Novel imaging of heritage objects and sites of Indigenous Australians

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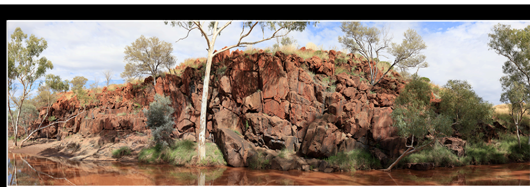
Contents

- High resolution imaging : panorama and mosaic
- Multispectral imaging (bonus, not in the paper)
- 3D reconstruction from photographs

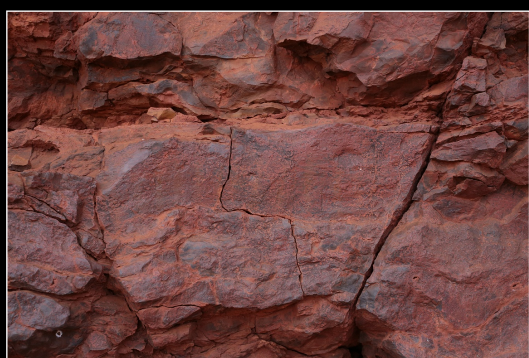
Examples from rock art archaeology
The University of Western Australia



Gigapixel panorama imaging

Gigapixel mosaic imaging

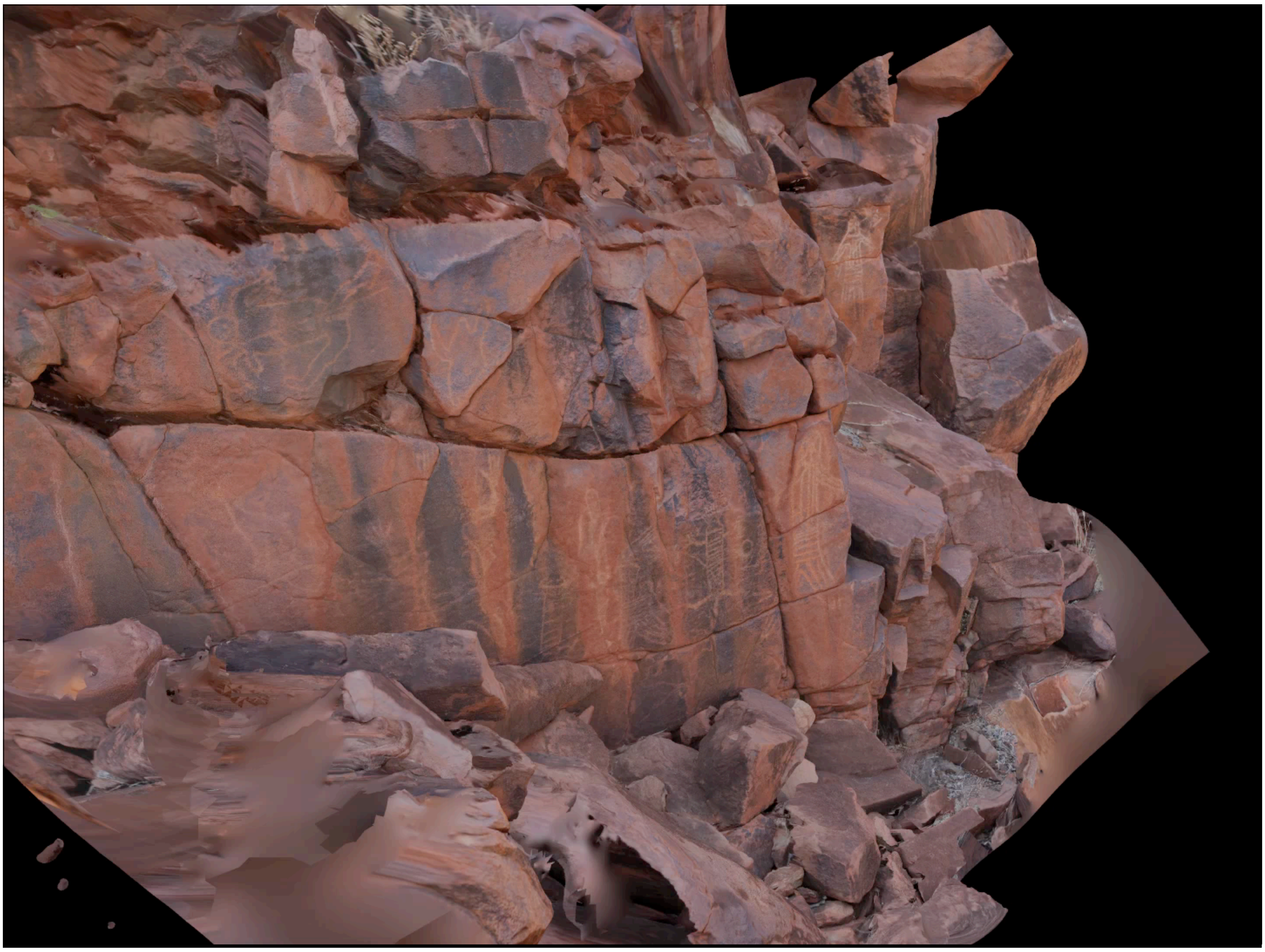
3D Reconstruction



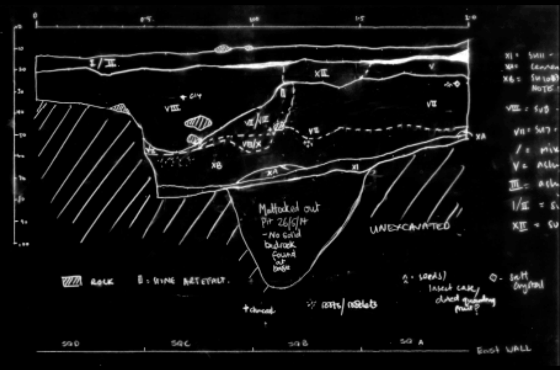
Hyperspectral imaging

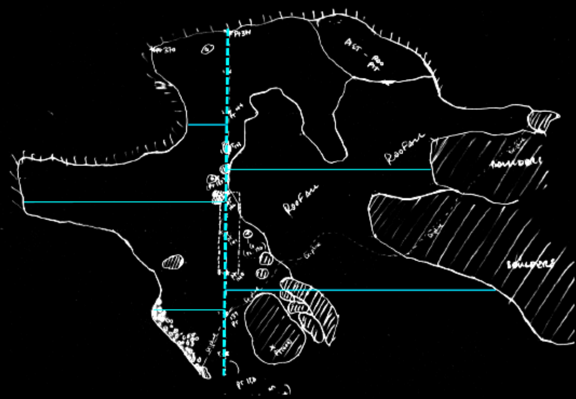
Motivation

- Characteristics of heritage sites in Western Australia
  - Extremely remote locations
  - Difficult access
  - Varied stakeholders: Traditional owners, farming lease holders, mining companies
  - Extreme conditions (~50 degrees at the wrong time of year)
  - Nasty creatures (some deadly snakes)
- When access is arranged / funded it is desirable to capture as rich assets as possible.
- Maximise future research potential, be able to ask unanticipated research questions.
- Site and/or object recording with minimal hardware payload.



Traditional methods





Observations

- Archaeologists like many of us are interested in new technologies.
- But often it is (simply) digital technologies as a replacement / upgrade to traditional ones.

  - iPad instead of sketch book.

  - GPS instead of maps and traditional surveying.

  - Photographs instead of drawings.

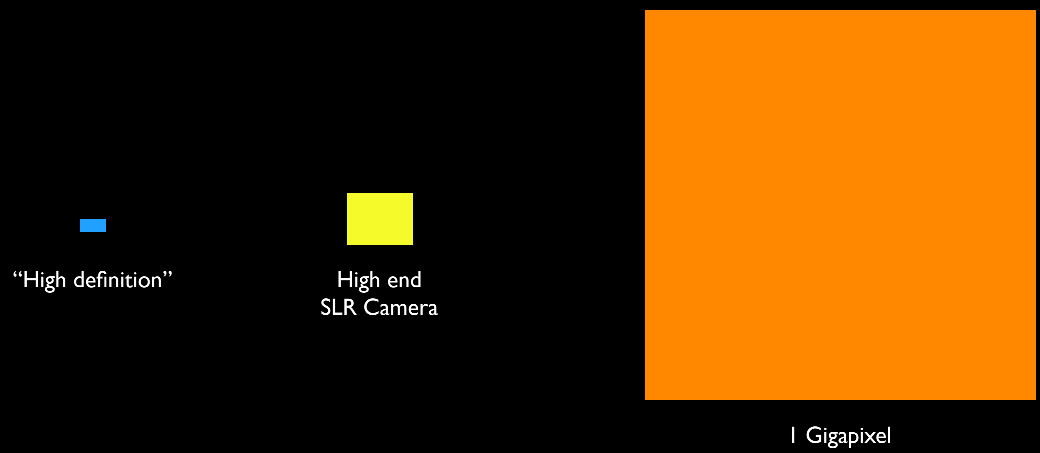
  - Annotating digital images instead of sketches.

  - Digital voice recordings instead of notes.

  - Online databases instead of the filing cabinet.
- Exploring and exposing researchers to different recording opportunities only made possible by digital techniques.
- Evaluation in order to determine what brings real value.

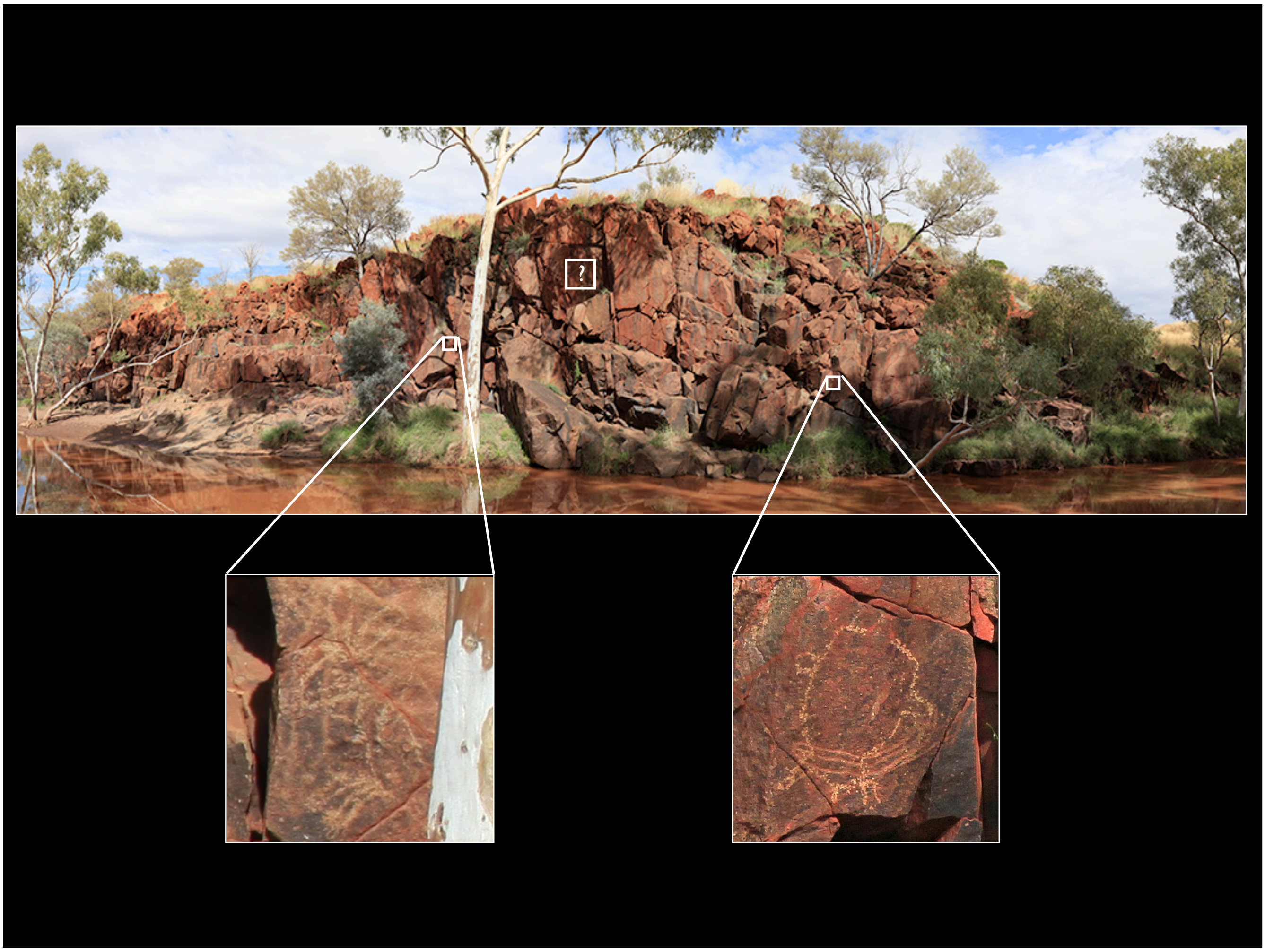
High resolution imaging

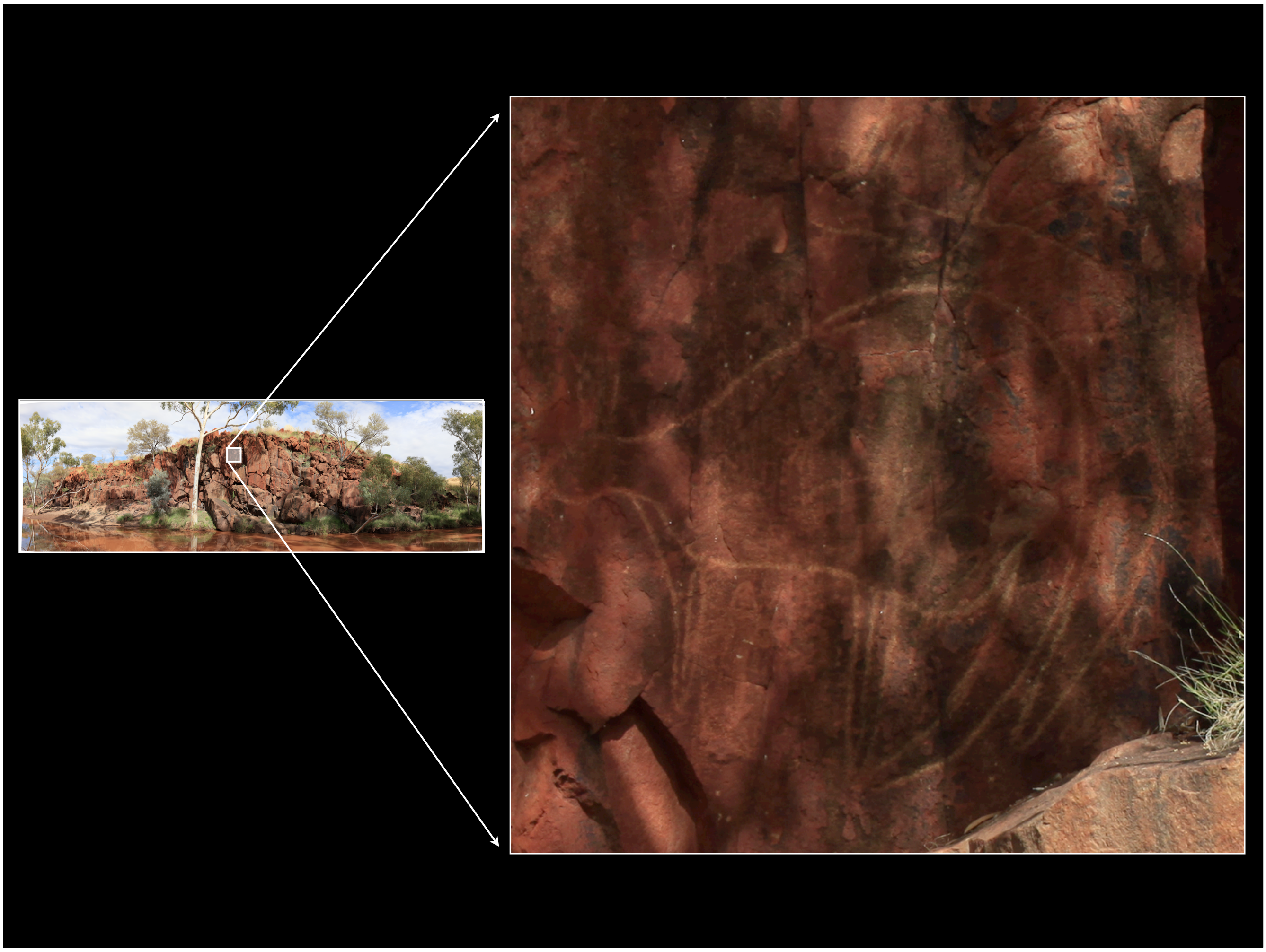
- Will define “high resolution” as over 30,000 (or 2^15) pixels on one axis.
- Not arbitrary, at this point two things happen
  - Many standard file formats can no longer be used, eg: jpeg.
  - Increasingly becomes inefficient to read whole image into memory.
- “Gigapixel” (10^9 pixels) is also around 30,000 x 30,000 pixels.



Approach

- One cannot purchase an arbitrarily high resolution photographic sensor.
- Solution is to capture a number of overlapping images, usually but not always in a regular grid pattern, and stitch/blend together for a higher resolution composite.
- Scalable - resolution is largely determined by the field of view of the lens. The narrower the FOV the more images captured and the higher the resulting resolution.
- Is employed across a wide range of disciplines, from microscopy (camera attached to a microscope) to astronomy (imager on the Hubble space telescope).
- Motorised rigs employed to simply the process and ensure complete image set with sufficient overlap.
- A regular grid is not required but a common simplified approach.





High resolution mosaic imaging

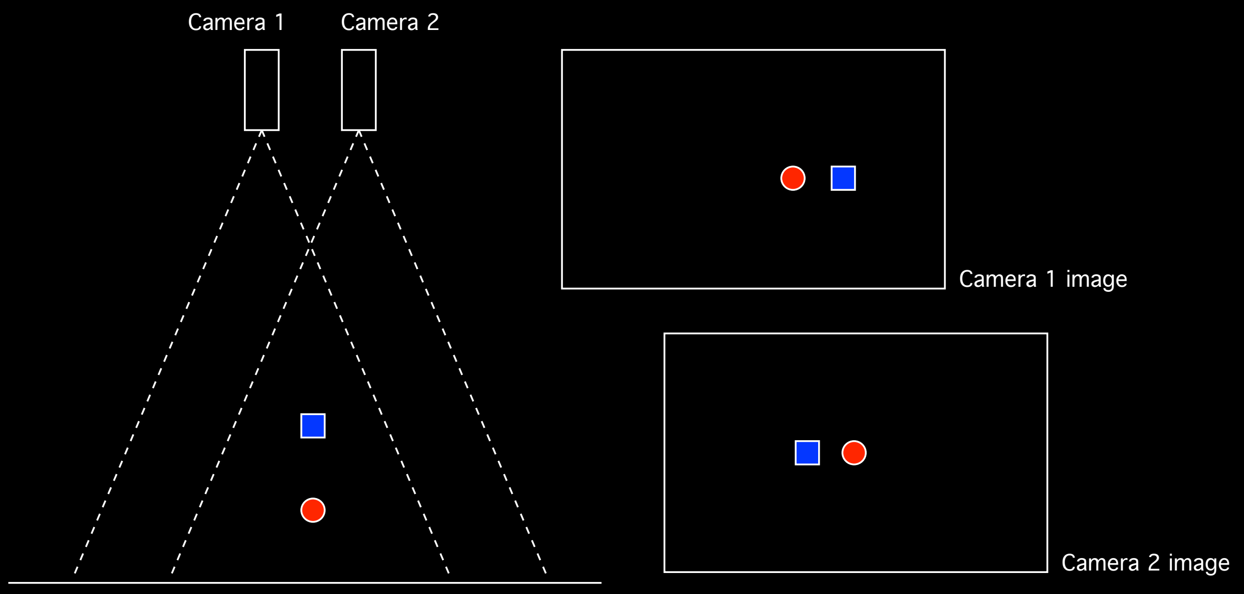
- Basic idea is to take a number of photographs, each overlapping with its neighbours.
- Feature points betweens pairs of images are found across the overlap region.
- Images spatially aligned based upon those feature points and mapped into the final projection space.
- Overlap region blended between overlapping image pairs.
- Two main categories:

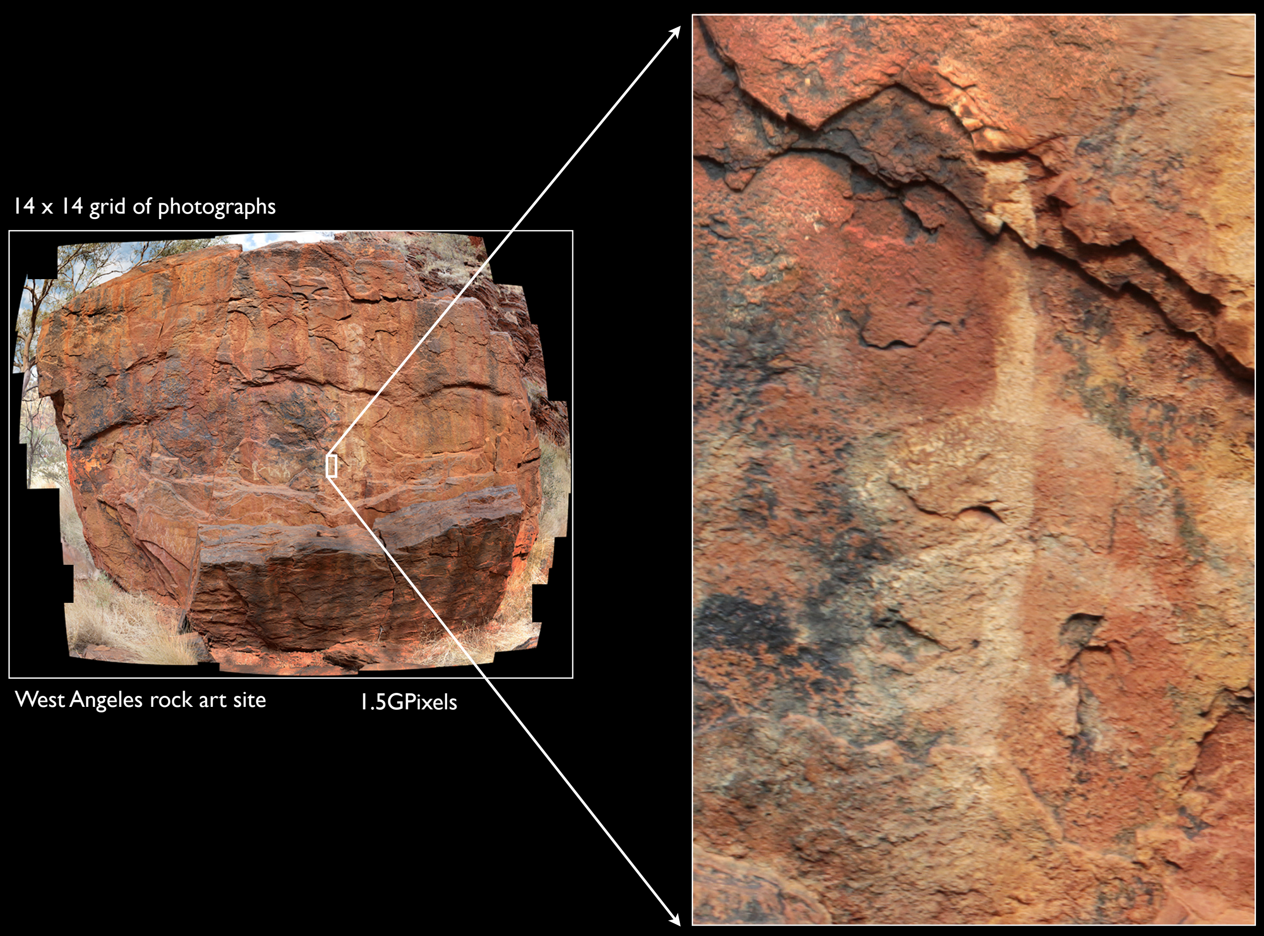
  - Stationary camera, panorama style.
  Perfect stitching possible, camera rotates about its "nodal point".
  An example are the gigapixel images shown previously.

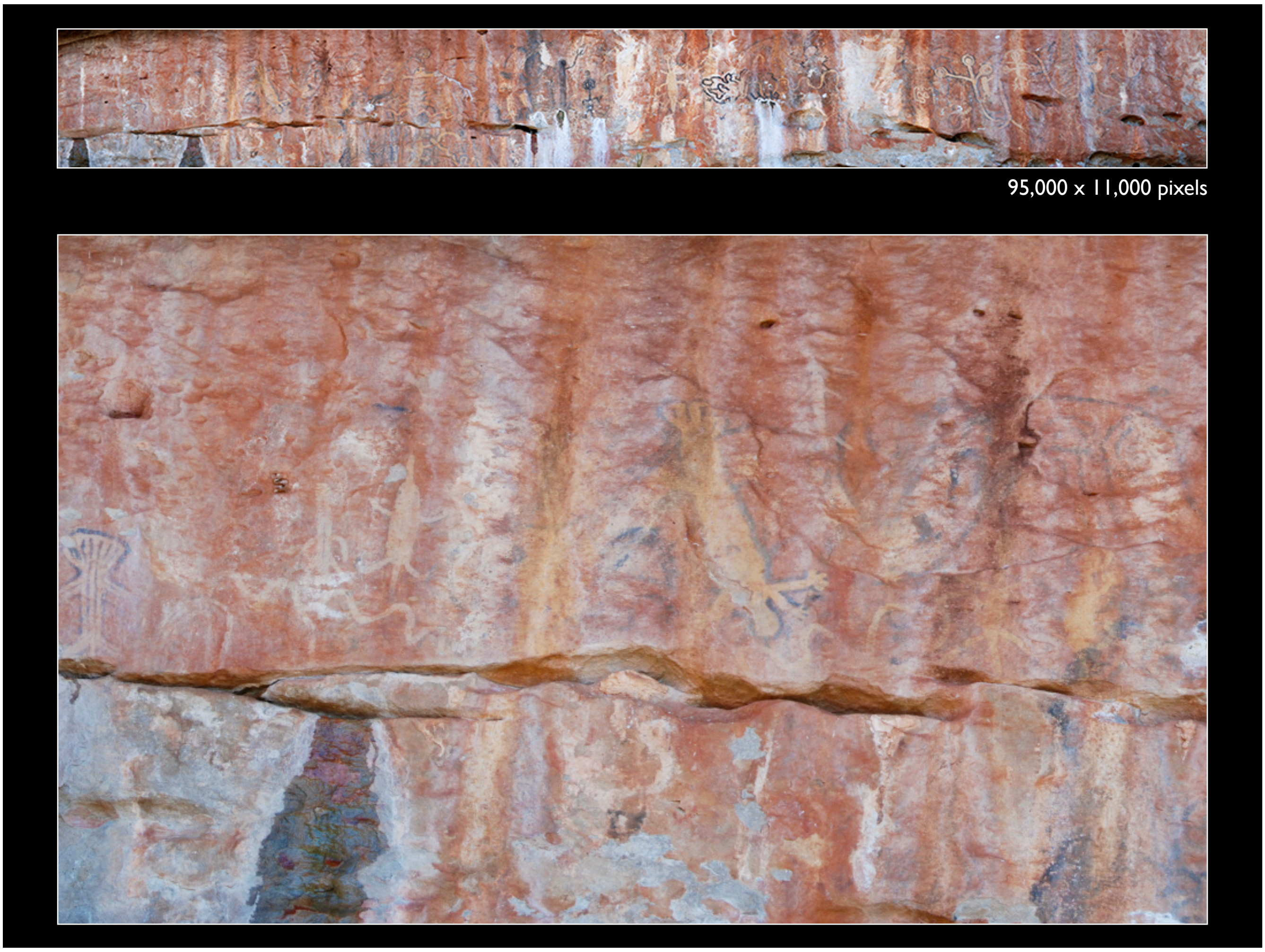
  - Moving camera, mosaic style
  Suited to largely flat objects as stitching cannot be perfect except at a single depth.

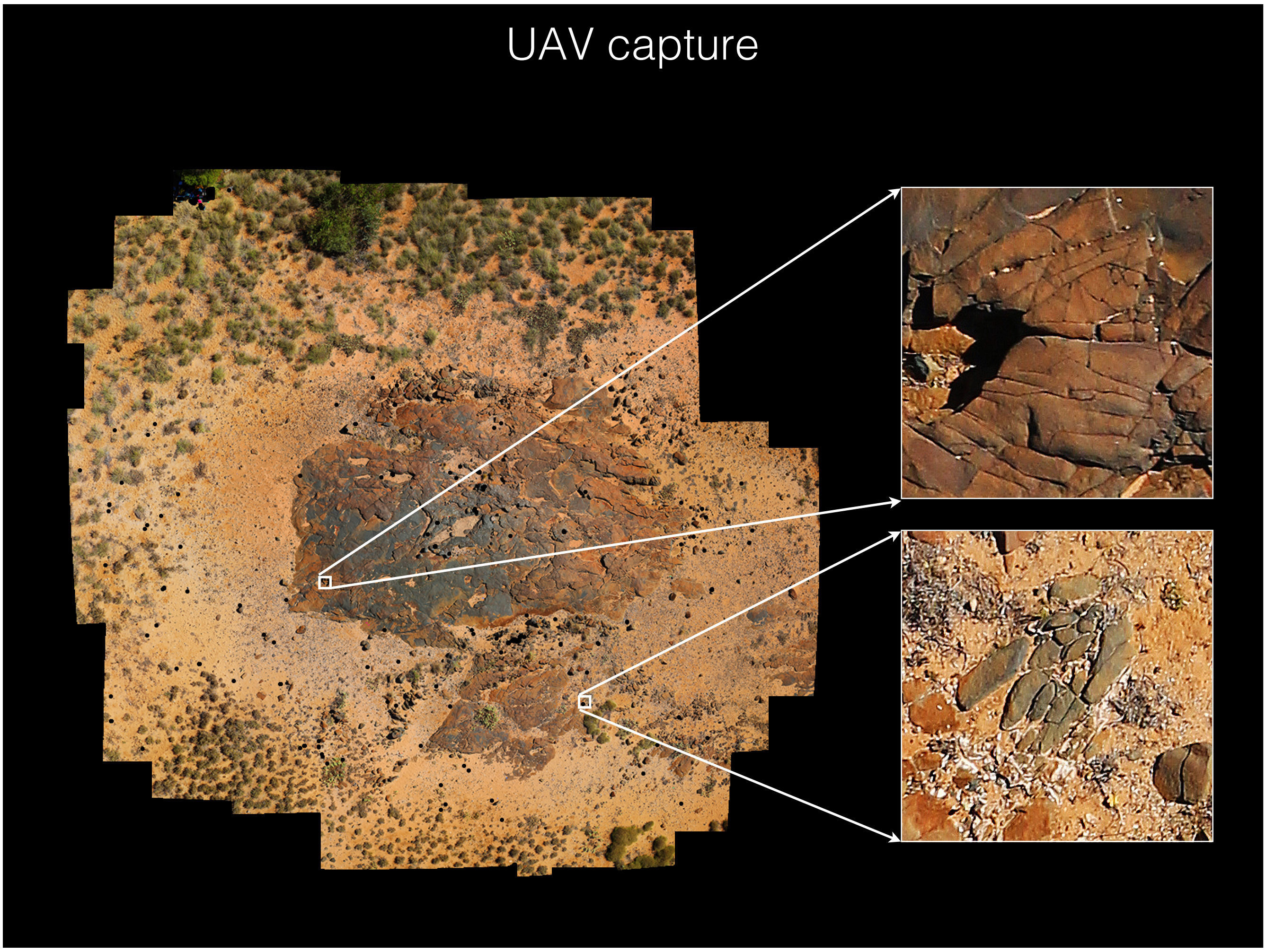
High resolution mosaic imaging

- Mosaics refer to a camera that moves, typically across a largely 2D object.
- For fundamental reasons the stitching/blending cannot be perfect across all depths.
- Same reason why current 360 video multiple camera rigs cannot stitch perfectly at all depths.






95,000 x 11,000 pixels

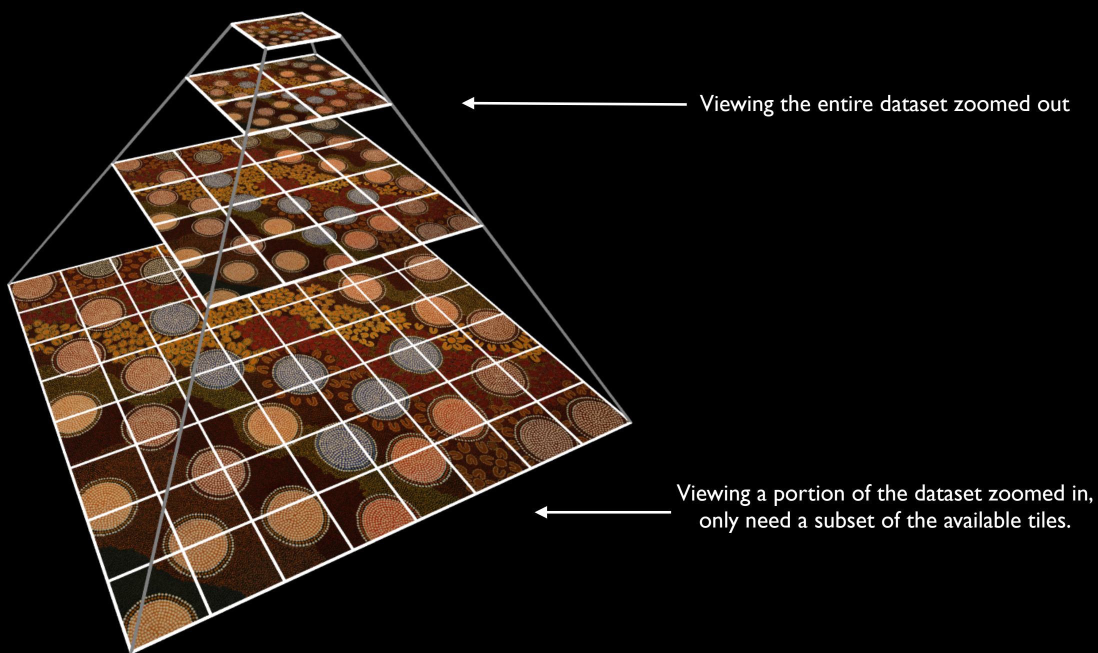

UAV capture

Challenges

- These are "just images" so one might expect it to be a solved space.
  Capture yes. Data storage, management and distribution ... not so!
- Candidate file formats such as:
  TIFF, Pyramidal tiff, bigtiff - JPEG 2000 - Photoshop large image format - ...
  Generally poorly supported.
- The vast majority of software expect to read the whole image into RAM. Increasingly inefficient, one can now readily capture images of many 10's GBytes.
- There are very few standards based hierarchical or progressive image formats.
- Candidates
  - JPEG 2000 Wavelet based.
  - Pyramidal TIFF.
  Both are standards based but poor uptake.
- Even fewer standards for online delivery and poorly supported.
- Lots of options but most are bespoke (including what we're using) and others are proprietary with corresponding lack of support and questionable future.

Pyramidal image formats

- The tiles visible depends on where in the image one is exploring and the zoom level.
- A scalable solution: principle is only load/transfer/display what is visible.
- Unfortunately not widely supported.



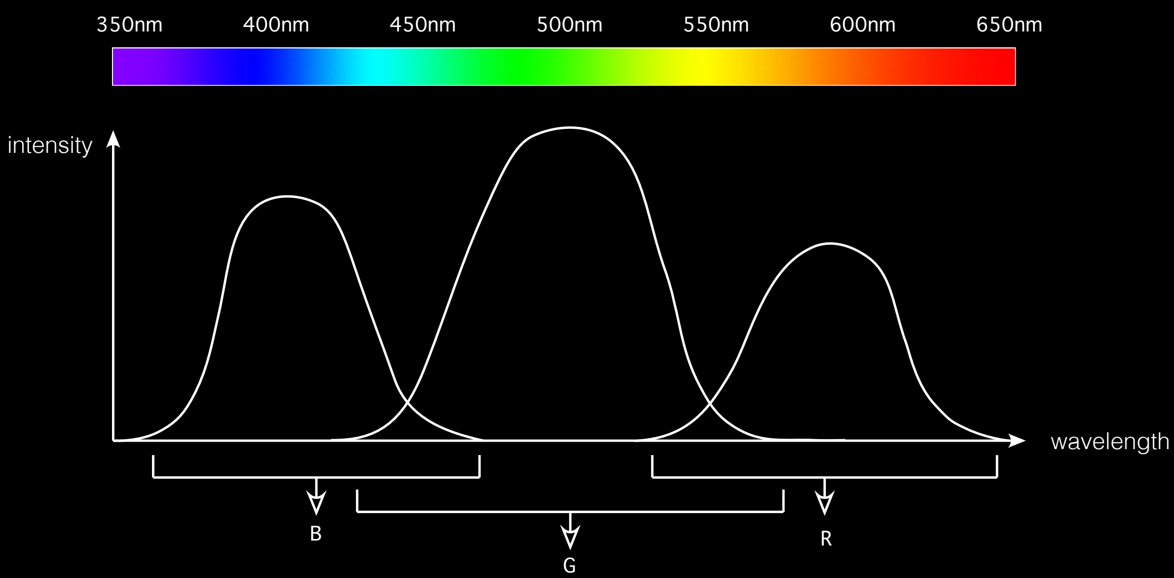
Multispectral imaging

Rock art is often very obvious

Other times less so

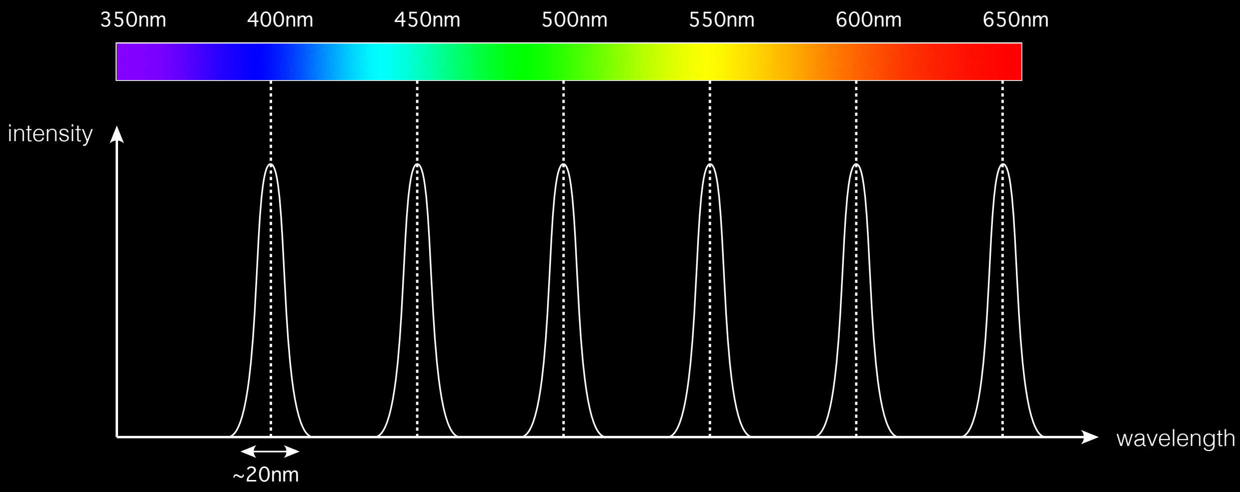
Concept

- A normal photograph is throwing away a huge amount of information.
- The energy across a range of wavelengths is being (weighted summed) into just 3 numbers, single single R,G,B values.

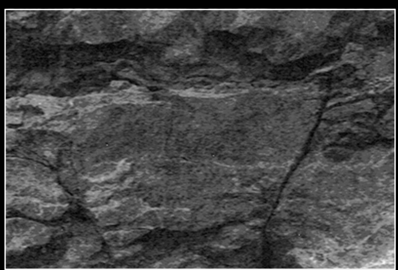


Method

- What if we captured narrow wavelength ranges and created a greyscale (intensity) image for each band.
- For this initial experiment used 8 interference bandpass filters.
- 50nm apart and 20nm wide.



Example



400nm

450nm

500nm

550nm

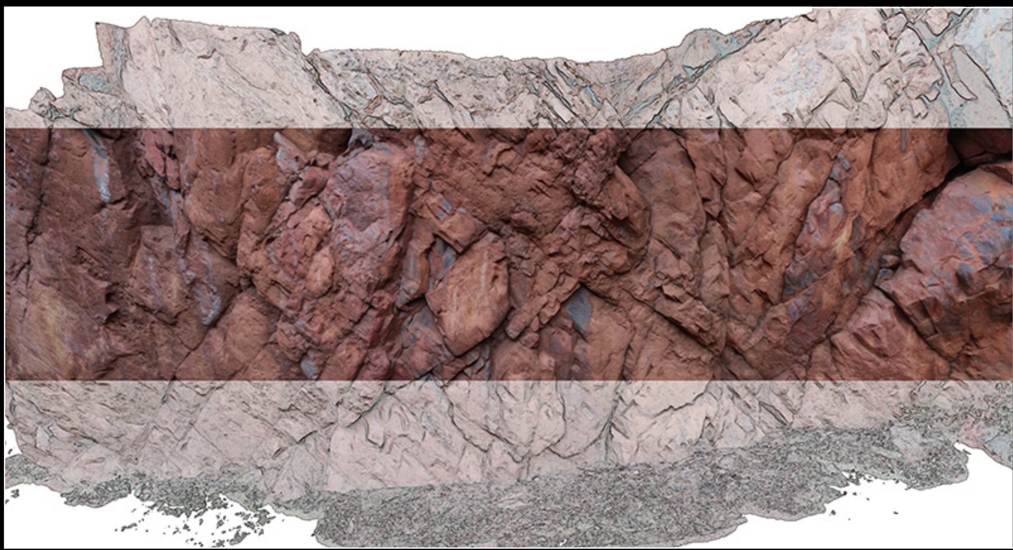
600nm

650nm

- Might imagine multiplying 500nm and 550nm and subtracting 650nm.
- Note that here we are interested in identification, much of multispectral imaging is more about quantitative analysis.

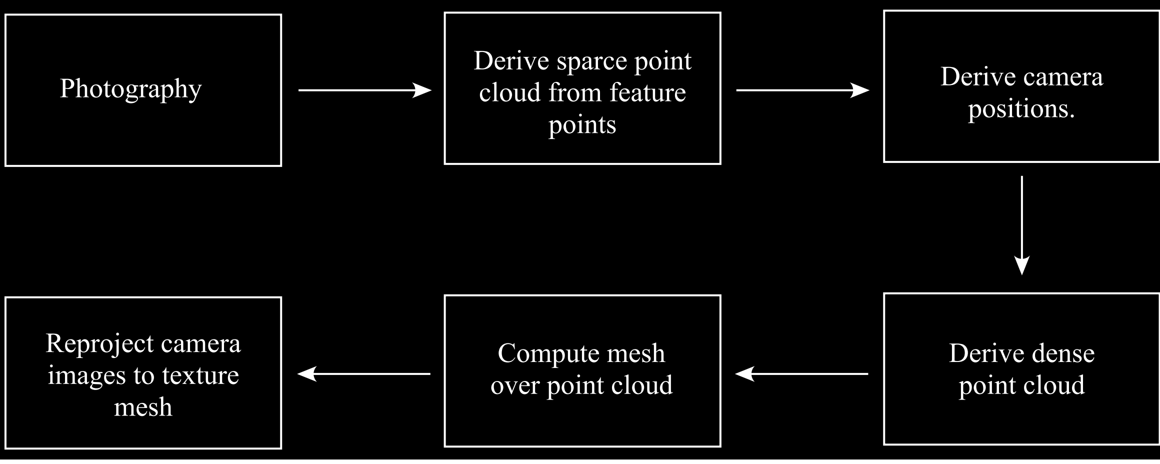
3D reconstruction from photographs

- Photogrammetry is the term given to any 3D measurement derived from 2 or more photographs.
- Simplest case might be deriving distance measures from a stereoscopic image pair.
- More recently advances in computer science, computer/machine vision in particular, and computational geometry have allowed full 3D textured mesh models to be derived.

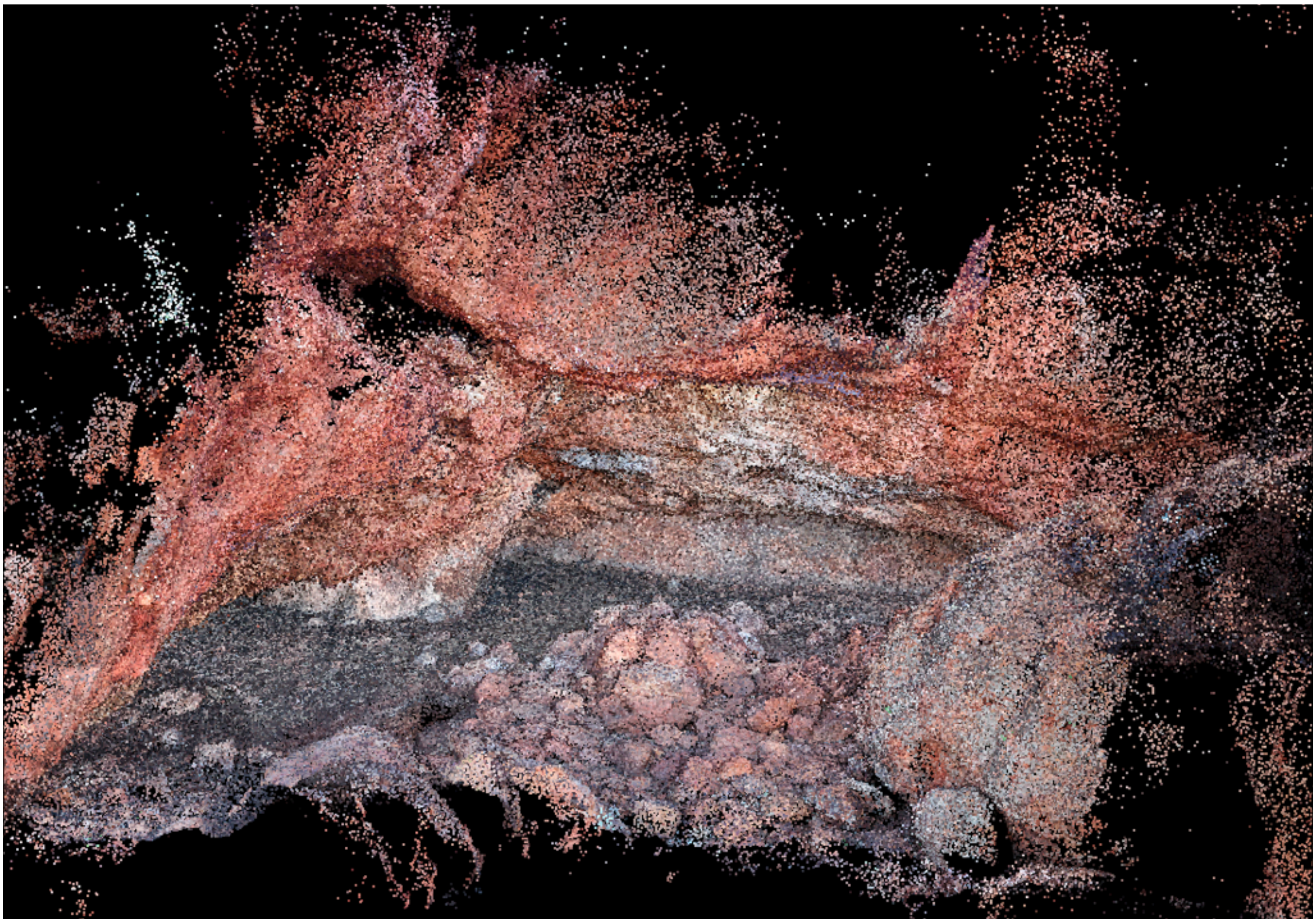


Methods

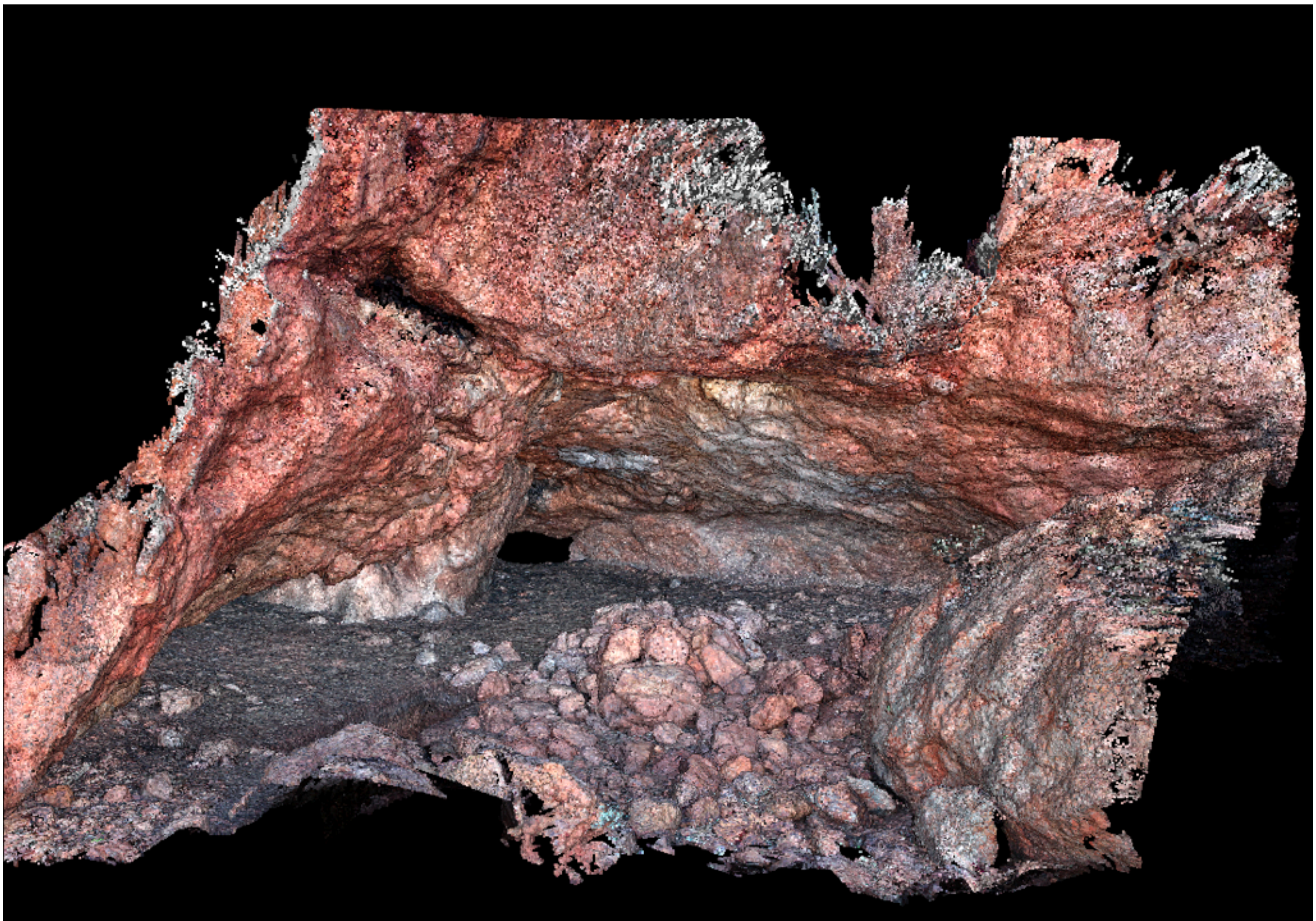
- Find matching feature points between any pair of images. Similar to first stage of processing of panoramic or mosaic images.
- Using these feature points and some knowledge of the camera optics, derive the 3D positions of the feature points and cameras. (Bundler algorithm)
- Using this new information derive a denser point cloud.
- Create a mesh based upon the dense point cloud, possibly decimate to a desired resolution.
- Re-project the images from the cameras onto this mesh to form texture images(s).



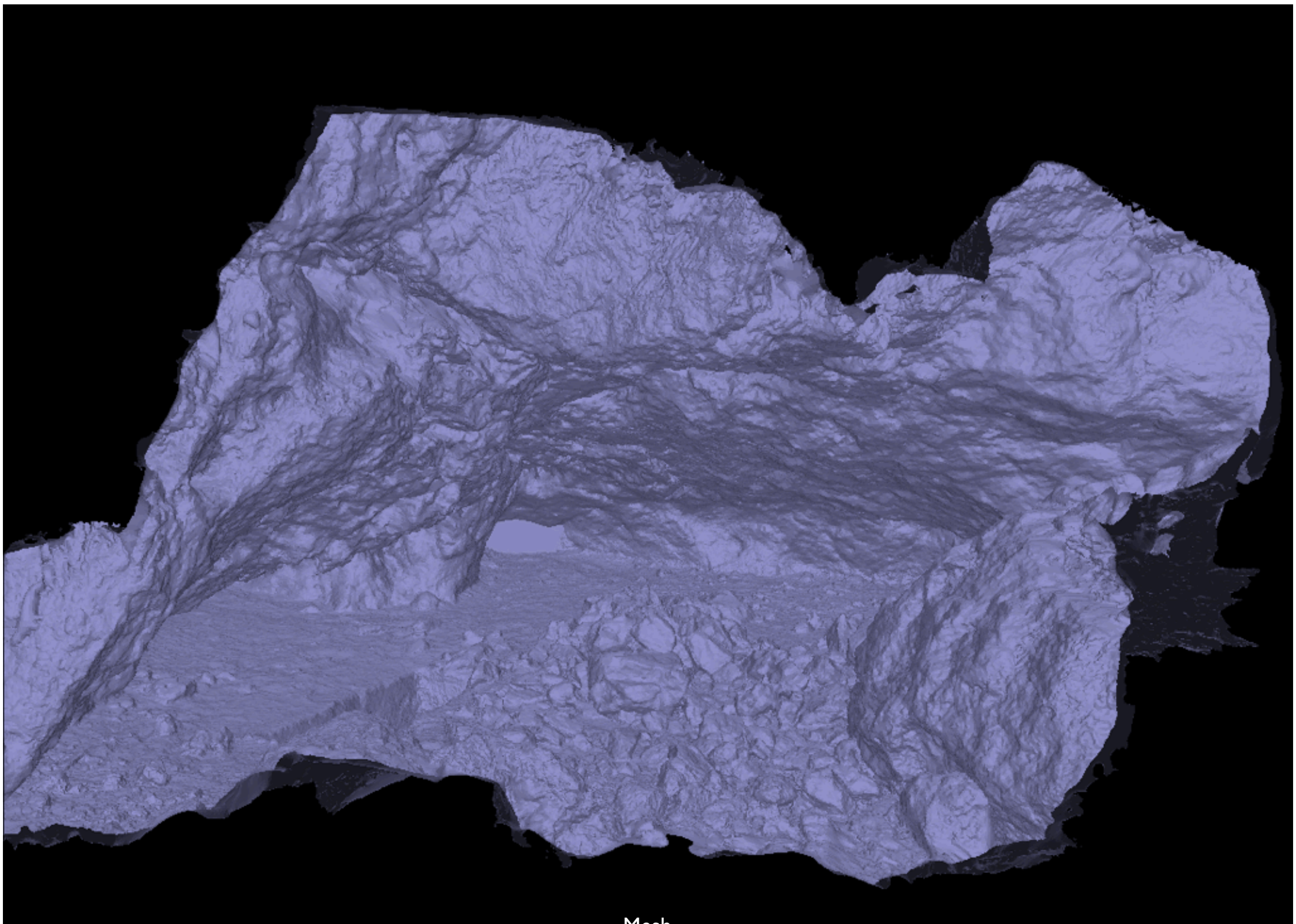
350 x 22MPixel photographs



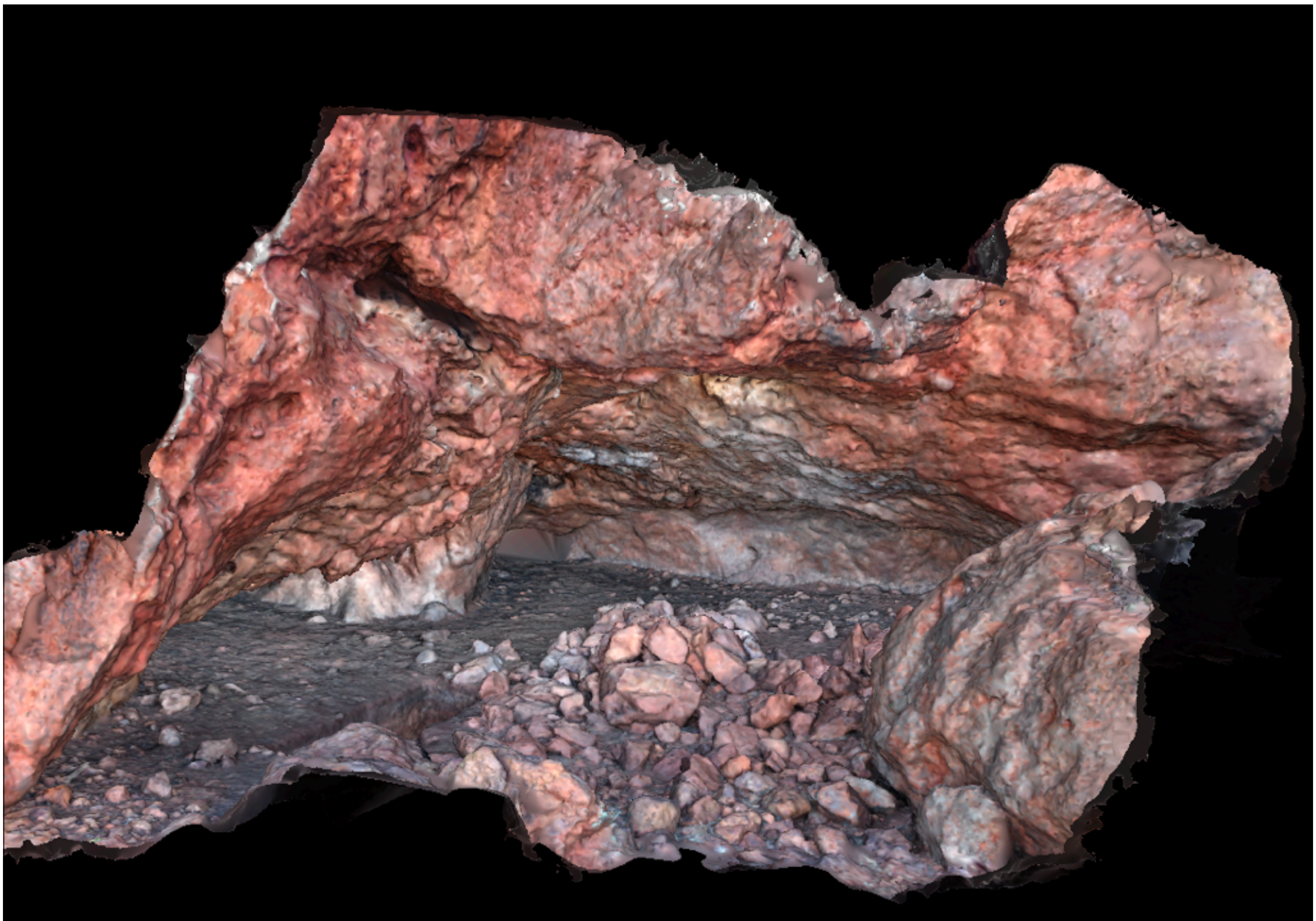
Sparse point cloud



Dense point cloud

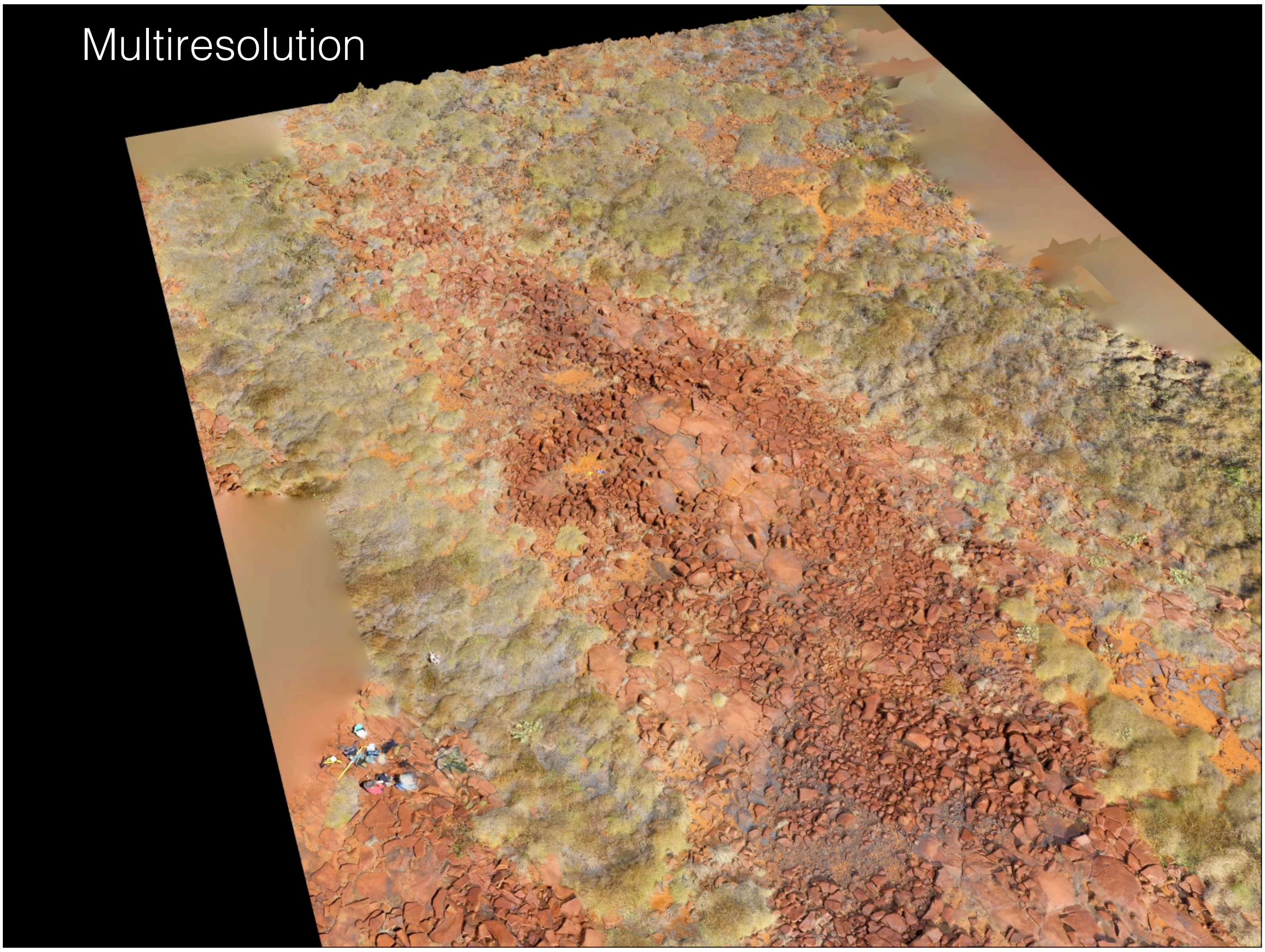


Mesh



Mesh with dense point cloud colour

Mesh with reprojected photographs


Multiresolution

Challenges

- Surprisingly (depressingly) even after all these years of the internet there are still no entirely satisfactory ways of distributing and presenting 3D data. As per gigapixel images there are some bespoke or proprietary ways.

- Archives and database are still “dumb’. They need to be 3D aware.

  Why can’t the archaeologists perform a search “show me all north-east facing rock art on greater than 2m rocks that are 100km from Newman”. Without baking that meta data into the database. It is all there in the geometry!

- Key missing components for delivery (not just for online)
  - progressive texture
  - progressive geometry

  Currently our collection of 3D models have at least 4 x 4Kx4K texture files and almost always much greater than 5 million triangles. Don’t want to deliver that raw to the browser, equally lots of inefficiencies of having N levels of detail in the database.

Summary

- Have presented various imaging techniques and how they are being applied in the context of indigenous archaeology in Western Australia.

- The capture of high resolution imagery and 3D models is reducing the need of returning to the site.

- Site specific constraints are addressed by only requiring a camera, and possibly tripod.

- Achieving high uptake (except for multispectral imaging) at the Centre for Rock Art Research and Management who are now regularly employing these techniques now in the standard practice.

- When will the 3D model be of sufficient quality to remove the need to take and store individual images?

- Largely the concern is around the archiving, search and presentation software that are lagging well behind the capturing capabilities.

Questions ?

West Angeles rock shelter, reconstructed from 400+ photographs