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Evaluation of a novel inclinometer device based on MMES technology through comparison with traditional inclinometers in landslide applications.

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The paper illustrates the efficiency of a novel inclinometer device system - based on MEMS technology - by comparing results obtained from a couple of installed prototypes and those derived from classic inclinometers. The new device, called MUMS (Modular Underground Monitoring System) is intended to be applied for natural and artificial slope deformation monitoring and landslides dynamics control, assessment and forecasting. In its initial part, the paper briefly describes the new instrumentation which should allow for a better understanding of the type, location and origin of unstable slope movement. The MUMS instrumentation was born from the idea of replacing the standard measurement procedure by locating nodes at known distances from each other along a connecting cable placed within a vertical borehole. Each node is able to measure its local orientation from the vertical (gravitational acceleration) by means of a micromechanical 3D digital linear acceleration sensor (MEMS). This will allow us to determine the direction cosines of the borehole axis in each node and, by means of linear geometry and trigonometry, calculate its 3D shape and deformation along the whole borehole. The basic hypotheses to be considered for this procedure are: a) the lower node must be located in a stable portion of the soil/rock and must be accurately cemented to it and b) the distance between two subsequent nodes along the pipe must not vary. This configuration - with 3D inclinometers only – would require that all of the nodes must be originally aligned along a single diametric plane of the cable. This mechanical condition could be achieved using a connecting pipe which would, however, generate installation problems and a possible incorrect assembly of the nodes; this inconvenience could degrade the evaluation of the displacement heading and therefore compromise their final measurement integration from the bottom up along the borehole. To avoid it, a 3D digital MEMS magnetic sensor was added to each 3D digital linear acceleration sensor, enabling us to determine the heading (azimuth) of each node related to the magnetic North. This added MEMS element eliminates the uncertainties and any errors due to spiraling or to system assembly imprecisions. Following, the paper deals with a series of significant errors like biases, drift and noises that are affecting the final output of MEMS sensor and illustrates how to achieve valuable and reliable outputs which allow the use of these sensors in the landslide monitoring field. Finally, a couple of example application are presented where prototypes of this system are installed on well documented and traditionally monitored slow moving active landslides. In these examples the MUMS results are compared with those obtained by traditional systems evidencing the new system potentials and effectiveness in terms of sensitivity, precision, reliability and automation.