Research and natural modeling of an inertial system on a mobile platform

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Abstract. This article is dedicated to the research of inertial sensors application. A number of issues of the measurements organization, the received data calibration and the results interpretation are investigated here. Theoretical researches are compared with the practically obtained data. The explored mobile platform is equipped with inertial sensors and high precision encoder. The mathematical model was constructed, the comparative experiments were carried out. It was concluded that the use of this method is a complement to the data obtained from the encoders.

1. Introduction
Nowadays the issue of positioning and defining the position of the mobile platforms is very relevant, because such platforms are widely used in storage systems, delivery systems and become widespread. This issue may be solved by different methods [1-4]. Inertial systems are well described and used for aircraft design (for example, quadcopter stabilization systems) [10]. The possibility of using inertial sensors for surface platforms can be researched scientifically. It’s worth noting the economic part – the cost of the encoder is much higher than the cost of the inertial sensors.

The main purposes of the platform development are creating motor control system with smooth power control [5-9]; providing motor speed tracking and management; current and voltage management; real-time regulation and synchronization of the motor speed; providing the autonomous trajectory construction according to the specified input parameters, realization of this trajectory.

The scheme of the electronic subsystem organization and the dimensional drawing of the mobile platform shown in the figure 1.

Figure 1. Electronic subsystem and dimensional drawing of the mobile platform.
2. Carrying out the experiment

Several tasks have been solved to provide a proper work and inertial systems research. The algorithm of joint work of two microcontrollers, data transmission by communication protocols, information retrieval from encoders and inertial sensors was worked out. A convenient protocol of interaction between a PC and a microcontroller was implemented, a mathematical model of the system consisting of two motors and the platform was worked out.

The experiments performed on the layout shown that using GPS sensors as a precise positioning sensors (including the definition of the initial position) is incorrect problem, because the accuracy of 1-3 meters in the laboratory space is not enough. Incremental encoders with a resolution (reduced to wheel diameter) of 0.98 mm/pulse were used as an independent speed/position sensor.

The next stage of the work was the evaluation of positioning by the method of double integration of accelerometer data and evaluation of intrinsic noise, several sensors were investigated (MPU 6050 и MPU 9250). The sensors were fixed strictly parallel to the XOY plane on the base of the platform. The sampling rate is 200 NS, 30 samples, 10 experiments. 30 samples corresponds to 6s, which corresponds to the average maneuver of the platform. The data were calibrated by averaging and offset accounting of the previous series of the experiment.

The mathematical formulation of the problem is quite simple. To get the traveled path (let's say the x coordinate), it’s enough to integrate the accelerometer data twice (1), i.e.

\[ S_x = \int_0^t \int_0^t a_{x} \, dt \, dz. \]  

(1)

However, the experimental use of this expression revealed several negative factors:

- discreteness of time samples; it requires a transition to a numerical integration scheme (the trapezoid method was used). The problem of errors accumulation can be solved by reset and recalibration of the sensor after the trajectory segment executed;
- vibration interference from running motors, the imperfection of the drive design, irregularities of the route and other unpredictable factors. Based on the nature of the interference, we can make some assumptions: since we obtained approximate mass-dimensional and inertial parameters of the mobile platform as a result of the simulation, it’s possible to estimate the spectral distribution of interference from the operating drives, knowing the approximate characteristics of the motors and their rotation speed.

As a result of the analysis of the obtained graph, a conclusion about the need for primary filtering of the obtained data was made. Three filter versions were considered. There are average, median and exponential filter versions. It was accepted that the errors affecting the mobile platform and the sensor-accelerometer have the same nature. The approach requiring the creation of the Kalman filter was simplified and reducing it to exponential (2).

\[ x_{n+1} = K_{z_{n+1}} z_{n+1} + (1 - K_{z_{n+1}}) x_n. \]  

(2)

After the designing of the system, several experiments were carried out and the profiles of acceleration/braking of the mobile platform, presented in figure 2, were constructed [9]. The results of the experiment were controlled due to encoders. The deviation was about 3-5% depending on the experiment. The research of the problem of using accelerometers in such tasks allowed us to conclude that the obtained deviation value is typical for these types of sensors.
At the next stage of work, a mathematical model of the drives was built, delays in the microcontroller were considered, regulators were developed to implement individual stabilization of the speed of each of the engines. This approach gives a satisfactory result. On the length of the path in 2000mm for 2s deviation from the straight path will not exceed 10mm, but the resolution of the encoder with a wheel diameter of 125 mm will be approximately 0.98 mm / s and possible ways to further clarify. It’s necessary to enter cross-links in the speed controller and estimate the speed of the motors by the encoder or the position of the mobile platform using the sensor (gyroscope/accelerometer) [10]. Suppose that it is possible to estimate the withdrawal of the platform. It’s possible to demonstrate the possibility of compensating this negative effect using the simplest P-regulator. The result of the simulation is shown in figure 3. It can be seen that theoretically it’s possible to obtain a deviation of less than 1.5 degrees. The accuracy is determined by the accuracy of the angle measurement, by the inertial system sensor, by the accuracy of the input action of the drives and the mechanics of the mobile platform.

As a result of real experiments, the efficiency of the synthesized regulator was confirmed. Comparison of simulated data with real data showed a difference of about 30%, which can be considered a very good result. A series of the experiments showed overshoot in speed, noticeable at the start but not affecting the trajectory.
3. Conclusions
As a result of the research, several important conclusions were made: inertial sensors, due to the nature of their work on the surface platform, can be used, but less effectively than in flight systems. Inertial systems on surface platforms should be used as an additional motion analysis system to calculate the dynamic characteristics of the system, to analyze the initial angular position of the system and trajectory correction. It is possible to recalculate the angular velocity of rotation of the mobile platform and estimate the trajectory.

In the future, it is planned to use several sensors with a complementary filter, modify the design of the mobile platform, replace the microcontroller with a more productive one to use more complex filtering algorithms and reduce delays in data processing and transmission.

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