Improving the Efficiency of the MPU-6050 Sensor Module for Inertial Drone Navigation

Article *in* Modeling Control and Information Technologies · November 2023

DOI: 10.31713/MCIT.2023.023

Elkhan N. Sabziev
Institute of Control Systems, Azerbaijan National Academy of Sciences

MCIT Modeling, control & information technologies

Improving the Efficiency of the MPU-6050 Sensor Module for Inertial Drone Navigation

https://doi.org/10.31713/MCIT.2023.023

Elkhan Sabziev
Laboratory of modeling and control of continuous processes
Institute of Control Systems
Baku, Azerbaijan
elkhan.sabziev@gmail.com

Tahir Alizada
Laboratory of methods of recognition and intelligent analysis of signals
Institute of Control Systems
Baku, Azerbaijan
tahiralizada1973@gmail.com

Namig Heydarov
Innovative research group
Institute of Radiation Problems
Baku, Azerbaijan
nmq.heydarov91@gmail.com

Abstract—**We investigate the problems of noise reduction in navigation data supplied by an accelerometer and a gyroscope. The MPU-6050 sensor module, which is often a component of drone navigation systems, was used in the experiments. To smooth the data, the use of "simple averaging method" and "moving average method" is recommended. We show experimentally that the data smoothing methods reduce the errors by more than 10 times. It is also shown that the "simple averaging method" can reduce the hardware load by more than 10 times compared to other data processing methods.**

Keywords—navigation; drone; unmanned aerial vehicle; MPU-6050; inertial sensor; accelerometer; gyroscope; noise.

I. Introduction

As a rule, global navigation satellite systems (GNSS) such as GPS (USA), GLONASS (Russia), BeiDou (China), Galileo (Europe) and DORIS (France) are used to determine the location of drones [1], [2], [3]. All five systems are available with the use of dedicated navigation or geodetic receivers anywhere on the Earth's surface. In addition to global navigation systems, there are regional systems: IRNSS (India) and QZSS (Japan). These satellite navigation systems can be used only in India and Japan, respectively.

Despite the seemingly universal accessibility of satellite navigation, in certain conditions its use can be unreliable and sometimes impossible. One such condition is the use of drones (kamikaze drones, reconnaissance drones, etc.) in armed conflict areas. Satellite navigation signals in such areas are jammed by special radio electronic systems. Thus, there is a need to develop alternative navigation systems.

Among alternative navigation systems with respect to radio electronic (including satellite) systems, inertial navigation is considered to be the most effective [3], [4], [5], [6]. In recent years, many miniaturized, relatively cheap and quite accurate inertial sensors (accelerometers and gyroscopes) have appeared on the world market. It is especially convenient to use them as part of a single module, such as MPU-6000 or MPU-6050 (Fig. 1) [7].

Figure 1. MPU-6050 sensor module [8]

II. Problem Statement

In this paper, we aim to improve the efficiency of the MPU-6050 sensor module by selecting the optimal sampling frequency F of inertial sensors for collecting navigation data and the amount of navigation data N taken for averaging (in order to reduce the noise interference). Preliminary studies have shown that both parameters have an impact on the system and its result. For instance, an overestimation of the F parameter leads to a strain on the computational resources of the system, while an underestimation reduces the accuracy of the computed navigation data due to the influence of noise. An overestimation of the parameter N in turn also overloads the CPU of the system, while an underestimation increases the influence of noise.

Thus, in order to find the optimal values of the parameters F and N, appropriate computational experiments should be carried out. For this purpose, we built a hardware unit with the MPU-6050 module and the ability to connect to a computer via USB 2.0 Type A connector. Special software was also developed to control this hardware unit and record data from the inertial sensors (accelerometer and gyroscope) of the MPU-6050 module.

III. FINDING THE OPTIMAL VALUE OF THE PARAMETEER *F*

As mentioned above, the parameter F is the sampling frequency of the inertial sensors (accelerometer and gyroscope) to collect navigation data. As can be seen from the graphical interface (Fig. 2) of the hardware unit control program, for the computational experiment, the user is prompted to select the sensor sampling frequency within the range of 1 Hz to 10 Hz.

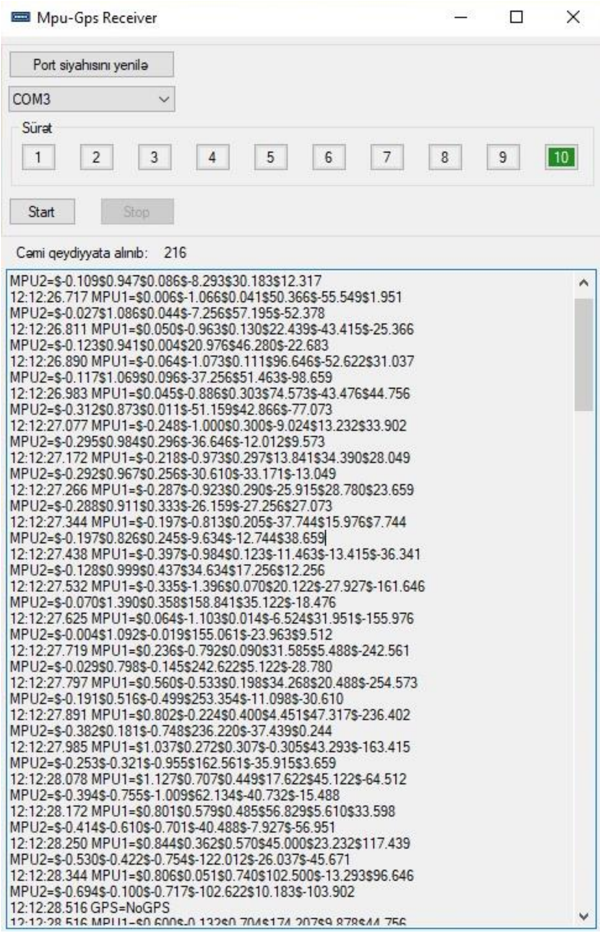

Figure 2. Graphical interface of the control program of the hardware unit equipped with the MPU-6050 sensor module

The computational experiment has shown that the accuracy of the end results, i.e., the averaged inertial data, increases with the increase of the sensor sampling frequency. The computational resources of the hardware unit here are quite sufficient for the maximum value of the sampling frequency (10 Hz). Thus, the sensor sampling frequency of 10 Hz of the MPU-6050 module is recommended as the most effective one available for use in inertial navigation of a drone in real conditions. Furthermore, for further improvement of the inertial navigation system, it is recommended to modify the hardware unit (containing the MPU-6050 sensor module) and the control program to increase the sampling frequency to the highest possible for the MPU-6050 module. In this way, the range of sensor sampling frequencies will be increased, opening up new possibilities for computational experiments.

IV. FINDING THE OPTIMAL VALUE OF THE PARAMETEER *N*

As mentioned earlier, the parameter N is the amount of navigation data taken for averaging (in order to reduce the noise interference). For this purpose, we propose to use two well-known smoothing methods - "simple averaging method" and "moving average method".

A. *Simple averaging method*

This method consists in the following. The MPU-6050 sensor module reads a certain amount N of inertial data, which are then averaged (summed and divided by their amount N):

$$A_j = \frac{1}{N}\sum_{i=1}^{N} A_{(j-1)N+i}\ ,$$

$$G_j = \frac{1}{N}\sum_{i=1}^{N} G_{(j-1)N+i}\ .$$

Here,

$A_{(j-1)N=i}$ is accelerometer data,

A_j is averaged accelerometer data,

$G_{(j-1)N=i}$ is gyroscope data,

G_j is averaged gyroscope data,

j is the sequence number of the averaging segment including N of sensor data,

N is the amount of sensor data in each averaging segment.

As a result of the application of the method, one result is calculated for each observation segment consisting of N inertial sensor data. For instance, with N equal to 10, the total number of averaged values A_j will be 10 times less than all accelerometer values.

B. *Moving average method*

Smoothing by the "moving average method" is performed according to the following algorithm:

$$A_j = \frac{1}{N+1}\sum_{i=j-N/2}^{j+N/2} A_i\ ,$$

$$G_j = \frac{1}{N+1}\sum_{i=j-N/2}^{j+N/2} G_i\ .$$

Here,

A_i is accelerometer data,

A_j is averaged accelerometer data ($\frac{N}{2} < j < i_{max} - \frac{N}{2}$),

G_i is gyroscope data,

G_j is averaged gyroscope data ($\frac{N}{2} < j < i_{max} - \frac{N}{2}$),

j is the sequence number of the averaging segment including N of sensor data,

N is the amount of sensor data in each averaging segment (N should be only even number).

Unlike the previous method, in this moving average method the amount of averaged data is practically the same as the number of measurements. Thus, we have a continuous supply of averaged inertial data, which makes it possible to maintain increased navigation efficiency compared to the application of the "simple averaging method". This is an advantage of the "moving average method". The disadvantage is the increased load on the computational component of the navigation system due to the processing of a large amount of averaged data.

V. Results of Computational Experiments

In this section, the results of the computational experiments are outlined and analyzed. For the experiments, we have built a hardware unit (Fig. 3) containing the MPU-6050 sensor module inside and a GPS module that can connect to an external GPS antenna. The GPS in the hardware unit is designed to be used during intensive movement and was not used in this experiment.

Figure 3. Hardware unit containing the MPU-6050 sensor module

The software program described in Section III (Fig. 2) was developed to control the hardware unit.

In this paper, we present the results of a 20 s long observation of a stationary MPU-6050 sensor module. During the observation, the module was sampled at a frequency of 10 Hz. Thus, 200 pieces of navigation data for each component (x, y, z) from accelerometer and each component (x, z) from gyroscope that make up the MPU-6050 module were recorded. The control program (Fig. 2) generated MS Excel spreadsheets with the recorded navigation data of the MPU-6050 sensor module.

TABLE I. Results of the Computational Experiment without the Application of Smoothing Methods (F=10 Hz)

Data type	**Data processing results**		
	Average value	***Variance, 10^{-6}***	***Relative error, 10^{-3}***
Ax	-0.006	12.394	2.747
Ay	-0.991	11.504	2.687
Az	-0.032	26.482	4.178
Gx	-0.036	7411.86	68.460
Gz	-1.180	6154.46	61.673

TABLE II. Results of the Computational Experiment with the Application of the Simple Averaging Method (F=10 Hz, N=10)

Data type	**Data processing results**		
	Average value	***Variance, 10^{-6}***	***Relative error, 10^{-3}***
Ax	-0.006	0.833	0.209
Ay	-0.991	0.804	0.201
Az	-0.032	2.434	0.414
Gx	-0.036	611.863	5.334
Gz	-1.180	554.463	5.112

TABLE III. Results of the Computational Experiment with the Application of the Moving Average Method (F=10 Hz, N=10)

Data type	**Data processing results**		
	Average value	***Variance, 10^{-6}***	***Relative error, 10^{-3}***
Ax	-0.006	0.830	0.201
Ay	-0.991	0.801	0.199
Az	-0.032	2.429	0.411
Gx	-0.036	611.859	5.329
Gz	-1.180	554.448	5.101

The conducted experiments have confirmed the conclusions of our previous studies about the significant noise contamination in navigation data supplied by the accelerometer and gyroscope of the MPU-6050 sensor module.

As can be seen from the tables, the average value of navigation data does not change, which is to be expected based on the averaging mechanism. At the same time, the variance and the average relative error were reduced by more than 10 times after smoothing. This confirms the effectiveness of the applied smoothing methods at F=10 Hz and N=10 points in each averaging segment. Thus, the application of the above methods will make it possible to significantly reduce the noise in the navigation data obtained from the MPU-6050 sensor module and thus improve drone navigation.

VI. Conclusion

Analysis of the results of the computational experiments yields the following conclusions:

- Navigation data are extremely noisy. Therefore, it is necessary to apply one of the smoothing methods.
- The "simple averaging method" and the "moving average method" give satisfactory results for smoothing navigation data. The errors are reduced by 10 times and more.
- The "simple averaging method" requires much less computational resources and is therefore recommended for drone navigation as more efficient than the "moving average method".
- A maximum frequency of 10 Hz is recommended as the most effective sensor sampling frequency available for the MPU-6050 module (1 Hz to 10 Hz). We assume that the optimal frequency will be higher than 10 Hz. To find it, a modification of the hardware unit and control program is recommended with the possibility of increasing the sampling frequency of the MPU-6050 module sensors to at least 100 Hz.

REFERENCES

[1] C. Rhodes, "Global Navigation Satellite Systems," Murphy & Moore Publishing, 2022.

[2] B. Bhatta, "Global Navigation Satellite Systems: New Technologies and Applications," CRC Press, 2nd edition, 2023.

[3] M.S. Grewal, A.P. Andrews, and C.G. Bartone, "Global Navigation Satellite Systems, Inertial Navigation, and Integration," Wiley, 4th edition, 2020.

[4] D.A.A. Cicci, "A Short Course in Inertial Navigation and Missile Guidance (Short Courses in Aerospace Engineering)," Independently published, 2022.

[5] M. Braasch, "Fundamentals of Inertial Navigation Systems and Aiding," Scitech Publishing, 2023.

[6] C. Jekeli, "Inertial Navigation Systems with Geodetic Applications," 2nd edition, Walter de Gruyter, 2023.

[7] "Sensors Modules MPU-6050 Gyroscope Accelerometer." [Online]. Available: https://www.electronicwings.com/sensors-modules/mpu6050-gyroscope-accelerometer-temperature-sensor-module. [Accessed: Octember 15, 2023].

[8] "MPU-6050 Module." [Online]. Available: http://wiki.sunfounder.cc/index.php?title=MPU6050_Module. [Accessed: Octember 15, 2023].