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Preliminary Tests of Application of RV3 Robot for IMU Testing and Calibration

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Abstract. The procedure of calibration of IMU sensors is a very challenging and time consuming task. In order to simplify this process a proposition of an automatic station for IMU calibration is presented in this paper. The use of industrial robot allows for unlimited test trajectory design with high precision reference data. In the article a test stand based on the industrial Mitsubishi RV3 robot is presented. The preliminary test included series of movements of ADIS 16354 6DOF IMU sensor mounted on the robot header. The data gained simultaneously from the IMU sensor and the the robot header trajectory were recorded with the PC. Next, the obtained sets of data in the time domain were translated to the unified coordinates and compared. Finally the differences betwen information comming from both sources were calculated and sensor gyro drift was estimated. The results presented in the the paper show that assumed conception makes it possible to determine the drift of the gyroscope in dynamic conditions.

Keywords: IMU, industrial robot, calibration.

Conference topic: technologies of geodesy and cadastre.

Introduction

The MEMS (Micro Electro Mechanical Systems) is the technology of microscopic devices with moving parts. There is a variety of MEMS devices among which IMU-s (Inertial Measurement Unit) are of major importance. These devices are present in almost every modern smartphone or tablet. People are using it to control virtual and augmented reality. They have also a lot of applications in navigation, medical and mechanical industries.

The MEMS IMU-s are not very precise devices but their small size and low price designates them to wide use. There is a lot of research topics related to these sensors. One of them is their accuracy characteristics (Tomaszewski *et al.* 2015; Titterton, Weston 2009).

The IMU errors can be classified in two categories – systematic and random errors. Random errors are modelled stochastically in order to mitigate their effects. The most common errors are (Groves 2008):

– Bias stability.
– Scale factor instability.
– White noise.

The most common systematic errors are (Noureldin *et al.* 2013):

– Constant bias.
– Scale factor error.
– Scale factor sign asymmetry.
– Dead zone.
– Non-orthogonality error.
– Misalignment error.

The character of systematic errors is permanent. They must be determined in laboratory calibrations and compensated during measurements. To determine the size of systematic errors a dedicated devices (like rotation plates) are used. In this paper the idea of replacing the laboratory devices with RV3 robot is presented.

RV3 robot and experiment setup description

In order to test the IMU device the experimental station was prepared. This station allows to make repeating sequences of the robots tool. In order to obtain a large flexibility of the designed trajectory the 6-degree of freedom industrial robot was used. Figure 1 depicts the setup of the experiment. It consists of an industrial Mitsubishi RV3 robot together with a PC used for data registration. In this tests ADIS 16354 IMU unit was used (ANALOG DEVICES Data Sheet ADIS16354).

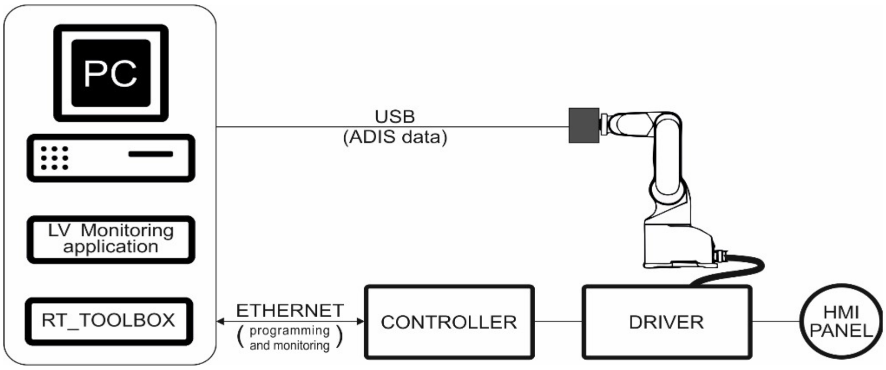

Fig. 1. Experiment setup

The coordinate system of a robots workspace is presented in Figure 2 while its construction is presented in Figure 3. The coordinate system is a Cartesian left handed system with z axis along the robot rotation axis and x axis to its front.

Fig. 2. Coordinate system of a robot (MITSUBISHI 2009)

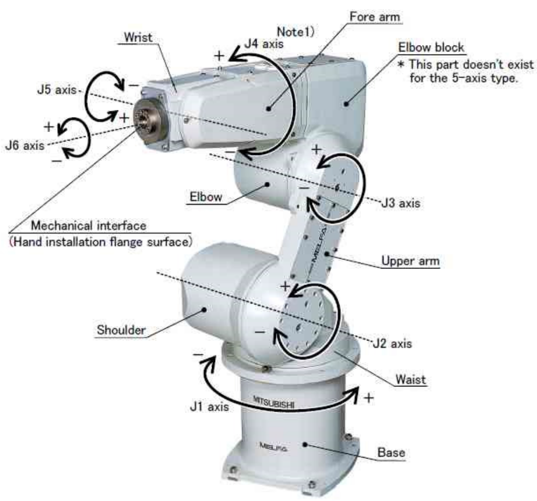

Fig. 3. Construction of the robot (MITSUBISHI 2009)

Movement of the robot head in time and space was controlled by a dedicated PLC controller (marked CONTROLLER in Fig. 1) connected to the robots driver with fiber wire network SSCNET III. ADIS IMU was mounted on the robots head. Pose repeatability of the robot header in accordance with JIS 8432 and ISO 9283:1998 is ±0.02 mm. The used current position detection method was based on the absolute encoders feedback values (J1, J2, J3, J4, J5, J6).

The ADIS sensor mounted on the robots head is depicted in Figure 4. ADIS16354 is an integrated inertial navigation unit developed by Analog Devices. It contain a tri-axis accelerometer with 0.135 m/s/h velocity random walk and ±1.7 g dynamic range and tri – axis gyroscope with 4.2 °/h angular random walk and dynamic range from ±75 to ±300 °/s (ANALOG DEVICES 2009).

The trajectory of the IMU coordinate frame origin and rotation synchronization was programmed in the robots software Rt_toolbox. During the tests robot head coordinates (XYZ) and rotation angles along robot axis (ABC) were recorded simultaneously with IMU accelerations and angular velocities. Data read from robot were transmitted to the PC using UDP Ethernet protocol. IMU data was transferred using USB working in CDC class. Data received by the PC were visualized on-line using application prepared in Lab View environment. Figure 5 depicts an example of on-line visualization.

Fig. 4. Robot head with ADIS

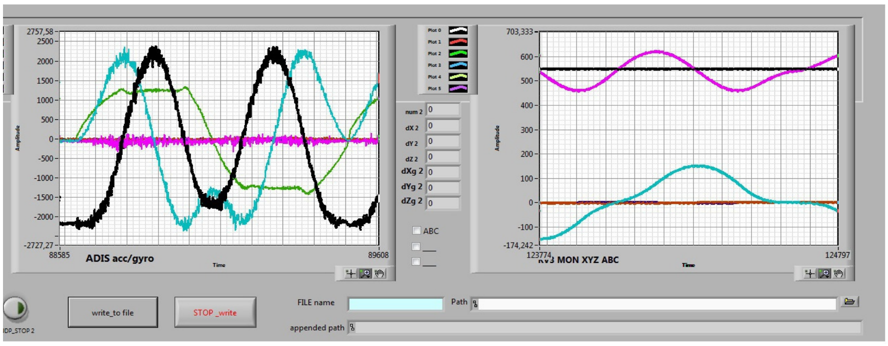

Fig. 5. Example data visualization

The results presented in this paper were obtained as a result of the head movement along the trajectory presented in Figure 6.

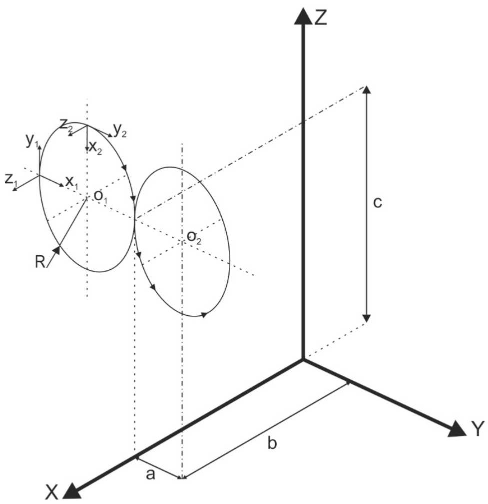

Fig. 6. Trajectory of robot head

The x1, y1, z1 and x2, y2, z2 coordinate systems depicted in Figure 6 are related to the momentary location of the IMU.

For this test the movement was conducted in the ZY plane, but any other trajectory is possible.

Results of the preliminary tests

For the purpose of this elaboration, the gyroscope readings were used. The IMU unit was moving along the trajectory presented in Figure 6. Resulting gyroscope readings are presented in Figure 7.

In order to obtain angles around each axis the results must be integrated (neglecting the errors for now). From Figure 7 it can be noticed that vast part of the rotation is around z-axis of the IMU unit which corresponds to the x axis of the robot. Integrated gyroscope readings for z-axis along with robot rotation around x axis are presented in Figure 8.

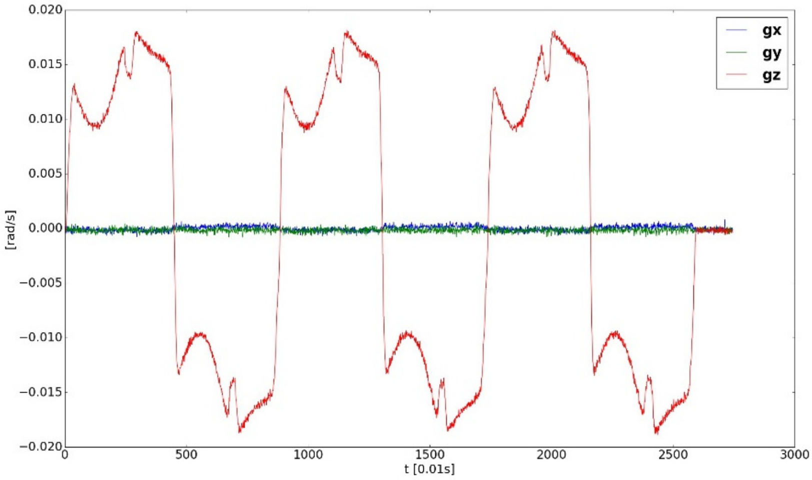

Fig. 7. Raw gyroscope readings

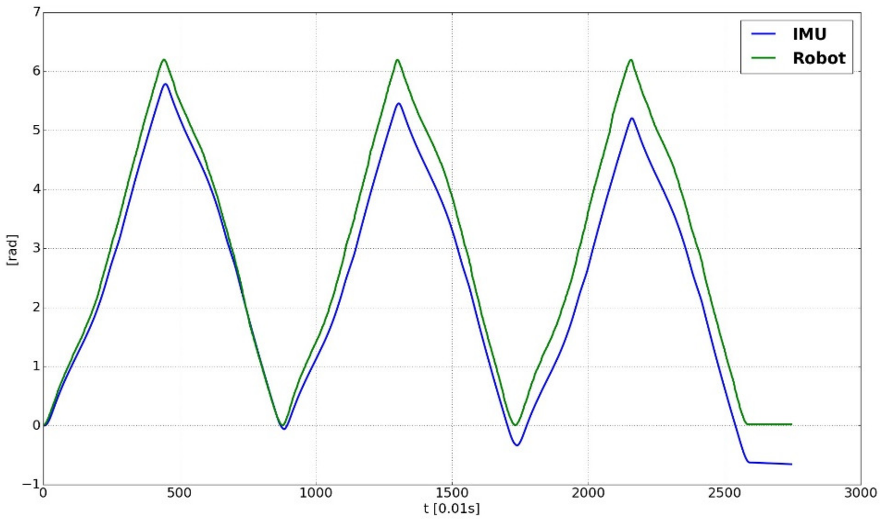

Fig. 8. Integrated gyro readings and RV3 angle measurements

It can be observed that the gyro readings are drifting away from the robot readings. This is caused by the gyroscope drift. In order to estimate the size of the drift a line was fitted into the differences between the above data. The results are depicted in Figure 9.

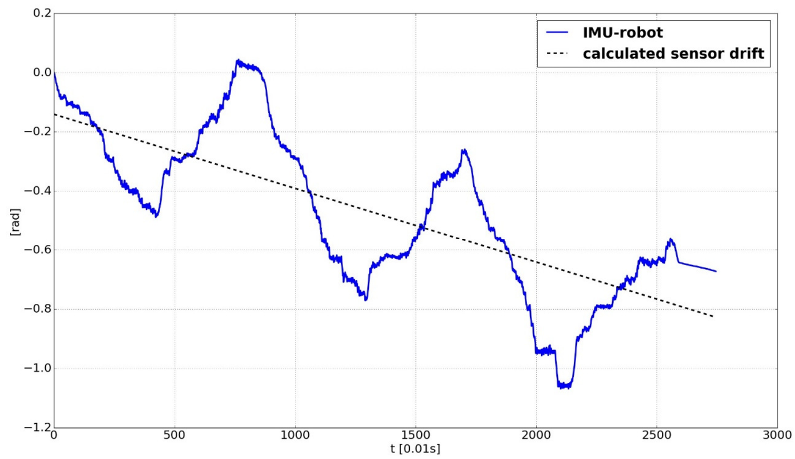

Fig. 9. Difference between robot readings and IMU readings

The residual oscillations are caused by the imperfection in the experiment setup. For the test purposes the IMU was not mounted perfectly parallel to robot axis. Resulting bias stability is about 1.45 deg/s. This is much better result than the one stated in the datasheet. After correcting the gyro results with the calculated drift, the results can be compared again with robot readings (Fig. 10).

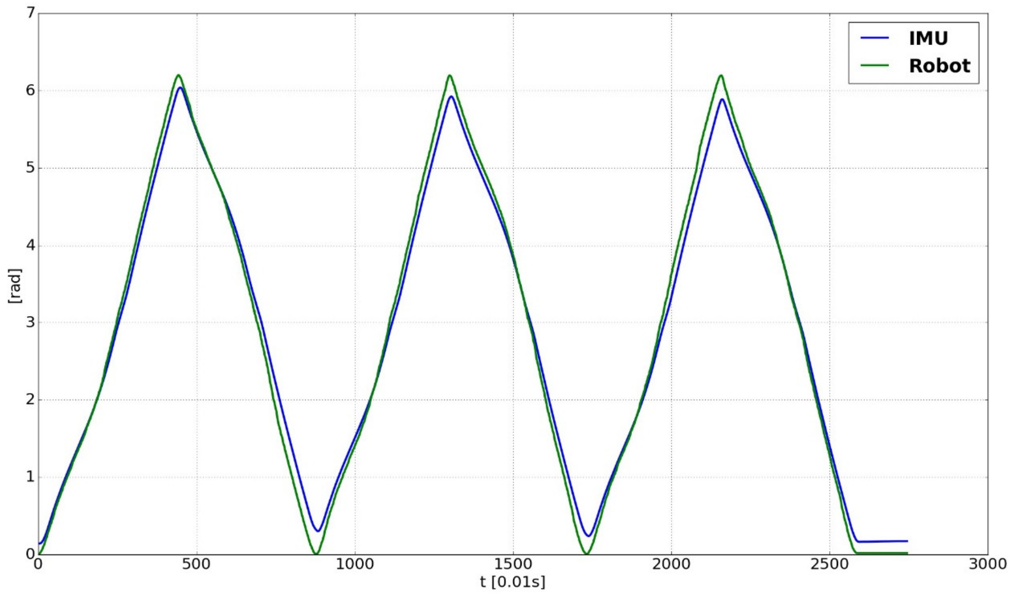

Fig. 10. Comparison of the results after removing the drift

Results shows that the bias was removed successfully. The difference in scale can be caused either by not correctly determined scale factor or axis being not orthogonal.

Discussion

Obtained results encourages for further tests and development of the IMU testing and calibration platform. The use of industrial robot allows for unlimited trajectory design with high precision reference data. In the presented example the drift of the gyroscope in dynamic conditions was successfully determined and removed.

On the basis of further analysis a scale factor instability, offsets and many more factors can be calculated. As a result of this and further research a station for automatic calibration of IMU sensors will be developed.

Conclusions and future works

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