Automatic 3D Reconstruction from Photographs: Applications in Archaeology and Heritage

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    Wanmanna (near Newman)
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Rock art, Wanmanna (West Australia)

Introduction and motivation

- Creating richer objects (compared to photographs) for recordings in archaeology and heritage.

- Creation of assets for virtual environments and serious games. Avoid the need for manual and time consuming model generation and the inevitable interpretation on the part of a human modeller.

- Create models for 3D analysis.
  For example: geoscience applications.

- 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].

Temple facade
Commateswara (India)

Algorithm/pipeline outline

- Compute lens calibration (only done once)
- 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
- Create sparse 3D point cloud, called “bundle adjustment” (eg: Bundler)
- Create dense point cloud (eg: PMVS2 - patch-based multi-view stereo)
- Form mesh from dense point cloud (eg: ball pivoting)
- Reproject images 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 options

- Photosynth: Not possible to extract the geometry, only exist as an online experience.
  Based upon Bundler.

- PhotoScan (AgiSoft): Seems like older algorithms, in any case didn't compete well with other options.

- Visual SfM (University of Washington)
  Based upon Bundler.

- PhotoModeller (EOS Systems): High end commercial software. Not entirely automated. In general requires a larger number of photographs with significant overlap.

- 123D Catch (AutoDesk): Very easy to use highly reliable cloud base software.

- Developed work flows using Bundler and various algorithms to reconstruct the mesh from the point cloud and re-project photographs to derive textures.

- Otherwise 123D catch and PhotoModeller performed the best. The former for a hands-off solution, the later for higher precision at the price of greater rigour and manual guiding.

Low photograph count : 2.5D

- 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 typically require between 3 and 6 images.
- Photographs can be orientated at any angle.
- Each object takes perhaps 15 sec to capture,
  10 minutes (on average) to process.






Ho Ann temple, Terrenganu

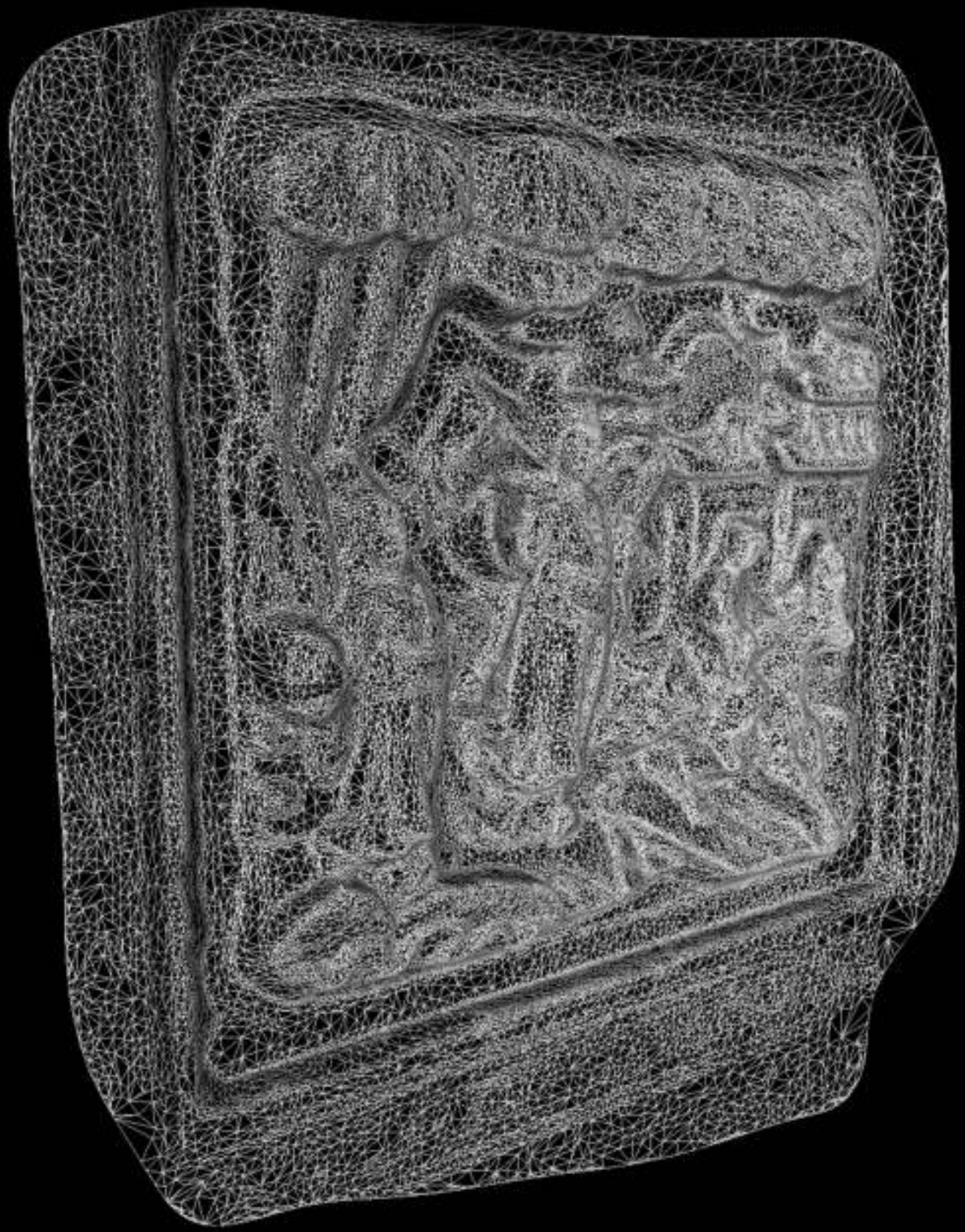


Image relighting

Full 3D objects

- Require significantly more images.
- Some algorithms perform better if the images are captured in sequence with the best matches at the start of the bundle adjustment.
- Move to more rigorous capture: fixed focal lens combined with lens calibration.

Aphrodite (Lady of Cythera)
33 images

Rock art example: Wanmanna

Rock art example: Cape Lambert

Rock art example



18 images


Cape Lambert (West Australia)

Limitations

- Baked on shadows. Solution: Choose cloudy diffuse lit days.
- Movement of the object during capture, eg: grass in the wind. Testing solution taking pairs of images at each location and find moving objects and removing them.
- Thin structures, eg: grass.
- Access to all sides of 3D object can be problematic. Only hand held shots.
- Difficult to control the boundary shape. May clean up manually, testing culling boundary shapes.

Mesh simplification

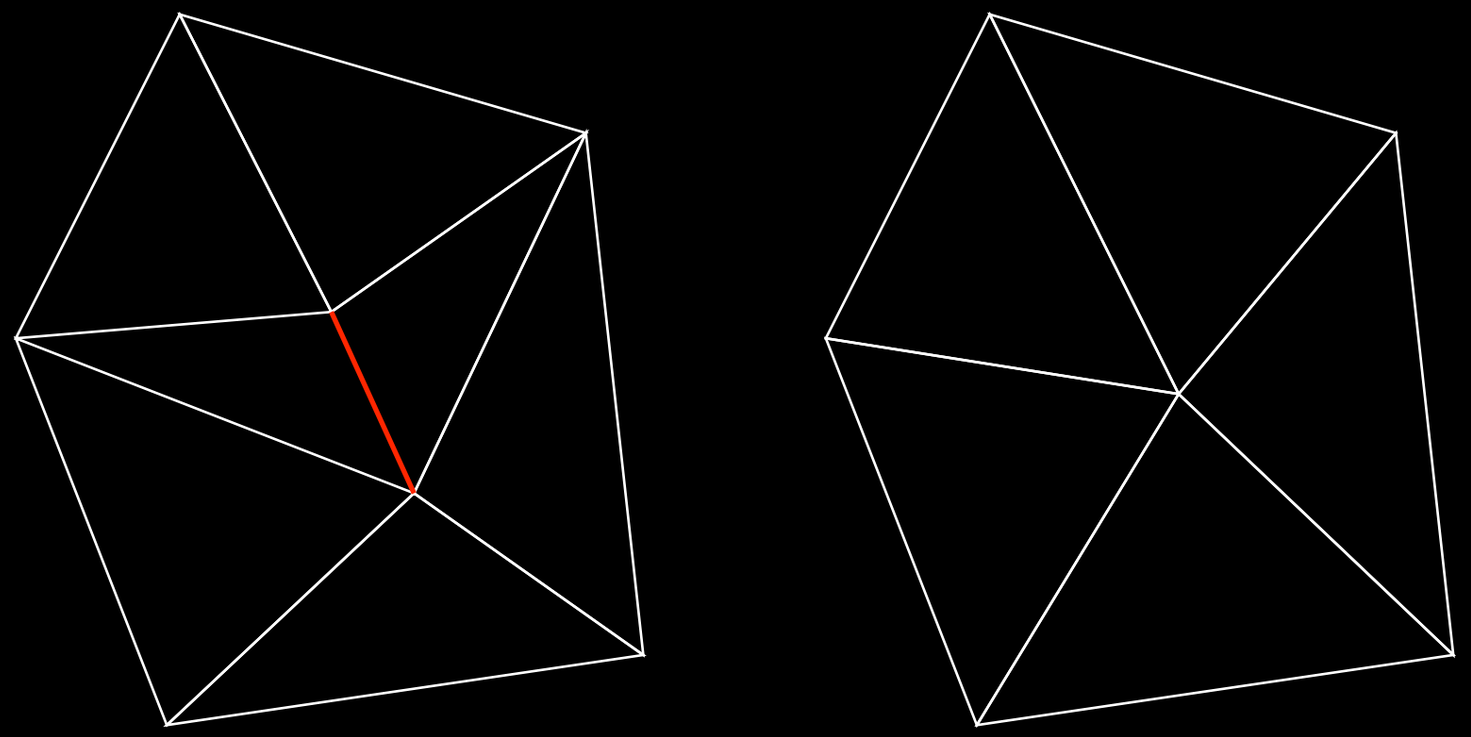
- Meshes directly from the reconstruction (generated from the dense point cloud) are generally inefficient. Need to reduce them for realtime applications and web based delivery.

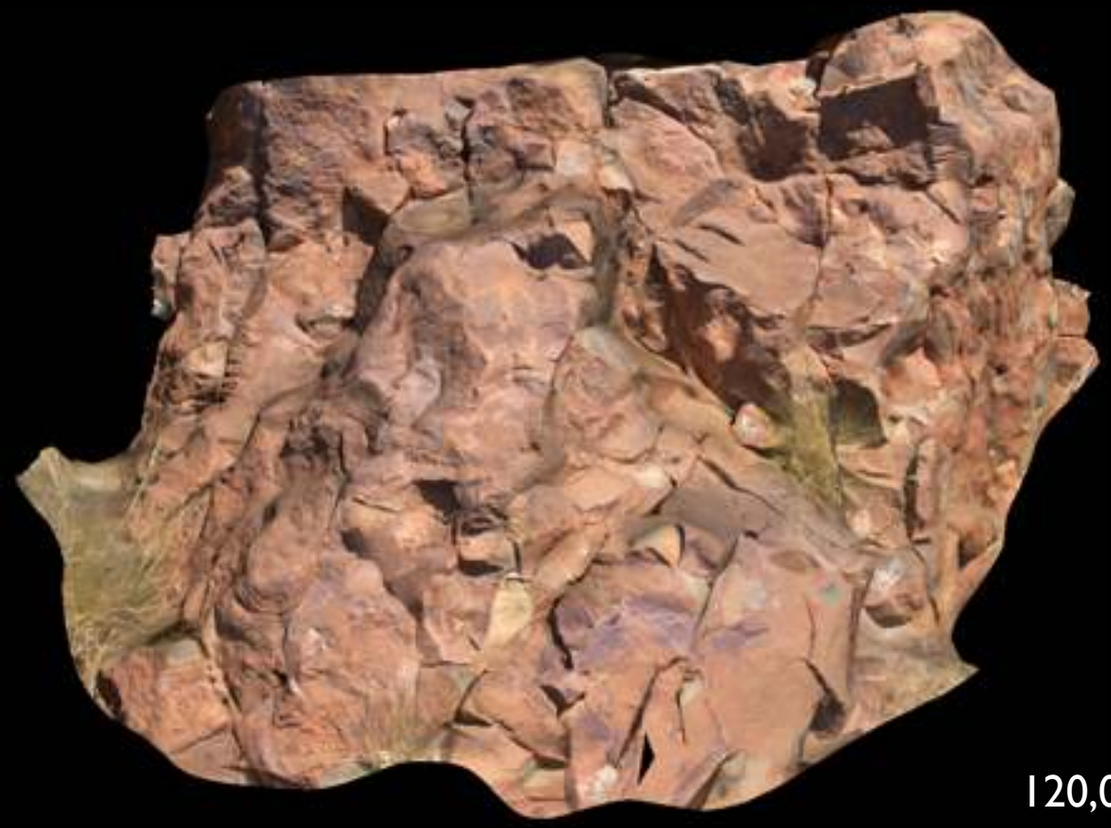
- Simplest case is to iteratively remove the shortest edges. (Example below)

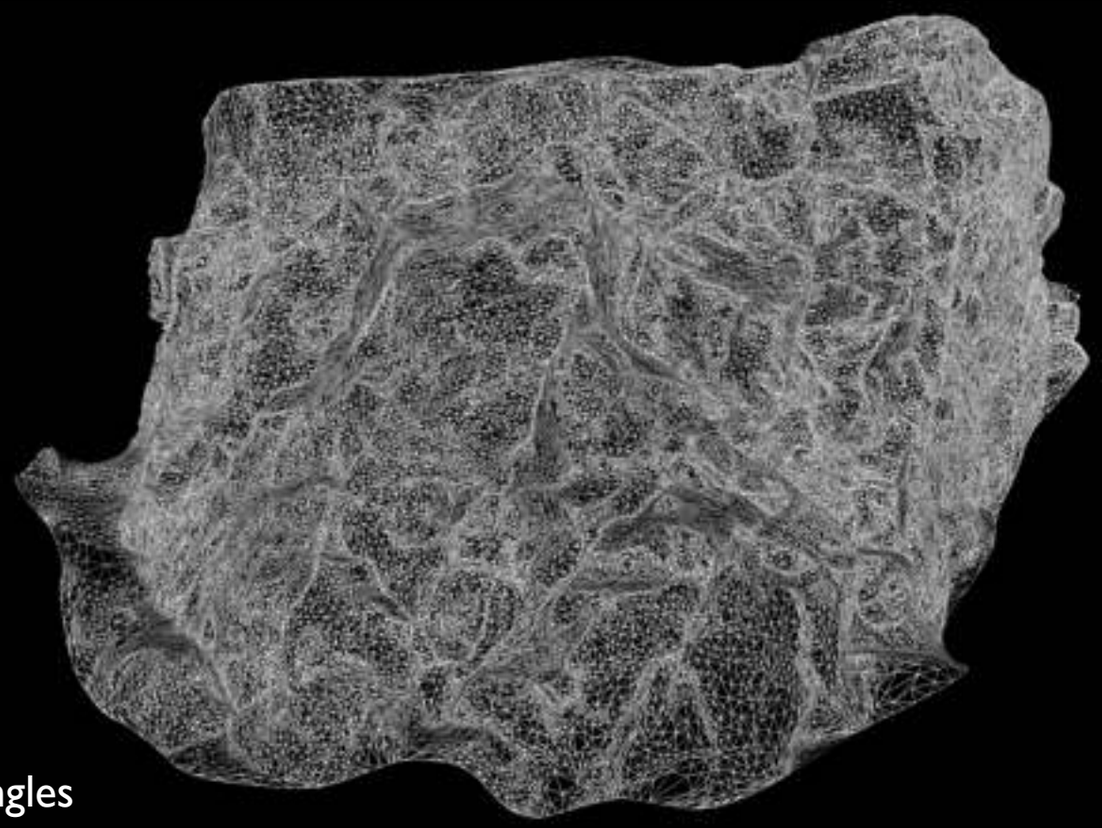
- The refinement is how the edges are chosen and where to place the new vertex. Implemented the “quadratic edge collapse decimation” - edge selection weighted by edge length and surface flatness.

- A texture and geometry approximation.

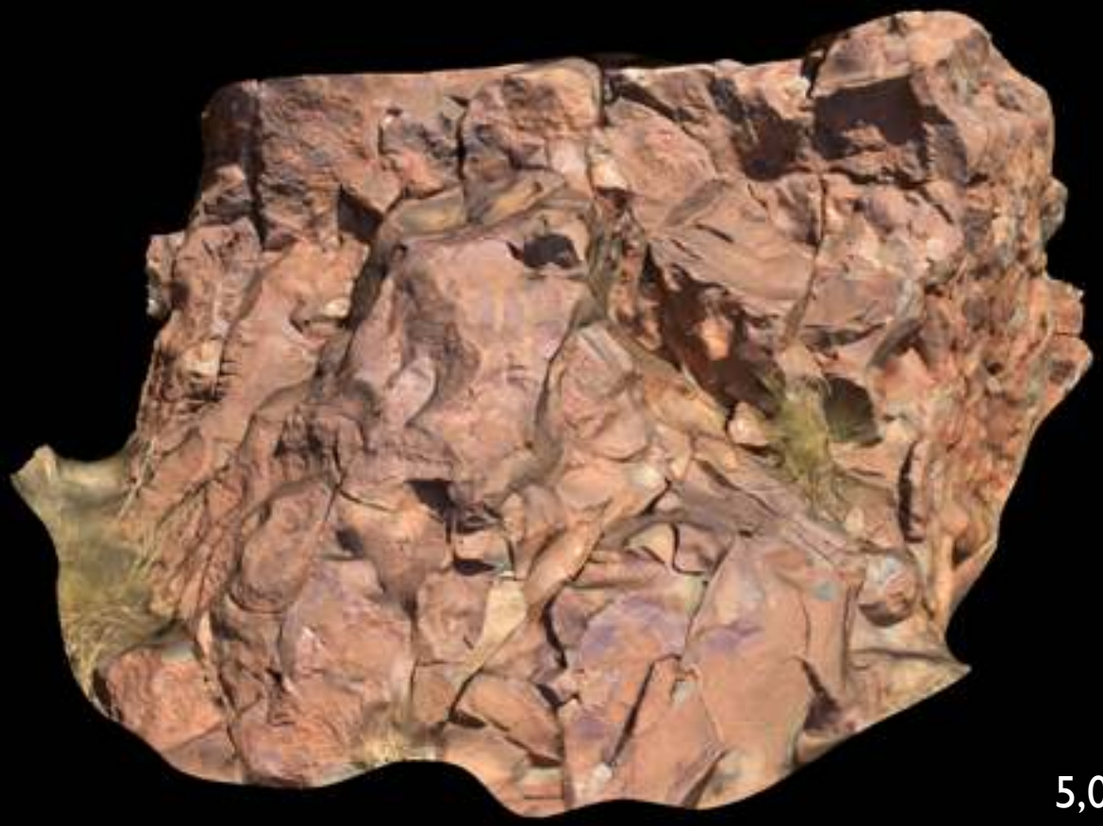
- Can preserve the boundary.

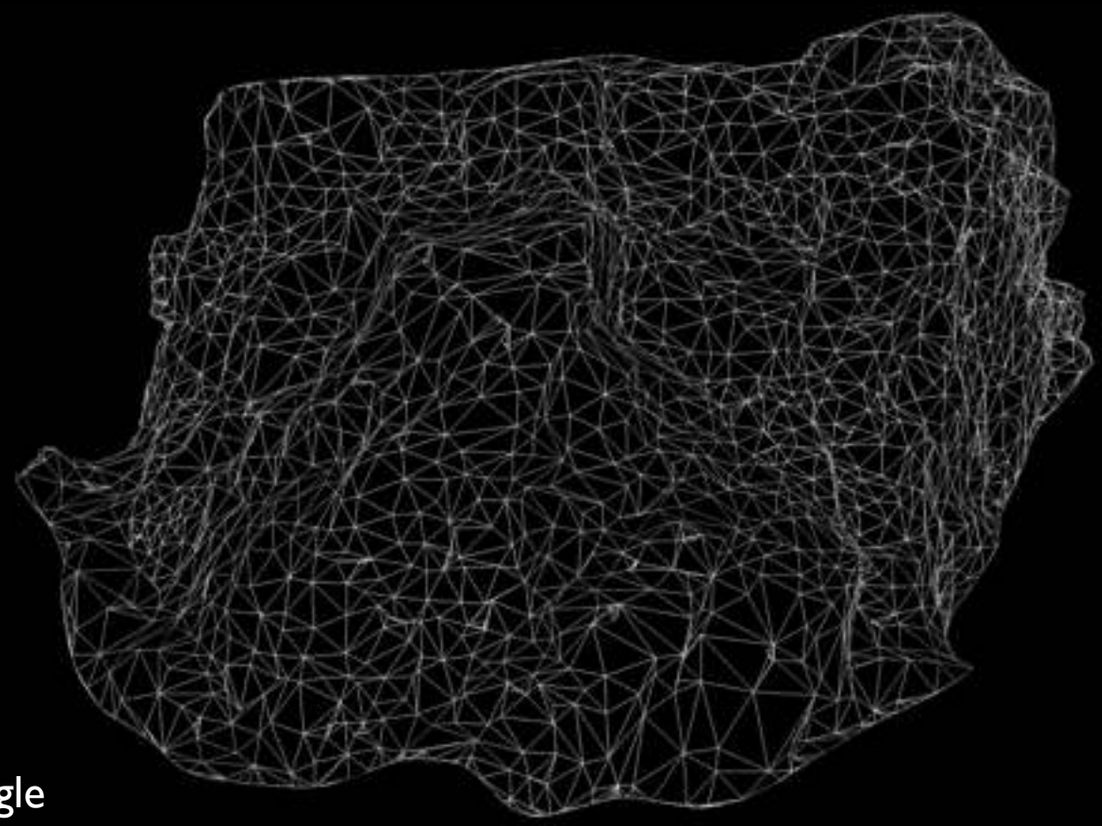






120,000 triangles





5,000 triangle

Annotating

- Textures from the reconstruction algorithms are often “interesting”.
- But can generally still be drawn on.

Online viewer

- Disappointed that there still does not seem to be a widely used - cross platform - browser independent viewer for textured meshes.

- 3D PDF support seems patchy. Even Adobe products don't all support it.

- VRML / X3D seems to be in the same poorly supported situation it has always been in.

- CS student project in 2012 developed a browser based viewer for textured OBJ files.

- Doesn't require external downloads, plugins etc.
  Javascript and HTML5 (canvas) based, no hardware acceleration.

- Has been tested and known to work on the following browsers:
  Mac OS X: Safari, FireFox and Chrome
  Windows 7: FireFox, Chrome, Internet Explorer (V9 or later)
  Linux: (Tested set incomplete)

- Also works on IOS devices (iPhone, iPad) except for 2K texture limitations.

Summary

- Exploring our own workflows for photographing and reconstructing 3D textured meshes from a series of photographs.

- Identified the process trade-offs between fast but less accurate reconstructions vs more rigorous slower processes that (may) result in more accurate models.

- Identified range of tools for transforming, editing, simplifying, and annotating the 3D meshes.

- Developed online browser for the textured meshes, works directly from the wavefront OBJ meshfiles and JPEG textures.

- Applying techniques learnt to projects in Australian rock art, virtual heritage in India and shipwreck/marine archaeology.

Future projects

- Apply to more demanding environments, namely underwater archaeology.

Torpedo bay
HMAS Sydney

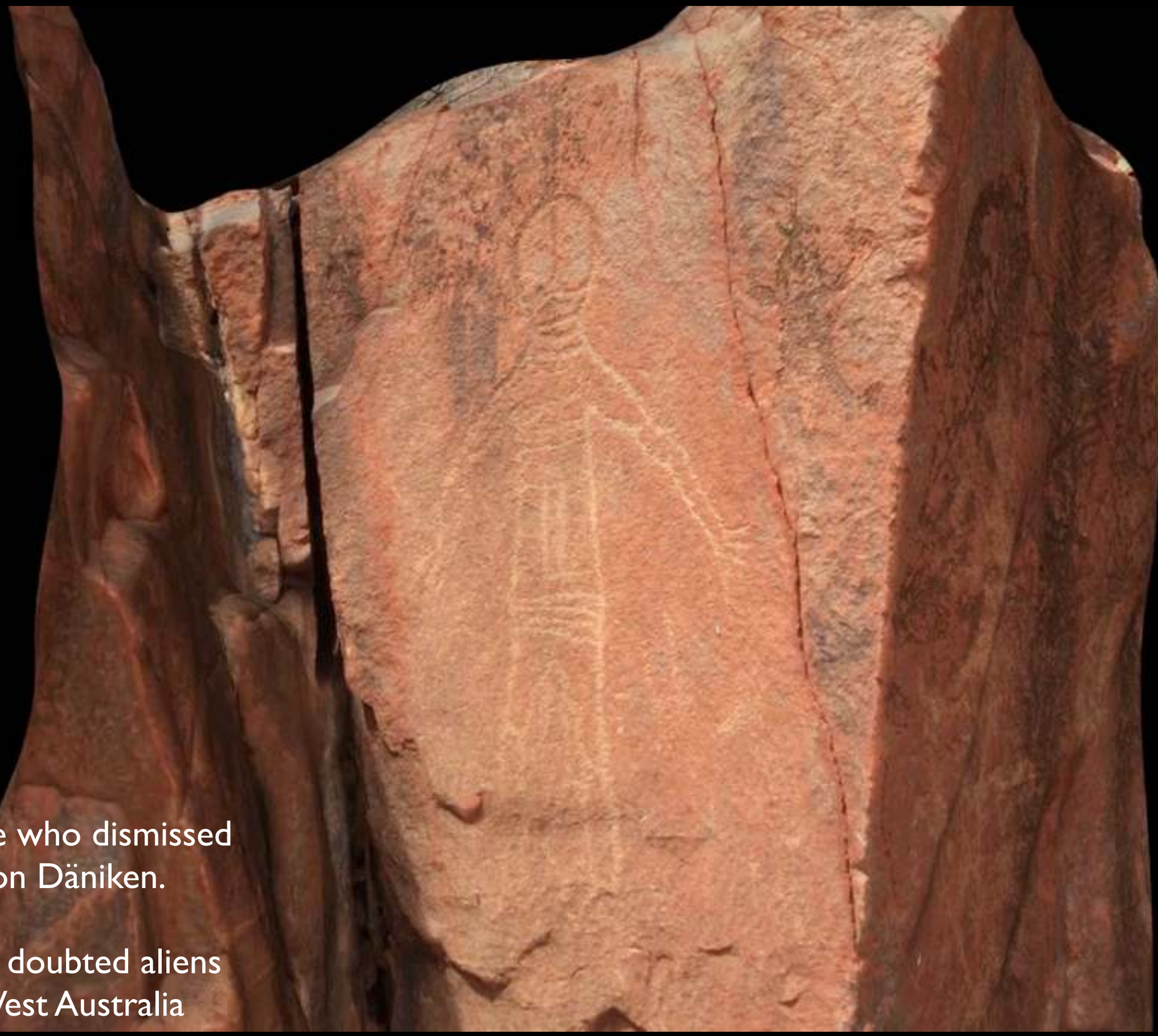
The 3D tourist

- I find myself taking photographs suited to 3D reconstruction while travelling.

- Sitting in my hotel at night processing the results and uploading the 3D mesh to make it available online.

Cairn to
HMAS Sydney
(Carnarvon)

Questions?



For all those who dismissed
Erich von Däniken.

In case you doubted aliens
visited West Australia