Imaging and visualisation of heritage

Paul Bourke

iVEC @UWA

Malaysia

India

China

Alternative title

Choosing a research activity that lets you travel the world

Paul Bourke

iVEC @UWA

iVEC

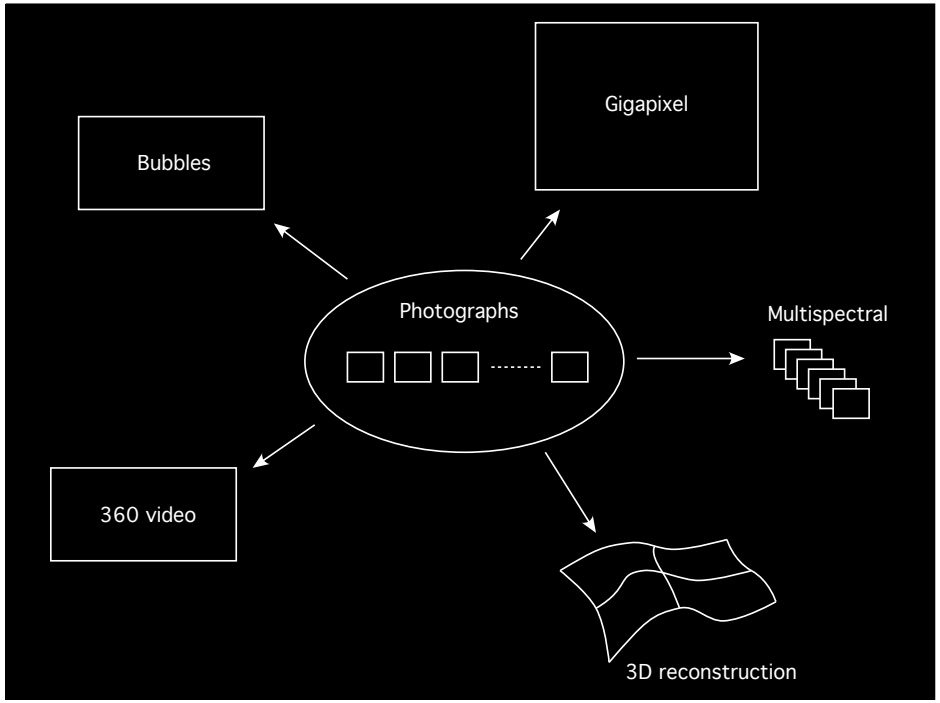
- Partnership between the 5 main research organisation in the state.
  4 public Universities and CSIRO.
- Has three main teams / activities.
  - Supercomputing
  - Data
  - Visualisation
- Currently manages.
  - Pawsey supercomputer, EPIC (at Murdoch), and Fornax (at UWA)
  - Multi petabyte storage facilities
  - Cloud service (soon)
  - Three visualisation laboratories
- iVEC@UWA is the Centre I manage at UWA, the iVEC facility at UWA.
- Employ all three team leads as well as many of the team members.
- Also manage video conferencing room and video production facility.

iVEC @UWA

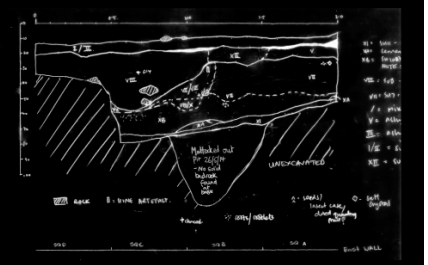
Contents

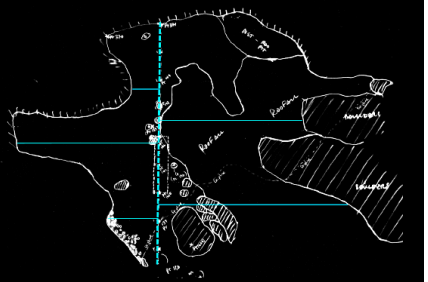
Acquisition	Presentation
Site capture - bubbles	Virtual tours
High resolution photography	High resolution displays
Multispectral recording	
360 video	Immersive/interactive cinema
3D reconstruction	Virtual environments

Questions ?



Traditional methods in heritage recording





Personal observations

- The traditional methods are tried and familiar.
- Heritage practitioners are interested in new technologies.
- But often it is digital technologies as a replacement / upgrade to traditional ones.

  - iPad instead of sketch book.

  - GPS instead of maps.

  - Photographs instead of drawings.

  - Annotated photographs instead of sketches.

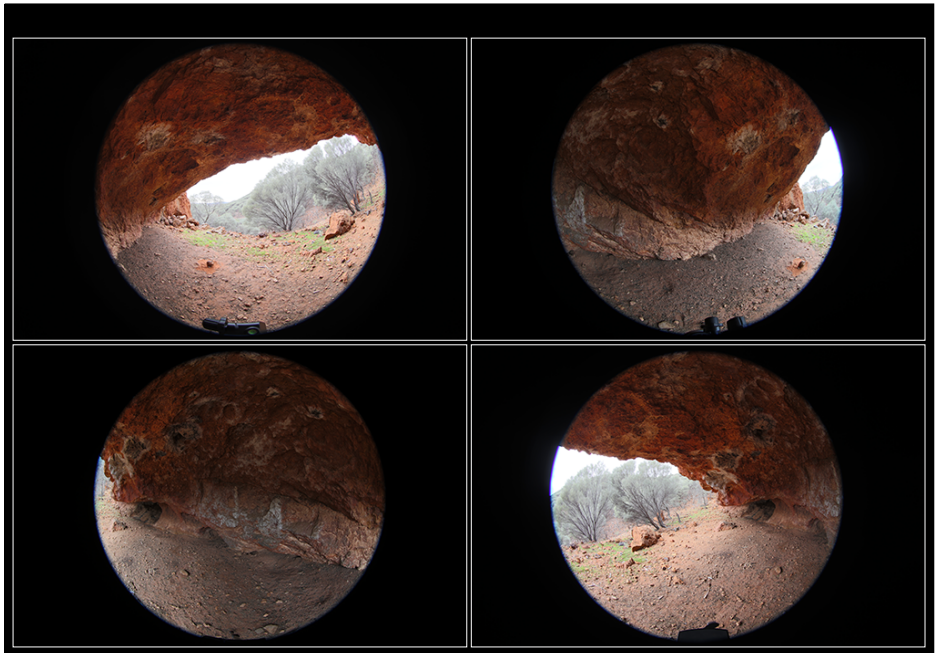
  - Digital voice recordings instead of notes.

  - Online database vs filing cabinet.

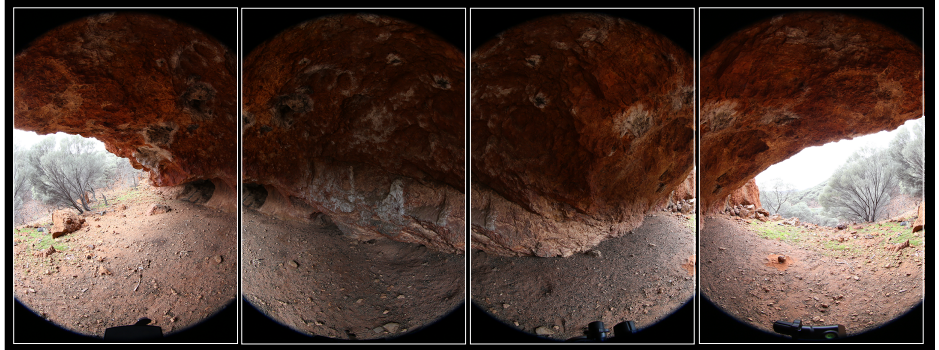
- My involvement has been around exploring and exposing researchers to different recording opportunities only made possible by digital techniques.
- Explore and evaluate those that bring value to the profession.
- Have to date been very successful, most of the techniques to be discussed are being regularly used by archaeology, and in particular, rock art research at UWA.

Bubbles

- “Bubbles” capture all that is visible from a single position.
- Not new, been used for giving virtual tours, online views of apartments, etc.
- Now possible to capture reasonable resolution bubbles with only 3 or 4 images.
  Use a 180 degree fisheye lens and good SLR camera.
- Represented “flat” as spherical projections. Apparent distortion at the poles arising from different topology between a plane and a sphere. No distortion when viewed correctly.



4 fisheye views of Weld Range rock shelter



Only possible due to 8-15mm zoomable Canon fisheye
Creates almost an 12K spherical rather than a 8K spherical projection

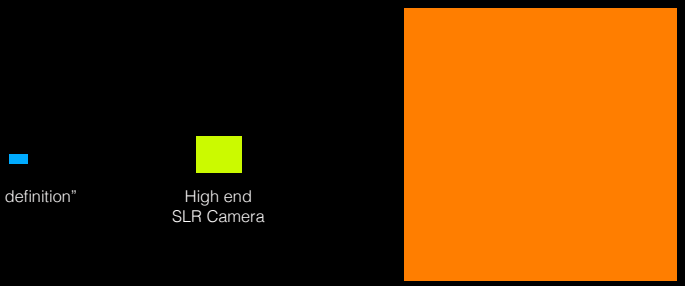
Algorithms

- The algorithms involved are very similar to much that will presented today.
- Feature points are found between pairs of images, generally using the SIFT (Scale-invariant feature transform) algorithm.
- Detection normally extremely good for these high texture photographs.
- Images are then transformed and blended to the destination projection, in this case spherical.

Spherical projection, 8000x4000 pixels

High resolution photography

- 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.



Motivation

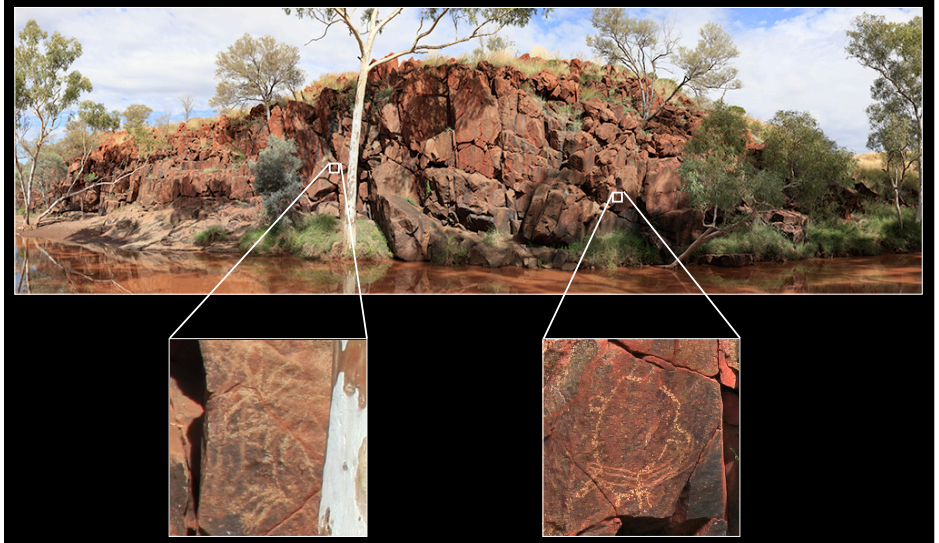
- Capture the detail as well as the context in a single image.
- Result in richer research assets than separate distant and closeup images.
- In the context of remote locations access may be problematic/expensive, goal is to capture as high a value recording as possible.
- For destructive processes one only gets a single chance, again, record at as high a resolution possible to maximise future research outcomes.
- Well known example is panorama photography.

View from entrance of rock shelter 50,000 x 15,000 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 approach.

Wanmanna



My favourite example of rock art

Movie

Techniques

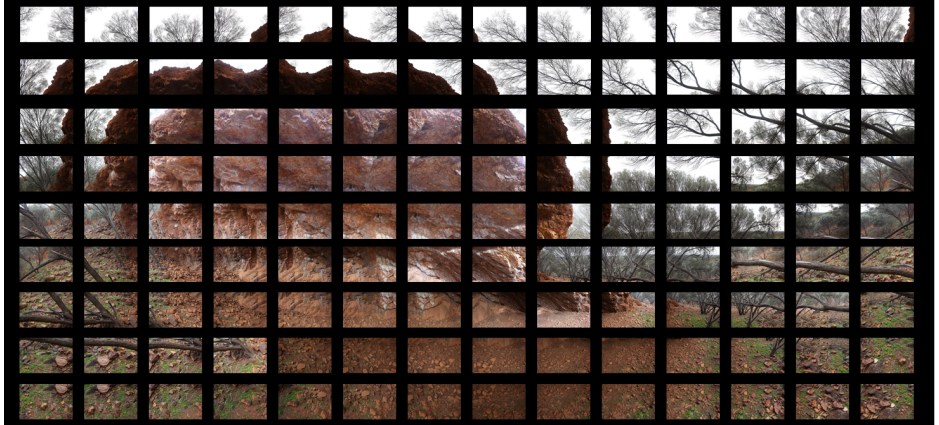
- Basic idea is to take a number of photographs, each overlapping with its neighbours.
- Generally using a motorised rig to automate the process.
- Feature points betweens pairs of images are found across the overlap region.
- Images spatially aligned based upon those feature points and mapped into the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

  - Stationary camera, panorama style.

  - Moving camera, mosaic style (suited to largely flat objects).
- For panorama style the camera is arranged to rotate about it's so called "nodal" point.
  Well known by panorama photographers.
- Stitching can be perfect.

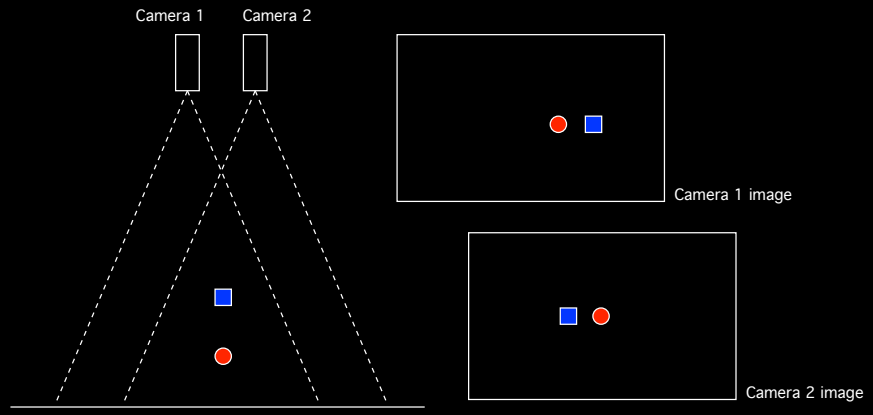
Panorama style

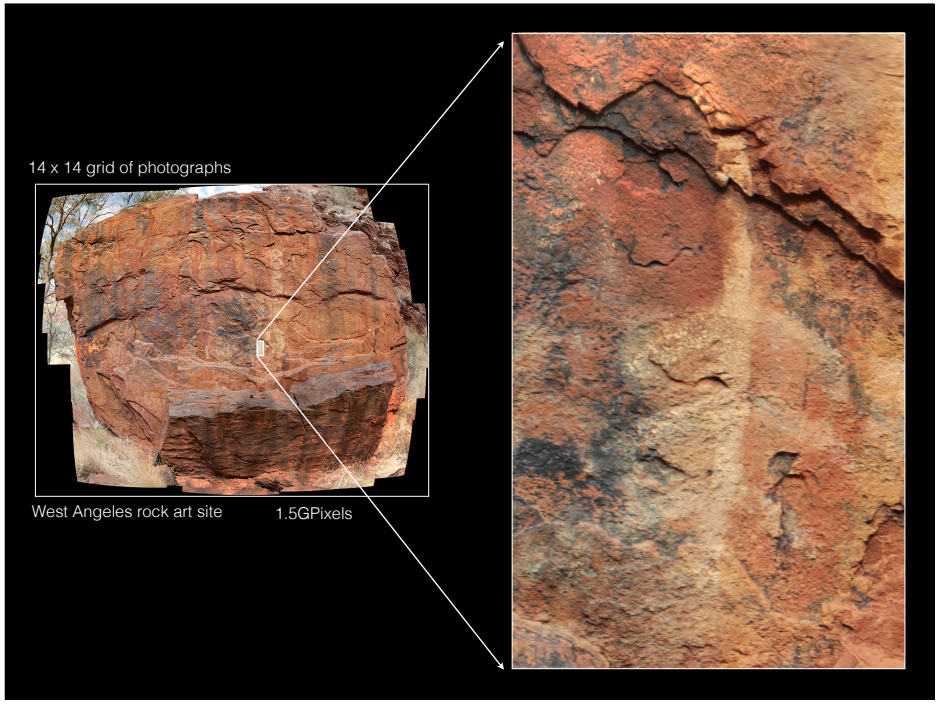
- The final resolution is largely dependent on the field of view of the lens. The narrower the lens the more photographs and the higher the final resolution.
- Use approximately 1/3 image overlap.

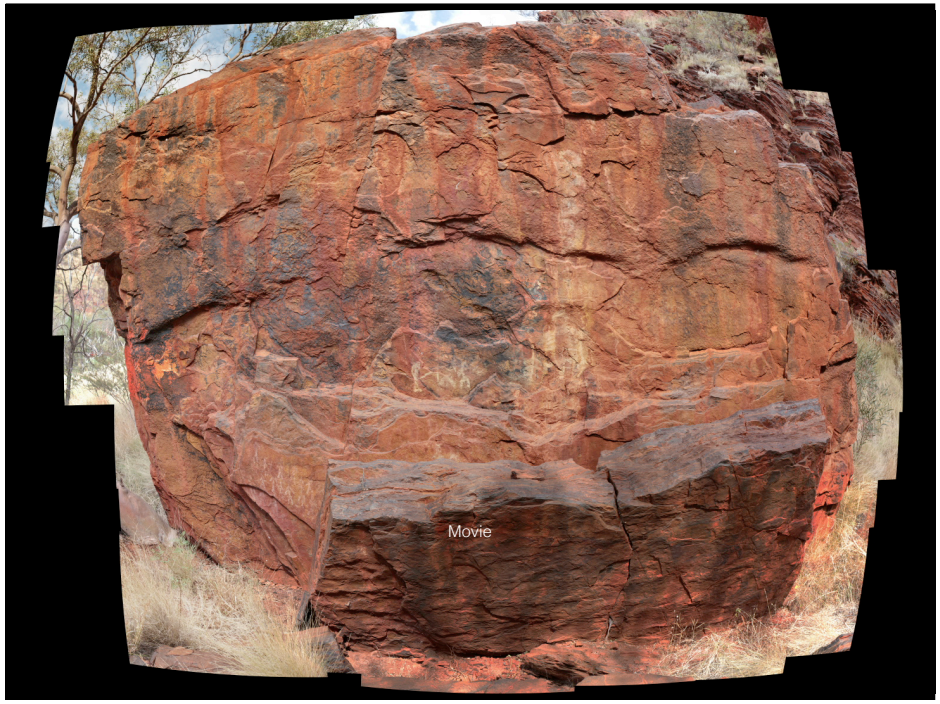


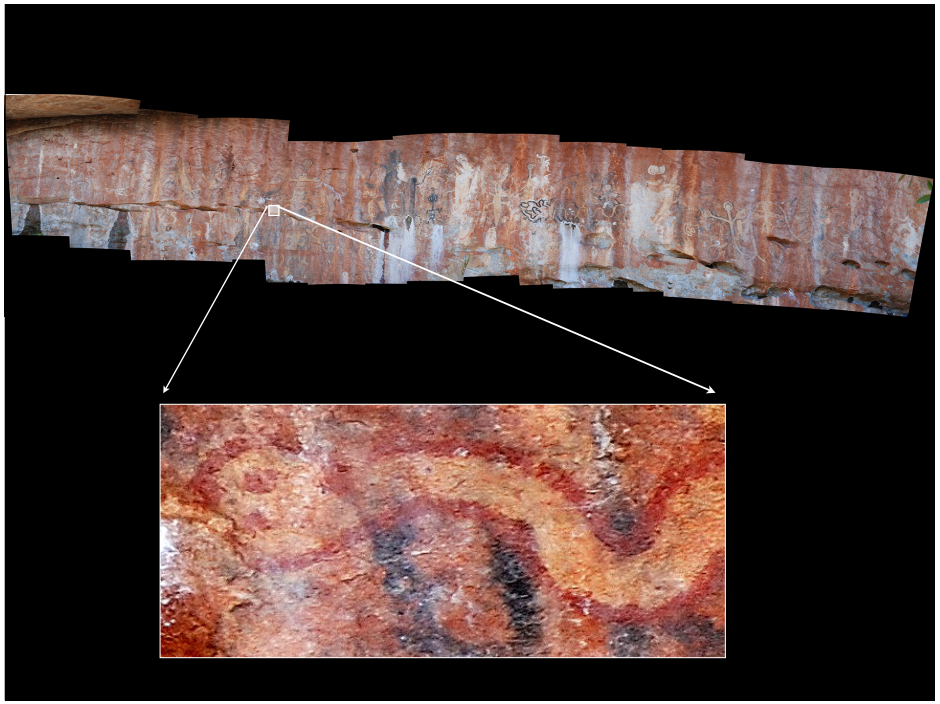
Mosaic style

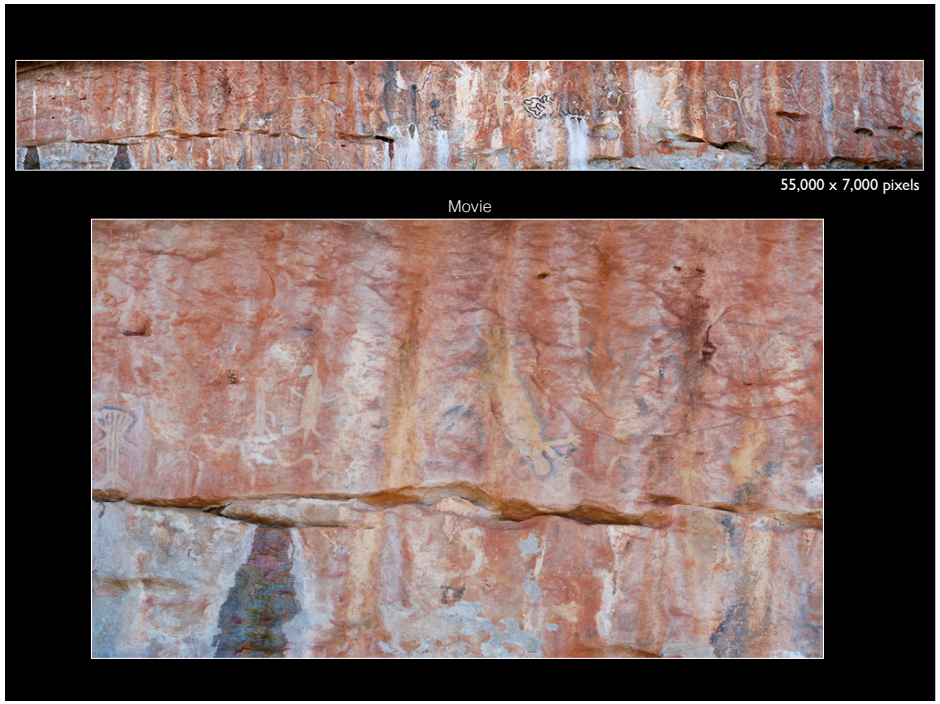
- Mosaics refer to a camera that moves, typically across a largely 2D object.
- For fundamental reasons the stitching/blending cannot be perfect across all depths.
  Thus more suited to surfaces with minimal depth variation.



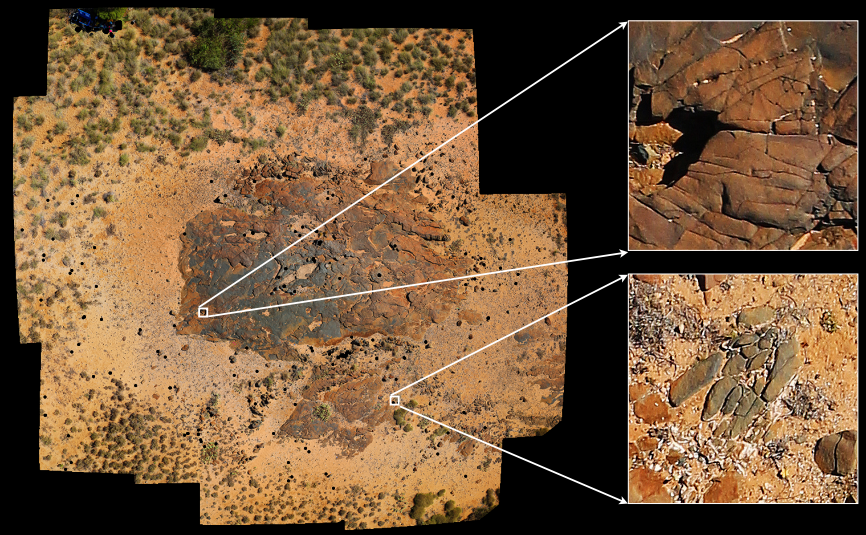

14 x 14 grid of photographs
West Angeles rock art site
1.5GPixels


Movie




55,000 x 7,000 pixels
Movie

UAV capture



Centre for Exploration Targeting, UWA

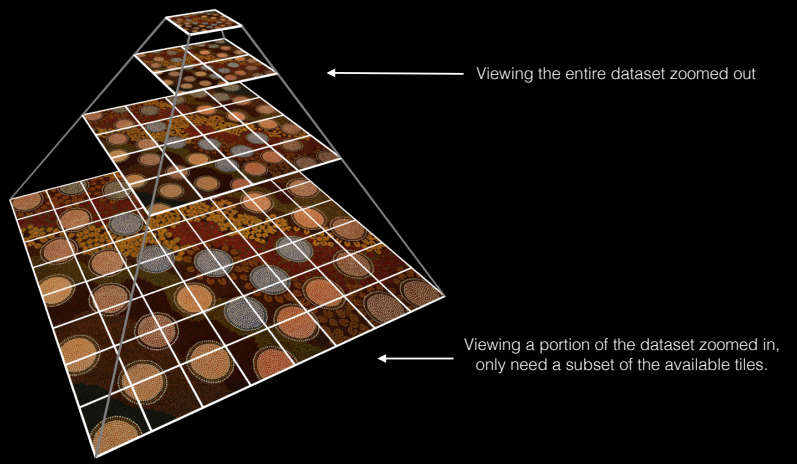
Forensics

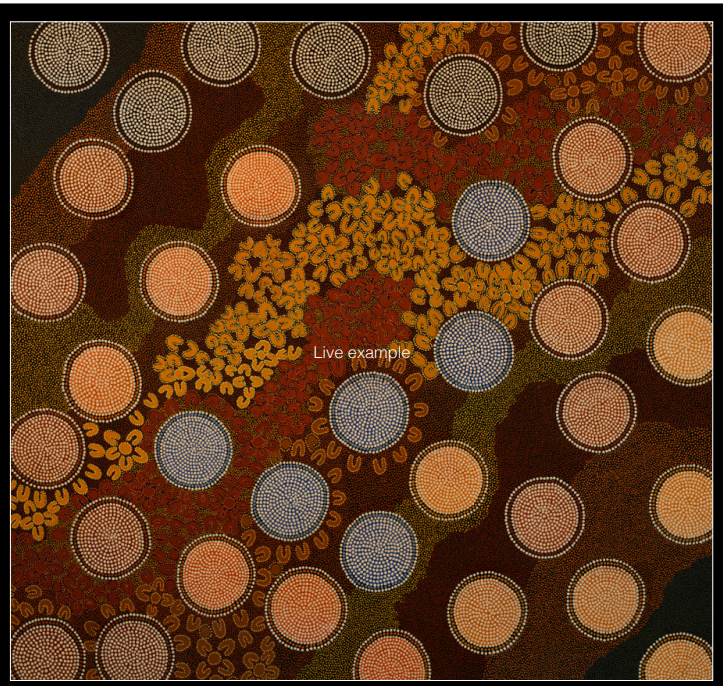
Challenges

- 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 by storage and analysis software.
- The vast majority of software expect to read the whole image into RAM.
- Increasingly inefficient, one can now readily capture images requiring 10’s GBytes.
- Problems with databases that try to create thumbnail images, for example.
- 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 largely bespoke (because of the lack of standards) with corresponding lack of support and questionable future.

Pyramidal tiff

- 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.





Presentation

- Tiled displays: a space and cost effective means of getting a large numbers of pixels to engage the resolving power of our visual system.
- Save the zooming in and out that is commonplace with lower resolution devices. Seeing the detail and the context.
- Researchers report benefits in large scale, perhaps 1:1 representations.

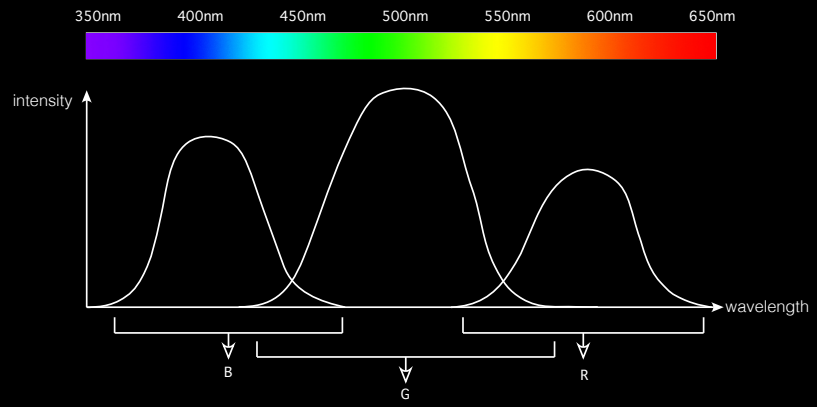
Multispectral recording

Rock art is often very obvious

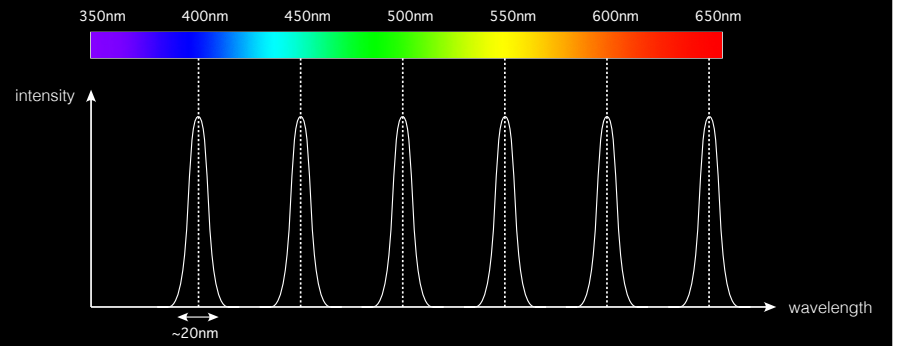
Other times less so (and less inspiring)

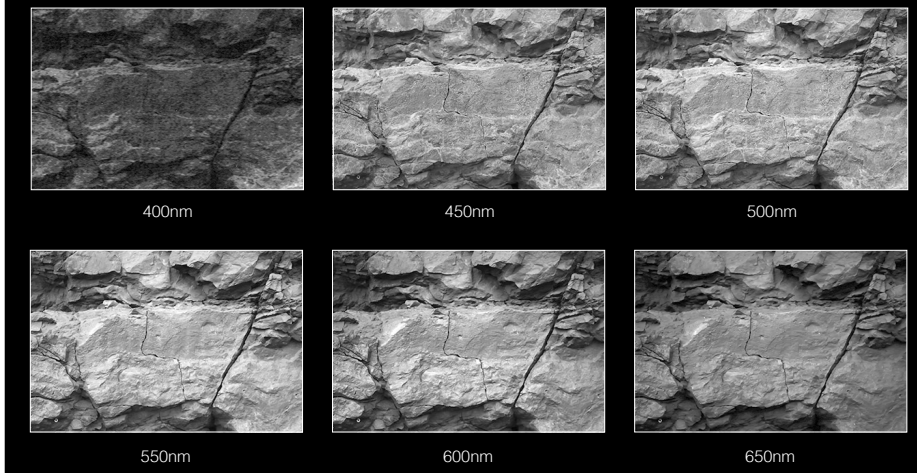
Motivation

- 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.



- 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.





- 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.

Challenges

- Need better methods of swapping the filters in front of the camera.
- There are dedicated multispectral cameras that capture a large number of wavelength bands, come at a cost.
- The current three examples this has been applied to revealed rock art the skilled archaeologist would have found and identified, need a more compelling example.
- Interested in more sophisticated methods for enhancing features across a multispectral image set.

360 video

- Spoken so far about the capture of objects and places.
- Cultural heritage is about the recording of culturally significant events.
- Many of these happen around within a space, or around a person or object.
- Traditional video with it's directed nature doesn't always capture the event.
- If everything is captured from a position it also allows one to experience the event from that position, for example in a surround displays.
- Has a very old history
  - In 1787 Robert Baker was awarded the patent for "La Nature a Coup d'Oeil". (Nature at a Glance)

"to make observers,
on whatever situation he may choose they should imagine themselves,
feel as if really on the very spot"

- In 1896 Charles Chase employed recent advances in photography to create more literal panoramic experiences.

"everything in view from the point where the photograph is taken will be reproduced exactly as it appears when seen from such point"

Method

- As with previous discussion of high resolution images, there is only a limited resolution achievable with a single camera.
- The solution then is to arrange an array of video cameras.
- The multiple streams are stitched together to form the composite video, generally either a cylindrical or spherical projection.

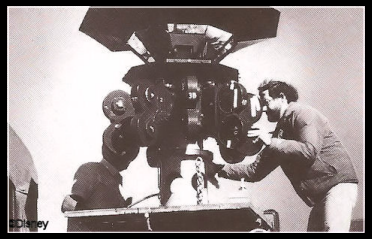
UNSW

UNSW

Kolor

Thank goodness for miniaturisation

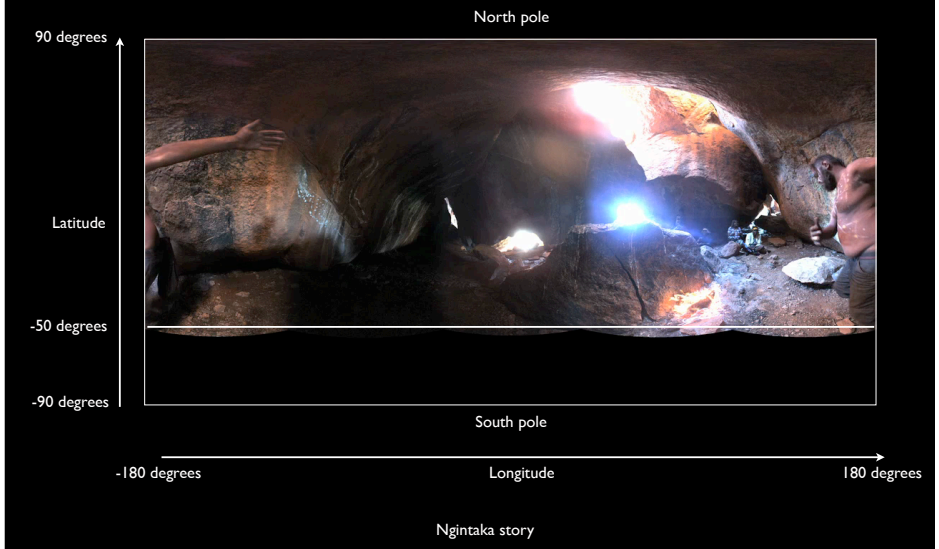
Disneys CircleVision 360 camera ... circa 1950.



Camera

- We have largely used the LadyBug 3 and 5 cameras.
- LadyBug-3: 5400 x 2700 pixel video
  LadyBug-5: 8000 x 4000 pixel video
- Attempts to get the projection point of the cameras as close as possible.

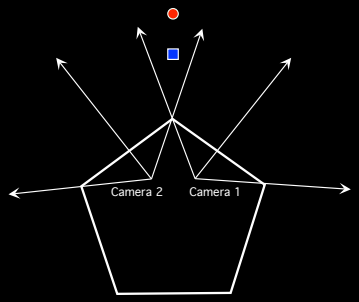
Spherical projections

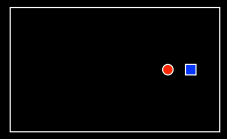


Ngintaka story

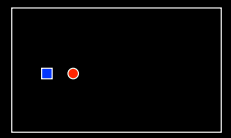
Stitching

- Same problem applies as for mosaic gigapixel images when it comes to stitching streams from displaced cameras.
- Perfect stitch not possible except at a single depth.



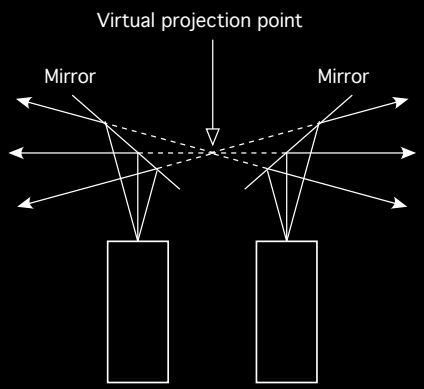


Camera 2 image



Camera 1 image

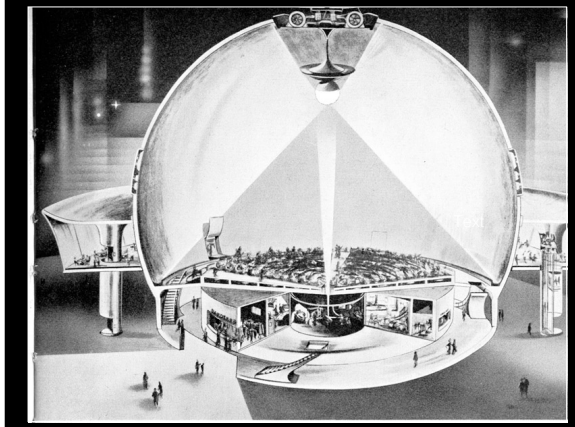
One solution



Cross section through
2 cameras

Movie

History of immersive video



Hamburg planetarium, 1957

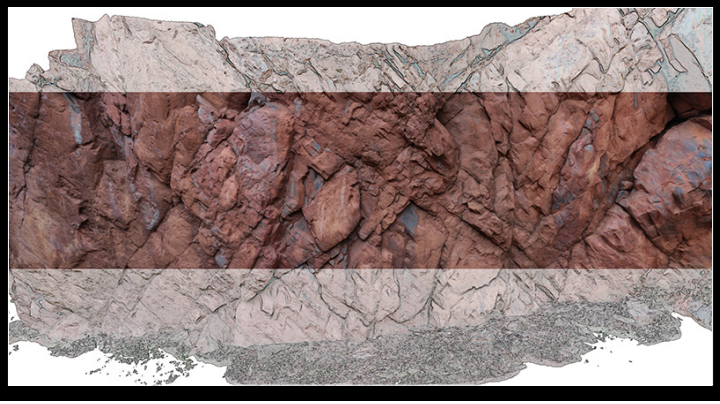
Presentation

- iDome display engages our peripheral vision. Ideal for being inside something.
- Gives a sense of “being there”, often referred to as “presence”.

Exhibition designed for the South Australia Museum

3D reconstruction

- 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 computation geometry have allowed full 3D textured models to be derived.
- Active area of research in computer science, quality of results improving steadily.

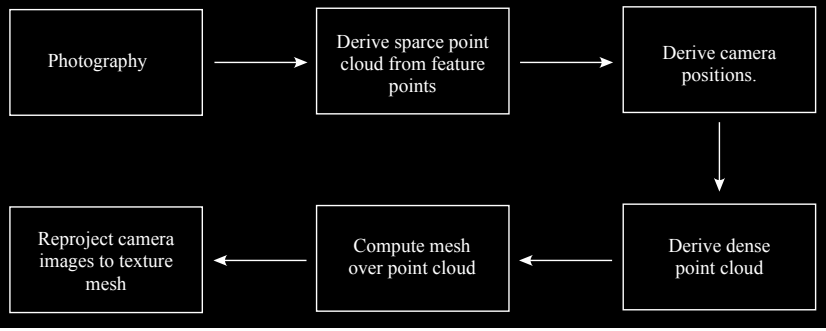


Motivation

- Capture geometry of significant objects and sites.
- In archaeology there are often some unique characteristics
  - Remote sites may preclude large equipment payloads
  - Objects are often delicate precluding illumination, markers
  - Object may be precious and not touched, moved or even illuminated
  - Sites may be remote, underwater, difficult climatic conditions

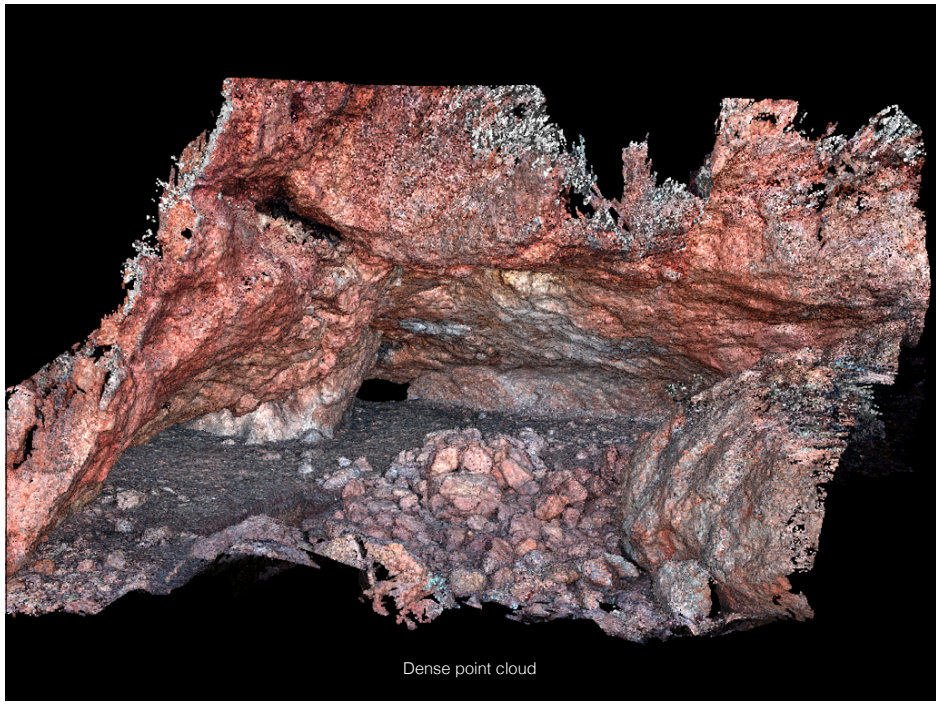
Methods

- 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).

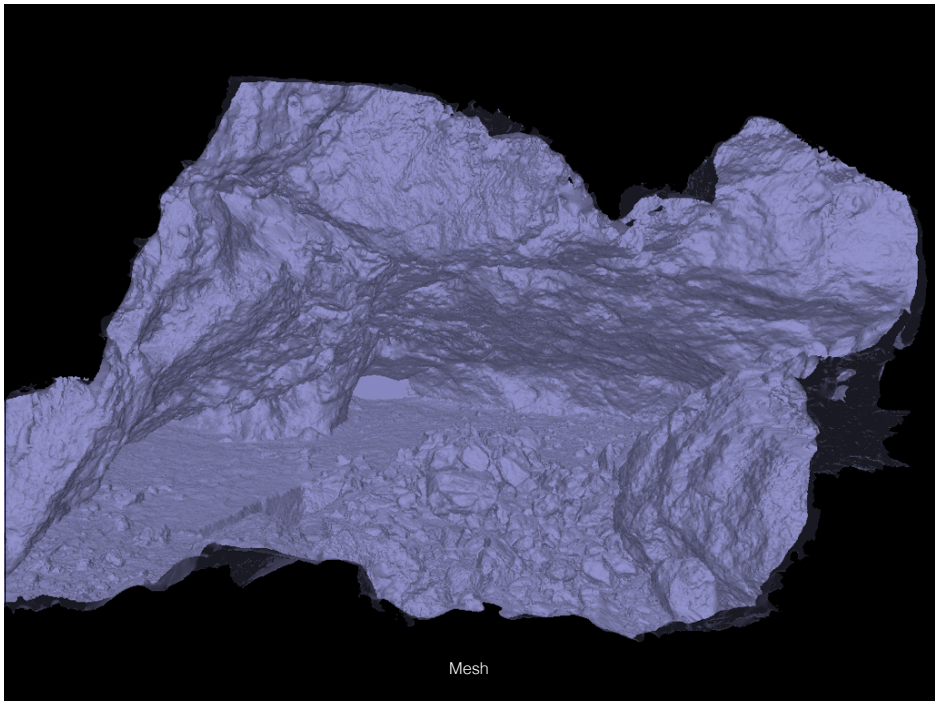


350 x 22MPixel photographs

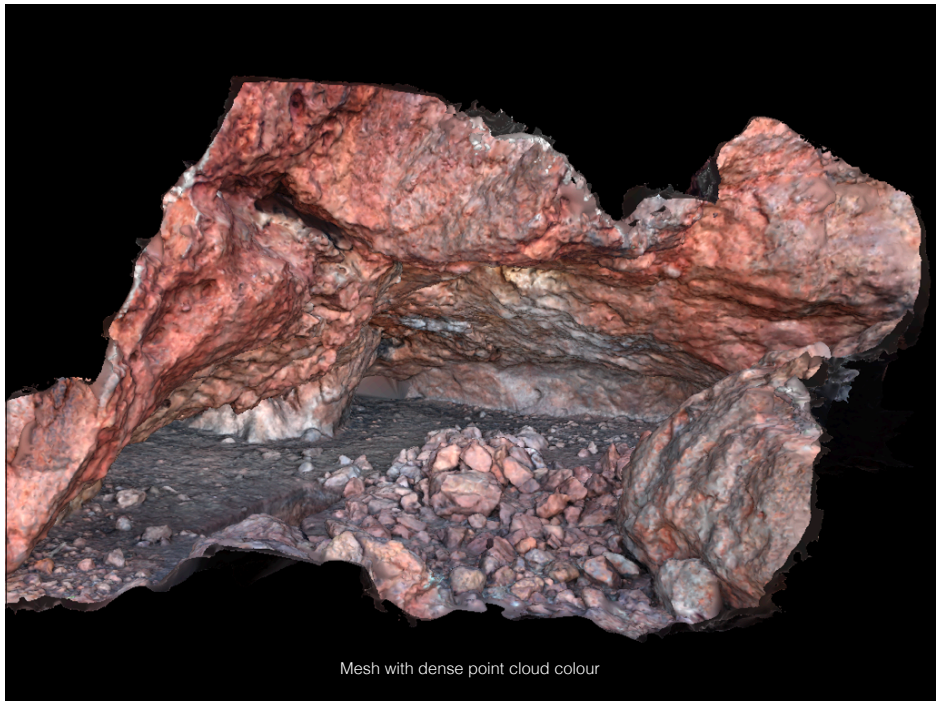
Sparse point cloud



Dense point cloud

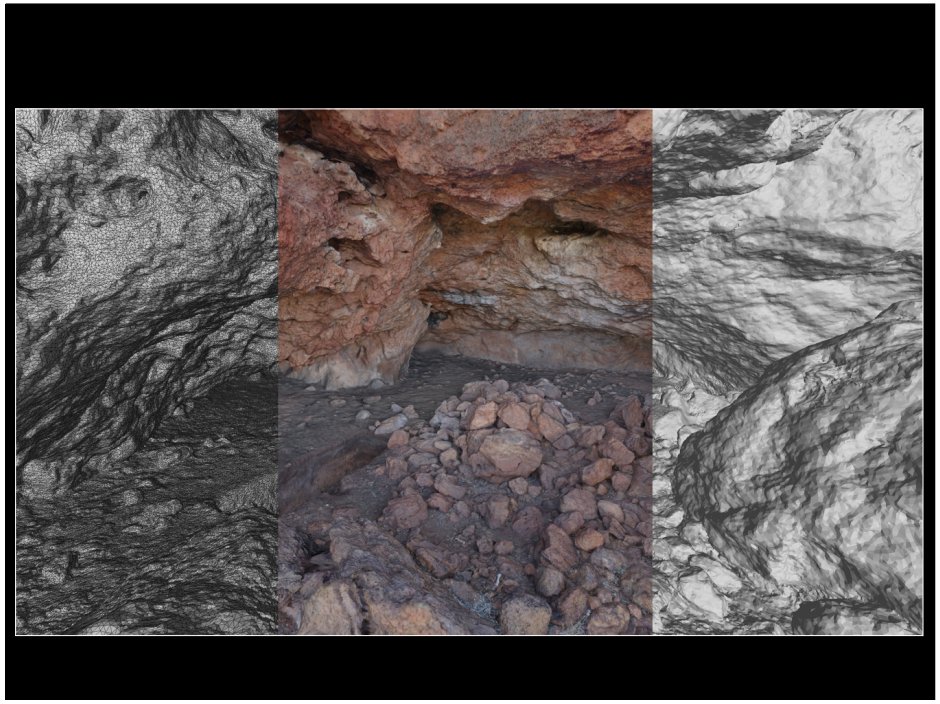


Mesh



Mesh with dense point cloud colour

Mesh with reprojected photographs



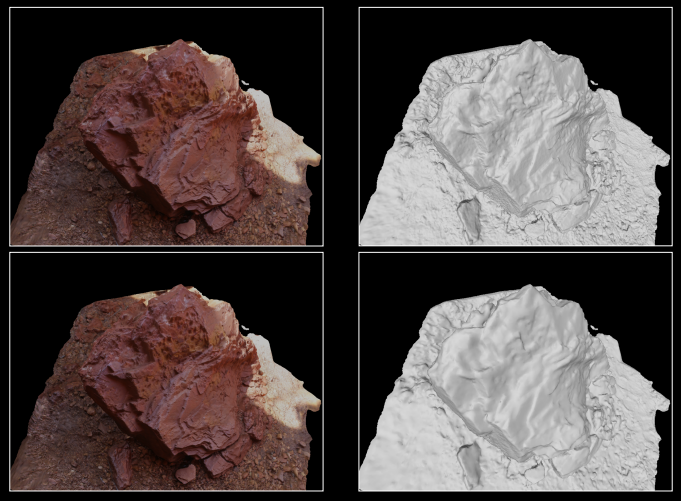
Movie

Geometric vs texture resolution

- Texture quality vs geometric quality.
- Former is easier to achieve with 3D reconstruction from photographs.
- Geometric quality depends on the application.

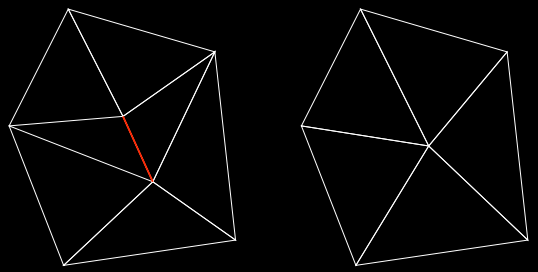
2,000,000 triangles

200,000 triangles



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.



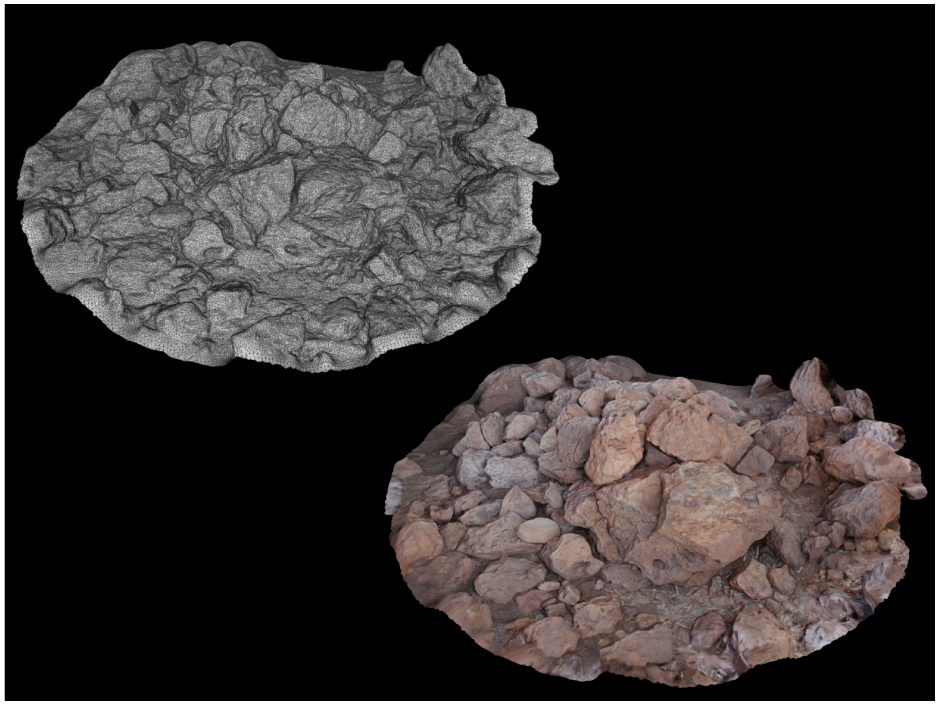
Red edge removed, results in two fewer triangles

Texture/visual quality vs geometric quality.

	Geometric resolution	Texture resolution
Gaming / VR	Low	High
Analysis	High	May not care
Education	Medium	High
Archive	High	High
Online	Low/Average	Low/Average

Comparison with laser scanning.

	3D reconstruction	Laser scanning
Geometric accuracy	Improving	High
Effort	Low	High
Time	Fast	Often long
Visual quality	Potentially high	Average
Occlusion issues	Less problematic	More problematic



Assets for virtual environments

- Combine 3D reconstructed models and bubbles to create virtual environments.
- "Serious gaming" ... using the Unity3D engine.

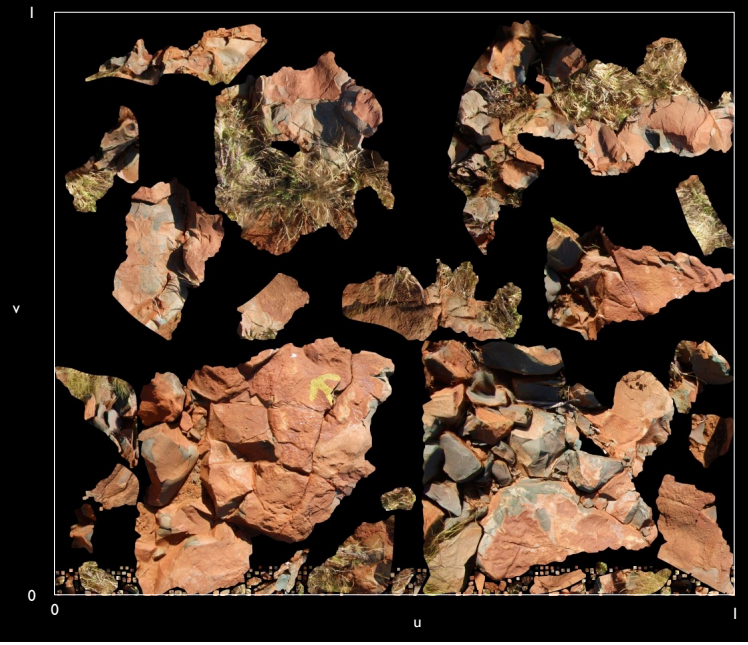
Capture of objects

Movie

Relighting

Movie

Annotating



Movie

Alternative methods for presenting

3D printing

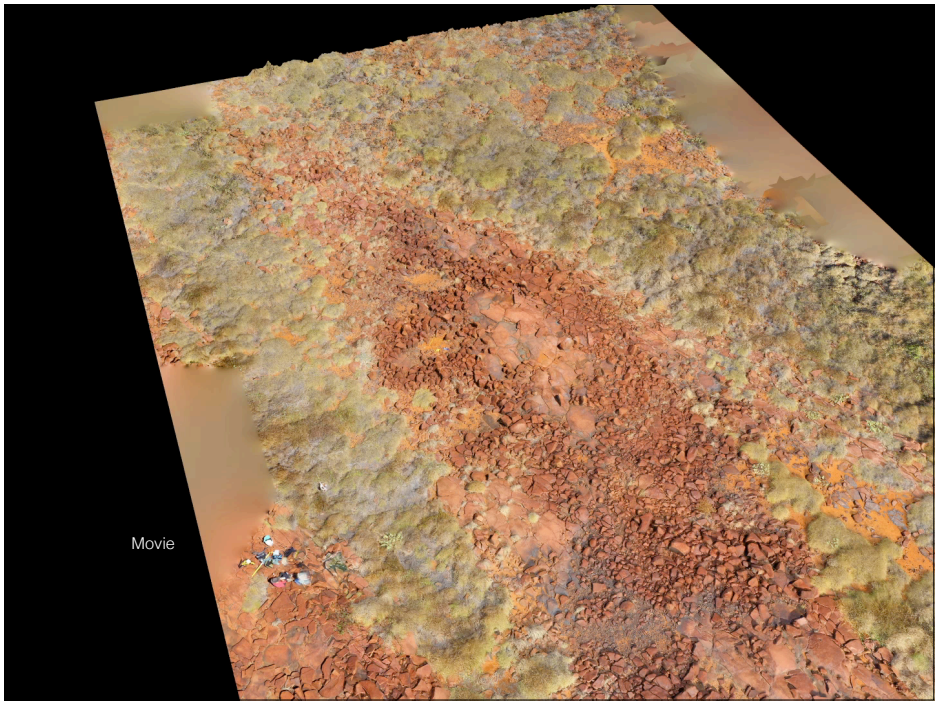
Lenticular glasses free (autostereoscopic) printing

Challenges

- Movement in the scene.

Movie

- Despite 20 years of the internet it is still problematic to (reliably) present 3D models online.
- No progressive mesh and texture options available.
  Need to be able to incrementally refine a mesh that is streamed.
- Don't have databases with smart support for 3D geometry. Should be able to interrogate a database of 3D structures for computable quantities other than those predefined or precomputed in the meta data.



Movie

Questions

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