Path Tracking with iGPS

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1 Summary

iGPS technology is a laser-based indoor system with optical sensors and transmitters to determine the 3D position of static or moving objects. The technology is based on internal time measurements related to spatial rays that intersect at sensors in the measuring volume. Due to the measurement principle of iGPS, tracking measurements can cause a delay time which will lead to deviations in spatiotemporal positioning. Utilizing the new Digital Input Module it is possible to analyze the kinematic performance of the iGPS metrology system with the time-referenced 4D test and calibration system. By using the latest equipment and Surveyor software it was possible to show that the iGPS system has made significant improvement in tracking capability. In this experimental set-up, the system could collect and process data up to object velocities of 3 m/s. At this high velocity, the tracking deviations for the 3D position were less than 0.3 mm and the 4D tracking deviations were less than 1.5 mm.

2 Path Tracking with iGPS

The typical components of an iGPS network are at least two transmitters, a mini-vector bar with two sensors, an amplifier as analog-digital converter and the position calculation engine (PCE) that measures the arrival time of each signal with an internal clock and manages the communication with the host PC. Each iGPS transmitter emits two different types of signals, the strobe signal and two fan-shaped beams which are projected from the rotating head of the transmitter. Each sensor in the working volume receives signals from each visible transmitter and the arrival time is measured. Based on these time measurements and the fan beam’s geometry, the angle values (azimuth, elevation) from transmitter to sensor are determined. The location of the sensor may be calculated using the process of triangulation in an analogous manner to a theodolite network. iGPS can be used for static or kinematic measurements. With the new PCE Digital Input Module (DIM) it is possible to synchronize an external digital input signal with iGPS data. To analyze the 4D kinematic performance of iGPS time-referenced measurements are strictly necessary. For tracking optical measuring systems of any kind a time-referenced 4D test and calibration system was developed at the Geodetic Institute at Karlsruhe Institute of Technology (KIT). This system consists of a tiltable rotating arm with a length of 2 m. A rotary direct drive is used as primary mover of the rotating arm and a real-time multi-axis servo motion controller is used for position and velocity control of the direct drive.

The kinematic measurements were executed in July 2009 in the Geodetic Laboratory of KIT. Four iGPS transmitters were arranged around the rotating arm and a 1 m scale bar was used for bundling (system calibration). A mini-vector bar was fixed on one end of the rotating arm. A frequency generator delivered the input for the DIM and the test equipment. The iGPS Surveyor software version 1.2.30 was used. For independent measurements a Leica laser tracker LTD 500 was employed, which was triggered also by the frequency generator. The rotating arm was placed in three different positions: horizontal, slant and vertical. Each time new transmitter network positions were calculated through a bundling calibration procedure. For the coordinate transformation a static reference measurement with both systems – iGPS and laser tracker – was carried out. Within the kinematic mode the laser tracker could only follow at vertical rotating arm position, because of the visibility of the CCR. In the kinematic mode angular velocities up to 160°/s (2.9 m/s) could be reached.

For every revolution of the rotating arm a 3D circle fitting was calculated using the least-squares method. The results were shown as planar deviations (perpendicular to the circle plane) and radial deviations. Tangential deviations were calculated after a coordinate transformation. The static measurement of the horizontal rotating arm position showed for the planar, radial and tangential deviations nearly the same deviations < ±50 µm for iGPS sensors and laser tracker. For the kinematic measuring with a velocity of 160°/s the planar deviations are nearly in the same order and the radial deviations are less than ±0.15 mm for iGPS for 3D path tracking. For the tangential deviations, spatial (3D) and spatiotemporal (4D) deviations must be distinguished. “Spatial” refers to the 3D position only, which can be expressed as path tracking. “Spatiotemporal” refers to position and time (4D), which means that the sensor has to be at the correct position at a specific time. In that way the result has to be split up into 3D and 4D deviations. The spatiotemporal tangential deviations show that there is a time offset of about 0.3 ms and it seems that the sensor is "running ahead". In order to show what happens with the 3D position, this time offset is considered for new calculations. The left figure shows the tangential deviations (after correction, top and bottom sensor iGPS) with a horizontal rotating arm position at an angular velocity of 160°/s for 4 revolutions of the rotating arm. The vertical rotating arm position has the advantage that both systems – iGPS and laser tracker – can be used simultaneously, but it should be noted that in this special experimental set-up the iGPS transmitter network configuration was regarded as poor and at the limits of the hardware functionality. The right figure shows the 4D tangential deviations (top and bottom sensor iGPS and LTD500) at an angular velocity of 120°/s for 4 revolutions of the rotating arm. The 3D tangential deviations (iGPS) are nearly in the same order as the deviations of the horizontal rotating arm position.

The sum of these findings shows that the development of the latest iGPS system has been successful in reducing the theoretical delay time. For path tracking (3D) up to velocities of 3 m/s the deviations are less than 0.3 mm. If spatiotemporal positions (4D) are required then there is a time offset about 0.3 ms and the deviations increase with the sensor velocity. Approximately 1 mm at 3 m/s was observed. iGPS can be used as a static or kinematic measuring system and due to the flexible measuring performance it provides an interesting range of applications.