PhotoMOB: Analyse semi-automatisée de la mobilité fractionnée du lit

PhotoMOB: Semi-automated fractional bed mobility analysis

Fanny VILLE* (Universitat de Lleida, Lleida, Spain), **Ramon J. BATALLA** (Universitat de Lleida, Lleida, Spain), **Colin RENNIE** (Ottawa University, Ottawa, Canada), **Damià VERICAT** (Universitat de Lleida, Lleida, Spain),
*fanny.ville@udl.cat

Riverbeds can be subject to varying degrees of mobility (or in the opposite, bed stability) which can be described in terms of the range of mobilized grain size and their proportion [1,2]. When the bedload Grain Size Distribution (GSD) resembles that to the surface bed GSD, the riverbed is subject to equal mobility. A lower mobility mode, called selective mobility, occurs when the (nearly) entire range of bed particle sizes fractions is mobilised but in different proportions. Finally, partial mobility represents a phase in which not all particle fractions are mobile. This makes particle entrainment a variable phenomenon in time and space in gravel-bed rivers and thus difficult to measure and predict.

Several direct or indirect methods to assess bed mobility exist, but all have limitations in terms of applicability or ease of implementation. One method inexpensive (money and fieldwork) is the use of a painted bed area [3]. A *representative* area of the bed is painted and then usually photographed to identify each grain and derive the pre-event surface GSD using automated tools such as Digital Gravelometer© or Basegrain [4,5]. Following a hydrological event, a new photograph of the initial patch can be taken and the entrained painted grain can be located downstream and transport distances measured. This method avoids altering natural grain imbrication without limitation of tracer size. However, mobilised painted grain can be transported over varying distances and may settle on the paint side down and/or be subsequently buried, resulting in a low recovery rate. The majority of measurements generally focus on the downstream particles, while a large amount of information from the original spot location is often not exploited. It should be noted that in some studies [6] the degree of mobility is sometimes estimated visually between the two photos, or by analysing the proportion of pixels that still have paint to determine the extent of partial mobility. This last gives the proportion of the sampled area that has not been disturbed (i.e. the proportion that has remained inactive, stable), but it can be unreliable if the paint is disappearing due to paint wear, and does not take into account grain size. Yet, the description of the different mobility phases mentioned above is based on the mobility proportion of each grain fraction. This information is present in the photos but is not systematically extracted, to our knowledge.

In order to draw on the data set provided by a successive photographic acquisition of a patch, coupled or not to transport distance observations, it is necessary to develop methods that allow a spatial grain-by-grain inter-analysis of the particles present in the two photographs. This enables subsequent analysis of many different areas of the bed (bar head, low and high bar, secondary channel), such that the spatial and temporal variability of bed grain entrainment and transport by fraction can be examined. In addition, new particles deposited on the study surface will be included in the analysis of the next hydrological event without having made any additional effort in the field other than the acquisition of a new photo. We base our work on existing robust grain segmentation methods [4,5,7,8] to go one step further by developing an operational GIS-based procedure (Figure 1) to (**i**) perform identification and characterisation of grains in digital images of gravel river beds to derive reliable surface GSD in Area-by-Number (AbN) and Grid-by-Number form (GbN) (as surface count method [9,10]) and (**ii**) perform local grain by grain area and shape comparison between pre and post photos. This allows for each grain present at the same coordinates, the classification as immobile or mobile using the pre- or post-event photo as reference. For each grain size fraction, the proportion of grain (number or area) that has remained stationary (identical), and the proportion that has been newly deposited in the study area (not identical at the same coordinates) can be calculated. Such a tool allows an easy handling of the results (i.e. polygon reproducing the grain contours with the attributes of size, orientation and mobility status) for the large community of ArcGIS® users, and an easy correction in case of erroneous grain segmentation or mobility classification since the GIS environment allows to edit layers in a simple and stable way.

From this image processing it is then possible, at each time step, to know the surface GSD of the *a* and *b* axes as continuous data and not by class, the orientation with respect to the north of the photo as well as the proportion of fine material (fine limit defined by the operator). However, in the case of partial mobility, entrained grain and the ones newly deposited on the area may be of similar size. Temporal analyses may show no significant apparent change in surface GSD between the two photographs despite actual sediment transport. This transport can still be approached by the proportion estimation of immobile and mobile particles for each fraction. If the sampled (photographed) area is large enough to characterise all the grains, even the largest ones (100 times the size of the largest particle [11]), it is possible to estimate the largest mobile diameter and the mobile GSD which would be a proxy of the bedload GSD.

A detailed analysis of the performance of this method was carried out on 10 sample images, for which a total of more than 6800 grains were extracted from the bed and measured with a Pebble-Box [12] (continuous data) and some of them additionally measured with template (discrete data). Under optimal photographic conditions (sampled area painted and shaded from direct sunlight) and respecting an adequate sampled area, all percentiles estimation shows root mean squared errors between 4 and 10%, either in the AbN or in the GbN form. However, if the GSDs are to be compared to sieve/ template data (discrete data) in GbN form, where the size retained by the square hole is influenced by flatness of grains, the apparent *b*-axis of the particles must first be converted to a function of the mean *c/b* axis ratio in order to achieve estimation errors <10% [13]. Finally, the estimation of the fractional mobility has an average error of 12%.

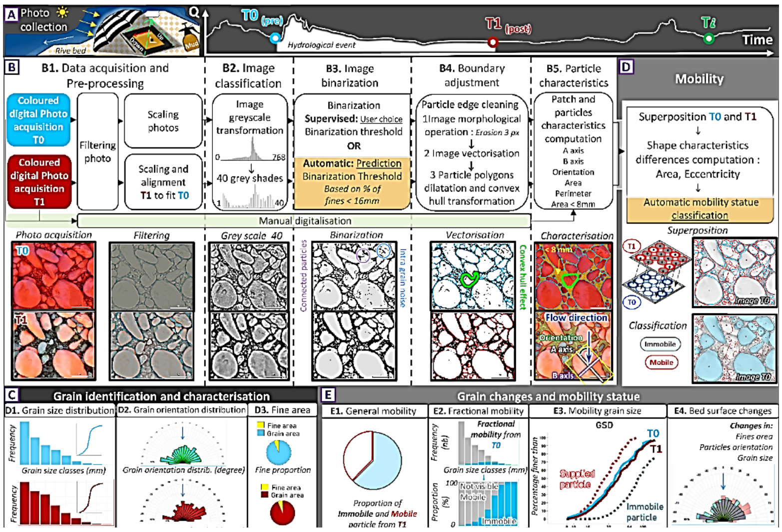

Figure 1 : Illustration of the entire workflow required to sample and characterise the bed surface sediment mobility. (A) Photo acquisition. (B) Extraction of grain and patch characteristics. (C) Possible output after patch surface characterisation. (D) Mobility characterisation and (E) possible output from mobility characterisation. The yellow boxes represent the developed models of dark threshold prediction and (ii) of particle classification. Note the effect of the convex hull transformation on the green particle in the centre of the two images in the Vectorisation and Characterisation columns. In the Characterisation column, the second image shows the sketch explaining how particle characteristics are derived.

REFERENCES

[1] P.R. Wilcock, B.W. McArdell, Partial transport of a sand/gravel sediment, Water Resources Research. 33 (1997) 235–245.

[2] J.G. Venditti, P.A. Nelson, R.W. Bradley, D. Haught, A.B. Gitto, Bedforms, Structures, Patches, and Sediment Supply in Gravel-Bed Rivers, in: Gravel-Bed Rivers, John Wiley & Sons, Ltd, Chichester, UK, 2017: pp. 439–466.

[3] G.M. Kondolf, H. Piégay, eds., Tools in fluvial geomorphology, Repr, Wiley, Chichester, 2009.

[4] D.J. Graham, I. Reid, S.P. Rice, Automated Sizing of Coarse-Grained Sediments: Image-Processing Procedures, Mathematical Geology. 37 (2005) 1–28.

[5] M. Detert, V. Weibrecht, User guide to gravelometric image analysis by basegrain, Advances in Science and Research. ISBN 978-1 (2013) 1789–1795.

[6] L. Mao, L. Picco, M.A. Lenzi, N. Surian, Bed material transport estimate in large gravel-bed rivers using the virtual velocity approach, Earth Surface Processes and Landforms. 42 (2017) 595–611.

[7] J.B. Butler, S.N. Lane, J.H. Chandler, Automated extraction of grain-size data from gravel surfaces using digital image processing, Journal of Hydraulic Research. 39 (2001) 519–529.

[8] L.C. Sime, R.I. Ferguson, Information on Grain Sizes in Gravel-Bed Rivers by Automated Image Analysis, Journal of Sedimentary Research. 73 (2003) 630–636.

[9] M.G. Wolman, A method of sampling coarse river-bed material, Transactions, American Geophysical Union. 35 (1954) 951.

[10] S. Rice, M. Church, Sampling surficial fluvial gravels ; the precision of size distribution percentile sediments, Journal of Sedimentary Research. 66 (1996) 654–665.

[11] P. Diplas, J.B. Fripp, Properties of Various Sediment Sampling Procedures, Journal of Hydraulic Engineering. 118 (1992) 955–970.

[12] H. Ibbeken, P. Denzer, Clast measurement : A simple manual device and its semiautomatic electronic equivalent, J. Sediment. Res. 58 (1988) 751–752.

[13] M.A. Church, D.G. McLean, J.F. Wolcott, River bed gravels : Sampling and analysis, in: Thorne (Ed.), Sediment Transport in Gravel-Bed Rivers, John willey&son, J. Wiley, 1987: pp. 43–88.