Research and Design of a Motion Sensor Based on MEMS

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Abstract. Carrier attitude is important parameters for carrier manipulation and control and is the key element for effective operation of ship-board equipment such as satellite communication devices, multi-beam and so on. The traditional attitude sensor has some defects in price, volume and electricity consumption, and it is difficult to meet the actual needs of the enterprise. In this paper, a three-dimensional attitude sensor based on MEMS is designed, and the Kalman filter is used to integrate data to improve the detection precision. The comparison experiment shows that the sensor can meet the actual demand in cost, precision and operation stability.

1. Introduction
In order to ensure the operation accuracy many ship-board equipment must effectively control the operating attitude, such as ship-board satellite communication receiving equipment must be required to be aligned with the satellite direction which can guarantee receiving and sending the signal effectively [1, 2]. The multi-beam sounding system gets the footprints of the seafloor terrain by transmitting wide sector sound waves to the sea bottom by using a transmitter array. With the proper processing of these footprints, one detection can give the depth of water depth measured by hundreds or even more of the seabed on the vertical plane of the vertical which can accurately and quickly measure the size, shape and height of the underwater target along a certain width, and reliably depict the three-dimensional characteristics of the seabed terrain. When the multi-beam is working the ship’s, posture will be changed inevitably affected by the waves, wind, tidal effect which will affect the measurement accuracy. The main reason is that the transmitted sound beam does not reach the predetermined seabed. Therefore, the size of the measuring ship and the measurement of the weather seriously affect the effect of the measurement [3, 4].

In order to effectively compensate for the influence of ship attitude change on the measurement accuracy, we develop the MRU (motion reference unit) to get the ship's attitude change and reduce the measurement error by real-time dynamic compensation in the measurement. At present, the attitude sensors in the world are commonly used by the British TSS company's MRU products for performance comparison, which can meet the actual precision requirements.

2. System implementation and analysis
At present, SGPS-MRU consists mainly of tilt sensor based on tilt sensor and inertial sensors based on gyroscope and accelerometer. Although the former has high accuracy in terms of accuracy and working temperature, it has the characteristics of slow reaction speed and unable to measure the...
navigation angle and so on, which cannot meet the needs of ship-board equipment. With the development of gyroscope and accelerometer inertial sensor technology, the sensor price has been greatly reduced, get the motion of the angular velocity and angular velocity information by using the sensor, and get instant 3D pose of an object, with more details and research in this field, can better meet the application and it has gradually become the mainstream of application because of the advantages of micro electro mechanical system in volume, precision and reaction speed. This paper uses the MEMS inertial sensor to complete three-dimensional sensor structure design, as shown in Fig. 1, in which the MEMS sensor mainly includes three axis gyroscope, accelerometer and magnetic device, DSP is used to deal effectively with the gyroscope data acquisition, the output of 3D pose, FLASH program, SDRAM is used to calculate the data stored in DSP JTAG, for download, RS232 serial port for PC communication.

![Three-dimensional motion attitude instrument](image)

**Figure 1. Three-dimensional motion attitude instrument**

Kalm filter can complete the signal from frequency domain to time domain conversion, is an important part of the modern control theory, the core of the theory is to obtain the current system according to the system state and measurement on a time the value of the state, does not need to store more data as before, and less storage space. The principle of the basic algorithm of Kalm filter is showed as:

\[ \theta_i = \theta_{i-1} + (\omega_i - \omega_{i-1}) \Delta t \]  
\[ c_2 = a_2 + b_2 \]
\[ c_2 = a_2 + b_2 \]

Among them, \( \theta_i \), \( \omega_i \) as the moment angle and acceleration, \( \Delta t \) as the sampling time interval, \( A \) as state transition matrix, \( B \) as matrix, \( H \) as the relationship between the state variables and the measured values of \( Z \), for measuring the value of this system, \( \phi, \psi \), respectively for the process noise and measurement noise, the establishment of general Gauss white noise model. In the above expression,
the relevant parameters are determined by collecting data and time intervals, and noise is obtained through the effective regression time series.

3. System implementation and analysis
The software part of the system mainly includes the interface program of STM32 and peripherals, STM32 control program, signal processing algorithm program and PC serial port program. User monitoring software (Fig. 2) mainly includes three functions: system configuration, data display and data recording. This software implements all user protocols, enabling users to configure the MRU devices through the boundary, and observe the measurement results in real time, and automatically save data to the file.

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![Figure 2. User monitoring software](image)

4. Experiment
In order to test the performance indicators of the independent research and development of SGPS-MRU, a comparative test was done between the MRU of the TSS company of the United Kingdom, which was borrowed from China Ocean first Institute. SGPS-MRU and TSS-DMS are fixed on the floor, and the direction is parallel and is on the ship with the direction parallel. In order to effectively test the performance of the laboratory under ideal environment and actual sea conditions, it was tested in the towing tank Laboratory of Zhejiang Ocean University and near the fishing port near Shenjiamen, Zhoushan, China. In the laboratory test, equipment was placed in the boat without power, and the boat rope is fixed on the operating platform for traction, fixed period and fixed wave by wave machine, 2 sets of MRU equipment at the same time collect and keep the attitude data, the test environment is shown in Fig. 3 as shown in the experimental results as shown in Fig. 4:
a. Laboratory tests

b. Actual sea test

Figure 3. Actual sea test

a. Laboratory pitch test
Figure 4. Laboratory roll test

b. Laboratory heaven test

c. Laboratory roll test

Figure 4. Laboratory roll test

Figure 4. Laboratory roll test

a. Sea pitch test

b. Sea heaven test
In Shenjiamen fishing port, a comparison test of 2 sets of MRU equipment was carried out, and a linear route was selected. The ship runs at a constant speed (about 3m/s), and a round trip constitutes a test. During the test, SGPS-MRU and TSS-DMS will output the roll, pitch and heave value in real time, and send it to PC through serial port. It will be displayed and recorded. The navigation node is shown in Table 1, and the 2 sets of equipment test data are shown in Fig. 5.

| Voyage route | start | 4th minutes | 13th minutes | 17th minutes | 25th minutes |
|--------------|-------|-------------|--------------|--------------|--------------|
| Starting equipment | Ship navigation | Ship turning | End the turn | End test |

5. Conclusion
In order to effectively solve the problem of ship sway impact measurement accuracy, a new three-dimensional attitude motion sensor is proposed in this paper. The sensor can get real-time angle information of the current equipment, complete the specified angle control, and meet the actual needs.

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