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Smart-pebbles in sediment transport studies: state of the art, future directions, and unsolved problems.

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The use of Inertial Measurement Units (IMUs) in geomorphological studies has exploded during the last decade. Scientists are deploying IMUs in a range of settings: from single grain flume experiments to full scale landslide motions and from capturing rock falls to measuring flows in glacial environments.

The vast majority of these experiments deploy sensing units that are partly customised for each application. However, there are limits to the level of IMU customisation geomorphologists can do as they rarely have access to bottom-up sensor assembly and production lines. Commercial IMUs and IMU components are built and calibrated for very different uses than the monitoring of dynamic sediment transport regimes, such as integration into electronic devices, wearables or Internet of Things applications.

Deploying commercial IMUs outside their nominal operational range has two main implications, the first being methodological. As the sensor is partly a "black box", we are obliged to do extensive testing in a trial-and-error manner and think deeply about the underlying physics of IMUs. If such difficulties are not acknowledged the results become difficult to interpret in the context of sediment movement.

The second implication concerns standardisation. The more our community uses commercial sensors and analytical tools, the more apparent becomes the need for open-source pre-processing and processing workflows that are fully validated and universally available to ensure comparability of published results.

This presentation aspires to contribute to this open debate about IMU sensors in geomorphology. The focus will be on the sensing requirements for grain motion detection, force capture and tracking by IMUs in the context of sediment transport. The presented calculations will use results published before the emergence of IMUs in geomorphology for a range of environments (fluvial, coastal, aeolian and glacial).

The above requirements capture will be accompanied by a meta-analysis of published IMU data in geomorphic applications which will be classified according to the exact type of sensor (accelerometer, full IMU, GPS (or equivalent)-aided IMU) and the sensors' specs (mainly sensing

range and frequency).

Finally, this presentation will explore the case study of using a commercially available IMU for the capture of fluvial sediment interactions. The deployed IMU will be subjected to a series of simple physical experiments (e.g., drop tests) and then deployed to a flume setting designed to model grain-grain and grain-substrate collisions. The novelty here is the use of an independent very high-speed camera (1μs exposure frame rate) to monitor the sensor during calibration, which allows for the coherent propagation of uncertainty for all the experiments. All the results are presented within a processing workflow based on free, open-source R libraries.