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Development of a Low-Cost Microelectromechanical System for the Digitisation Of Boreholes.

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Extended Abstract

The deviation of drill holes from their theoretical position can lead to failures or dangerous situations due to the risk of fly-rocks when blasting rock. The origin of these deviations may be due to several causes: poor positioning of the drilling machine, deviations of the drill string due to unfavourable geological conditions, wear of drilling tools, etc.

A novel equipment has been developed to evaluate boreholes efficiently and safely, being able to validate them and find and quantify potential deviations from the projected trajectory. The system consists of a probe that is introduced into the borehole to determine the heading (dip direction angle) and inclination (dip angle) of the borehole, comparing the real trajectory of the borehole with the projected one.

The trajectory of the borehole has been broken down in a set of linear trajectories of length *r*. Each one of these linear trajectories is fully defined by two angles: dip direction, α, and dip, β. The 9 DOF sensor BNO055 has been used to determine these angles [1], which integrates a 3-axis accelerometer, gyroscope and magnetometer. As it is only needed the 3-axis accelerometer to determine the inclination and the 3-axis magnetometer to determine the heading, it is used the *Fussion Mode Compass* of this sensor.

The measurement method starts with the probe inserted at the beginning of the borehole, with coordinates (x_0, y_0, z_0), pointing (with angles β_0, α_0) to a new point at a distance *r*, with coordinates (x_1, y_1, z_1). It is assummed as true the hypothesis that if the probe goes down a distance *r*, it will be at the point (x_1, y_1, z_1), pointing (with angles β_1, α_1) to a new point at a distance *r*, with coordinates (x_2, y_2, z_2). This procedure is repeated until the end of the borehole is reached. The coordinates of each new point *n+1* are computed from the previous coordinates and angles of point *n* by:

$$(x_{n+1}, y_{n+1}, z_{n+1}) = (x_n + \Delta x, y_n + \Delta y, z_n + \Delta z)$$
$$\Delta x = r\cos\beta_n \cdot \sin\alpha_n$$
$$\Delta y = r\cos\beta_n \cdot \cos\alpha_n$$
$$\Delta z = r \cdot \sin\alpha_n$$

The method has been tested on a guided path, comparing the sensor measurements with those of a total station. Results obtained (using *r*=1m and 13 points) show a fairly accurate calculation of the dip angle, while the dip direction angle shows a higher variability between measurements. Both angles are computed averaging 20 samples obtained in one second when the probe is completely still to reduce random error and improve repeatability. The dip angle (with a mean value 27º) has a maximum absolute error of 0.15º, considering all the 13 linear trajectories, achieving a better value than the sensor precision. The dip direction angle (with a mean value 23.5º) has a maximum absolute error of 1.5º, considering all the 13 linear trajectories. On the other hand, it is difficult to improve the dip direction angle error, because the magnetometer heading bias error after calibration is as high as ±2.5º. Increasing reliability by the use of multiple sensors through the averaging of their outputs can only be achieved if the measurements are independent, i.e. not having a common calibration error [2]. Thus, this last approach needs further research.

References

[1] BNO055: Smart sensor combining accelerometer, gyroscope, magnetometer and orientation software [Online]. Available: https://www.bosch-sensortec.com/products/smart-sensors/bno055/
[2] Béla G. Lipták and Kriszta Venczel, *Instrument and Automation Engineers' Handbook Fifth Edition*, CRC Press, 2017.