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Monitoring boulder movement using the Internet of Things: towards a landslide early warning system

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Boulder movement can be observed not only in rock fall activity, but also in association with other landslide types such as rock slides, soil slides in colluvium originated from previous rock slides and debris flows.

Large boulders pose a direct threat to life and key infrastructure, causing destruction along their paths and amplifying landslide and flood hazards, as they move from the slopes to the river network. Despite the hazard they pose, boulders are generally not directly accounted for in hazard assessment methods, nor have they been targeted in dedicated early warning systems or used as a mean to detect landslide movement. The ability to monitor boulder movement in real time and to provide local stakeholders with timely alerts thus represents an important step forward.

Our study focuses on an area in the upper Bhote Koshi catchment northeast of Kathmandu, where the Araniko highway, a critical link between Nepal and China, is subjected to periodic landsliding and floods during the Monsoons and was heavily affected by coseismic landslides after the 2015 Gorkha earthquake. In the area, damage by boulders to properties, roads and other key infrastructure, such as hydropower plants, is observed every year.

In April 2019, we installed an innovative monitoring system to observe boulder movement occurring in different geomorphological settings on slopes, before reaching the river system. We embedded trackers in 23 boulders spread between a landslide body and two debris flow channels. The trackers are equipped with accelerometers and can detect, in real time, small angular changes in boulder positions as well as large forces acting on them. They are programmed to send regular data but, crucially, they can be triggered by movement and immediately transmit the data via a long-range wide area network gateway to a server.

Preliminary results show that 10 of the tagged boulders present patterns in the accelerometer data compatible with downslope movements. Of these, 6 lying within the landslide body show small angular changes, indicating a reactivation during the rainfall period and a movement

consistent with the landslide mass. 4, located in a debris flow channel, show sharp changes in position, likely corresponding to larger free movements and rotations. The latter have not been found at their original location after the monsoon.

This study highlights that this innovative, cost-effective technology can be used to monitor boulders in prone sites and may set the basis for the development of an early warning system particularly in developing countries, where expensive mitigation strategies may be unfeasible.

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