Photogrammetry

https://paulbourke.net/flameu

https://www.agisoft.com/downloads/

Paul Bourke, January 2025

What is it?

How do you create a 3D model from a collection of photographs.

Chandigarh museum

Outline

- Applications, alternative technologies and brief history
- Software and workflow
- Worked example
- Photography: shooting guide
- Limitations, post production, advanced topics
- Questions/discussion

- Practical exercise

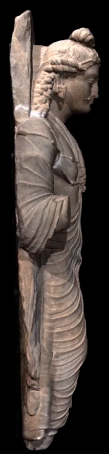
Applications

- Assets for 3D environments, eg: gaming, VR, AR.
- Cultural heritage (art, archaeology, and architecture).
- Surveying and mapping, earliest applications.
- Human face/body scanning, medicine and movie industry.
- Visual effects.
- Reverse engineering, reproducing mechanical parts.

Example

Perth, Western Australia

Example

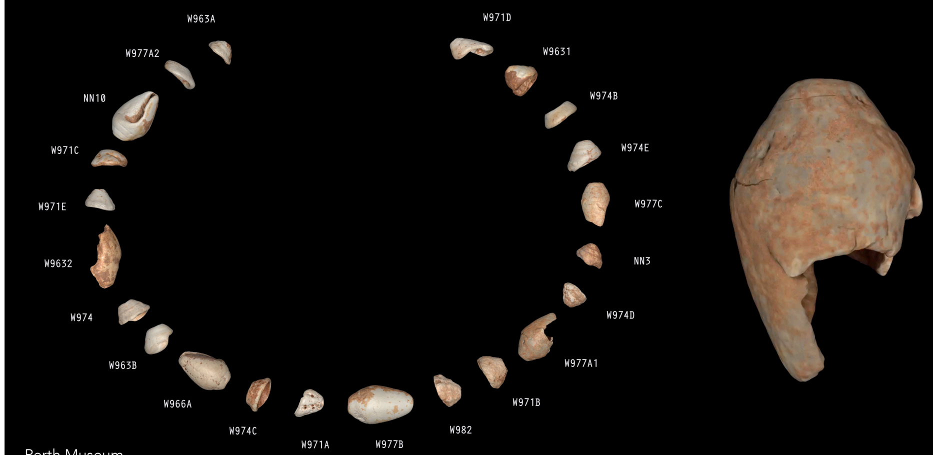


Chandigarh Museum

Example: drone

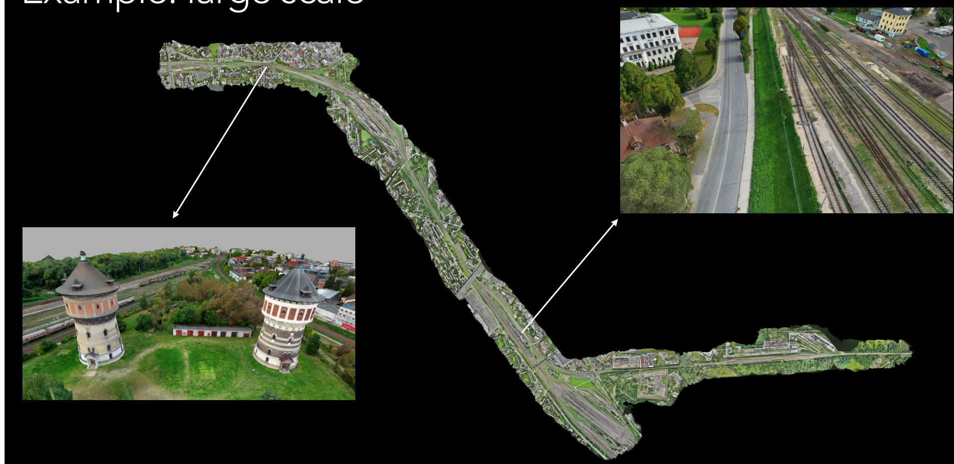
Castle

Example: small scale



Perth Museum

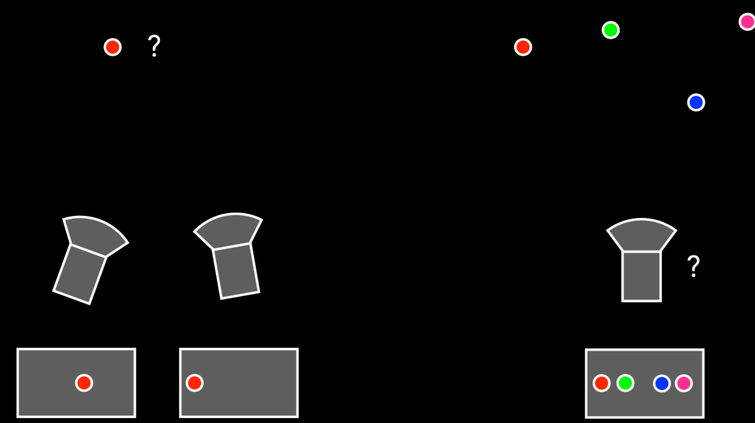
Example: large scale



Railway development, Lithuania

Brief history

- Photogrammetry is the general term given to deriving 3D geometric information from a series of images. Some people prefer P3DR "Photographic 3D Reconstruction"
- Initially largely used for aerial surveys, deriving landscape models. Originally only used a stereoscopic pair, that is, just two photographs to compute distances.
- 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".



Alternative 3D scanning technologies

- Structured light scanners.
- Return time of flight scanners.
- LIDAR scanners.
- Hand modelling.

The appropriate approach depends in the characteristics of the object and the intended use of the resulting 3D model.

Photogrammetry is also not necessarily the best approach for all model types.

Photogrammetry software

- Metashape (used in the example today). Agisoft. (Commercial)
- Realitycapture. EPIC games. (Free / Commercial)
- MeshRoom. Alicevision. (Open source)
- Zephyr. (Free for small models)
- Visual SFM, Colmap. (Tools)
- Regard3D (Free), Pix4d …
- …. a whole bunch of other more discipline specific softwares.

The principles presented here apply across all solutions.
Different packages support different degrees of automation, degree of adjustment and control of the process, maximum number of photographs …

Workflow

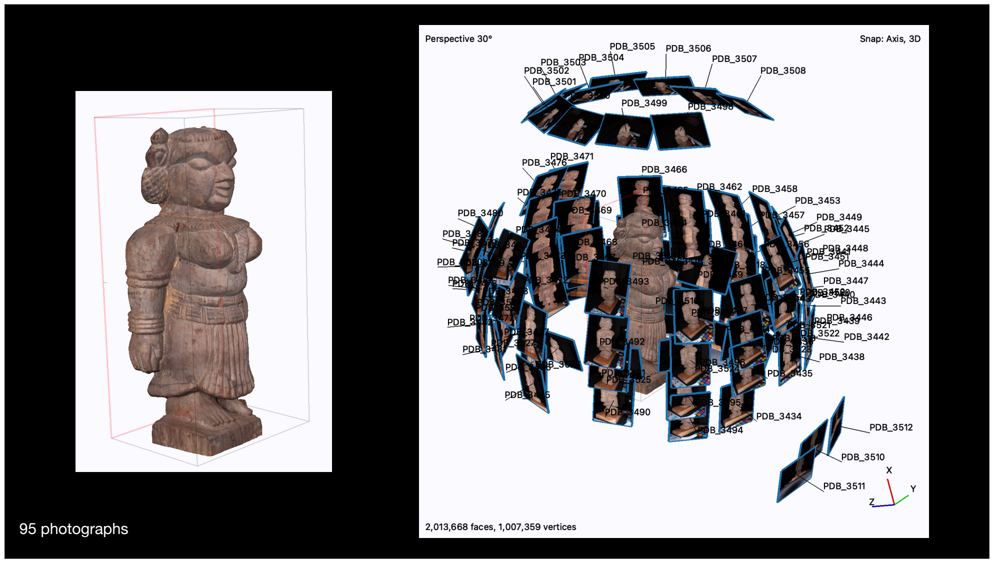
- Capture photographs. Camera + prime lens.
- Align points, and derive camera positions.
- Create mesh, derived from depth maps.
  Alternatively create dense point cloud.
- Cleanup
  1. remove “shrapnel”
  2. close holes, eg: base or after (1)
  3. apply scale (see later)
  4. perform other geometry edits
- Calculate textures, cameras act as data projectors.
- Apply colour corrections.
- Export in favourite 3D format for destination application.

Photography: Shooting guide

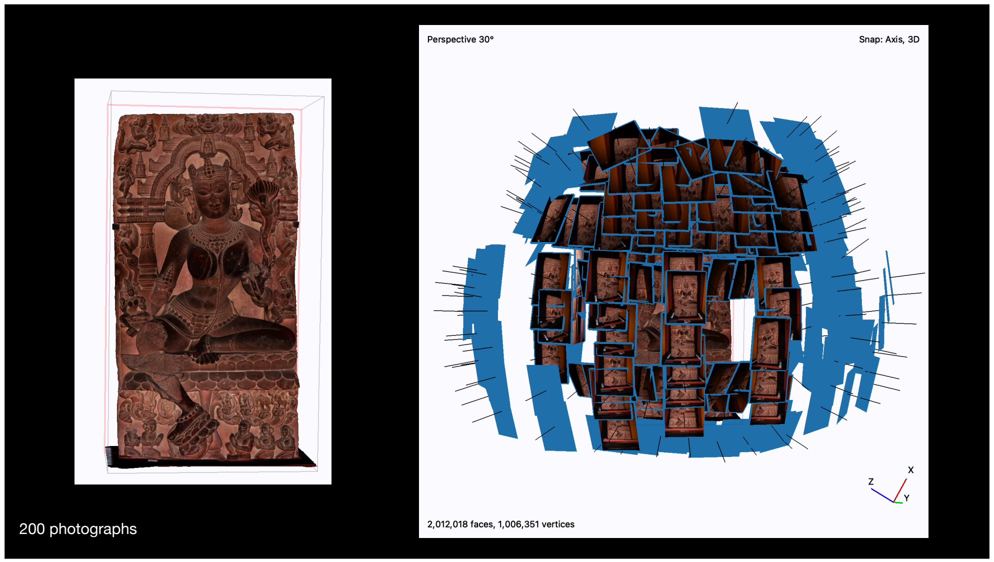
- One cannot expect parts that aren’t photographed to be reconstructed.
- Ideally use all manual settings for iso, exposure time, aperture and white point
- The number of photographs depends on the complexity of the object
  - 2.5D surfaces might only need 10-20
  - For contained 3D objects typically require 50-200
  - Extended landscapes may require 1000’s
- Each photograph should be taken from a different location.
  The opposite to panorama photography where camera should be at zero parallax point.
- Camera orientation doesn’t matter.
- Focus and depth of focus important. Details in the image will determine the number and quality of feature points.
- Best results with a single focal length, eg: Prime lens.

15 photographs

50 photographs



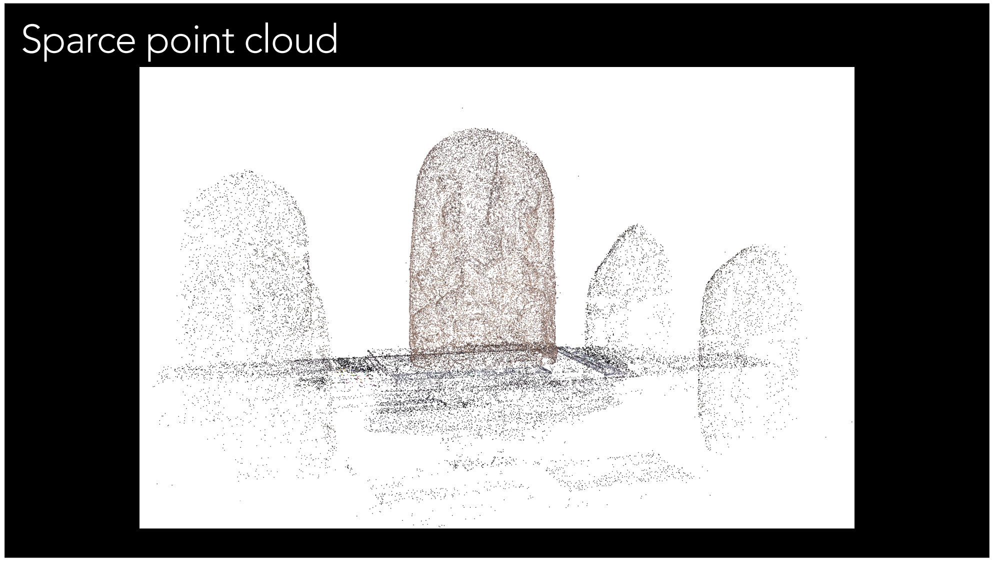
95 photographs

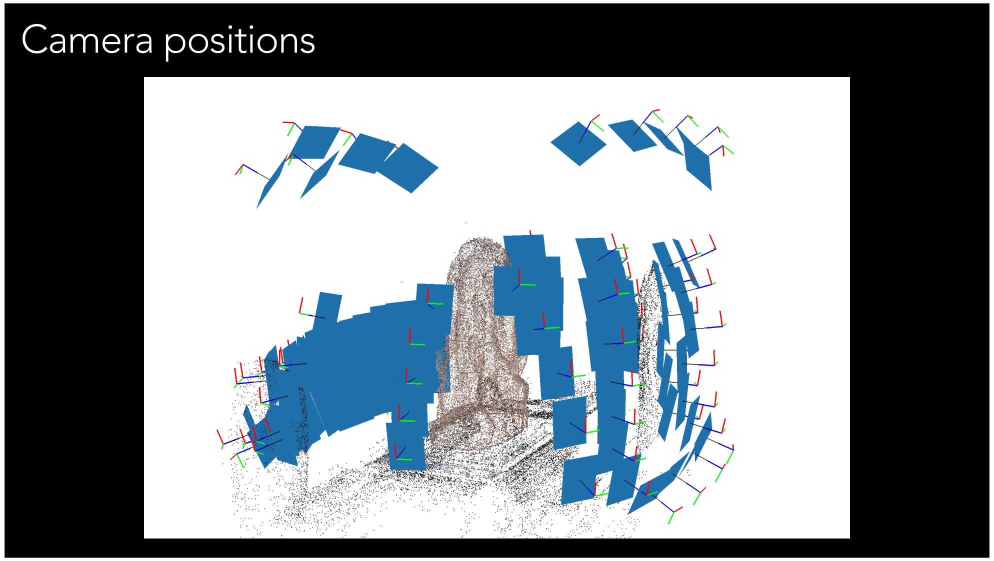


200 photographs


Worked example
Patna museum


Feature points, tiepoints


Sparce point cloud


Camera positions

Surface + texture

Quality

Camera positions

Live example

Post production

- Removing geometry not part of the desired model.
  eg: Removing base, other parts of the room.
- Closing holes.
  eg: After removing the base, or deleting protruding errors.
- Managing triangle count: Recommend MeshLab (free).
- Managing texture files: Any image processing software.
- Orientating the model.
- More advanced editing: Blender (free), zBrush (commercial).

Limitations

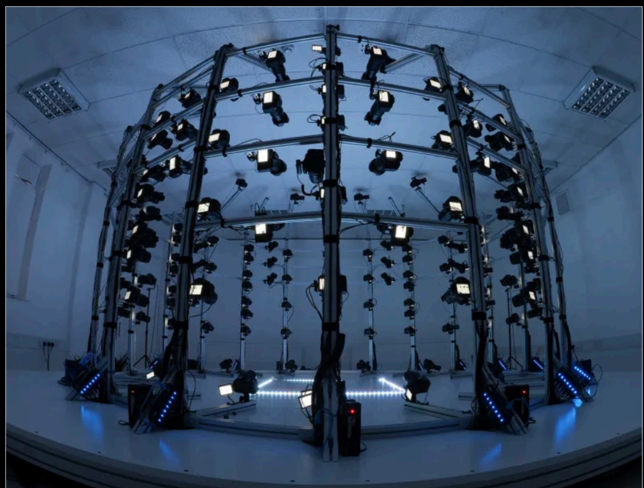
- Gaining access for camera shots.
  If it isn't photographed then it can't be reconstructed.
- Lighting. Baked in shadows and shading.
- Light types.
  Avoid different light sources = different white points.
- Mirror surfaces, a problem for almost all technologies.
- Glossy, specular surfaces.
- Moving objects or objects changing shape.
  Requires a camera rig with a large number of cameras.
- Very thin features.

Lighting

Lighting

Limitations: access

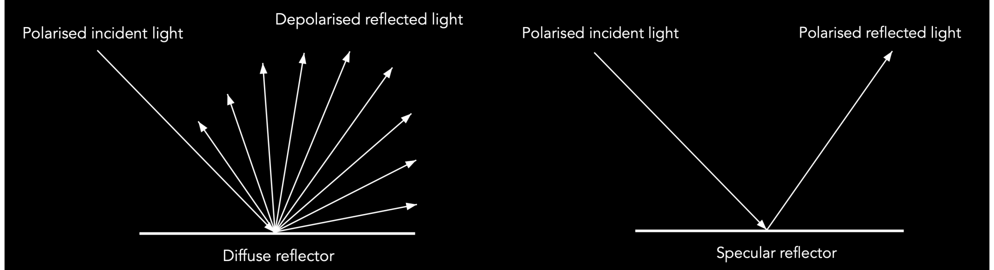
Limitations: moving objects



Limitations: specular highlights

- Specular reflections depend on the position of the camera with respect to light source. They are different for each camera position so the object is essentially changing between photographs.
- Specular reflections preserve polarised light.
  Diffuse surfaces depolarise polarised light.
  Cross polarisation involves polarising the source light and placing a polarising filter on the lens orientated at 90 degrees to the source polarisation.

Cross polarisation



Cross polarisation

Lighting: Ring light

Light types: white point

Sunlight Shade Fluorescent

Camera rig

Additional topics

- Desirable camera attributes.
  1. High resolution. Results in higher quality textures.
  2. Sharp infocus images.
     Result in more feature points, and higher quality textures.
  3. Fixed focal length (beware focus breathing).
     Required for better accuracy of the camera positions.
- Geometric resolution vs texture resolution.
- True scale and colour calibration.
- Accuracy.
- Automation.
  1. Turntables
  2. Robots

Geometric resolution vs texture resolution

- Geometric and texture resolution are two separate considerations.
- For example, for realtime graphics one might prefer simpler geometric resolution and higher texture resolution.
- For analysis one may prefer high geometric detail.
- For archiving purposes one generally wants to maximise both.

Good textures can often hide low geometric detail.
Always ask to see models without texture maps.

2 million triangles

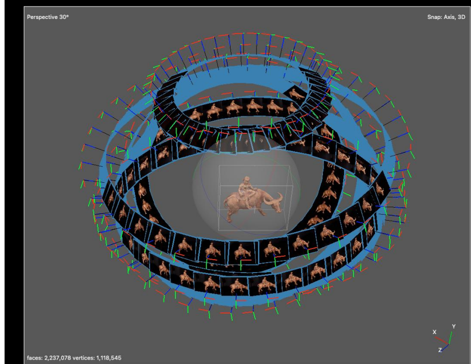
200,000 triangles

Accuracy

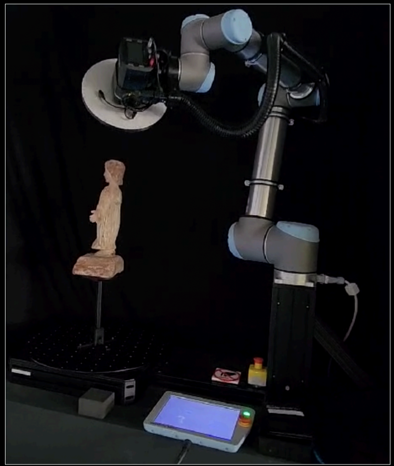
- It is a function of the numerical accuracy requested in the software (processing time), as well as camera resolution and lens quality. Also depends on the size of the model being captured.
- Resolving power: scale of smallest features that can be represented.
- Dimensions and differential dimensions.
- What does it mean to have some parts more accurate than others? How is that quantified. This is particularly misleading for some other scanning technologies that claim sub mm accuracy.
- I estimate for my standard gear the dimensions are accurate to +/- 2mm on a 1m object, resolving power of 1mm.

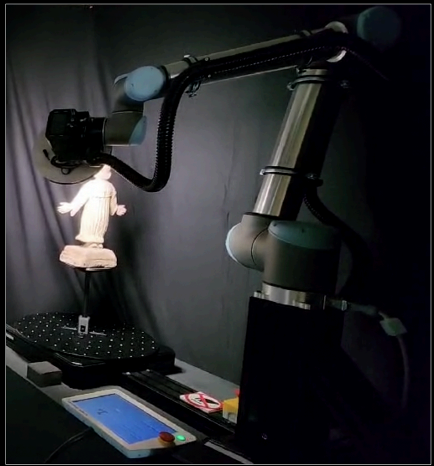
Scale and colour correction

Automation: turntable



Automation: robots





Questions and workshop