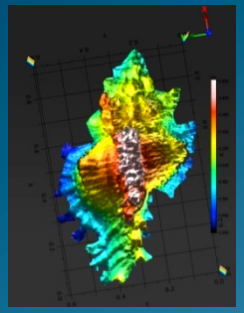
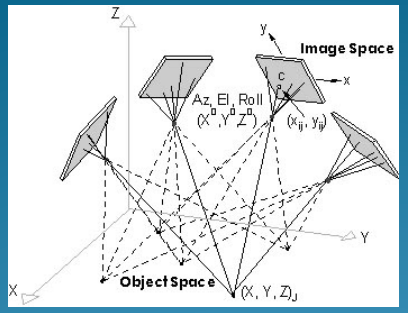
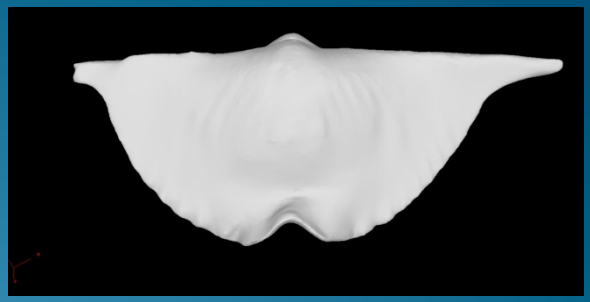
3D Imaging of Fossils Using Close-Range Photogrammetry

Daniel J. Miller

The University of Michigan Museum of Paleontology







iDigBio Workshop – Specimen Imaging for Paleontology

Austin Texas, April 29, 2014

3D Reconstructions – Potential Applications

- Virtual Collections –especially useful for Type and rare/fragile material
- Teaching & Research
- Public Education & Outreach
- Supplemental material to published works
- Etc.!

Criteria for choosing an appropriate digitization system

1 Cost
2 Material of digitization subject
3 Size of digitization subject
4 Portability of equipment
5 Accuracy of the system
6 Texture acquisition
7 Productivity of the technique
8 Skill requirements
9 Compliance of produced data with standards

From Pavlidis et al 2007

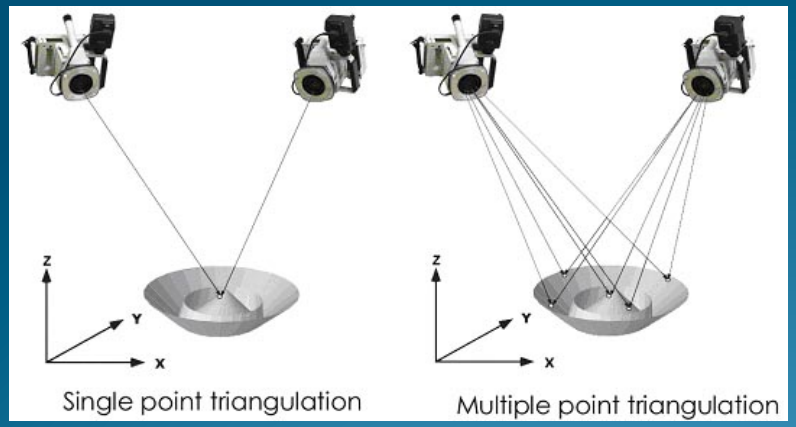
Acquiring 3D data - Methods

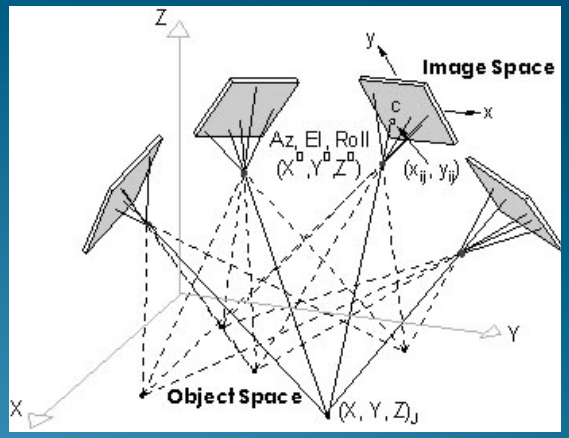
- Laser Scanning
- Structured light
- 3D stylus digitizers
- → Photogrammetry & Dense Stereo Matching
- Visual Hulls
- CT scans

Photogrammetry

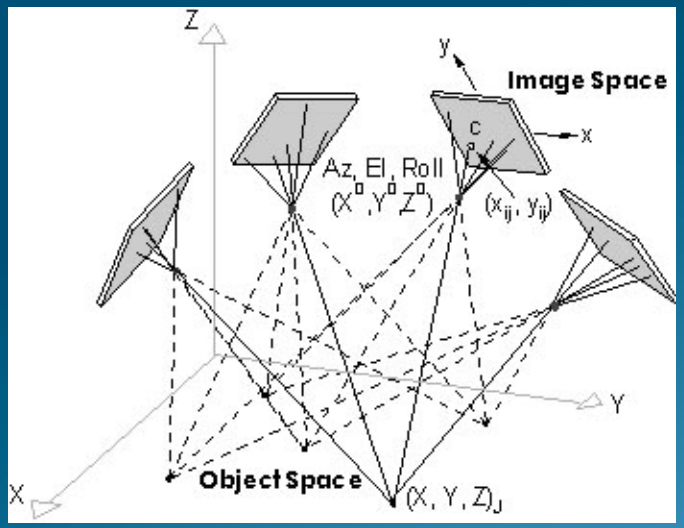
- Photogrammetry involves extracting reliable quantitative information about objects or the environment through the analysis of photographs or related sensors.
- Almost as old as photography itself.
- Based on triangulation.
- Can be used over a range of object dimensions (mountains to microfossils)

Photogrammetry

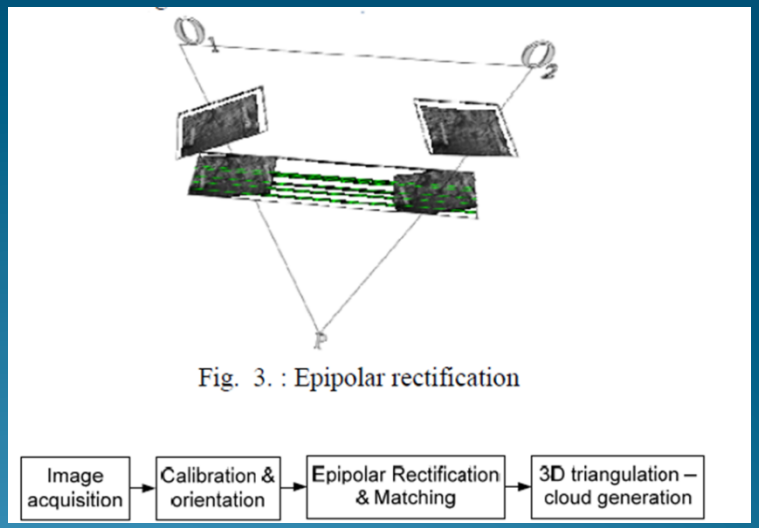




Photogrammetry



Bundle Adjustment



Dense Stereo Matching

(Hullo et al. 2007)

Photogrammetry

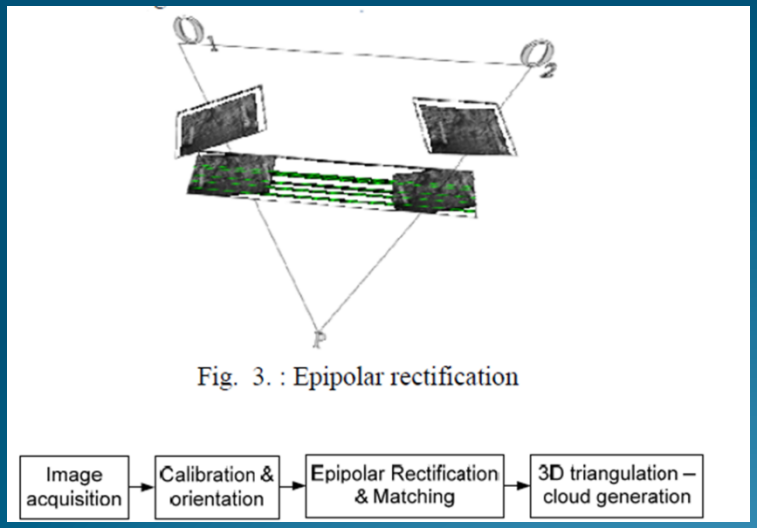


Fig. 3. : Epipolar rectification

Pixel matching & DSM

$$C((i_1,j_1),(i_2,j_2)) = \frac{\overrightarrow{V_1}(i_1,j_1).\overrightarrow{V_2}(i_2,j_2) - \mu_1.\mu_2}{\sigma_1.\sigma_2} \quad (1)$$

where $C((i_1,j_1),(i_2,j_2))$ = correlation score
$V_n(i_n,j_n)$ = neighbourhood intensity value vector
μ_n = average of V_n
σ_n = standard deviation of V_n

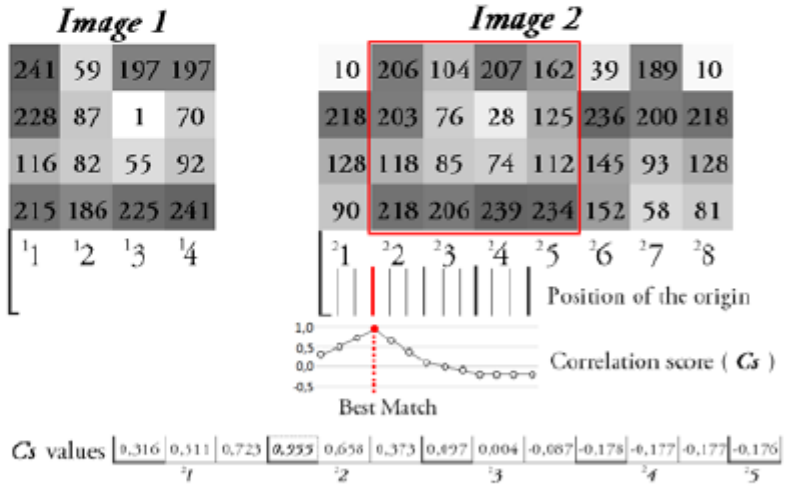


Fig. 1. Subpixellar ($^1/_3$ pixel interval) matching computation

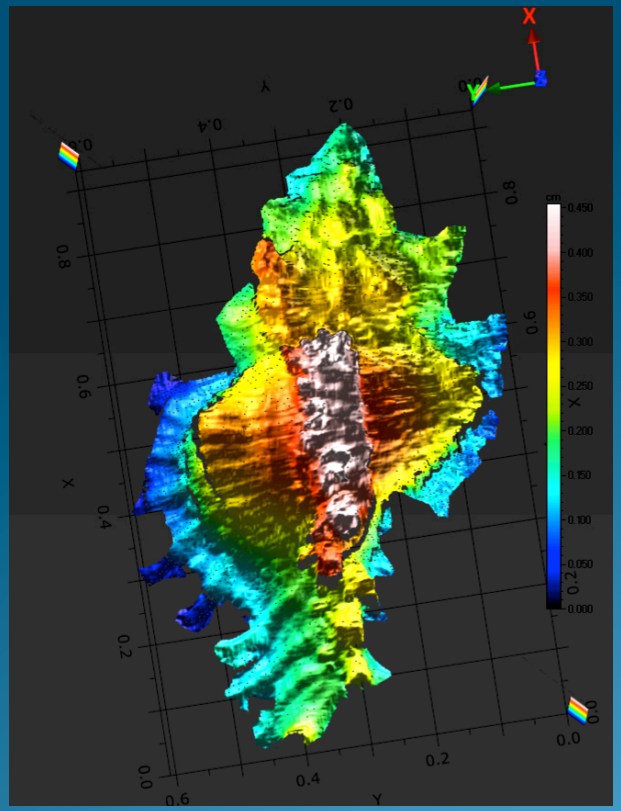
From Hullo et al. 2007

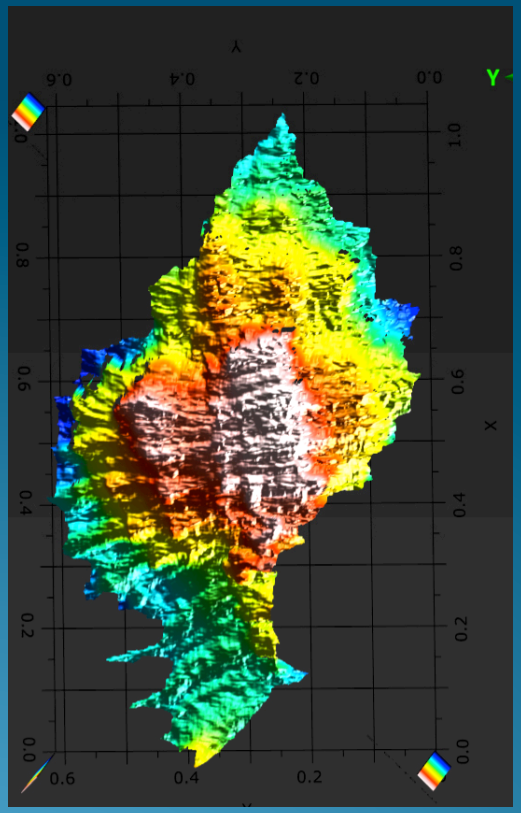
Some Factors to Consider When Starting a Project

(not an exhaustive list…..)

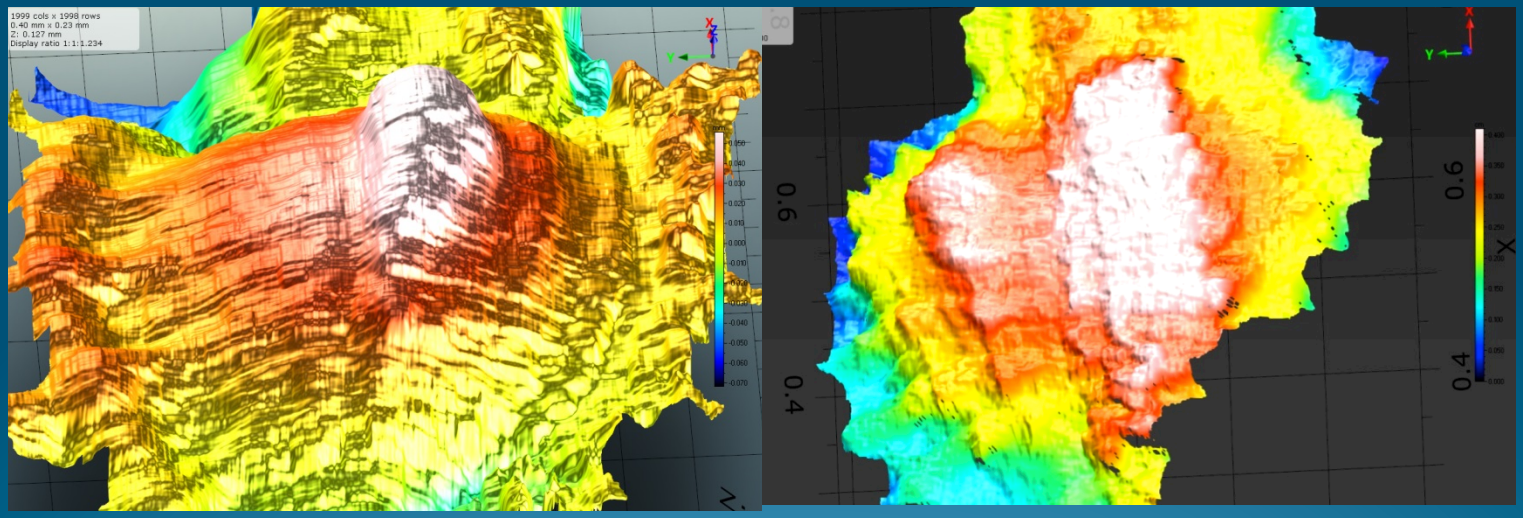
- Camera equipment & settings
  - good optics, high resolution sensor, solid construction
  - settings: good manual control, low ISO (less noise),stable white balance; high f-stop (for DOF but not too high or diffraction will degrade image); remote shutter release or timer; record all data.
- Lighting
  - even lighting, avoid strong shadows or highlights, caution when using flash (use diffusers),
- Staging
  - Turntable (“lazy Susan”,) or slide table useful. Solid tripod and focusing rail; good overlap and mix of camera angles.
- Properties of the object
  - Good color texture, good topographic detail helpful. Shiny, crystalline, or other reflective surfaces can cause problems.

PhotoModeler Scanner





(Miller & Pappas 2010, in prep.)



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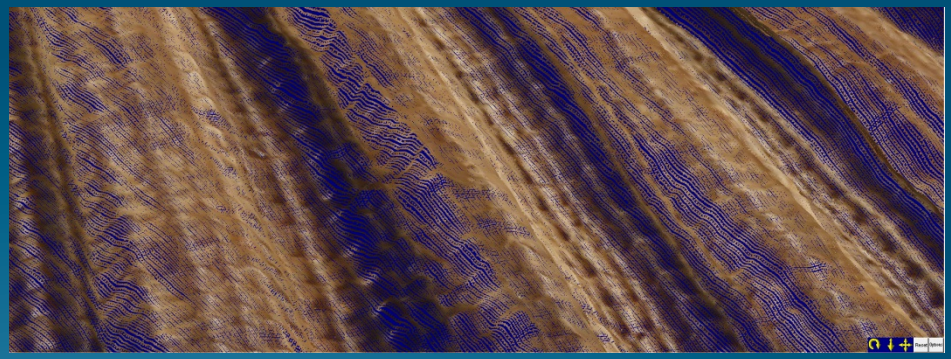
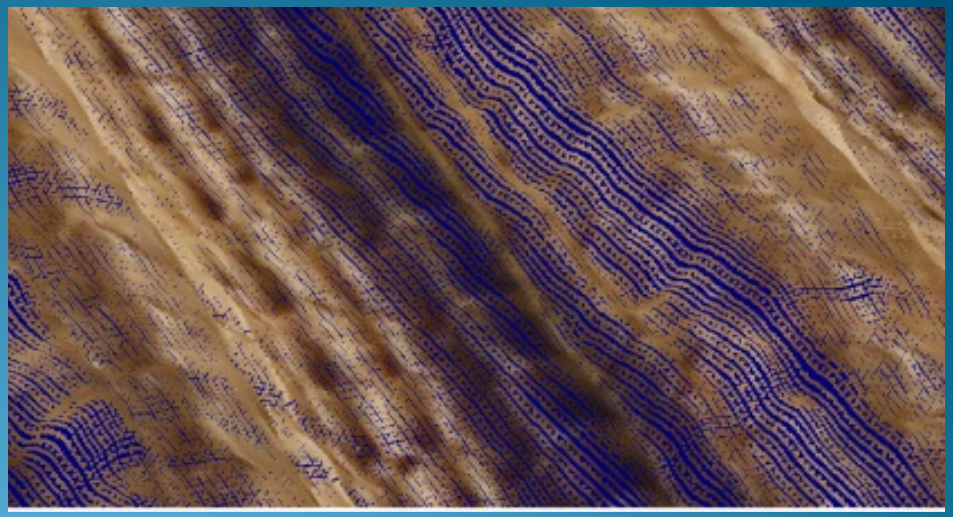
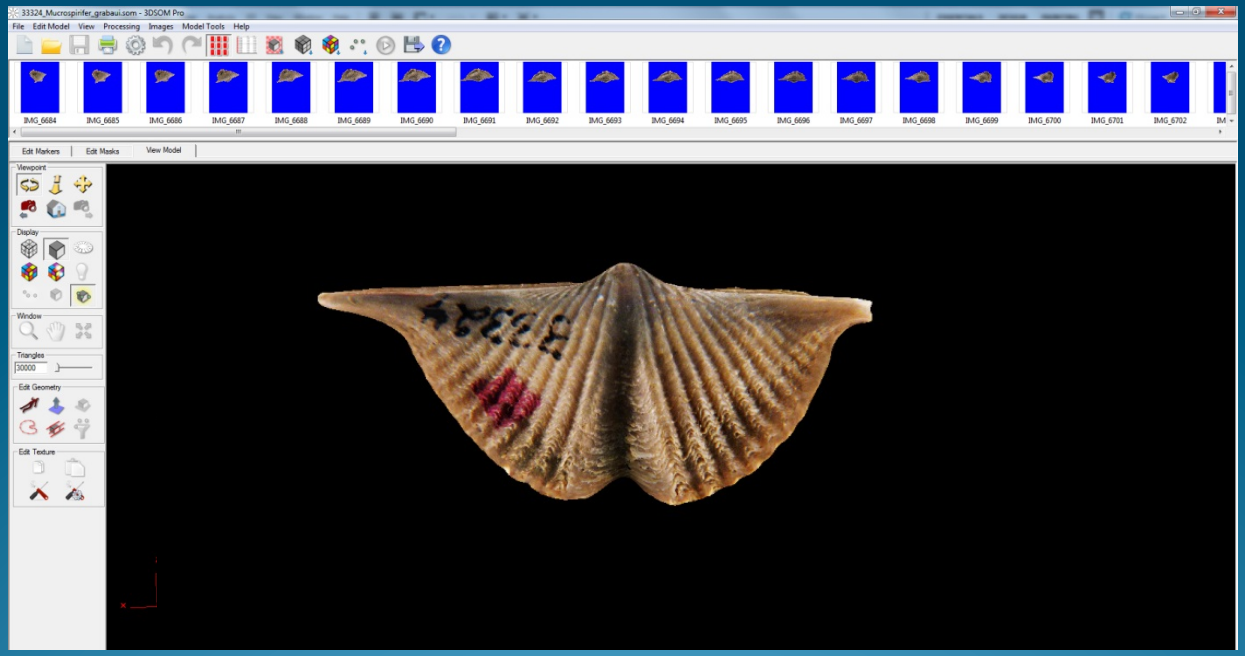


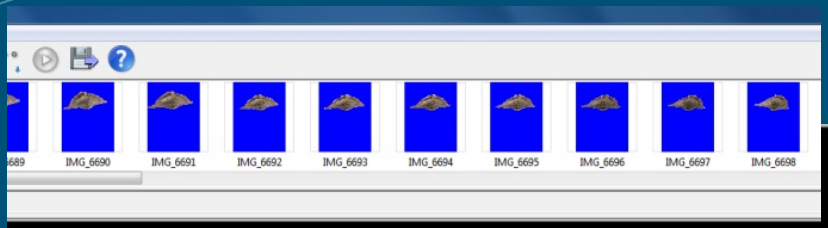


Highly textured surface with many small color variations facilitates image matching.

3D SOM



Can combine visual hulls with basic photogrammetry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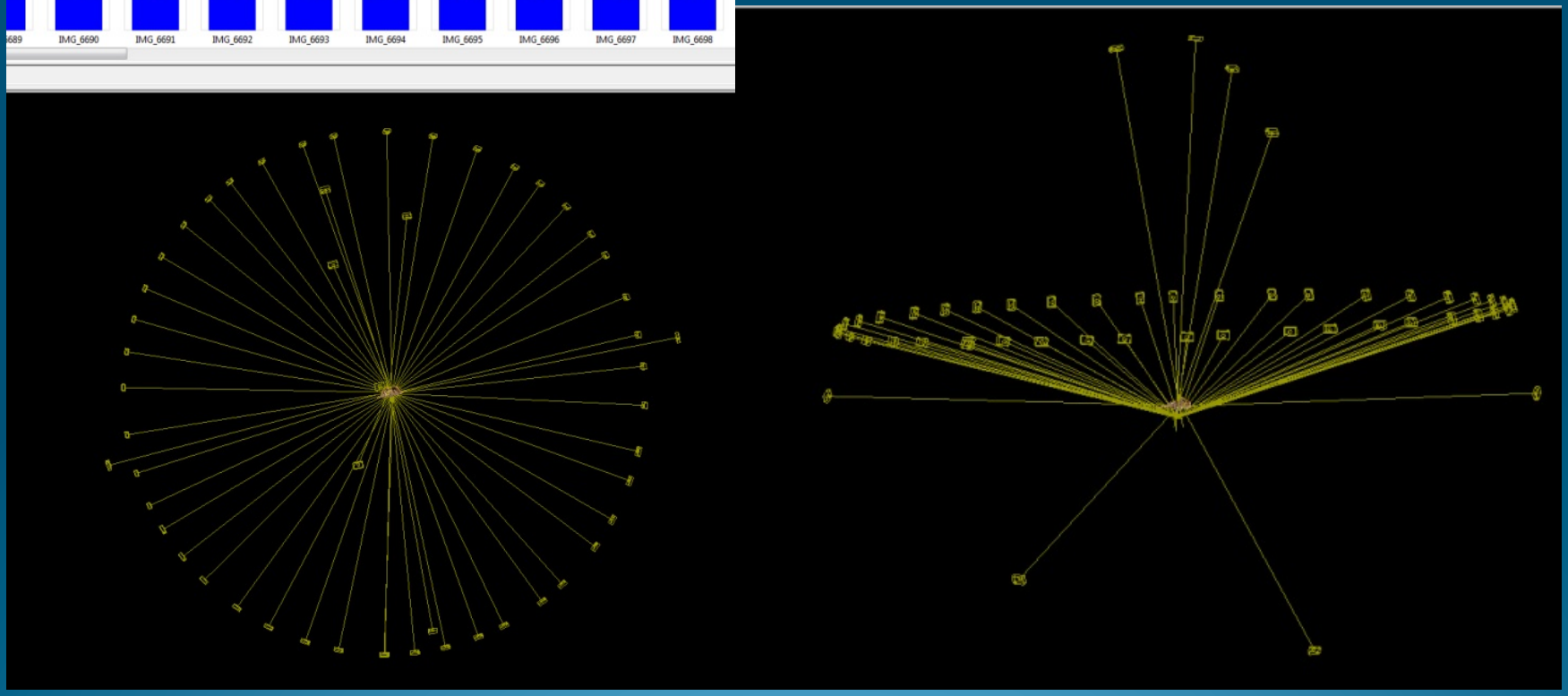

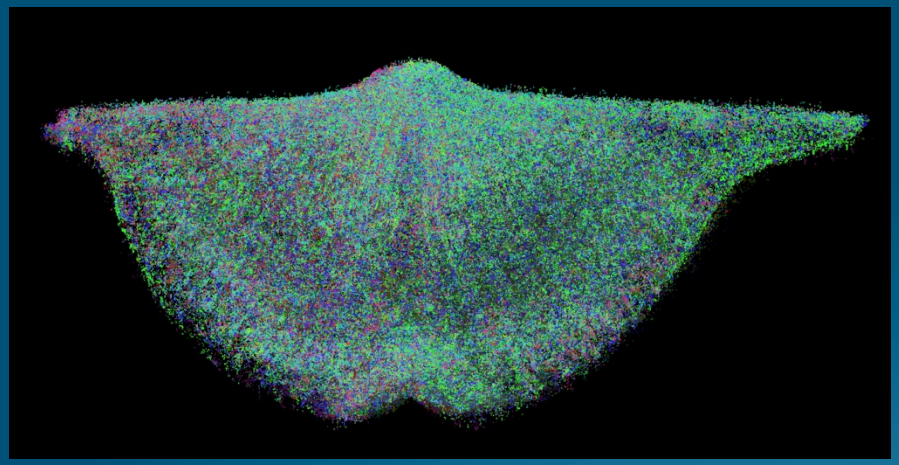

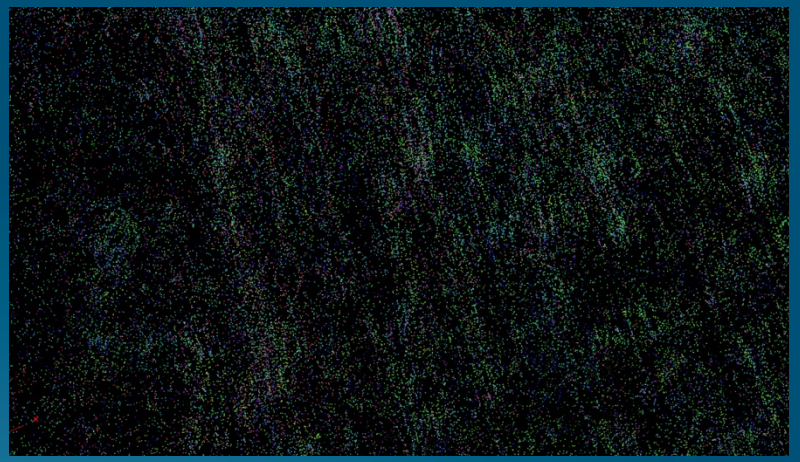

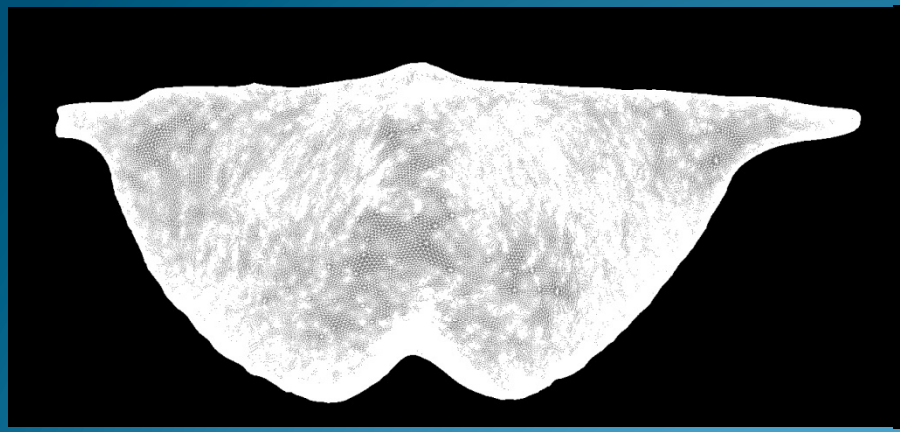

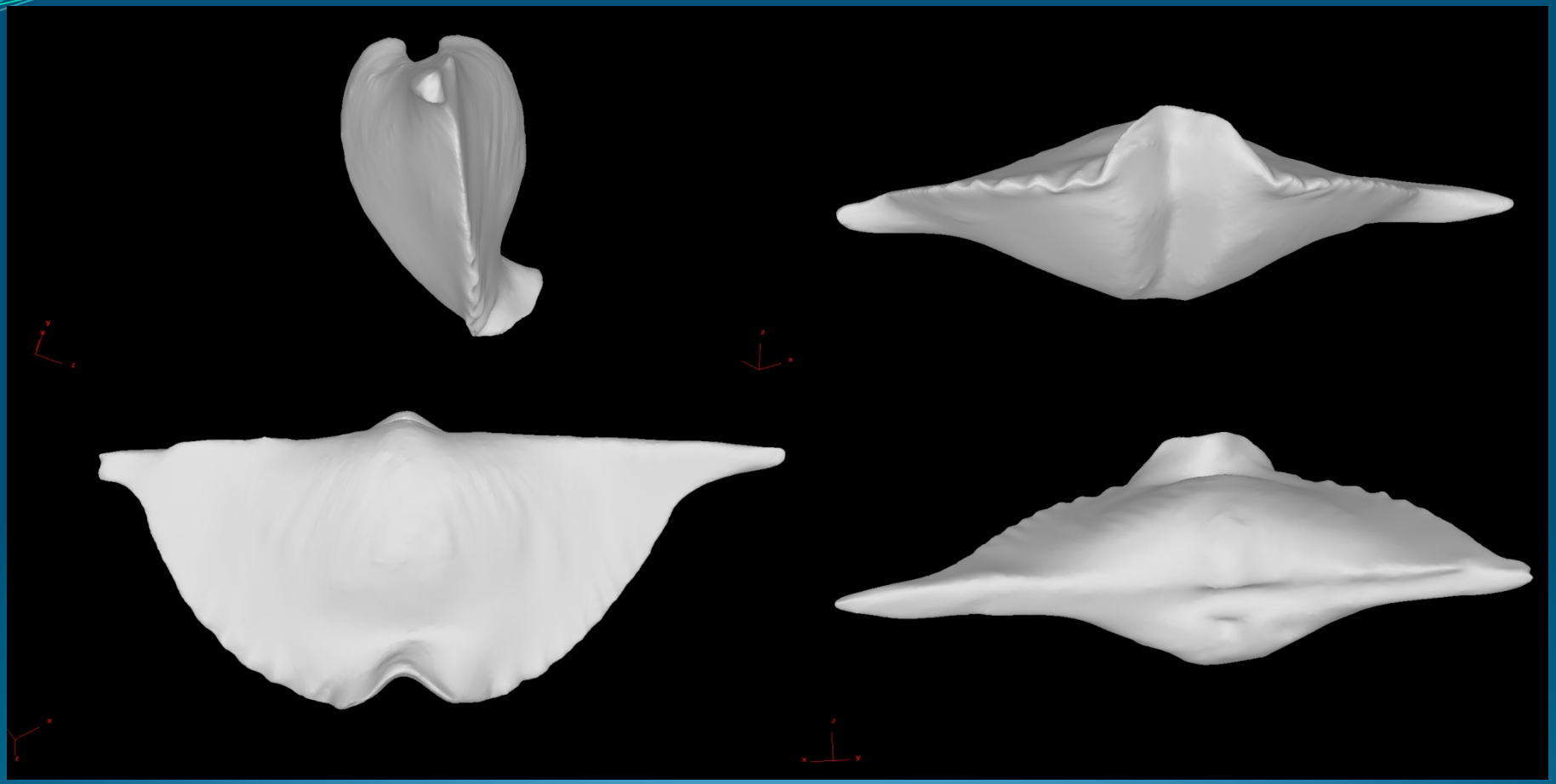

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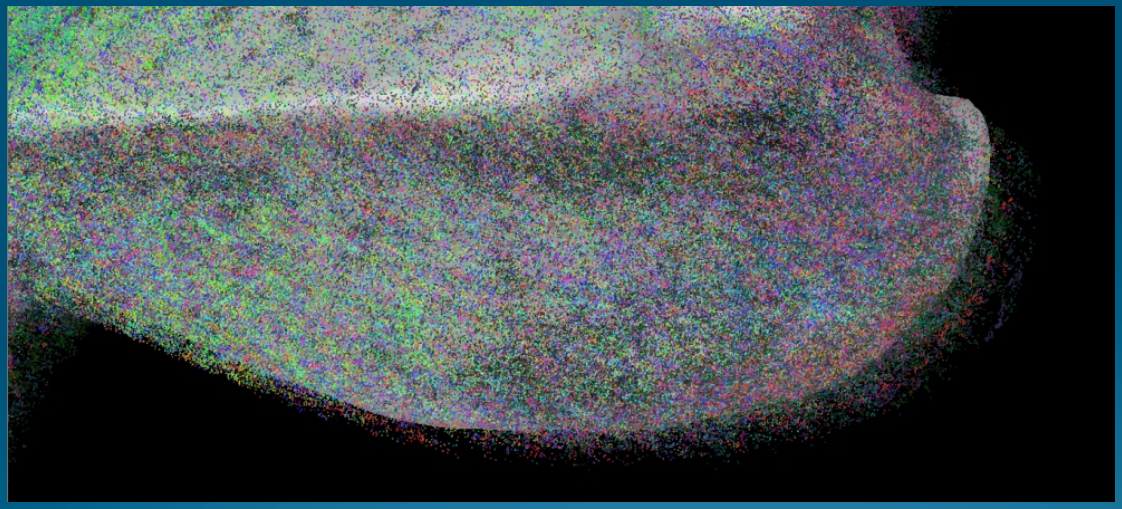
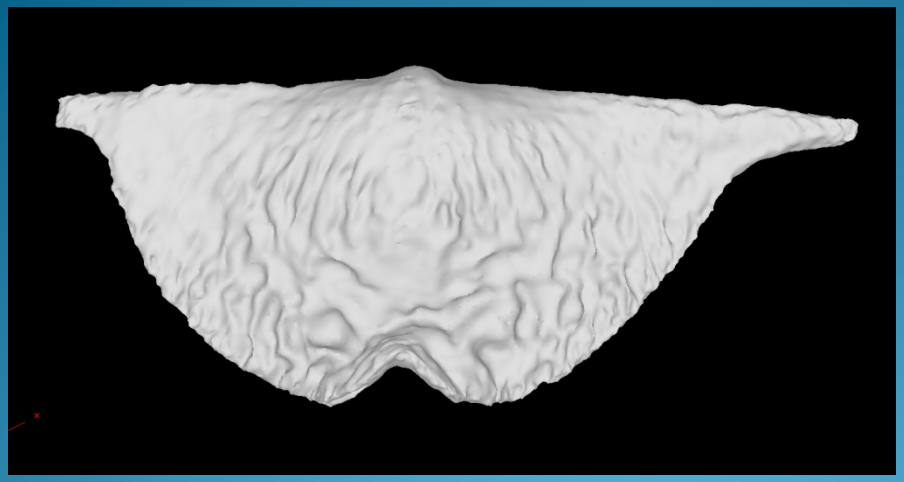
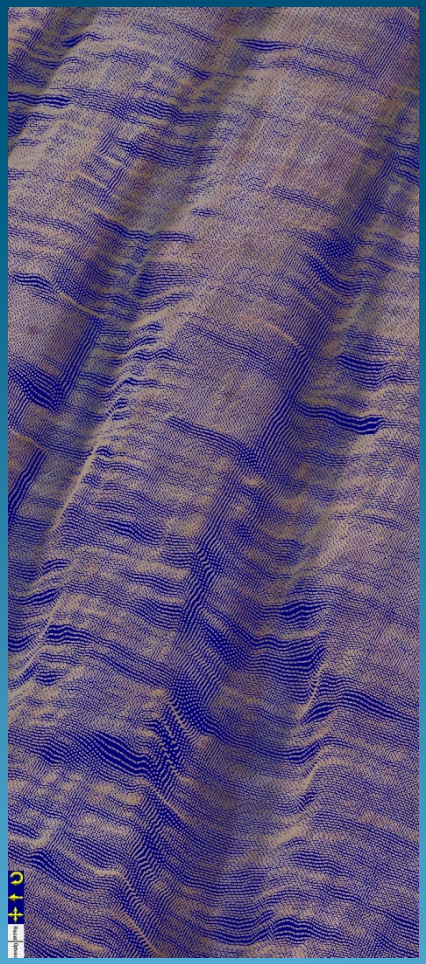
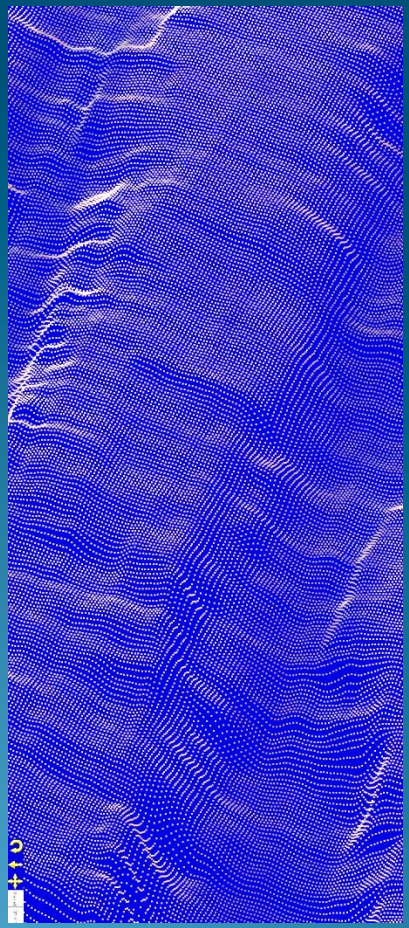
Inaccurate Solutions

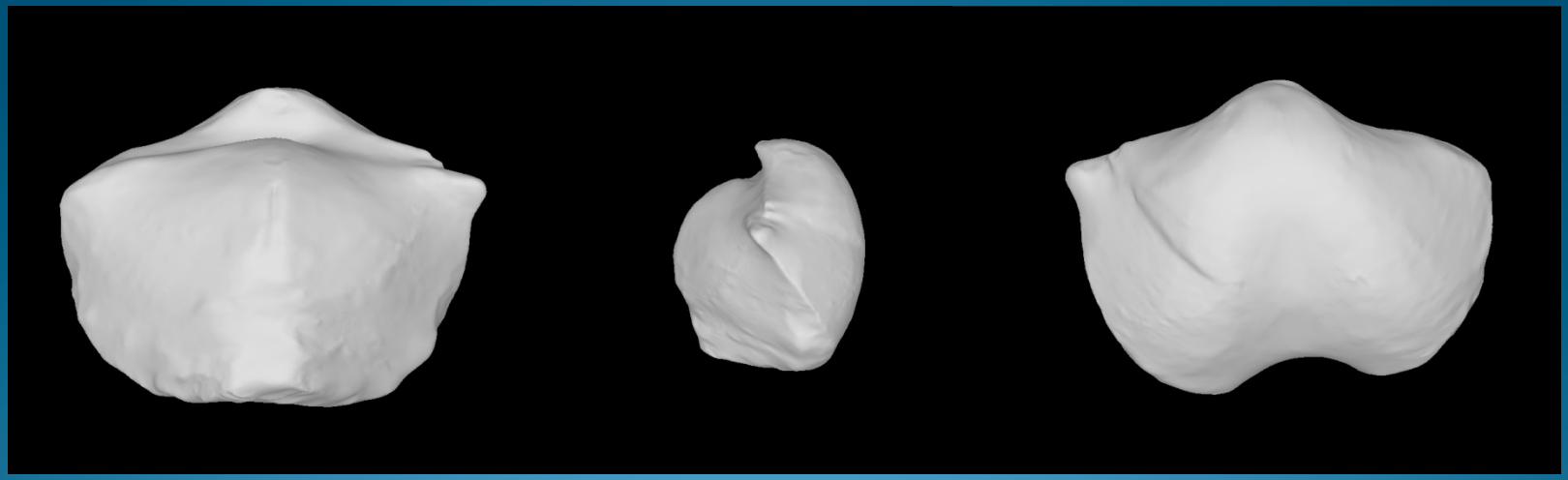




Errors in Matching Due to Lack of Texture and Color Variation







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Summary

- Close-range digital photogrammetry is an attractive option when 3D models and/or 3D coordinate measurements are required.
- Can be very accurate and can yield dense point clouds.
- Portable, flexible (same equipment can be used for a broad range of projects).
- Hardware is relatively inexpensive (camera equipment) compared to some other methods.
- High-end as well as low-end (cost, performance, difficulty) options are available (Bundler, Python Photogrammetry,123D Catch, etc.).

Summary

- High-quality results require a good understanding of photographic techniques as well as photogrammetric theory, but very useful results are obtainable with little knowledge.

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- Image matching algorithms can produce large errors under certain conditions.

- Development of new methods has been rapid and is likely to continue as CPU and GPU capabilities grow.

Acknowledgements

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