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Interactive comment on "Development of smart boulders to monitor mass movements via the Internet of Things: A pilot study in Nepal" *by* Benedetta Dini et al.

Anonymous Referee #2

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The presented work focuses on the deployment of accelerometers and its real-time data transmission as possible low cost means of surveillance for large single blocks to identifiy mass movement associated with landslide type of rock slides. It presents a substantial an thoroughly carried out field measurement campaign and careful data analysis. The use of IMU technology for boulder tracking and its possible applications for early warning systems is a highly relevant topic. The comprehensive presentation of this pilot study definitevly merits publication after some minor revisions.

Generally, the presentation of the entire work is very nicely done. I also have to thank the authors to present a carefully edited and proofread manuscript, which made read-

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ing easy and enjoyable.

In the following some content and technical suggestions for improvement and additional context are provided. IMHO the manuscript would benefit of some remarks on remaining challenges and disadvantages of IMU tracking/signal processing.

Introduction l41: Large boulder movement rarely comes isolated. While the approach to use large boulders as particle marker for mass movements with modern technology is new, the general statement that the motion of large boulders and its damage potential is not discussed in literature may be a bit exaggerated.

L54: large boulders can be detected via RADAR/LiDAR technology, which is truly remote. The target boulders here predominantly are early warning signs

L64: State-of-the art RADAR (no interferometric RADAR of course) techniques are able to deliver real-time data for immediate mitigation actions such as road closures etc. See https://ui.adsabs.harvard.edu/abs/2020EGUGA..22.5138W/abstract for the lack of better reference sake.

General remark: With all the advantages listed for the IMU technology applied, one crucial disadvantage needs to me mentioned: The installation of the sensors do require physical presence at the block. While this may not be a problem for large boulder instrumentation in slowly evolving mass movements, this is certainly a major drawback to deploy the presented technique in active sites.

Methodology 3.1 Network setup and components Really nicely presented methodology!

Notation remarks: âĂć Generally throughout the manuscript, change the notation of the local gravitational field of Earth to \texit{g} or g as it denotes a physical constant usually denoted in italic font. This also removes the ambiguity of mg and mg. âĂć The same holds for x,y and z axis, variables denoted by italic characters. Any given coordinate system is given by its n-space.

3.2 Choice of tracked boulders l298 coherently → collectively/mutually. Coherence would imply that the motion pattern is the same, as a laser has coherent wavelengths. Large boulders can move with the landslide but usually succumb to a slightly different kinematical regime. True coherence in nature is extremely rare.

3.3 Sensor Settings l323ff replace the "∼" with \approx or the word roughly, about, etc.. Tilde means "similar to" and is usually used in plain mathematical context.

l352 maybe add "before the peak when sampled at 2 Hz." If sampled at higher frequency, such double or three peak hits are not that uncommon.

4 Result Thorough presentation of the results. Only notation of axis and g and "∼" characters would need some attention.

5 Discussion Validation of motion is partly done via camera imagery. While I would agree that only tilting motion of an embedded rock is not feasible to be detected via imagery, I would argue with the progress in resolution an image processing, a pixel tracking via cross correlation analysis of interval imagery might well track slow motion onsets. The spatial resolution is then given by the camera's resolution. Just one of a zoo of cross-correlation papers (https://nhess.copernicus.org/articles/17/2143/2017/)

L668 while in the introduction the heritage of animal tracking is mentioned, a comparison with state of the art logistic tracking devices such as MSR sensors or trusted global devices (just to name two), would be interesting. Modern logistic shock tracker do also work with acceleration and angular velocity IMUs and sometimes even come with satellite network coverage to send the reports.

L688 As stated by the authors, independce of GPS/GNSS signals is of paramount importance.

L731 Accurate position information from IMU sensor integration requires sophisticated post-processing procedures in order to minimize integration error accumulation. This is feasible in case of periodic motion or motion patterns, where at specific positions in

time a zeroing of the errors is possible. If this is not the case, accurate position tracking via IMU is extremely challenging, especially for fast motion. If GNSS (maybe refer to GNSS than GPS alone, as there are many other systems in the sky then GPS only) measurements will become obsolete in the future, one will see.

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