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In-situ measurement of riverbed sediment porosity using Structure-from-Motion image analysis

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Sediment porosity defined as the ratio of pore space volume to the total volume of a sediment sample is an important sediment property with relevance to geomorphological processes and ecological conditions of river systems. The porosity (n) is calculated by

$n=V_p/V_t = 1-V_s/V_t$

where V_p is the pore volume, V_t the total sediment volume and V_s the solid fraction volume.

Due to the difficulty of in-situ porosity measurement in fluvial deposits, knowledge about spatial variation of riverbed porosity is limited. As a result, the porosity value is mostly considered as constant over a relatively large spatial scale. The objective of this study was to develop a new method to improve and facilitate the in-situ porosity measurement of fluvial deposits. For this purpose, a Structure-from-Motion (SfM) photogrammetry-based method is applied to determine the in-situ total sample volume. V_t is then combined with Vs measured by water displacement method to calculate the porosity.

Several sets of experiments were carried out to analyse the uncertainty of the new method. Comparison of the modelled with the measured volumes of the known geometry objects showed that the averaged systematic error was less than 0.5 %. This result revealed a low random error distribution and proved a successful volume estimation. Besides, the stochastic uncertainty analysis of the total volume was less than 0.5 %, showing that the V_t was accurately measured. Combination of V_t and V_s stochastic errors using standard error propagation formula showed the relative uncertainty of the porosity to be less than 1%.

Compared to the existing methods, this new SfM method increases significantly the measurement accuracy and strongly speeds up the porosity measurements, as it is independent from field calibration and initial sediment sample stabilization. This method will improve our understanding for spatial variation of riverbed porosity, which is essential for the validation of porosity predictors, and thus it will help to improve morphological computer models in the future.