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Investigating boulder motions with smart sensors in lab experiments

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Events such as landslides, rockslides, debris flows, and flash floods can have destructive and possibly fatal outcomes. In these events, boulders and cobbles are carried downstream under the action of gravity and the study of their transport and movement can give important insight on the dynamics and hazards related to these processes. Recently, boulder motion has been investigated by the use of smart sensors in geomorphology applications both in lab and field experiments. Smart sensors are small and light-weighted devices that are able to collect different environmental data with low battery consumption communicating to a server through a wireless connection. However, the reliability of smart sensors still needs to be evaluated for monitoring purposes and for developing early warning systems.

In the present study, dedicated laboratory experiments were designed to assess the ability of the sensors to detect movements and distinguish between intensity and type of movement (e.g. sliding or rolling) within a well-constrained setting. For this purpose, a tag equipped with an accelerometer, a gyroscope, and a magnetometer sensor has been installed inside a cobble of 10.0 cm diameter within a borehole of 4.0 cm diameter, closed hermetically before each experiment. The experiments consisted in letting the cobble fall on an experimental table composed of an inclined plane of 1.5 m, followed by a horizontal one of 2.0 m. The inclined plane can be tilted at different angles (18˚- 55˚) and different types of movement have been generated by letting the cobble roll, bounce, or slide. Sliding was generated by embedding the cobble within a layer of sand. The position of the cobble travelling down the slope was derived from camera videos by a tracking algorithm developed within the study.

Raw sensor data allowed detection of movement and separation of two modes of movement, namely rolling and sliding. Furthermore, raw datasets approximated the magnitude of movement

even without any calibration. On the other hand, by coupling smart-sensor measurements and camera-based positions, it was possible to develop a filter to derive reliable values for the position, orientation, velocity, and acceleration to fully represent cobble motions. These findings show how the raw data can provide information about the type and an indication of the magnitude of movement, and confirm the potential to use these sensors to improve early warning systems, although further studies are in progress to assess response time in a field setting. At the same time, the development of a filter that gives more precise and reliable data from the sensors enables assessment of the rotational and linear acceleration of the tracked element. If used in more sophisticated lab and field experiments, this has the potential to give new insights on the behaviour of cobbles within different types of processes and can shed new light on the dynamics of complex hazardous flows.