

Nine-Axis IMU sensor fusion using the AHRS algorithm and neural networks

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Abstract—This paper presents data processing method for Attitude Heading and Reference System (AHRS) based on Artificial Neural Networks (ANN). The system consist of MEMS (Micro Electro-Mechanical Systems) based on Inertial Measurement Unit (IMU) consisting of tri-axis gyroscopes, accelerometers and magnetometers providing three dimensional linear accelerations and angular rates. Training data was generated by simulation fusion of samples collected during the flight of Quadcopter. The presented results shows proper functioning of the neural network. Moreover, the presented system provide the possibility to easily add other sensors e.g. GPS, in order to achieve better performance.

Index Terms—AHRS; IMU; sensor fusion; neural network; inertial navigation.

I. INTRODUCTION

The precise location in space plays an important role in many fields such as robotics [1], [2], navigation [3], [4], human motion analysis [5] and human-machine interface [6]. The sensors are used to accurately map the movement in space. However, the sensors are not perfect and not each one is suitable for everything. Often, multiple sensors are used to measure various physical values such as: linear acceleration, angular acceleration and the magnetic field. Data collected from these sensors must be combined in order to obtain complete information on the position in space. Data connections are made by using mathematical transformations describing the position in space using quaternions.

$$q_0 = e_x \sin\left(\frac{\vartheta}{2}\right) \quad (1)$$

$$q_1 = e_y \sin\left(\frac{\vartheta}{2}\right) \quad (2)$$

$$q_2 = e_z \sin\left(\frac{\vartheta}{2}\right) \quad (3)$$

$$q_3 = \cos\left(\frac{\vartheta}{2}\right) \quad (4)$$

A quaternion is a four-dimensional complex number that can be used to represent the orientation of a rigid body or

coordinate frame in three-dimensional space. Equations (1)-(4) show the components q_0 , q_1 , q_2 that contain vector of quaternion, q_3 is the scalar component, where e_x , e_y , e_z are the principal axis and ϑ is the principal angle [7], [8].

$$roll = \tan^{-1}\left(\frac{2(q_1q_2 + q_0q_3)}{q_3^2 - q_2^2 - q_1^2 + q_0^2}\right) \quad (5)$$

$$pitch = \sin^{-1}(-2(q_0q_2 + q_1q_3)) \quad (6)$$

$$yaw = \tan^{-1}\left(\frac{2(q_0q_1 + q_3q_2)}{q_3^2 - q_2^2 - q_1^2 + q_0^2}\right) \quad (7)$$

Transforming the quaternion to the Euler representation of angles is simple. It is done via Equations (5)-(7).

Calculations made using the AHRS algorithm were used to learn ANN. Designed ANN has nine inputs representing the various axes of each of the sensors, while at the output there are three signals corresponding to the description of the position in space of Euler angles (Roll, Pitch, Yaw).

II. MULTISENSOR DATA FUSION

Attitude Heading and Reference Systems are able to provide a complete measurement of orientation relatively to the direction of gravity and the earth's magnetic field. An orientation estimation algorithm is a fundamental component of any IMU system. It is required to fuse together the separate sensor data into a single, optimal estimation of orientation.

The first step is to read the sensors data. Then performed to normalize samples from inertial sensors and the reference sensor magnetic field of the earth. The next step is to determine vectors of acceleration due to gravity and the earth's magnetic field. Displacements are calculated on the basis of feedback and integral position designated in the preceding iteration of the algorithm. The rate of change of quaternion is calculated and used to calculate the position. The final step is to determine the position in space of Euler angles [9].

The use of ANNs allow for a faster determination of the current position due to faster time-to-answer. Trained ANN

allows to answer with better results than by making fusion calculations of multiple sensors without the use of advanced trigonometric calculations.

III. EXPERIMENTAL RESULTS

Fig. 1 shows the data collected from the three axes of three sensors. The samples were then analyzed with the help of the algorithm described in Section II, so processed data is shown in Fig. 2. That data were used to learn ANN.

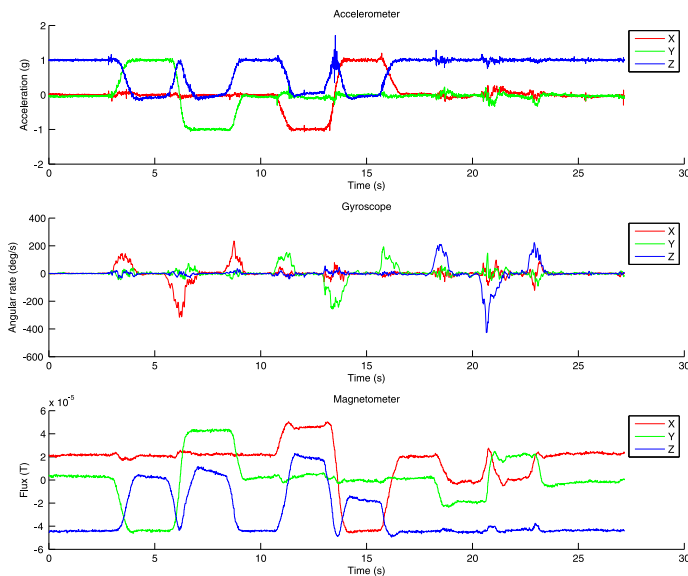


Fig. 1: Collected data samples

Comparison of the results obtained by direct calculation using the presented algorithm, and by the implementation of the ANN for Roll axis is shown in Figure 3.

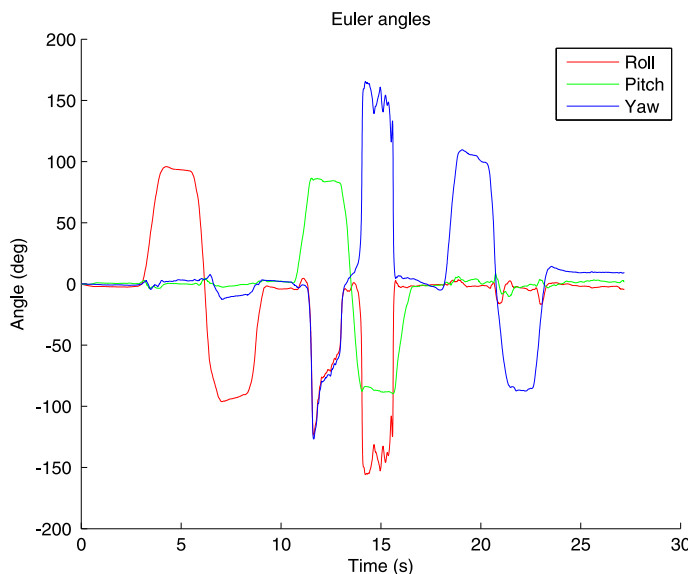


Fig. 2: Data after the fusion

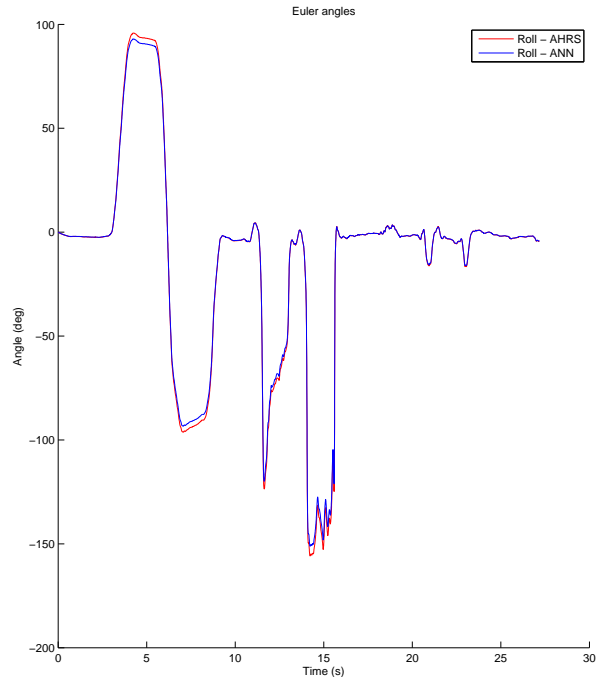


Fig. 3: Comparison of the results

IV. CONCLUSION

As can be seen from the comparison of the results in Fig. 3 the results of calculations using the AHRS algorithm and using an ANN to approximate this algorithm are sufficiently similar. This means that we can successfully use ANN for data fusion measurement of systems with multiple sensors. To get the better approximation, it is necessary to prepare a large data set for neural network learning.

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