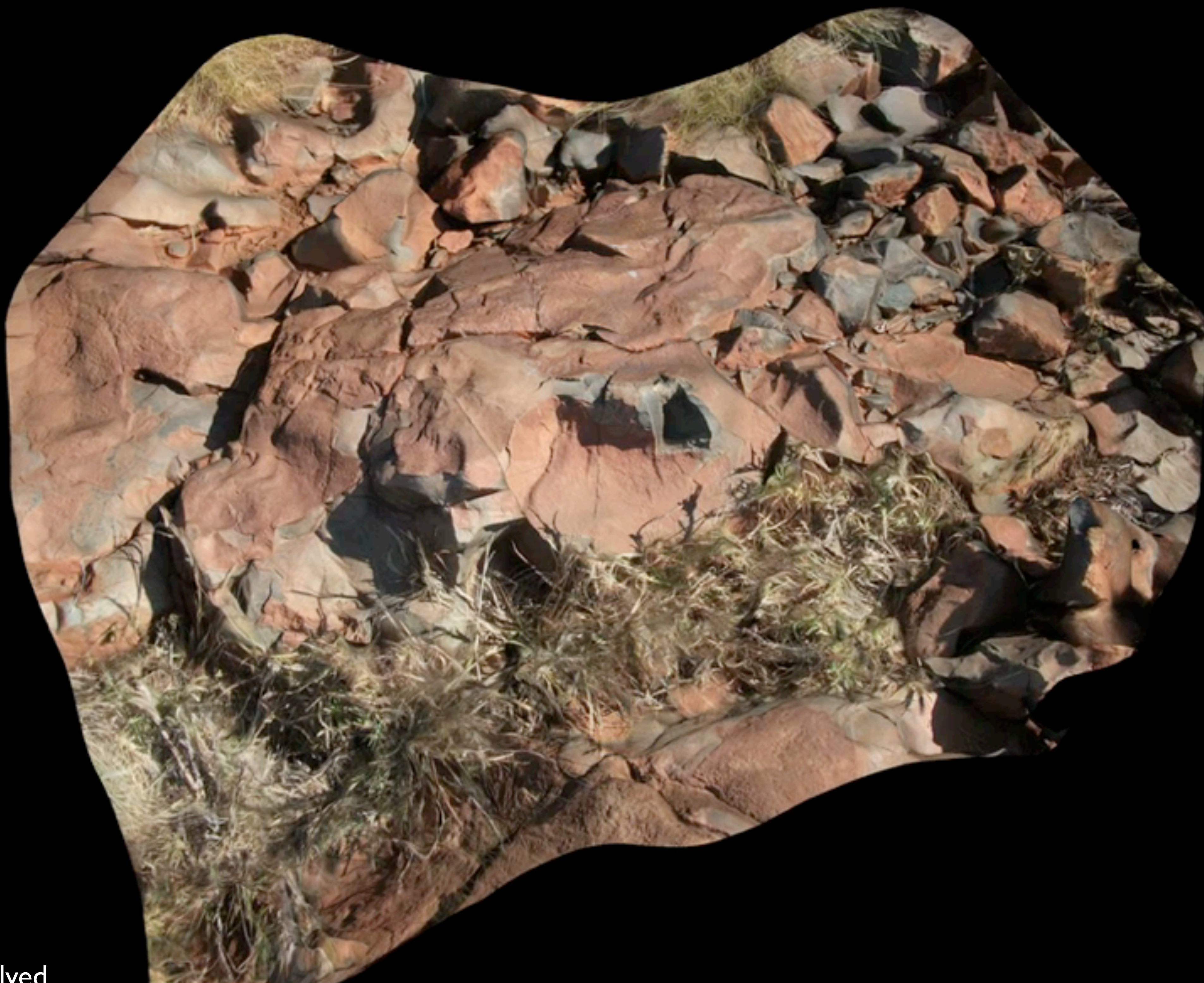
- Objects to be reconstructed obviously need to be stationary across photographs
- Grass moving in the wind is a common problem for field work
- Solution is to create a camera array for time simultaneous photography.



Limitations : Thin structures

- Difficult to reconstruct objects approaching a few pixels in the images (sampling theory)
- Example of grasses in the rock art reconstruction

Limitations : Thin structures

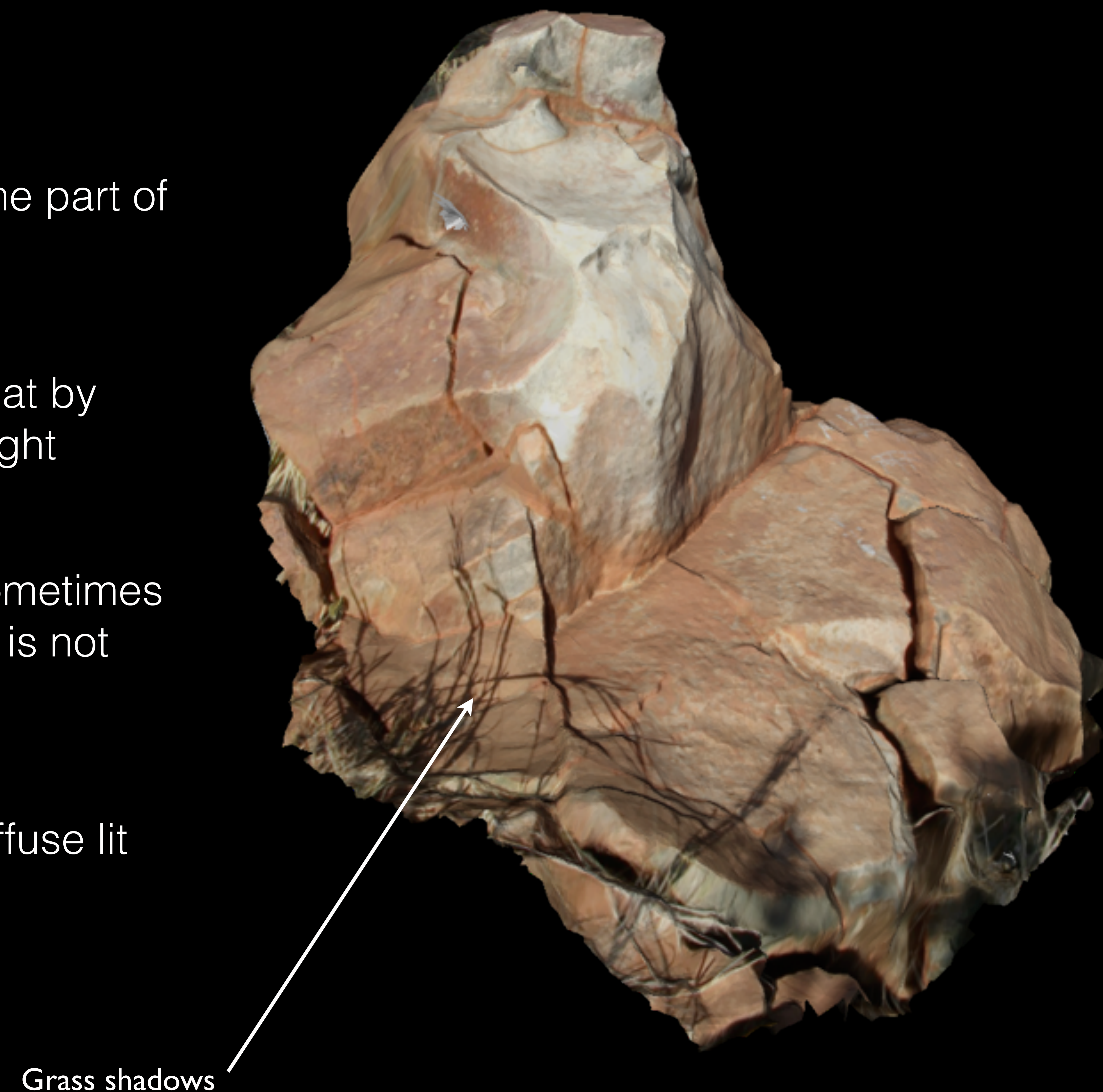


Movie

Grass not resolved

Limitations : Baked on shadows

- Shadows obviously become part of the texture maps
- Can be alleviated somewhat by photographing in diffuse light
- For outside objects can sometimes choose times when object is not directly lit
- Can sometimes choose diffuse lit days, cloudy



Limitations : Baked on shadows

Movie

HMAS Sydney Cairn, Canarvon

Limitations : Lighting changes and access

- For field work access to preferred positions for photographs may be problematic
- Similarly capturing photographs from above the object, elevated positions
- When capturing 30+ photographs for 3D objects the lighting conditions may change
  eg: clouds passing overhead
  Processes generally insensitive to this except for variations in resulting textures
- Shadows of the photographer

Limitations: Reflective surfaces

- Mirror surfaces can provide a non-linear reflection of the world that will influence the feature point detection
- Gives rise to a new art form - Photogrammetry that goes wrong in “interesting” ways

Fort Canning, Singapore

Limitations : database/online representations

- Claim that the need to store these higher level forms of data capture will increase
- Will this replace the need for storing photographic data?
- Surprisingly (depressingly) even after all these years of online delivery there are still no entirely satisfactory ways of distributing 3D data
- Options
  - VRML, x3d : very poor cross platform support
  - 3D PDF : dropped by Adobe some years back
  - WebGL? HTML5 / Canvas?
- Key missing components:
  - progressive texture
  - progressive geometry

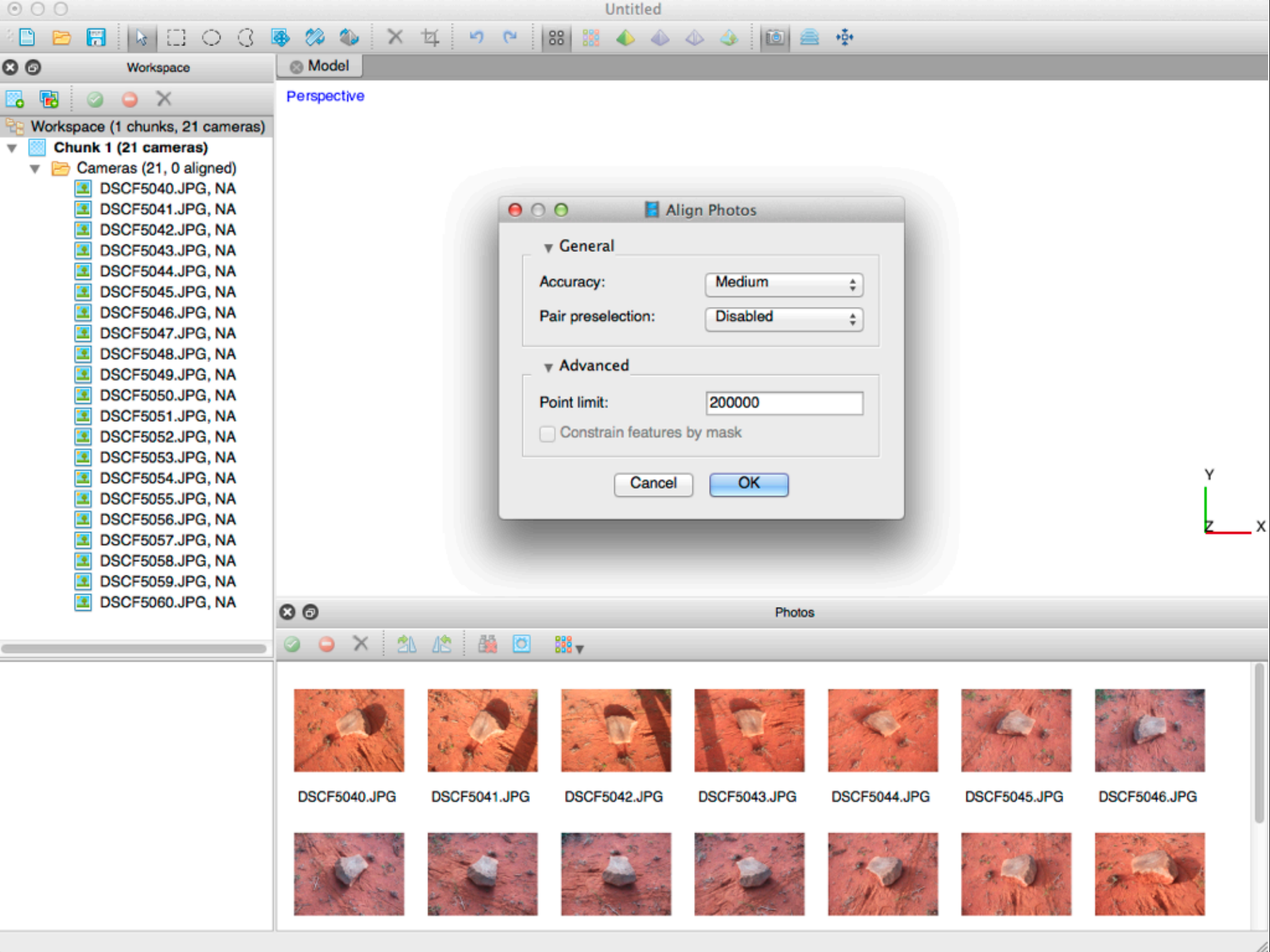
Movie

Gommateswara, Manipal, India

Case study 3: Grinding stone

- Will do a full worked example based upon grinding stone from the Ngintaka story
- 22 photographs around the stone
- Example of light/colour changes due to polarising filter and angle to sun direction

Case study 3: Grinding stone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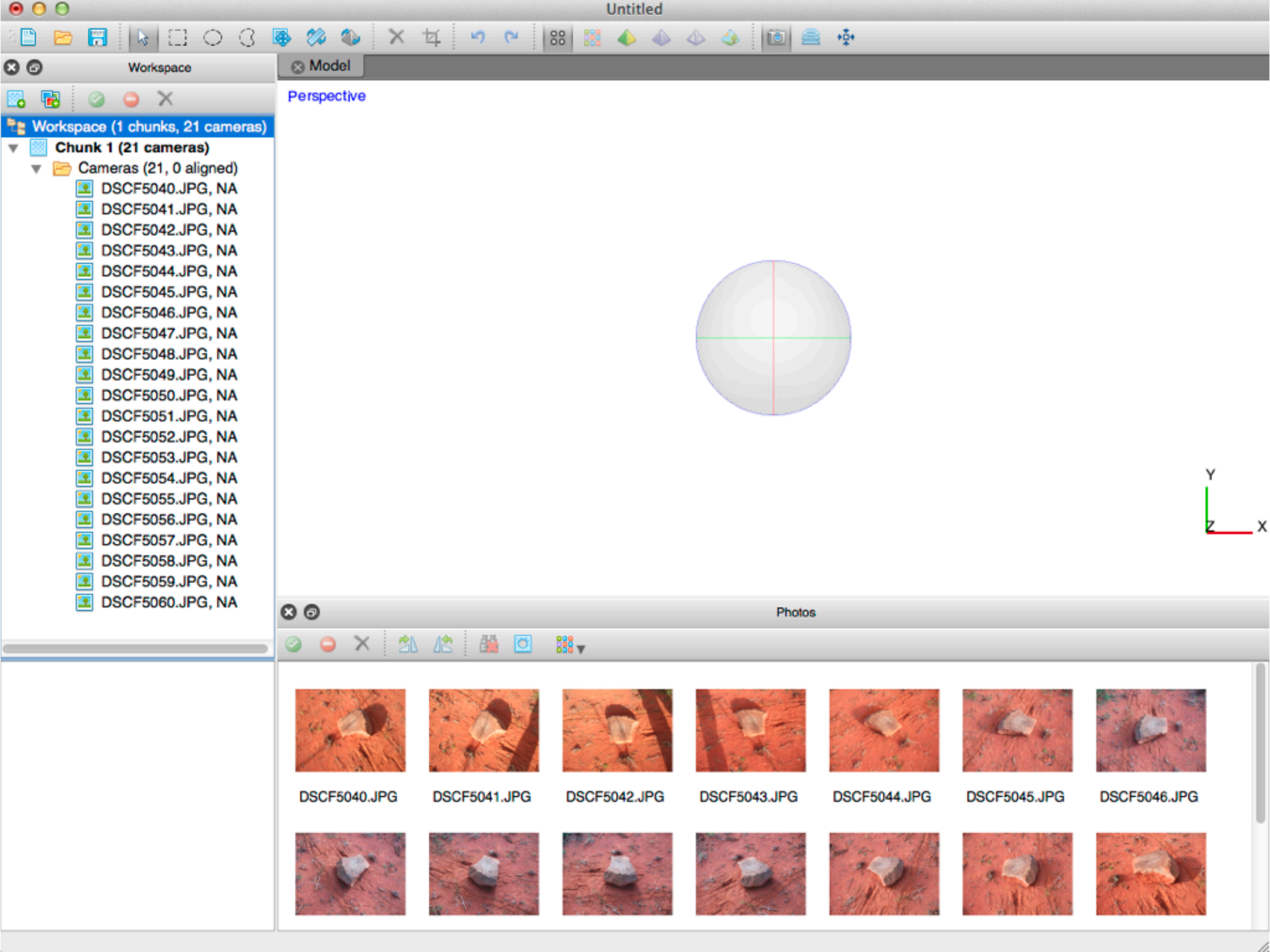
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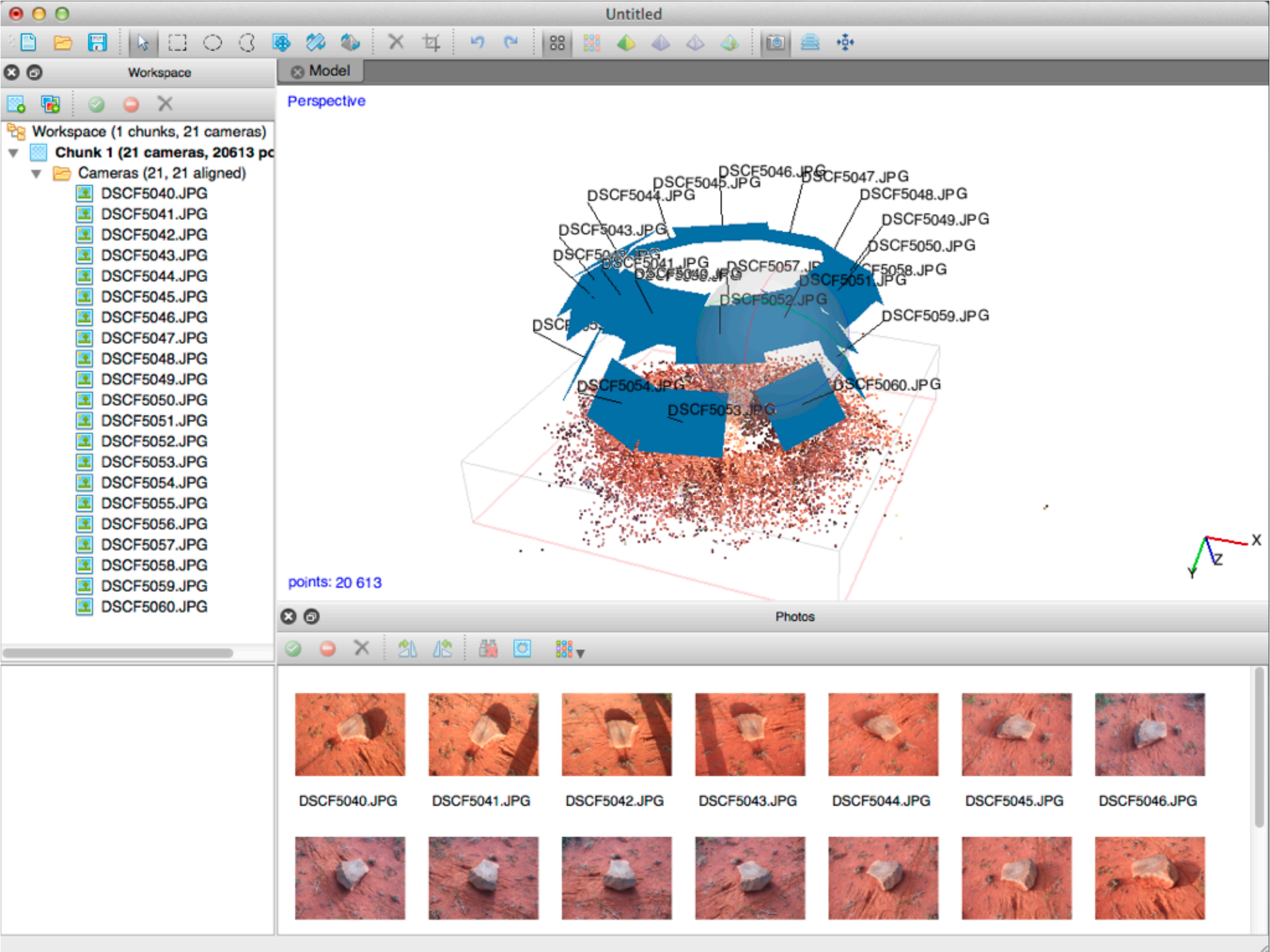

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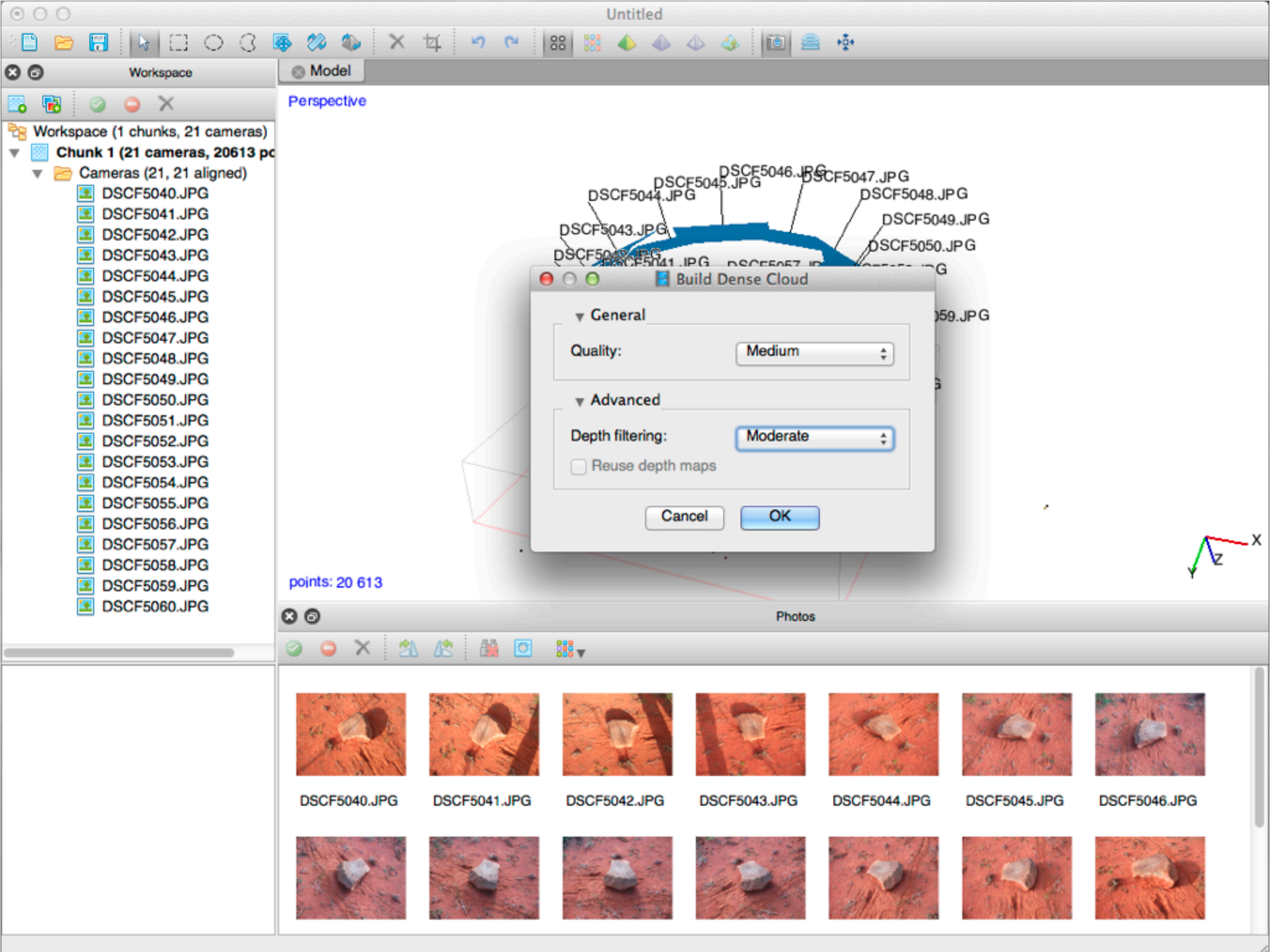
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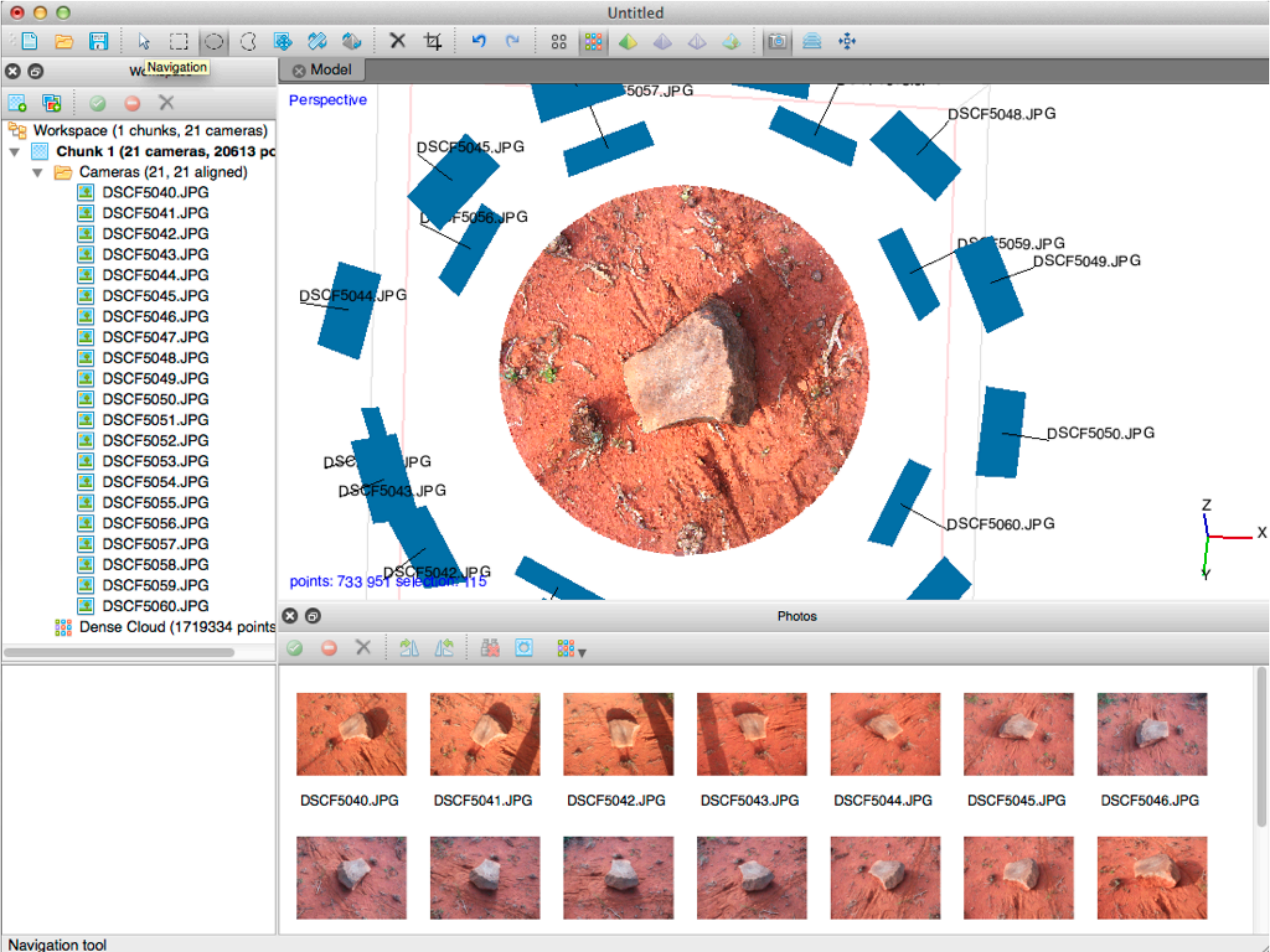
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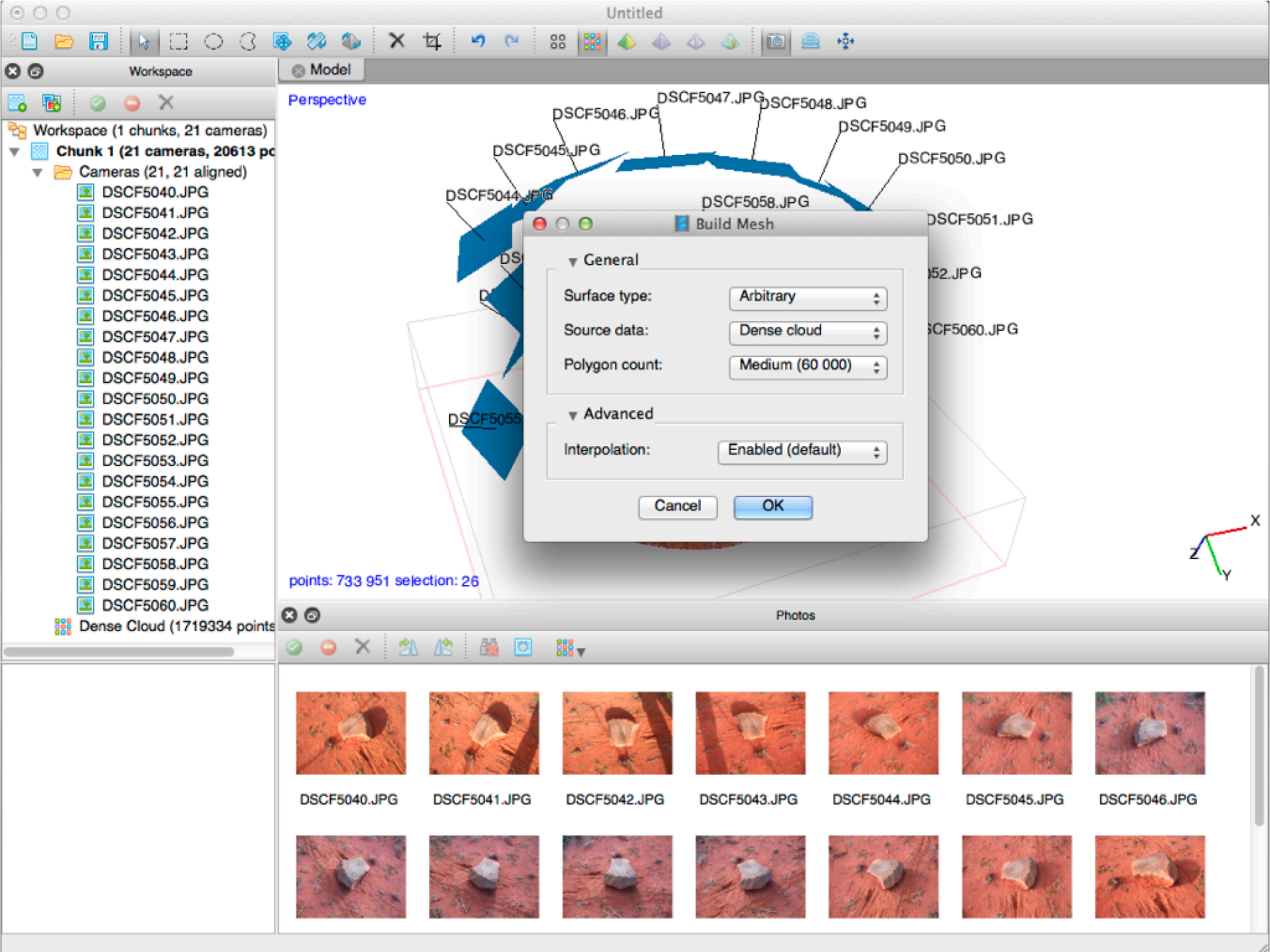

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Dense Cloud (1719334 points
Build Mesh
General
Surface type:
Arbitrary
Source data:
Dense cloud
Polygon count:
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Interpolation:
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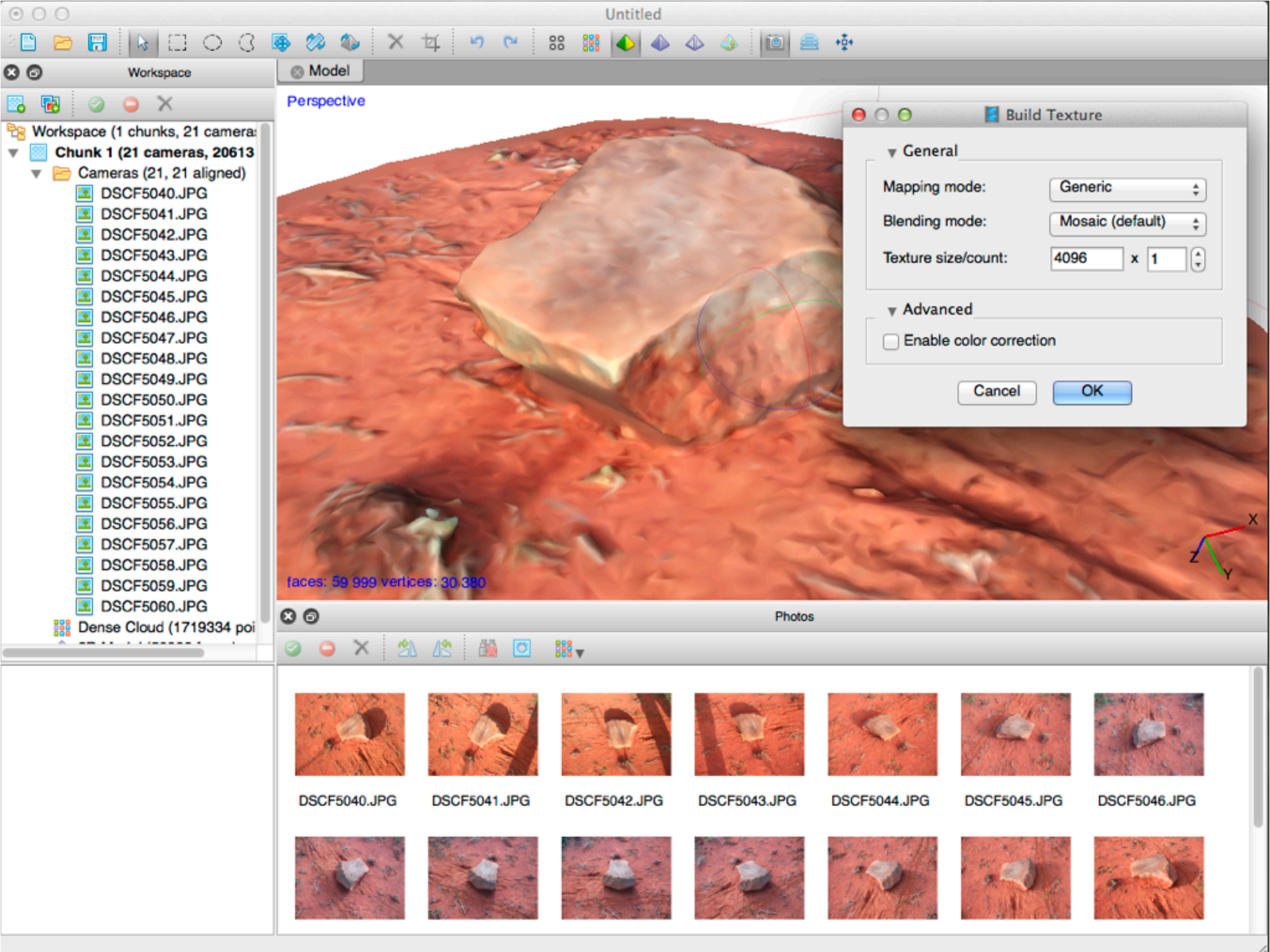
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Model
Perspective
Workspace (1 chunks, 21 cameras
Chunk 1 (21 cameras, 20613
Cameras (21, 21 aligned)
DSCF5040.JPG
DSCF5041.JPG
DSCF5042.JPG
DSCF5043.JPG
DSCF5044.JPG
DSCF5045.JPG
DSCF5046.JPG
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DSCF5050.JPG
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DSCF5053.JPG
DSCF5054.JPG
DSCF5055.JPG
DSCF5056.JPG
DSCF5057.JPG
DSCF5058.JPG
DSCF5059.JPG
DSCF5060.JPG
Dense Cloud (1719334 poi
Build Texture
General
Mapping mode:
Generic
Blending mode:
Mosaic (default)
Texture size/count:
4096
x
1
Advanced
Enable color correction
Cancel
OK
faces: 59 999 vertices: 30 380
X
Y
Z
Photos
DSCF5040.JPG
DSCF5041.JPG
DSCF5042.JPG
DSCF5043.JPG
DSCF5044.JPG
DSCF5045.JPG
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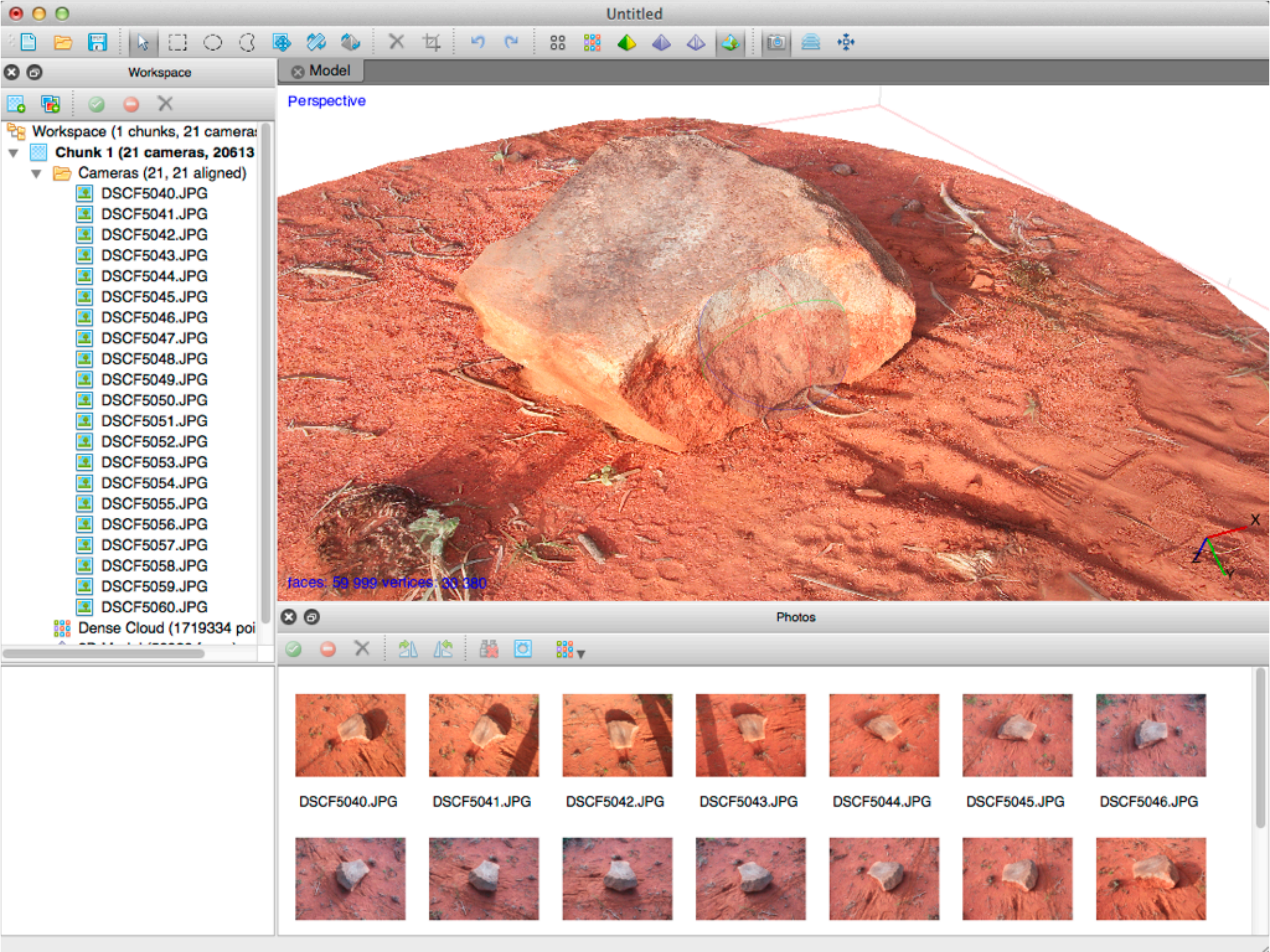

Untitled
Workspace
Model
Perspective
Workspace (1 chunks, 21 cameras
Chunk 1 (21 cameras, 20613
Cameras (21, 21 aligned)
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Dense Cloud (1719334 poi
faces: 59 999 vertices: 30 380
Photos
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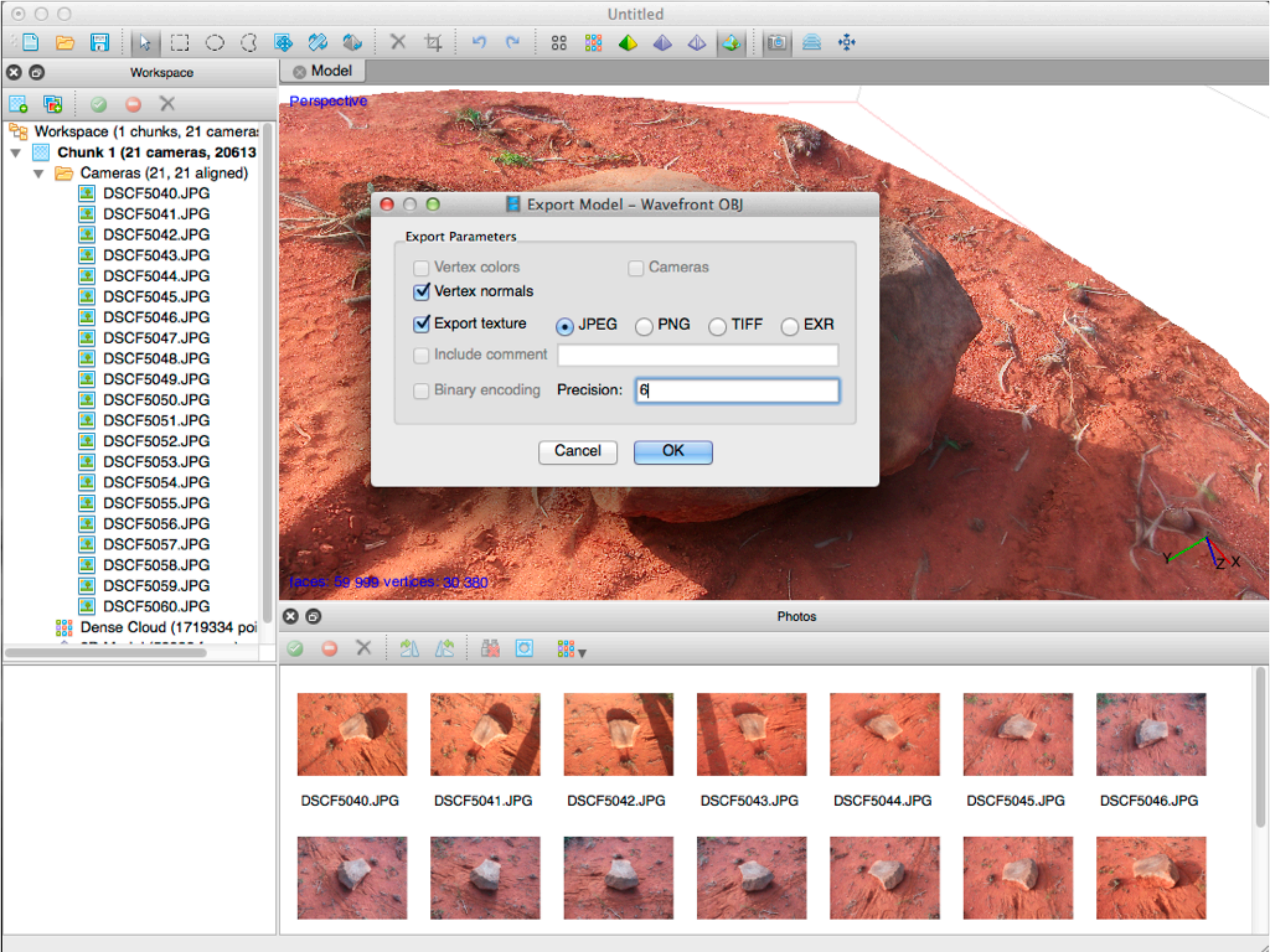
Untitled
Workspace
Model
Perspective
Workspace (1 chunks, 21 cameras
Chunk 1 (21 cameras, 20613
Cameras (21, 21 aligned)
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DSCF5057.JPG
DSCF5058.JPG
DSCF5059.JPG
DSCF5060.JPG
Dense Cloud (1719334 poi
Export Model – Wavefront OBJ
Export Parameters
Vertex colors
Cameras
Vertex normals
Export texture
JPEG
PNG
TIFF
EXR
Include comment
Binary encoding
Precision:
6
Cancel
OK
faces: 59 999 vertices: 30 380
Y
Z
X
Photos
DSCF5040.JPG
DSCF5041.JPG
DSCF5042.JPG
DSCF5043.JPG
DSCF5044.JPG
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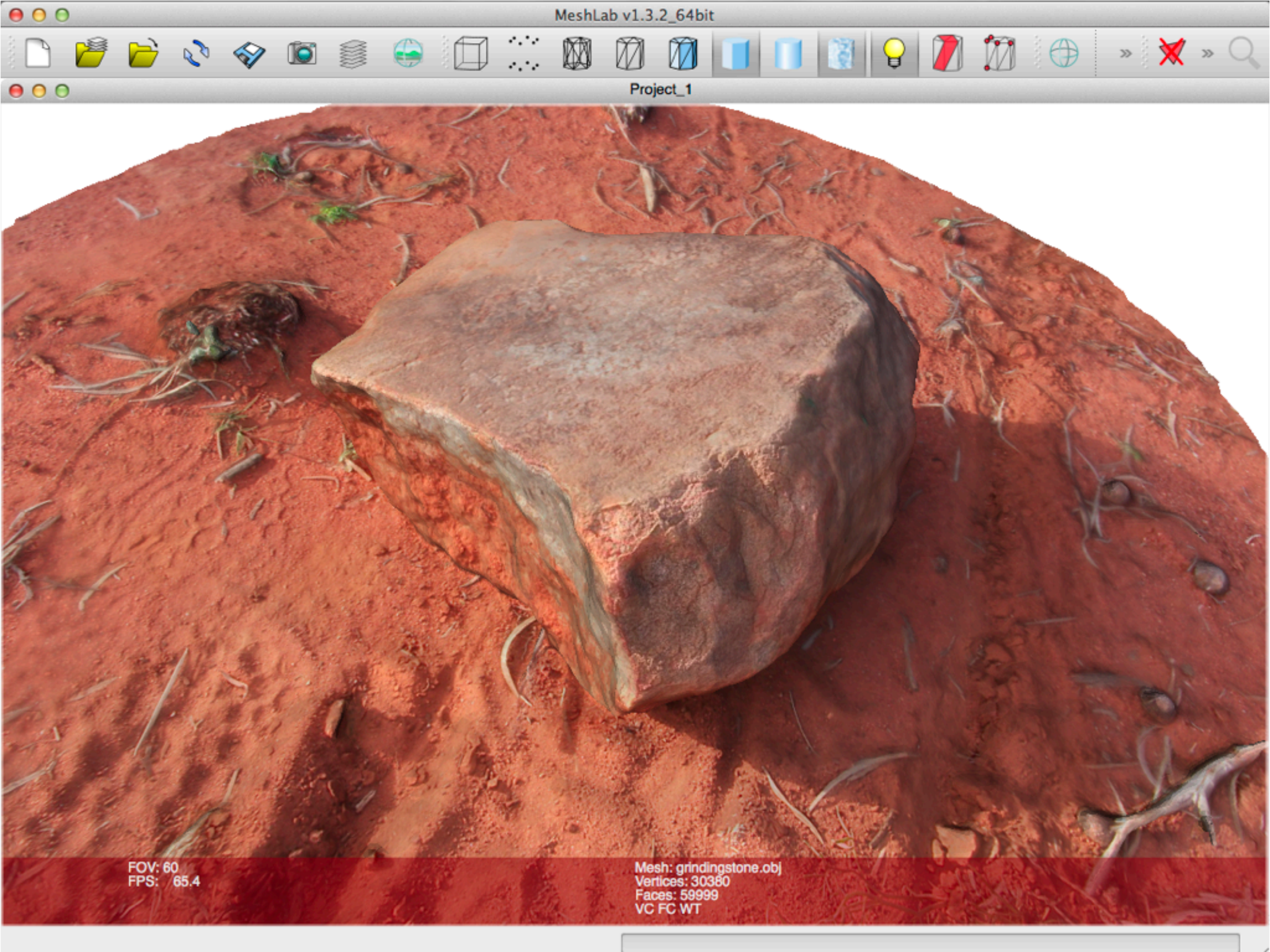
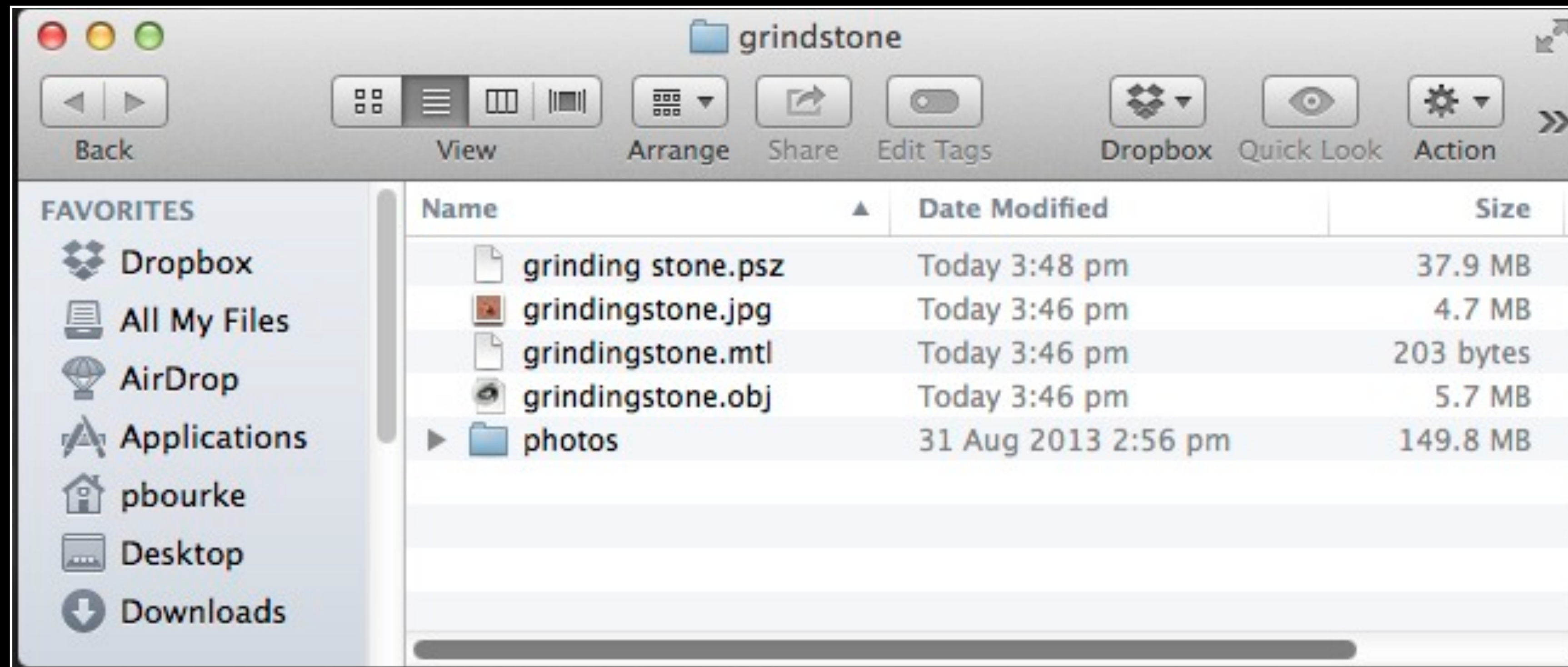
DSCF5046.JPG


MeshLab v1.3.2_64bit
Project_1
FOV: 60
FPS: 65.4
Mesh: grindingstone.obj
Vertices: 30380
Faces: 59999
VC FC WT


grindstone
Back
View
Arrange
Share
Edit Tags
Dropbox
Quick Look
Action
FAVORITES
Dropbox
All My Files
AirDrop
Applications
pbourke
Desktop
Downloads
Name
Date Modified
Size
grinding stone.psz
Today 3:48 pm
37.9 MB
grindingstone.jpg
Today 3:46 pm
4.7 MB
grindingstone.mtl
Today 3:46 pm
203 bytes
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photos
31 Aug 2013 2:56 pm
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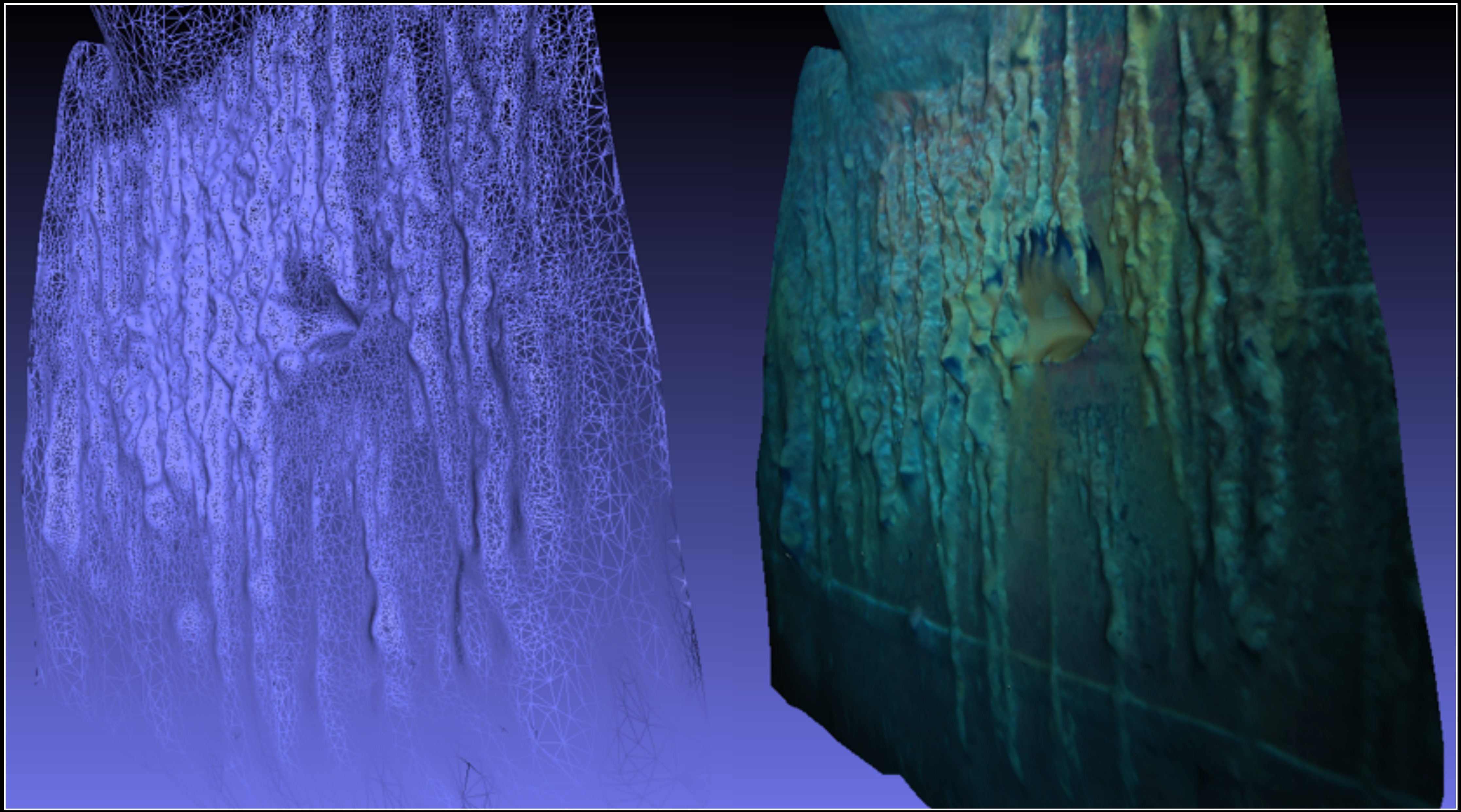
Additional applications

- Underwater
- Aerial photography
- Rapid Prototypes



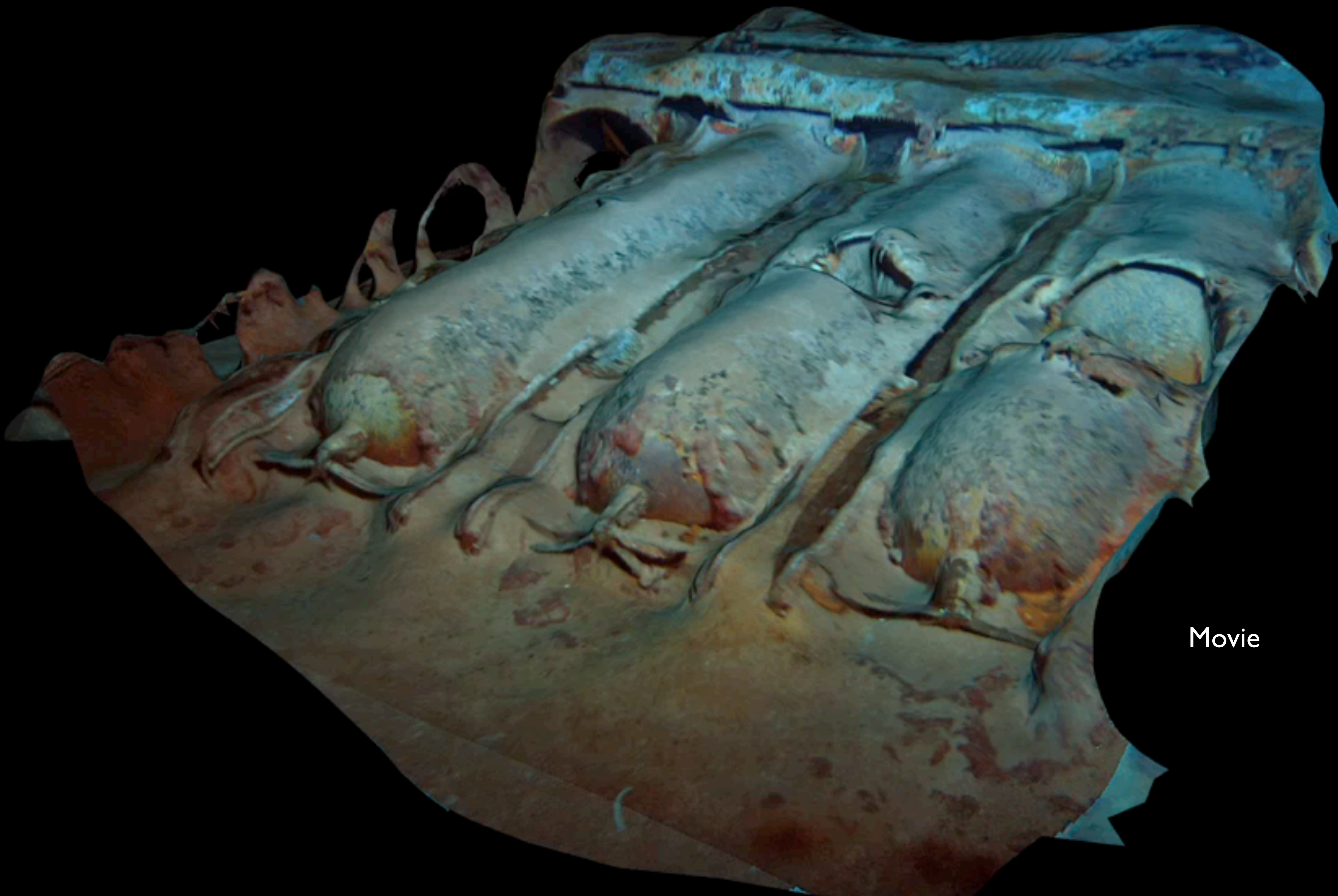
Kormoran

Additional applications : Underwater

- Capture of underwater object more challenging
- How to compensate for the light absorption through a column of water
- Example: HMAS Sydney in 2.5KM of water

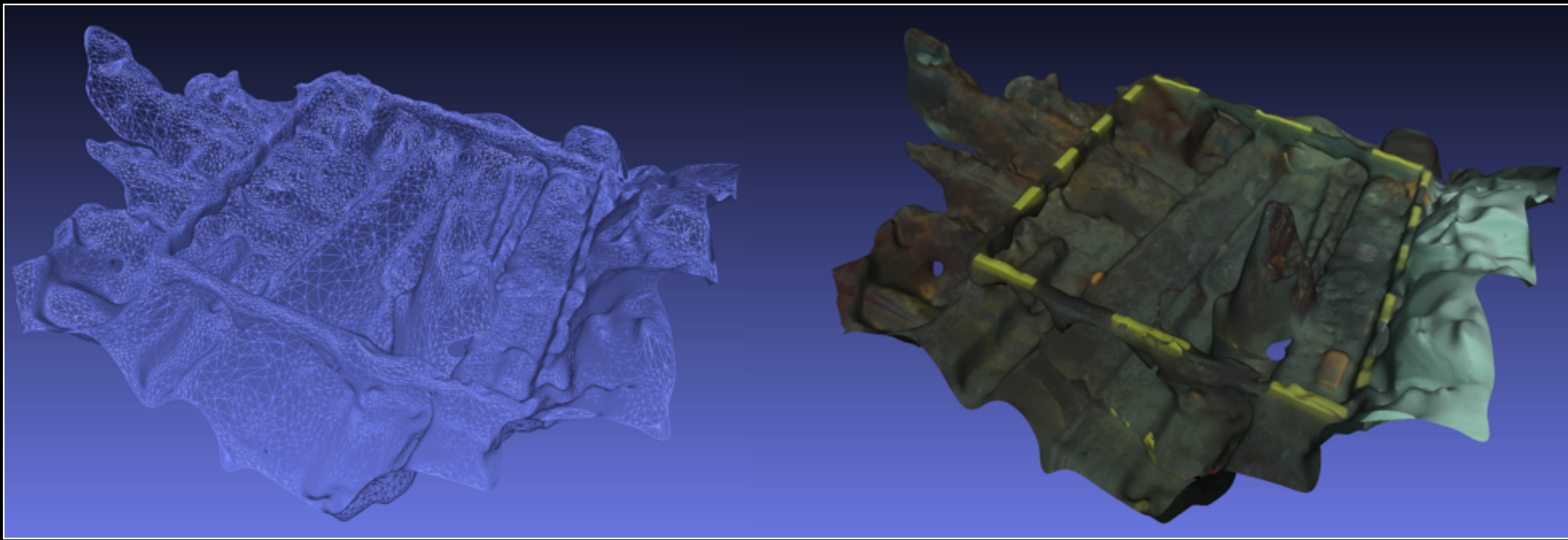
HMAS Sydney

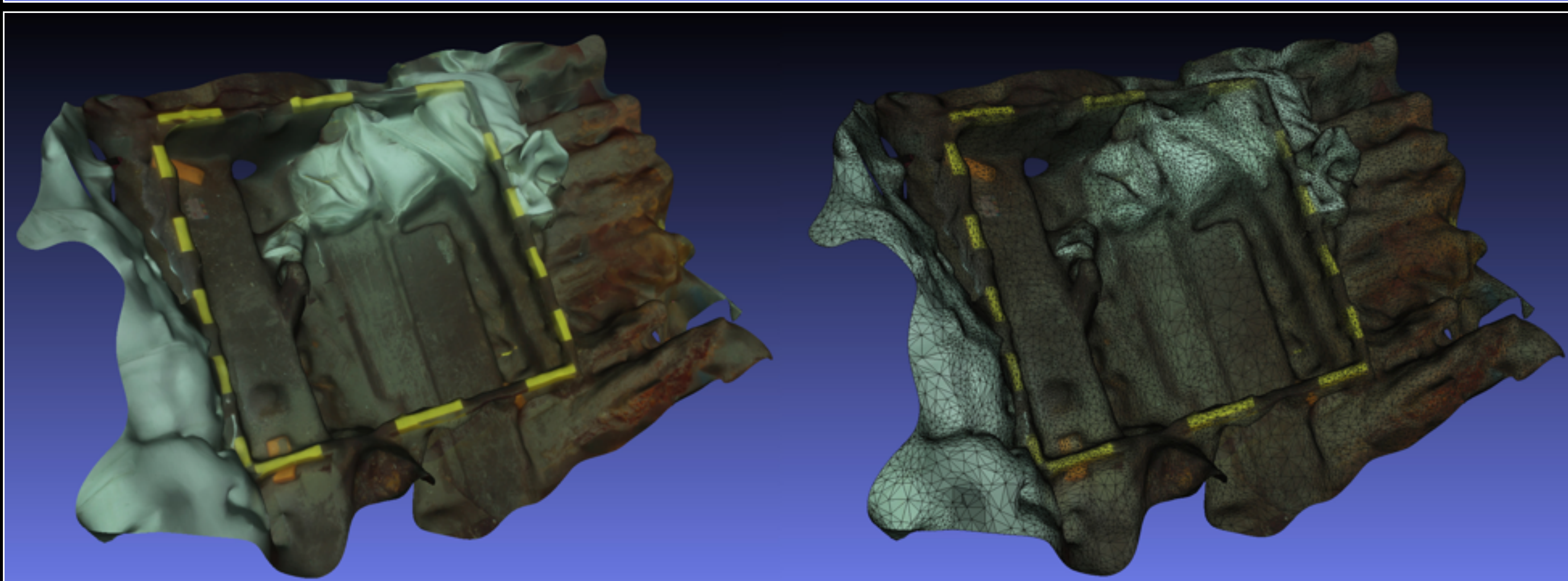
Additional applications : Underwater



Movie

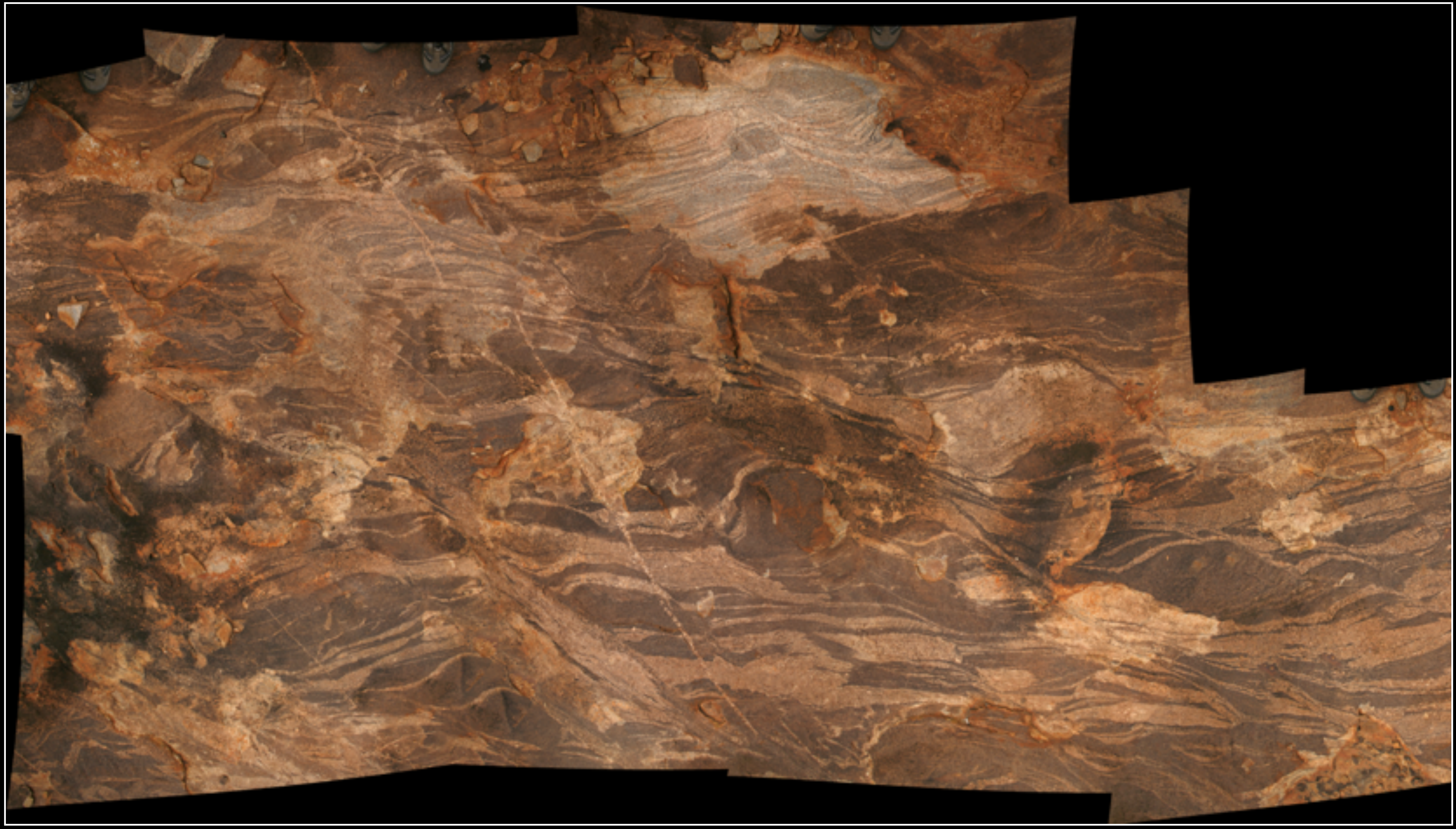
Additional applications : Underwater Archaeology





Additional applications : Aerial photography

- Capturing inaccessible geological formations
- Also building structures out of reach
- Vibration and rolling shutter issues



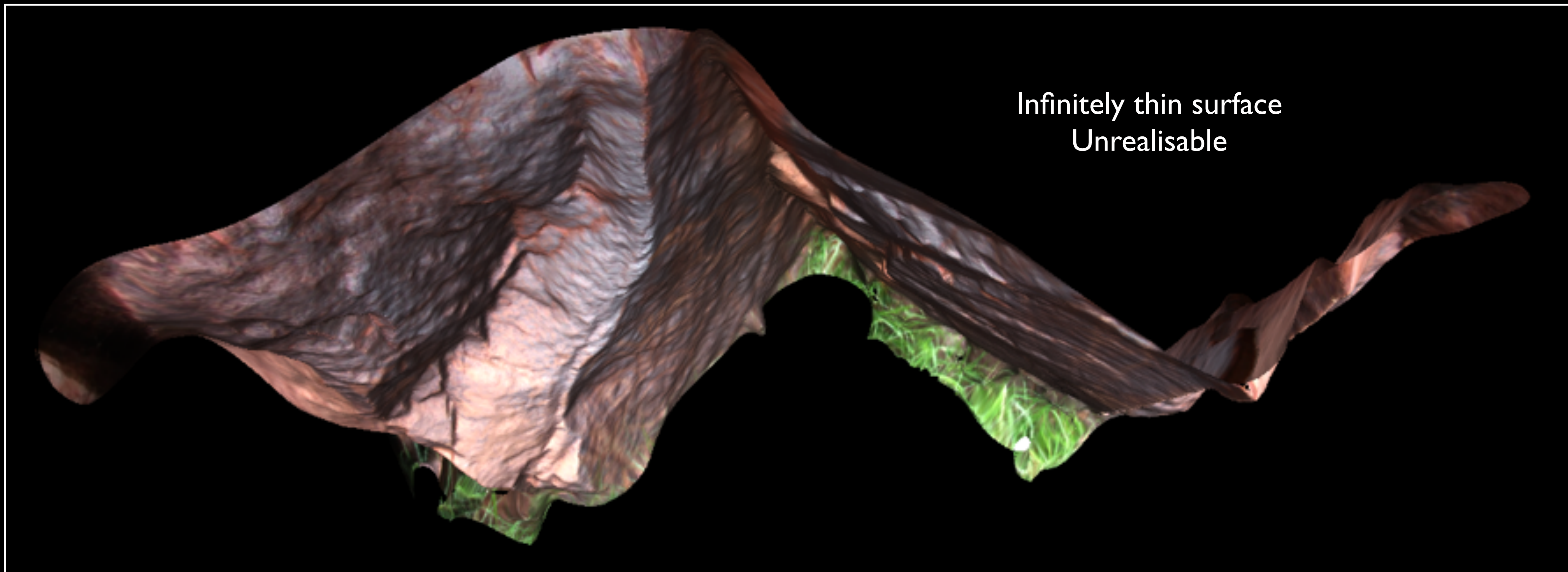
Additional applications : Aerial photography

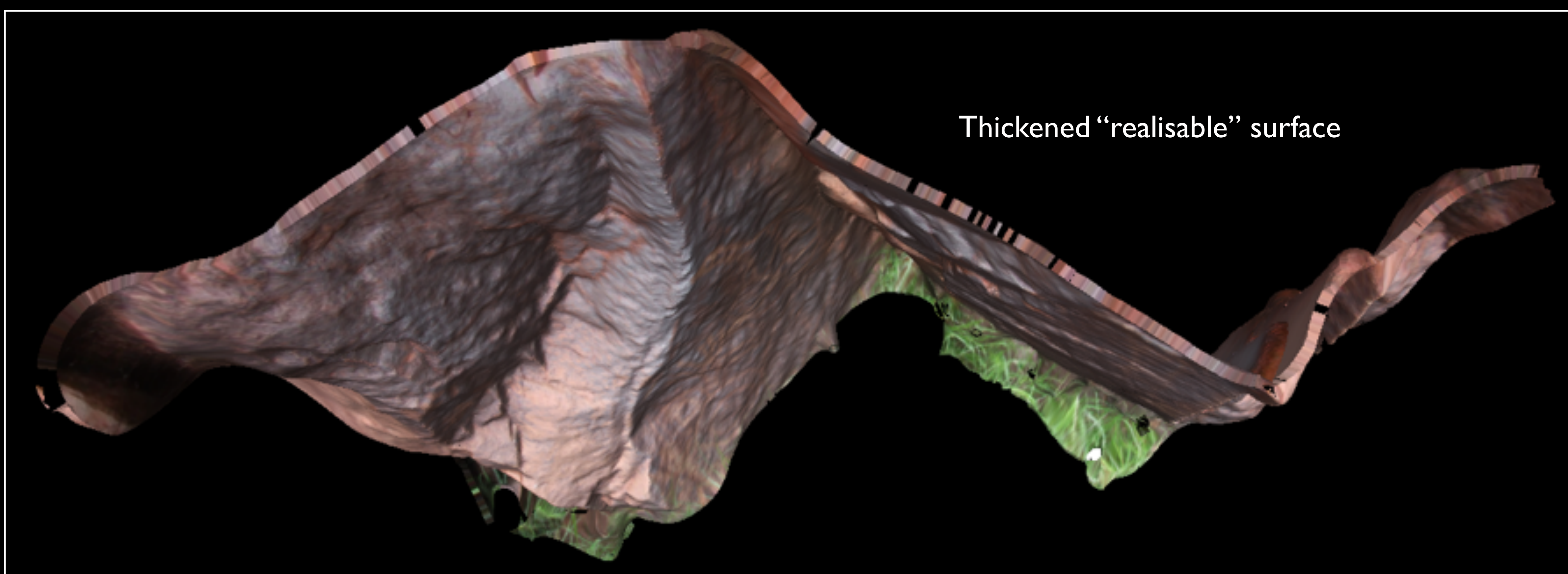
Movie

Additional applications : Rapid prototypes

- Can complete the loop:
  capture a real object photographically - reconstruct it - generate a real object
- Requires a solid object (thickened), with enough structural integrity
- Models need to be “watertight”, hence hole closing algorithms
- Main printer for colour prints is the ZCorp
- http://www.zcorp.com/
- Recommend using online services such as Shapeways.
  http://www.shapeways.com

Additional applications : Rapid prototypes





Additional applications : Rapid prototypes

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Summary for high quality reconstruction

- High quality SLR camera (and know how to use it)
- Good quality prime lens
- Perform lens calibration
- Err on the side of taking more images
- Distinguished reference objects in shot can assist reconstruction
- Select best software currently on the market
  (PhotoScan is hard to beat at time of writing)
- Results benefit from crisp high resolution photographs
  Not particularly sensitive to colour detail

Questions / discussion / test yourself

The new digital tourist?