BOOK REVIEW

STRUCTURE FROM MOTION IN THE GEOSCIENCES. By JONATHAN CARRAVICK, MARK SMITH, and DUNCAN QUINCEY. *Wiley-Blackwell, Chichester, UK*. 2016. ISBN 978-1-4665-6647-7. 208 pages with 143 colour plates. Price: £ 75.00.

ONE OF THE MOST POPULAR application areas for readers of the *Record* over the last 30 years has been in the field of earth science, particularly geomorphology. Innovations in photogrammetry and terrestrial laser scanning have provided new opportunities to derive 3D surface representations for earth scientists ever more rapidly, at increasing resolution and with less expertise. The introduction of structure-from-motion (SfM) photogrammetry and multi-view stereo (MVS) has provided fresh impetus to this trend and this new book attempts to provide academics/students and industry professionals with the technical knowledge of the SfM workflow and practical guidelines for its use.

After introducing the aims, scope and structure, the authors place SfM-MVS in context with other non-contact techniques and selective surveying methods (total stations and differential GNSS). Somewhat provocatively, the question is posed whether SfM-MVS provides a new paradigm in topographic surveying. This is a brave and interesting question to ask, not least because there have been rather too many journal papers that have attempted to introduce SfM-MVS as a totally new technique, without fully recognising its heritage. Although this trap is largely avoided, some of the comparisons between "traditional photogrammetry" and SfM-MVS are questionable. For example, both are affected by "fog/mist" and both use automated methods and workflows. I would argue that trying to create a distinction using words like "traditional/ conventional" photogrammetry is actually unhelpful and it is what is shared that is of greater significance. Critically, both use *imagery* as the prime data source, with all the advantages this brings (flexible scale with commensurate precision; automation providing efficiency and high-density data capture; non-contact measurement that can also be retrospective; and finally, the possibility of capturing dynamic objects and processes). It is certainly true that the SfM-MVS workflow has made the task of generating 3D data far more practicable and the many freely accessible "black box" software tools have truly "democratised" use of SfM-MVS photogrammetry for all. This explains the rush to adopt the method, somewhat reminiscent to the introduction of terrestrial laser scanning some 15 years ago.

The next chapter provides a useful explanation of SfM procedures, correctly identifying its heritage in image processing, machine vision and photogrammetry. Feature detection, image matching, bundle adjustment and georeferencing are explained, including a brief reference to some of the dangers associated with self-calibration using weak image geometry. This chapter is technically demanding, but the explanations combined with the extensive references will allow the reader to gain a deeper insight.

Chapter 4 is more straightforward and reviews both platforms and sensors. The list is comprehensive and each is assessed objectively. Of course the ubiquitous quadcopter features highly, but I liked the recognition that simpler sensor-support solutions like a camera pole can be more practicable than a UAV, particularly for capturing small areas

(50 × 50 m) in exposed and windy locations. Some useful guidance of image capture is provided; including convergent image sets and photo spacing. I would have preferred reference to our traditional base/distance ratio (1:5 - 1:10), which is independent of scale and that each object point should appear on at least three images rather than just two. Current software packages are reviewed, with appropriate emphasis given to Agisoft PhotoScan. There are some factual inaccuracies which could upset some manufacturers. For instance, PhotoModeler does *not* require manual feature-matching, their "SmartPoints" feature is fully automated and has been available since 2010! The chapter concludes with a section on "key issues", which was overly short. This section could usefully have been expanded to explore the issue of sampling frequency, both spatial (point density) and temporal. I believe earth scientists need to move beyond simply creating pretty 3D models and should focus more on capturing data appropriate to answer specific research questions. We are beginning to drown in overly dense point clouds that attempt to represent surfaces, when we do not fully understand what a surface actually is and how it should best be represented.

Chapter 5 does focus upon data quality, mainly by comparing RMSE, mean average error and standard deviation results from recently published work. This approach is not entirely convincing as the key control is surely image scale, as clearly recognised by readers of the *Record*. It would have been useful to convert the RMSE values to "relative accuracy" statistics (e.g. 1:1100) before trying to relate to other factors such as platform, software and terrain type. The chapter summary would then have avoided the somewhat obvious statement that "the effect of survey range on precision of the resulting topography is clear and appears to be the main limiting factor"! The chapter does, however, include a useful case study, warning users of the potential of introducing systematic errors or "domes" into surface representations. The dangers of combining wholly vertical image sets with black-box self-calibration tools, appears to require regular voicing to the earth science community and is achieved effectively here.

Chapter 6 provides an opportunity for a range of users to showcase their work, providing a good illustration of the range of applications, at a range of scales. Many are excellent and show how captured spatial data can be used beyond the pretty picture. Good examples include modelling and measuring dynamic field processes involving water and lava. The penultimate chapter examines future directions, including use of improved hardware/video and multiple synchronised cameras. Challenges exist, not least the efficient management of image sets and capturing dynamic surface motion using moving sensors. This so-called "non-rigid SfM" appears problematic but could be solved by multiple synchronised sensors, which are becoming ever cheaper and practicable.

Overall, this is an excellent book which goes some way to achieving the stated aim. I would certainly recommend it to anyone considering using imagery to generate 3D surface representations in the geosciences. Note that a précis version has recently been published (Smith et al., 2015), which may provide a useful "taster" before purchase.

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REFERENCE

SMITH, M. W., CARRIVICK, J. L. and QUINCEY, D. J., 2015. Structure from motion photogrammetry in physical geography. *Progress in Physical Geography*, 40(2): 47–275. [A1]