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Long-range Probe for Metrology Applications

The continuous development of industry increasingly demands precise measurements, especially in the field of spatial acquisition using 6DoF (Six Degrees of Freedom) probes. Current devices, such as Hexagon's T-Probe, offer a working range of up to 30 meters. However, there is a growing need for devices that provide high accuracy over even greater distances. This Master's thesis aims to investigate the feasibility of developing a robust long-range probe that combines AP20 technology and laser tracker capabilities to achieve accuracies in the range of 0.5 mm to 1 mm.

Construction of the long-range probe

The functional model consists of the Leica AP20 (IMU), an RRR target that can be measured by any laser tracker. The RRR target is held by a modified Leica mini prism equipped with a nest. The mini prism holder is mounted on a short pole via an SBB bolt, and this pole can be inserted into the AP20. Since this pole has a 5/8'' thread, the FHNW workshop must fabricate an adapter with a 5/8'' external thread and an M5 internal thread to facilitate the mounting of the 1.5'' tip. Additionally, the long-range probe can be extended with inserts.

Fig. 1: First prototype of a long-range probe with integrated IMU of the AP20 (short pole)

Unlike the T-Probe, the newly developed long-range probe is compatible with any laser tracker as it does not require a camera system. Moreover, it offers an extended range because it measures directly via the IMU rather than capturing 6DoF data through a camera like the T-Probe. Consequently, the maximum measurable distance equals the maximum measurement range of the laser tracker.

AP20 IMU initialization time

To find the optimal initialization time for the AP20's IMU, tests were conducted for durations between 30 seconds and 2 minutes. Results indicated that 30 seconds led to significant drift, while 45 seconds reduced drift to 2-3 mm. The best stability was achieved with a one-minute initialization, as extending to two minutes provided no additional benefit. A one-minute initialization maintained stability for up to four minutes, with slight drift appearing after eight minutes.
An experiment without TPS correction data showed drifts of -21 mm, 17 mm, and -9 mm for Z, Y, and X coordinates, respectively, after three seconds. These results suggest the AP20 IMU or its initialization method is more accurate than those reported by Linghui et al. (2022).

Time synchronization of AP20 and laser tracker

The time synchronization between the AP20 and the laser tracker is critical and must achieve a precision of 0.0001 seconds. Two synchronization methods were tested, but neither achieved the necessary accuracy. The main causes are irregular triggering and different start and end times from die AP20 and the laser tracker.

AP20 and TS60 accuracy check

For the AP20 in conjunction with the TS60, it is found that using a short pole (352.2718 mm) in vertical and overhead positions results in a 3D deviation that does not exceed 3 mm. However, horizontal measurements show deviations of up to 6 mm. These results indicate that sensor fusion (IMU and laser tracker) must bring about an improvement of 5 millimeters.

Sensor fusion based on python

To fuse the IMU and laser tracker data, a Python script is written. The script calibrates the AP20 by guiding the probe over a known point and determining the calibration values using the BFGS optimization function. These values, along with the IMU quaternions and the updated position of the laser tracker, are integrated into the Kalman filter. Subsequently, the position of the tip is calculated based on the pole length. The best results are achieved with vertical measurements, where no 3D deviation exceeds 17 mm. However, the Python script does not achieve the required accuracy, primarily due to implementation difficulties with the Kalman filter and insufficient time synchronization.

Fig. 2: Workflow accuracy analysis of the long-range probe

Future investigations

First the time synchronization problem must be solved, achieving an accuracy of at least 0.0001 seconds. Hexagon products like the AP20 and T-Probe, where time synchronization already works, could help solve the problem. Once all these points are clarified, Leica's sensor fusion script (AP20) could be used to fuse the data, considering the improvements brought by the laser tracker. This would allow effective testing of different pole lengths and determine whether the AP20 is suitable for a metrology touch probe.

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