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Interactive comment on "A low-cost technique to measure bank erosion proces ses along middle-size river reaches" *by* Gonzalo Duró et al.

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General Comments

This work attempts to deploy established SfM techniques over a 1.2 km rver bank characterised by bays and pseudo-headlands and with numerous vertical faces along the banks. The work does present some points of interest but the authors display an understanding of SfM-photogrammetry which is average/good and as a result seem to have missed many important points. The general pitch and justification of novelty for this paper is weak. This is expressed in the second sentence of the abstract stating 'Yet, no technique provides low-cost and high-resolution to survey small-scale bank processes along a river reach'. This is quite simply not true and is ultimately self-defeating as a

statement. The authors have deployed a widely used commercial drone and processed the data with an equally widely used commercial SfM package usng the standard workflow. There is no new technique in this work. The authors have cited other work that has delivered similar resolutions at slightly smaller scales or that have worked at lower resolutions at larger scales. Therefore the work occupies a very small niche of cm-scale resolution work over a 1.2km scale length. The workflow and techniques used by the authors are not at all new, they have merely benefited from better drone flight durations thus allowing them to cover a 1.2km river reach with repeated operations. In itself, this is not a sufficient justification for publication. However, the work does address an important and interesting problem. Using drone-based SfM for repeated coverage of a 1km river corridor, especially a very linear one as shown here, presents some very specific challenges. Moreover, when this reach presents some vertical surfaces prone to failure, additional photogrammetric challenges must be addressed. Unfortunately, the authors did not seem to realise that this was the key point and challenge of their work and, in addition to the misplaced pitch mentioned above, the data acquisition and processing approach is very sub-optimal for this specific problem.

Overall, I do think the data presented here has potential for publication without additional fieldwork, but some very significant revisions will be required which include both new analysis and re-writes of many sections. However, even if publishable without additional fieldwork, the workflow presented here is definitely not the optimal approach to survey long and highly linear river corridors and this will need to be clearly outlined in a new discussion.

Specific Comments

The key challenge in this work is the deployment of drone-based SfM over a very linear river reach characterised with near-vertical faces. This challenge can be understood if we consider the type of errors present in SfM point clouds. This is the main area where the authors understanding of SfM needs to improve. The error of georeferenced point clouds produced from SfM chan be partitionned in linear, non-linear and random components. Linear errors affect the point cloud as a rigid block and can be expressed in terms of translation errors, rotation errors and scaling errors. Non-linear errors are often caused by camera calibration problems and are manifest by warps and curvature effects that distort the geometry of the point cloud. One notable error in the authors understanding is that the seem to think that camera calibration errors can cause overall rotation of the block as 1 rigid body. This is not the case. Camera calibration errors cause errors such as the now famous dish effect. However rigid block rotation errors are caused by errors in the 7-parameter Helmert transform used to scale, rotate and translate a relative point cloud to georeferenced coordinates. The parameters of the Helmert transform are calculated by least squares regression of the control data, if the control data is highly co-linear, the lest squares regression could converge on a false solution that is rotated around the axis formed by the line of control points. This is not the same as the non-linear camera calibration errors. It is also different from random errors are localised errors (often expressed as elevation errors) that are generally not spatially correlated and represent the classic concept of precision. In this work, the authors have been rigorous about possible effects of camera calibration and small scale noise, but they have completely missed possible rotation errors caused by the geometry of their case study.

From a photogrammetric perspective, there are 2 challenges posed by this case study. First, it is a highly linear reach with a very high length:width ration. Second, the presences of vertical faces will require highly oblique views. It is the first challenge that the authors have missed. There are 2 main problems in the data acquisition plan. First, the location of the GCPs is almost co-linear. As stated above,this means that numerical solutions to the georeferencing of the model (via the Helmert transform) will have a degree of equifinality around a family of solutions that rotate around this co-linear axis of GCP points. The addition of 2-3 points perhaps 50 meters inland would have reduced the co-linearity of the model. The authors need to consider the cross-stream footprint of their GCP points relative to the errors in the RTK GPS and in the human error associated to locating the GCP in an image (see below) and make a case that

the model is stable. In the future, the authors must seek to distribute their GCPs in a very non-colinear pattern that, as much as possible, occupies the full X, Y and Z extent of the area covered by imagery. Second, the choice of flight patterns that are lines parallel to the shore does not help this situation. A possible option would have been to fly the drone in a much wider pattern that goes further inland and off-shore. However, in this case, the relatively high error of the drone GPS would have required a fairly wide (in the cross-stream direction) flight pattern in order for the drone GPS data to make a beneficial contribution to the rotational stability of the model. Ultimately, the entire data acquisition setup proposed here is prone to delivering models that will have a tendency to present rotation errors where the entire point model is tilted with respect to an axis that is parallel to the shore line. This is a very significant weakness of this workflow. With this consideration in mind, it is very worrying that the authors have chosen to cut the data and have selected a portion of the point cloud that is near the GCP axis. In figure 7, the authors need to show the readers all the available data. Additionally, if they do choose to cut some peripheral data, some objective criteria must be chosen. And the moment, the choice of area seems subjective and does not give the reader confidence that the authors have not cherry-picked the part of their point cloud with the least error. I note that in figure 9, cross sections 1,2 and 4 do seem to have a rotational effect. The authors will need to demonstrate their current GCP setup does prevent rotation or return to the field with a better, wider GCP arrangement.

Technical Corrections

Abstract. Whilst Westoby et al 2012 did use hyphens when writing Structure-from-motion, this is an error . In the computer vision domain, where SfM was invented, hyphens are not used and so it is corectly written as Structure from Motion.

Section 2.2 This section does not cover the needed material to adress this case study. Need more on GCP distribution and on how a point cloud is georefenrenced. See Fonstad et al 213 or Carbonneau and Dietrich 2017 (both aldready cited) for details

P7 line 7. By default, Cloud Compare computes differences along the Z axis. Did you use the M3C2 module which computes differences along the surface normals? Please clarify.

P8 line 13. Please add a photo of your target. If you have a 12cm diameter circle in the centre, then how do you accurately place the GCP in Photoscan? Are you using some machine assisted algorithm? At 25m, the P4 camera will give you 1.3 cm pixels at nadir. This means that you target centre could be almots 10 pixels wide. How do you find the exact centre and so benefit fully from the accuracy of the RTK GPS? Note that errors at this stage, combined with your co-linear steup of GCPS could contribute greatly to rotational errors of the whole point cloud.

P10 Figure 3. This is not a good view since scales are hard to determine. Better use a side view and a top view, both in orthometric perspectives so that a scale bar can be added.

Also, the choice of linear flight paths (here called tracks) parallel to the shore is again highly sub-optimal. This will only contribute to possible rotation errors. A grid pattern with multiple views would have been much more stable.

Figure 4. Please overlay the image footprints.

P11 From here you only use vertical error estimations to characterise method sucess. But as stated above, you could have other linear errors affecting the model. I note that the error distributions are bimodal with a dip for the number of errors in the 0 bin. This is consistent with a block rotation where few points (along the line of GCPs) are exactly corect. Many are either too high or too low. But this is not a vertical error in the photgrammetry process, it is the effect of rotation.

P13, Figure 7 Before you decide to crop data, you must show all the data. If you do crop, please select an objective criteria. e.g. 100 m buffer around each GCP. At the moment, the data looks manually cropped to variable distances away from the GCPs.

A more rigorous approach is needed.

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