Image compression degrades precision and accuracy in SfM surveys

James O'Connor[1] (James.OConnor@kingston.ac.uk), Mike Smith[2], Mike R. James[2]
[1]School of the Natural and Built Environment, Kingston University, UK
[2]School of Geography, Earth and Environmental Sciences, Plymouth University, Plymouth, UK,
[3]Lancaster Environment Centre, Lancaster University

1. Introduction

Motivation: Image quality is highly variable between structure-from-motion studies. This research aims to isolate the impact of image compression on 3D products by systematically applying JPEG compression at various levels.

Research question: How large an impact does image quality have on the accuracy and precision of photogrammetrically derived 3D point clouds?

2. Methods

A. Experimental setup (Figure 1):

i. Take a **high quality** image set (O'Connor et al. 2017) and compare the 3D photogrammetric point cloud from an SfM workflow against a reference point cloud from a terrestrial laser scanner (TLS).

ii. Use a total station (TS) survey to co-register the photogrammetric and TLS clouds onto the same coordinate system independently of one another.

iii. Dataset is a 40 image block of a vertical rock coastal cliff near Hunstanton, Norfolk, UK (Figure 2).

iv. Images taken at 8 points along a transect running parallel to the cliff face at angles ± 30° from cliff normal in 15° increments (Figure 3).

v. Images acquired using a Nikon D700, aperture of f/8, ISO 200 with shutter speed set automatically.

B. Input JPEG image subsets of varying quality were created by compressing them. These are designated 'medium' compression (equivalent to 'quality' 75), 'low' compression (equivalent to 'quality' 92) and no compression.

C. Accuracy Assessment is performed against a high accuracy laser scan (Leica P40) with surveying acquired simultaneously with the photogrammetric survey.

D. Precision Assessment performed using precision maps derived from 100 bundle adjustments of the sparse point clouds (James et al. 2017). It should be noted this is a relatively small number of iterations, as opposed to the 4,000 recommended in James et. al.

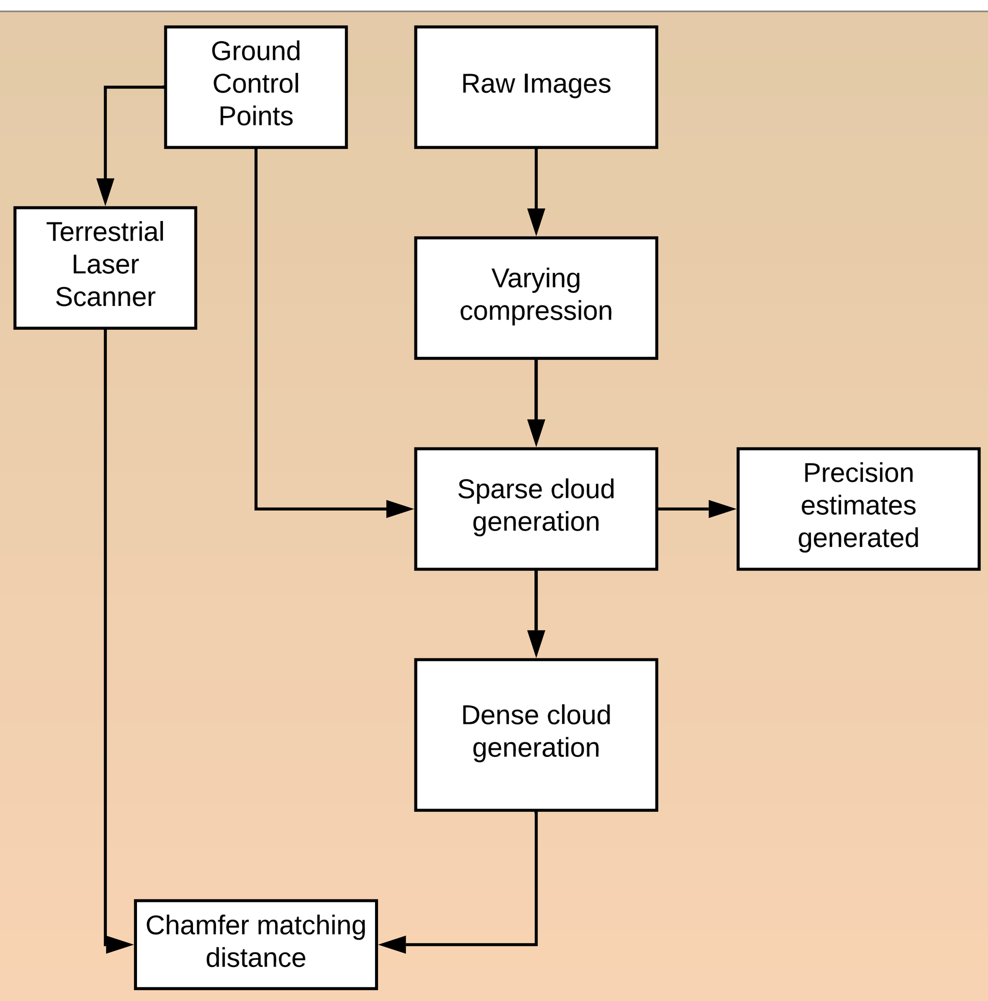

Figure 1. Workflow applied

3. Metrics

a) **Mean GCP error –** The average residual from the GCPs included in the sparse point cloud to their locations provided prior to workflow execution

b) **Mean image residual** – The average reprojection error across the images included within the SfM algorithms

c) **Mean point precision** – The average precision of sparse points included within the bundle adjustment, calculated using software described in James et al. (2017).

c) **Median C2C error** – The median distance of each point within a cloud mapped onto the next nearest point from the reference terrestrial laser scan

d) **Point count** – Number of points generated by the dense point cloud algorithm

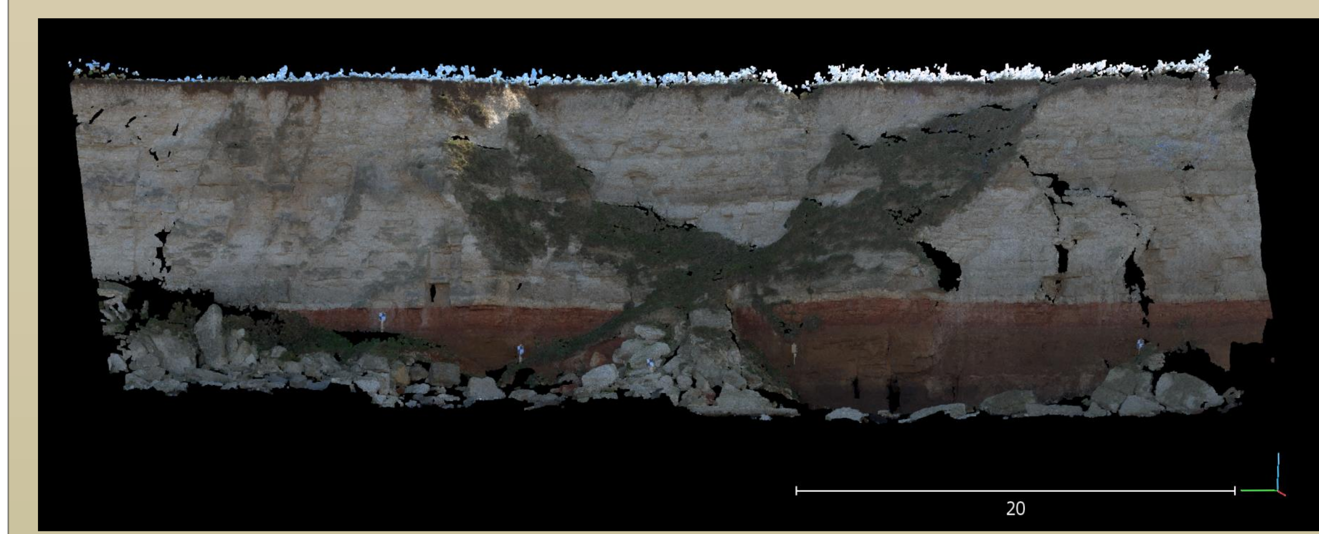

Figure 2. Hunstanton point cloud overview

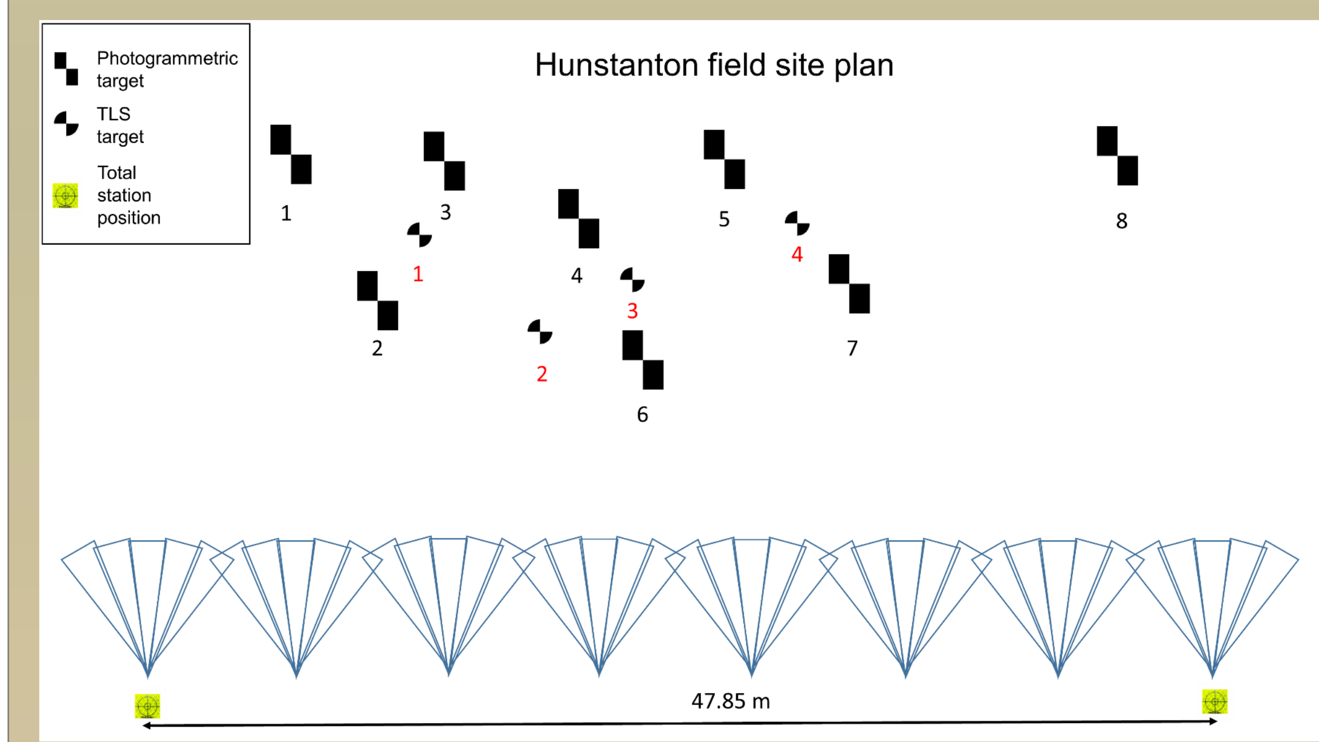

Figure 3. Field plan of Hunstanton study site showing camera positions

Image set	Medium compression	Low compression	No compression
Sparse cloud			
Mean GCP error (mm)	4.52	5.41	5.36
Mean image residual (pixel)	0.39	0.32	0.28
Number of sparse points	291997	393077	406169
Mean point precision (mm)	3.81	3.68	3.58
Dense cloud			
Median C2C error (mm)	6.7	6.49	6.22
Point count (millions)	19.4	19.63	19.84

Table 1. Summary of results for compression experiments

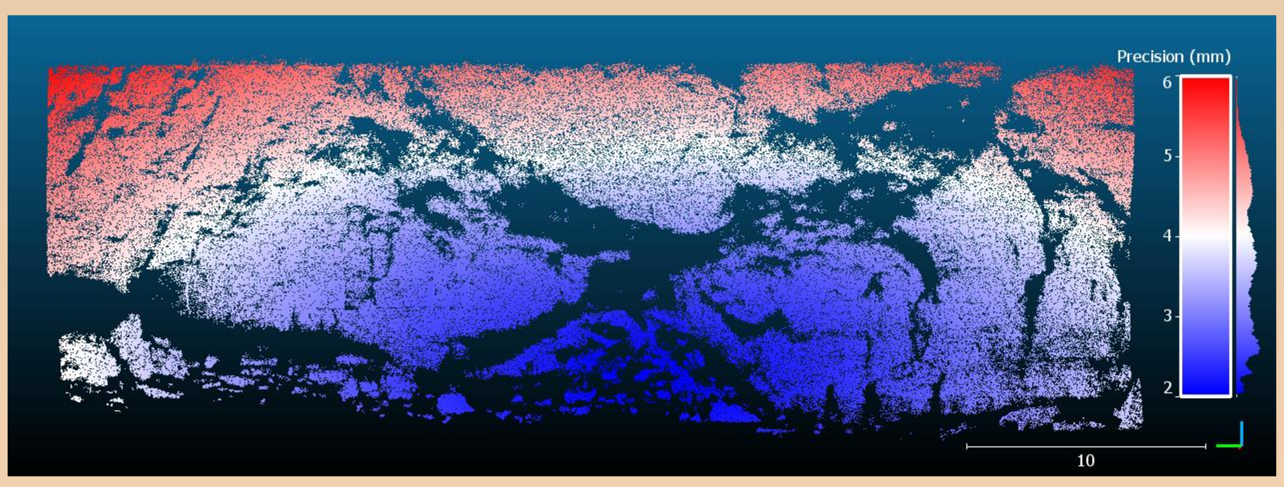

Figure 4. Points are most precise where image overlap is high, and distance to the target is lowest. Areas containing vegetation were generally not included within the sparse cloud.

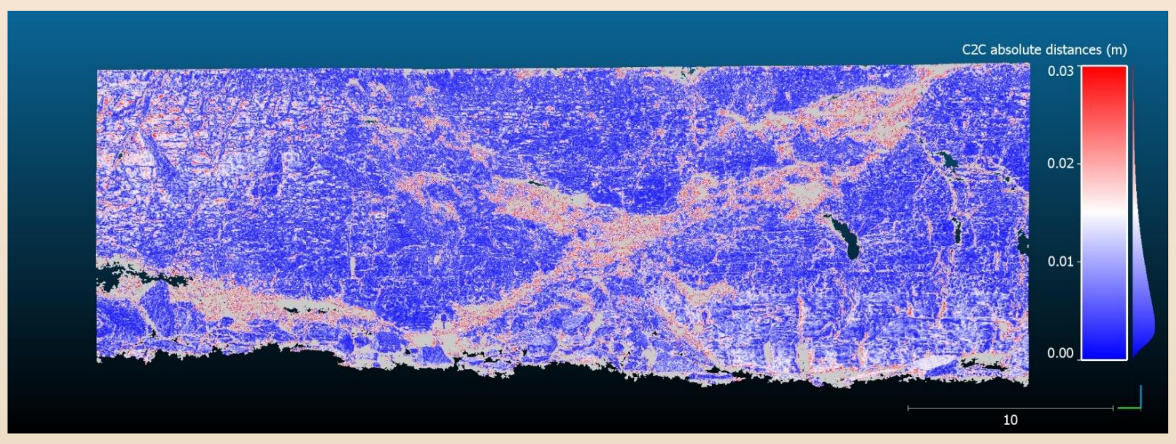

Figure 5. Cloud to cloud accuracy, when compared with the reference laser scan, was high on bare rock face, but low in vegetated areas and those with large depth discontinuities

4. Results

- A decrease in GCP error was seen as compression was increased. The SfM workflow fit more closely to GCPs when image quality was poorer.
- Image residuals increase when compression increases. In all scenarios, image residuals are low, indicating image registration is of good quality.
- The number of points in the sparse cloud decreases with increasing compression. The uncompressed image set show the highest number of points, with points rapidly reduce.
- Median cloud-cloud error increased with increasing compression, with the medium-compressed image sets showing a **7.7 %** increase in error when compared with the uncompressed images.
- Point count density decreased less dramatically across point clouds, with the medium-compressed image set returning **2.2 %** fewer points when compared with the uncompressed imagery.

5. Discussion

- Higher image compression negatively impacts point cloud **precision, accuracy, and density**. If we can estimate compression level, we can estimate its **impact on precision and accuracy.**
- The uncompressed images had no bit-loss compression and perform better than JPEGs – **shoot in RAW** when you can!

6. Future work

- Investigate other image degradations (blur, noise, over/under exposure) and their impact on accuracy/precision of point cloud products
- Extend this work to further study sites.
- Pre-process the imagery to enhance the accuracy and precision of derived point clouds, for, by example, exposure stacking or noise reduction.

Contact: jp-oconnor.com
Email: james.oconnor@Kingston.ac.uk

References

James, M.R.; Robson, S.; Smith, M.W. 3-D uncertainty-based topographic change detection with structure-from-motion photogrammetry: Precision maps for ground control and directly georeferenced surveys. *Earth Surf. Process. Landf.* 2017, *42*, 1769–1788.

O'Connor, J., Smith, M. J., and James, M. R.: Cameras and settings for aerial surveys in the geosciences: optimising image data, Progress in Physical Geography, 41, 1–20, https://doi.org/10.1177/0309133317703092, 2017