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Investigating coarse sediment particles transport using PTV and "smart-pebbles" instrumented with inertial sensors

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This study, reports on the analysis of appropriately designed fluvial experiments investigating the transport of coarse bed material using two approaches: particle tracking velocimetry (PTV) to extract bulk transport parameters and inertia sensor data (via the use of "smart-pebbles") to obtain refined statistics for the transport of the particle. The purpose of this study is to provide further insight on the use of technologies (optical techniques and inertial sensors) that are complementary one to another, towards producing improved estimates of bedload transport in natural rivers.

The experiments are conducted in the Water Engineering Lab at the University of Glasgow on a tilting re-circulating flume with 90 cm width. Ten different discharges have been implemented in this study. A couple of fake beds, made of well-packed beads of three different sizes have been set up in the flume. The particle motion is captured by two high-speed commercial cameras, responsible for recording the top view covering the full length of the fake beds over which the "smart-pebble" is allowed to be transported. "Smart-pebbles" of four different densities are initially located at the upstream end of the configuration, fully exposed to the instream flow. These are instrumented with appropriate inertial sensors that allow recording the particle's motion, in the Langrangian frame, in high resolution. Specifically, the "smart-pebble" employ a tri-axial gyroscope, magnetometer and accelerometer, which are utilized to obtain minute linear and angular displacements in high frequency (up to 200Hz). However, these are not enough to accurately reconstruct the full trajectory of the particles rolling downstream. To that goal optical methods are used. In particular, by using particle tracking velocimetry data and image processing techniques, the location, orientation and velocities of the "smart-pebble" are derived. Specific consideration is given to appropriately preprocess the obtained video, as the captured frames need to be flatted and calibrated due to lens distortion. Special effort is made to ensure the center of mass of the "smart-pebble" in each frame is well identified (using image thresholding techniques to improve colour contrast), so that its trajectory comprising of concequtive displacements is accurately defined.

It is sensible to follow a probabilistic analytical approach, considering the stochastic nature of particle transport at low transport rates. By using the output data from the camera and inertial sensor, particle transport velocity and acceleration time-series, are produced for each fluvial transport experiment. To that goal empirical probability distribution functions (PDFs) are derived for the particle's motion features from both techniques and best fits for these are estimated. The parameters of the probability distribution functions are plotted against the Reynolds particle number for all the transport experiments, to identify any trends. Such information can help calibrate the "smart-pebble" for sediment transport studies and can also offer novel insights on the mechanisms of particle transport, from a Lagnrangian perspective.