

# Photogrammetry of Bhuta models

<https://paulbourke.net/bhutaphotogrammetry>

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## Photogrammetry, what is it? Why?

- Create a 3D model from a collection of photographs.



## Outline

- Photogrammetry software
- Photography best practice
- Lighting
- Specularity
- Camera rig
- Photogrammetry pipeline
- Export format and specifics of the models
- Geometric vs texture resolution

Not discussed: Other 3D capture methods: Gaussian splats, Lidar, structured light, return of flight ...

## Photogrammetry software

- Metashape (used for the Bhuta models). Agisoft. (Commercial)
- Realitycapture. EPIC games. (Free / Commercial)
- MeshRoom. Alicevision. (Open source)
- Zephyr. (Free for small models). Regard3D (Free), Pix4d ...
- Visual SFM, Colmap. (Tools)
- .... 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 ...
- Gaussian Splats are a different technology, happy to discuss separately.

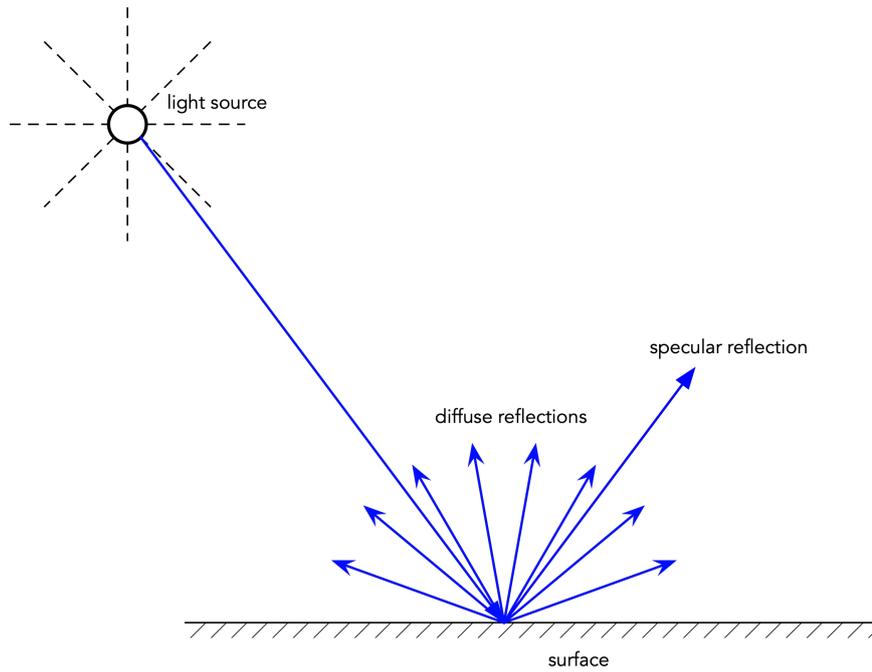
## Photography

- 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 and eventual texture.
- Best results with a single focal length, eg: Prime lens.

## Lighting

- If one uses environmental lighting then shadows will be baked into the model
  - Cannot (easily) relight the model later.
  - Colours can no longer be correct due to shading.
- To remove environmental lighting use a (bright) light adjacent to the camera lens, eg: ring light
- What is the correct colour of a surface?  
The perceived colour (reflected spectrum) depends on the light source spectrum.
- For colour control use a light with a known temperature, high CRI (colour rendering index) value.  
Typically use sunlight, temperature of 5600 Kelvin.
- Specular highlights shift with the relative light and camera position  
Remove with a cross polarisation arrangement.

## Diffuse vs specular reflections

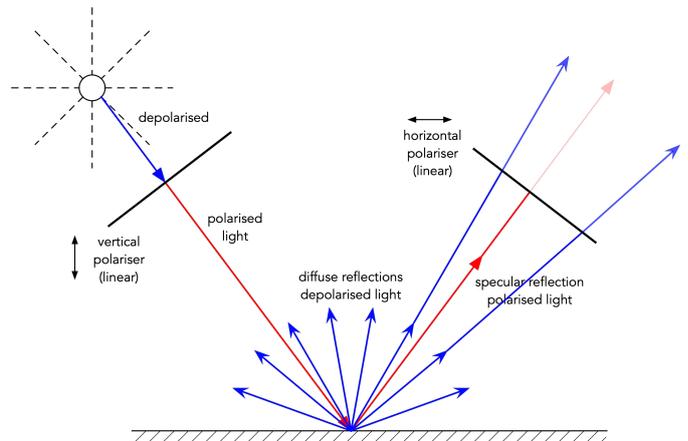
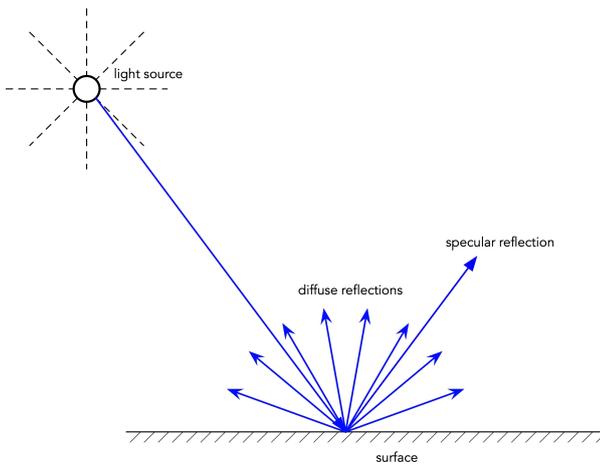


## Baked in shadows and shading

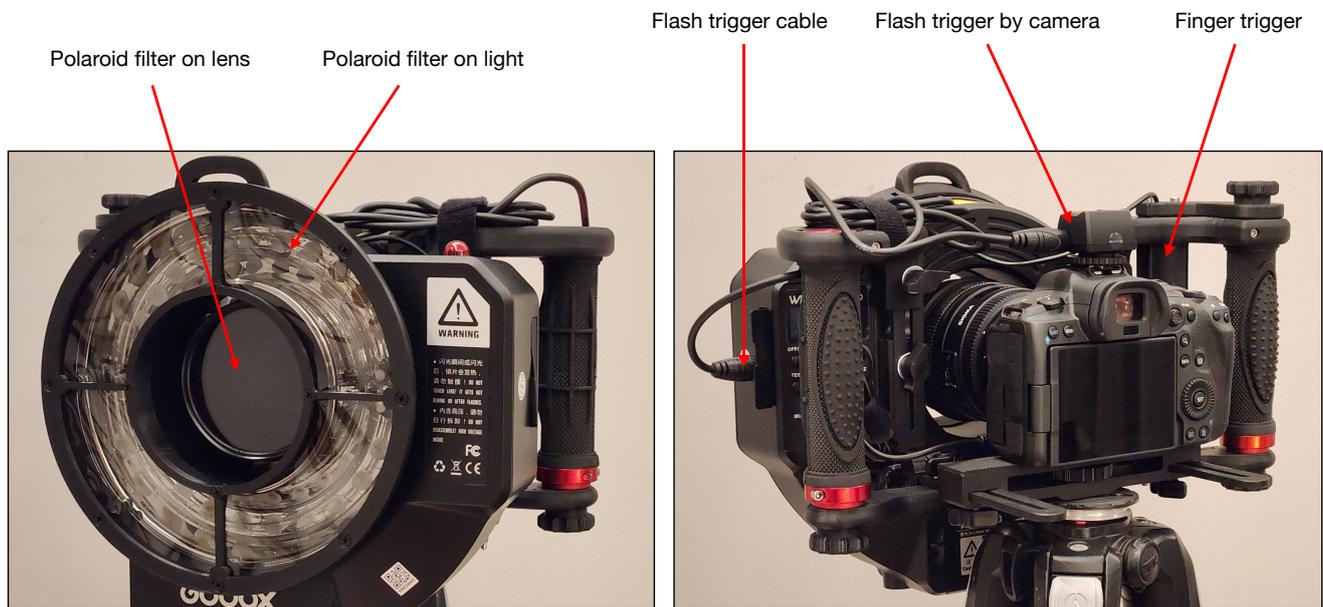




## Cross polarisation to remove specular highlights



## Camera rig



## Pipeline

- Take photographs, each from a unique position, every point on the model should be in at least 4 photographs. Apply colour correction.
- Find feature points between the image, estimate camera position+pose and point cloud using Bundler algorithm.
- Create 3D mesh after calculating depth maps.
- Map photographs from camera position/pose onto mesh forming a texture map.
- Edit and otherwise clean up the mesh
  1. remove "shrapnel"
  2. close holes, eg: base or after (1)
  3. apply scale
  4. perform any other geometric edits
  5. apply edits to texture maps
- Export as favourite 3D mesh format.

## Photography

- Example using model 636b0b67



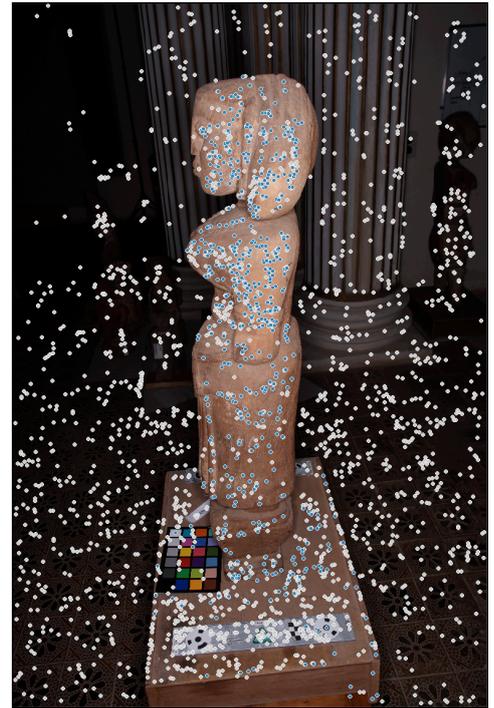
## Photographs

- Include scale rule and colour swatch
- In this case 140 photographs
- Capture RAW files and later convert to 16 bit tiff after performing colour corrections.

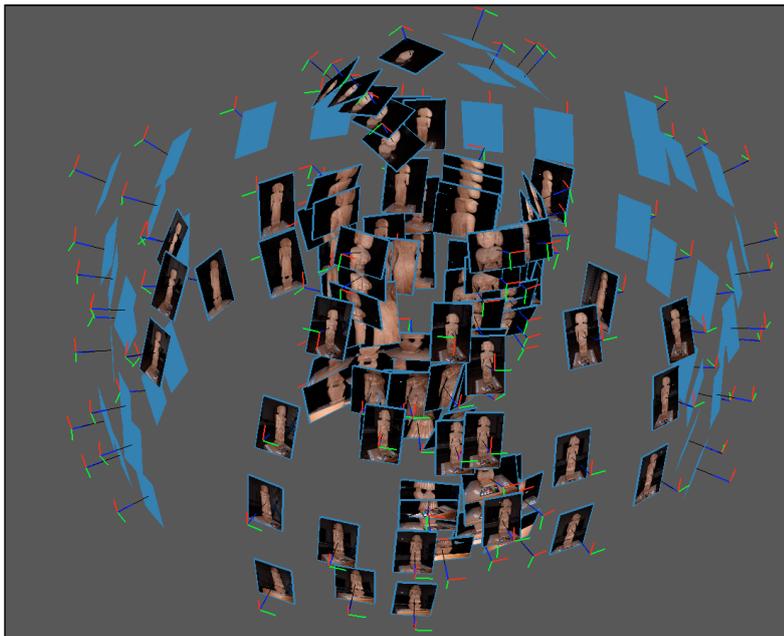


## Derive feature points

- Feature points are points in the photographs determined to be the same between photographs.
- This is a core machine vision algorithm.
- Tie points (in blue) are feature points determined to be common to 3 or more photographs.



## Compute camera positions and pose

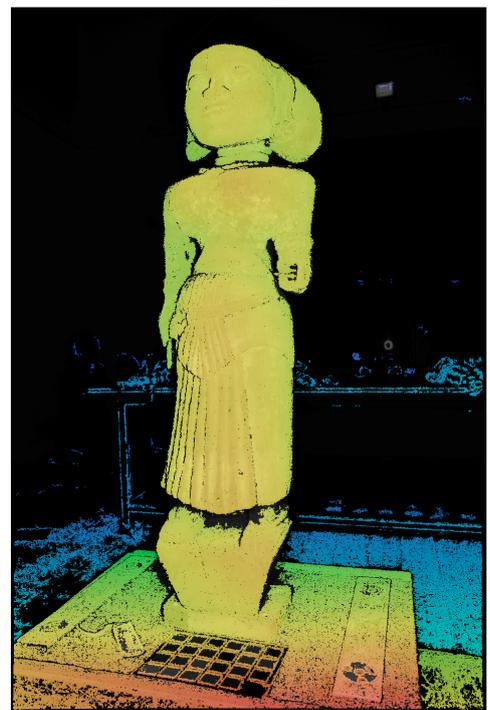


## Compute point cloud



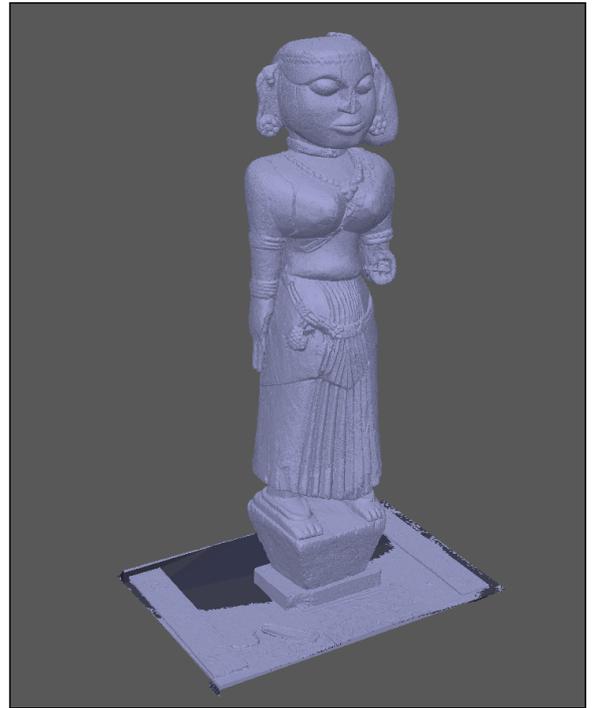
## Depth maps

- Given tie points and camera locations one can triangulate to estimate depth for each point.
- There is a depth map created for every photograph.



## Form 3D mesh

- Combine all the depth maps



## Apply scale



## Clean up

- Metashape has some mesh cleaning/edits tools
  - shrapnel selection and removal
  - hole filling
  - smoothing noise
  - decimating mesh
- Almost any 3D modelling package can be used, common choices include:
  - Blender, good for remeshing to a regular mesh
  - Zbrush, good for smoothing
  - Meshlab,



## Apply texture maps



## Edit textures

- Remove old numberings written directly on the statue.
- Remove other tags, cobwebs, dust/dirt ...

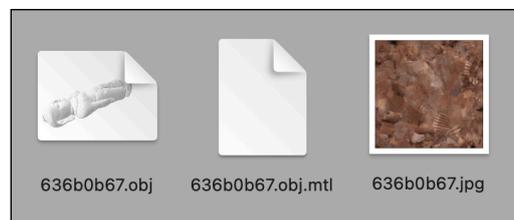


## Consequence of lighting



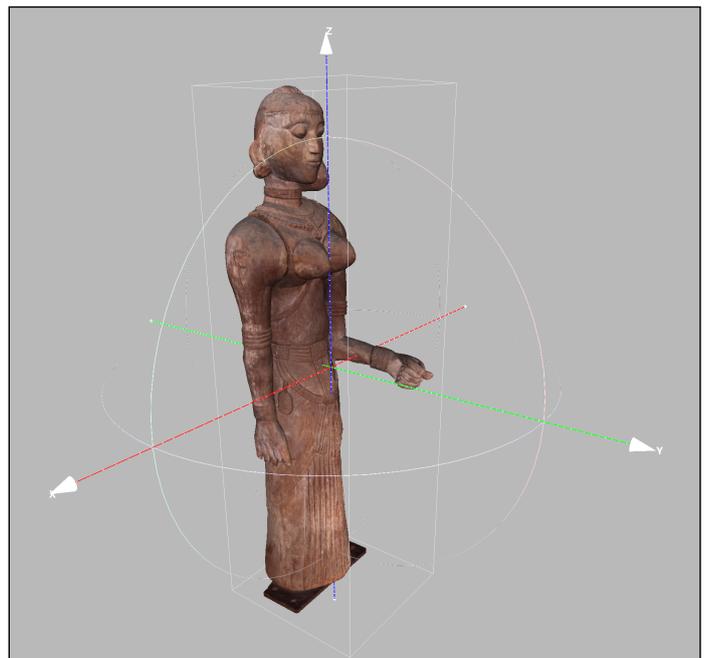
## Export 3D model

- Will use OBJ format here, simple and software agnostic.
- An old format but widely supported.  
The base format for import into other software and more sophisticated formats.
- Typically comprises of 3 files
  - .obj file, this contains the geometry as vertices, normals, texture coordinates, faces
  - .mtl file, material file creating the mapping between texture in the .objfile and texture images
  - One or more texture images
- The Bhuta models here are exported as meshes with between 2 or 4 million faces (depends on the model complexity) and a single 16K texture image.



## Alignment

- Models from photogrammetry are typically arbitrary rotated.
- Alignment of Bhuta models includes
  - Center at the origin
  - Rotated such that "z" axis is up
  - Rotated such that "y" axis is forward
- Performed in MeshLab



## Geometric resolution vs texture resolution

- Geometric and texture resolution are two separate considerations.
- For example, for realtime graphics one might prefer (or require) low geometric resolution and higher texture resolution.
- For analysis one may prefer high geometric detail.
- For archiving purposes one generally wants to maximise both.
  
- Resize textures in a paint program, eg: PhotoShop (Image size)  
Resample mesh in a 3D program, eg: MeshLab (Quadratic edge collapse, with texture)

Good textures can often hide low geometric detail.

Always evaluate the quality of photogrammetric models by viewing without texture maps.



