Raw image processing in structure-from-motion surveys

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1. Introduction

Motivation: Structure-from-motion (SfM) is a technology which takes multiple 2D photos of a common scene as an input. Image inputs are often highly variable in quality between studies. This research aims to clarify the impact of image quality on 3D products by processing RAW imagery in a variety of ways

Research question: Does image quality have an impact on the *accuracy* and *density* of photogrammetrically derived 3D point clouds

2. Methods

A. Experimental setup:

i. Take a **high quality** image set 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 survey to co-register the photogrammetric and TLS clouds onto the same coordinate system independently from one another

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

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

B. **Input** image subsets of various image quality to the SfM workflow by compressing them and changing exposure settings

i. 15 image subsets are constructed and models generated for each set. Error (Cloud-to-truth) clouds are then generated for each subset

C. **Assessment** is done against a very high quality laser scan which was taken simultaneously with the photogrammetric survey using a Leica P40 TLS

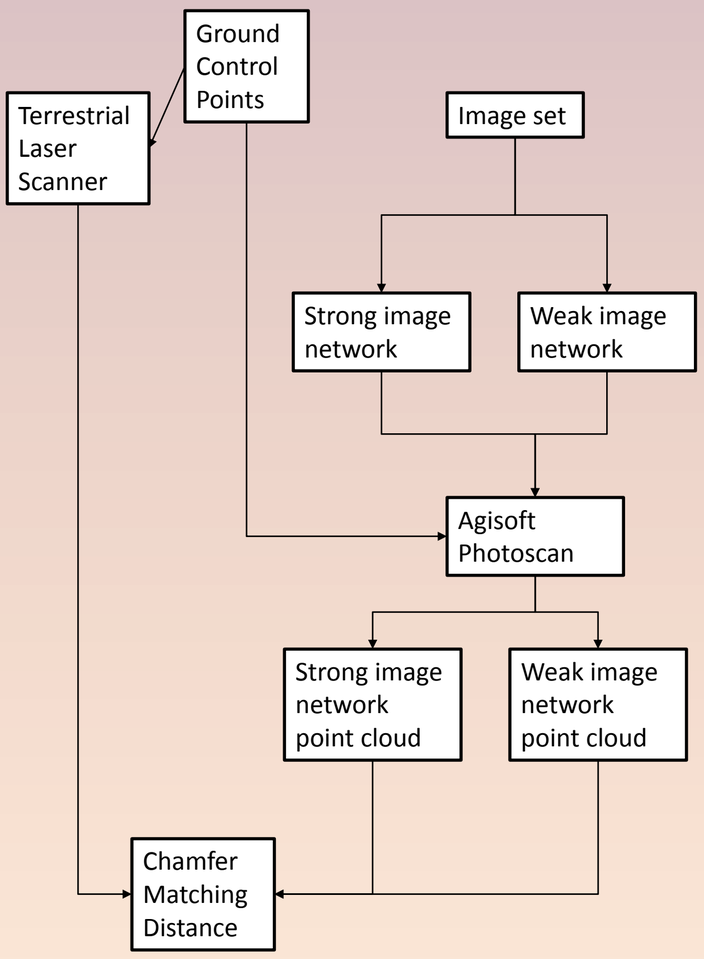

Figure 1. Workflow applied

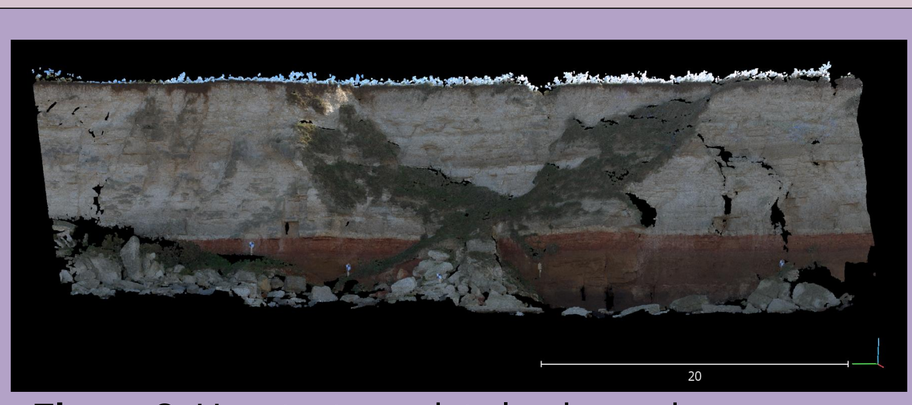

Figure 2. Hunstanton point cloud overview

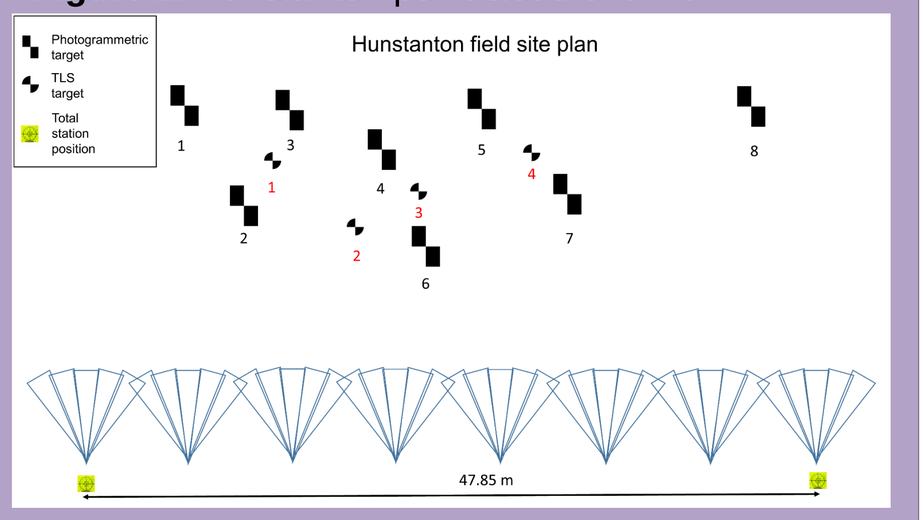

Figure 3. Field plan of Hunstanton study site showing camera positions

Figure 4. Image blocks with higher levels of compression show greater error and lower point counts. Labels are 'quality' settings of compression, a lower number is a higher level of compression

Figure 5. Underexposing increases error and decreases point count when compared with overexposing without saturation of the sensor

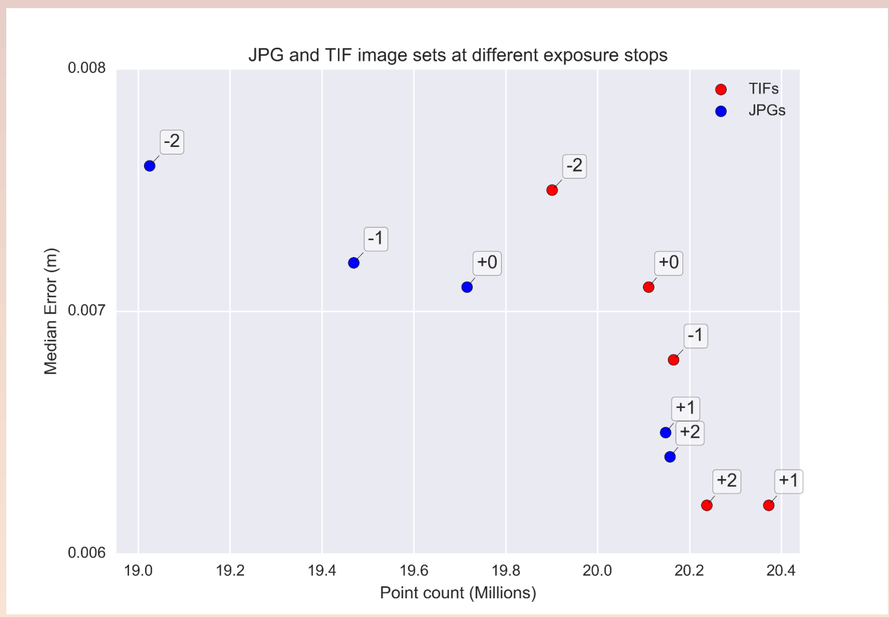

Figure 6. TIF image blocks perform slightly better than JPG image blocks ('quality' = 92) with regards to both point count and accuracy at every exposure level

3. Description of tests

- **Image compression vs. quality?**

Images were compressed using various 'quality' settings. This compression leads to **blocky artifacts** and **posterization.** A range of 5 'quality' settings were selected to apply to **RAW** image files for degraded set generation

- **Exposure vs. quality?**

Exposing-to-the-right is a method of reducing noise by over-exposing the sensor to light, without saturation. In this test, a range of shutter speeds modify the apparent brightness of an image, and we compare these tests for product fidelity

- **Bit depth vs. quality?**

Within the final experiment, we produce uncompressed 16-bits-per-channel TIF images, and compare products with high quality 8-bits-per-channel JPEGs

4. Results

- Image compression has a measurable impact on point cloud **accuracy,** with **density** reducing in very high correlation with accuracy
- A **60%** increase in error and **43%** reduction in point count was seen between the worst (10) and best (92) performing sets
- Image sets where the automatic camera settings were set to overexpose +1EV produced the best results out of all exposures
- TIF images performed better than JPEGs across all exposure sets

5. Discussion

- Higher image compression negatively impacts point cloud **accuracy and density**. If we can estimate compression level, we can estimate **impact on accuracy**
- Automatic exposure compensation does not always produce well exposed images
- 16-bit-per-channel uncompressed TIFs perform better than JPEGs – **shoot in RAW** when you can!

6. Future work

- Image stacking, the averaging of multiple images from the same position, for noise reduction
- High Dynamic Range images, stacking multiple exposures into one frame, for contrast enhancement
- Colour processing for greyscale optimization (O'Connor 2016)

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References

O'Connor, James, Mike J. Smith, and Mike R. James. "Image inputs in Structure-from-Motion Photogrammetry: optimising image greyscaling." *EGU General Assembly Conference Abstracts*. Vol. 18. 2016.