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An in-flow sensor system for data acquisition in snow avalanches

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The dynamics of snow avalanches and in particular their rheology is of big importance to develop improved avalanche models and thus increase safety in mountainous areas. Existing measurement systems only allow a limited in situ view of the dynamics of snow avalanches and therefore demand the development of innovative measurement systems. Furthermore, due to the limited measurement capability of existing systems, comprehensible motion reconstruction is currently not possible. Therefore, the aim of this work is to present a measurement system that enables accurate in flow observations of snow avalanches and has the mechanical properties of a typical snow granule. A main objective of the measurement system is to allow a full motion reconstruction regarding translations and rotations with a high sampling rate and without exceeding sensor ranges.

The newly developed system, denoted as AvaNode, has the shape of a concave cube with a variable density to fit typical snow granules in flowing avalanches and their deposits. The AvaNode contains a strapdown inertial navigation sensor capable of measuring accelerations, angular velocities, and magnetic flux densities with up to 400Hz and allows for an estimation of the orientations, velocities, and positions of the AvaNode using state of the art motion reconstruction algorithms. The reconstruction is significantly improved due to precise calibration of all sensors using reference measurements with a 6R robot and onsite magnetic field calibration. In order to get a refined motion trajectory, the AvaNodes are also equipped with radio ranging modules. These modules allow performing time of flight (TOF) measurements, determining the distance between several nodes. A Global Navigation Satellite System (GNSS) module determines longitude, latitude, and altitude, as well as world time, however, with low frequency resolution and larger errors due to snow coverage. To measure the temperature evolution in avalanches, an infrared temperature sensor is attached. Multiple recovery systems like Recco rescue reflector (passive), Pieps TX600 (active), and Lambda4 Smilla (active) are integrated to allow fast retrieval of the sensors.

As first results, we present the employed sensor calibration approaches for the inertial navigation with corresponding laboratory data signatures. The sensor calibration allows in-depth analysis of motion data, identifying typical data signatures observed in avalanches. Furthermore, we show

first data acquired from in-flow snow avalanche measurements, which prove the functionality of the system and allow the first insights into trajectories of snow granules, regarding accelerations, angular velocities, rotations, and position.