Proceedings of the 5th WSEAS Int. Conf. on Instrumentation, Measurement, Circuits and Systems, Hangzhou, China, April 16-18, 2006 (pp80-83)

Design and Implementation of Micro Inertial Measurement System

JIE LI, JUN LIU, WENDONG ZHANG

The Key Laboratory of the State Education Ministry on Instrumentation Science & *Dynamic Measurement, North China Institute of Technology, Taiyuan 030051, China*

Department of electronic science and technology, North University of China, Taiyuan 030051, China

Abstract:- Based on Micro Inertial Instruments, the integrated Micro Inertial Measurement System (MIMS) was researched. The system was designed with a variety of new design methods, such as software design, hardware design and system integration design. Both the working principle and the structure of the system were described. Finally, as an example of its experimentation, the running attitude of the swivel table was tested by the system and the relevant graph based on the tested data were presented, consequently the validity of MIMS was proved.

Key-words: - Micro Inertial instruments (MII); Micro Inertial Measurement System (MIMS); Testing system

1 Introduction

With the rapid development of micro/nano technology in recent years, The Micro Electro Mechanical System (MEMS) became one of the current research hotspots. Micro Inertia Measurement System (herein referred to as MIMS) is an important branch of MEMS used in the field of inertial measurement and navigation. It is a micro inertia device that performs the integrated measurement of six-dimensional movement parameters (pitch, yaw, roll, the accelerometers in *X*, *Y* and *Z* axle separately) in dynamic and harsh environments. In this way, the position and orientation of a flying object can be acquired. By adopting many advanced technologies, such as the design and machining of MEMS, and micro-packaging technology, MIMS features firm structure, small volume, light weight, high stability and low consumption, fitting for harsh environments and rapid response. The above advantages make MIMS a key part for the intelligentization and auto-target-seeking renovation of the conventional weapons, and also an imperative inertia guiding component of new tactics weapons, antiaircraft weapons and antiflying object weapons. In addition, through advanced manufacturing and assembling technology and integrated testing technology, MIMS can acquire high measure precision at lower cost. MIMS can be applied to many areas such as the military, space exploration, industrial robots, vehicles and even in toys! In civil field, it can also be used to measure the inertial parameters in car safety, super-precision manufacture and smart house appliances, etc. So, MIMS is of great significance in many aspects of our life [1-5].

Micro gyroscopes and micro accelerometers compose the sensor module of the Micro Inertial Measurement System (MIMS), an important part of system. With the introduction of micro/nano technology to the research and manufacture field of inertial sensors, micro inertial sensors emerged. They make the use of research achievements of modern physics and micro/nano technology in their material, craft and design, etc. Compared with the traditional inertial sensors, their size, weight and cost were decreased, and their stability, reliability and bearing capacity were increased.

The MEMS piezoresistance accelerometer was first studied in American in the early of 1979. Now the companies, such as Analog Device, Motorola and EG&G IC, etc. have produced accelerometers. The institutions like Draper Lab, GEC Company, Watson Company and JPL Lab in American, HSG-IMIT Company in German, etc. are researching micro-gyro. In China, micro-gyro and micro-accelerometer are studied by the Institute of Microelectronics of Tsinghua University, Peking University, Southeast University, Shanghai Institute of Micosystem and Information Technology, and the 13th Research Institute (Electronics) of MII. But for MIMS, few institutions are studying it.

2 Design of MIMS

2.1 Working principle of MIMS

The MIMS includes three-dimensional micromachined accelerometers, three-dimensional micromachined gyroscopes, a signal conditioning circuit and a signal calibrating circuit. It can be used to sense the position and attitude information of a flying object [1].

When the MIMS is been installed on the flying object, the angular speed of the flying object is measured by the gyroscope unit of MIMS and is further transferred into attitude information though a coordinate conversion matrix; the accelerations of the flying object is measured by the micromachined accelerometer of MIMS, this is further transferred into the acceleration information. If the above gyroscopes are velocity gyroscopes, it is called a velocity strapdown system. This kind of system can provide six independent inertial parameters including the attitude and position information of the flying object in real time manner. The core parts are the sensitive element and ASIC. The key technology is the orthogonality, repetition and error micro-compensation of element's testing vectors.

Fig.1 presents the combination of the sensitive head of MIMS with three integrated micro-accelerometers and three orthogonal micro-gyroscopes.

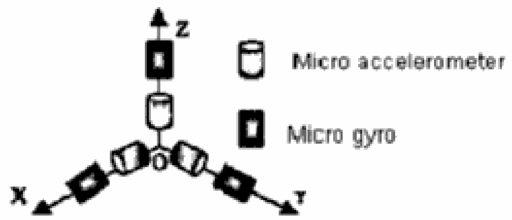

Fig.1 The sensing unit of MIMS

2.2. Structure design of MIMS

All sensing elements of the MIMS are solid-state devices. Three angular rate sensors are bulk micromachined vibratory MEMS sensors using Coriolis force to measure angular rate independently. Three MEMS accelerometers are surface micromachined silicon devices using differential capacitances to sense accelerations.The MIMS is an integrated micro system. Its angular signals and acceleration signals are detected with independent sensing heads. The angular and acceleration information can be directly acquired after the signal conditioning circuit. It adopts weak signal detecting technology, ASIC technology, dynamic compensation circuit design, interface technology, the integration technology of micro system and studies on the calibration of the whole system. Its structure includes shell, power module, sensor module, sensing conditioning and processing module and output interface socket. The structure sketch of MIMS is shown in Fig. 2.

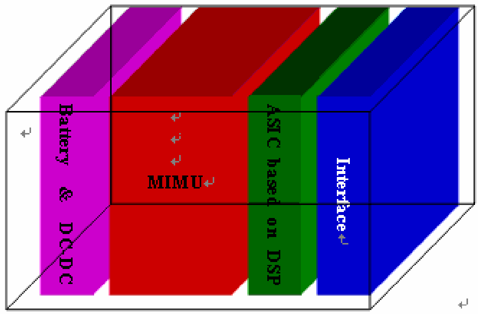

Fig.2.The structure of MIMS.

In Fig.2, the power module, the energy interface of the MIMS, receives +8V input voltage and provides the power of +5, +3.3, and + 1.8V voltages. The input and output power does not share the same ground. Sensor module is composed of three integrated orthogonal micro-accelerometers and three orthogonal micro-gyroscopes, it is also called as Micro inertial measurement unit (herein referred to as MIMU), and it is used to sense individually the angular speed and the accelerations of the flying object along its axes. sensing conditioning and processing module is composed of ASIC based on DSP, it perform the tasks such as the conditioning, the acquisition and the procession of the sensing information.Output interface socket, including input power supply, ground, three attitude angles and three position information (pitch, yaw, roll, the accelerometers in X, Y and Z axle separately).

2.3. Hardware design of MIMS

The hardware sketch of MIMS and connection ways between them are shown in Fig. 3. The system includes a sensor module, signal conditioning module,data acquisition, DSP signal process module, asynchronism serial communication module, and CPLD timing control module. In order to decrease size, weight and power consumption, all the selected components are microminiaturized. The size of system is 16cm×7cm×6cm, the mass is about 600g, and the power consumption is less than 5W.

The working process of the whole hardware is as following: MIMU sense the angle speed and the acceleration information of the moving object, then send these information to the signal module for transforming gain, enhancing drive and filtering, then send the new information after conditioning to the data acquisition module for transforming them to the digital signal, finally many computation (including coordinate transform, attitude matrix computation, and attitude and position computation) are performed in the DSP signal process module based on these digital information. During the working process, CPLD timing control module take charge the whole hardware timing, insure the normal running of MIMS, and asynchronous serial communication module answer for the communication with the portable computer by the RS232.

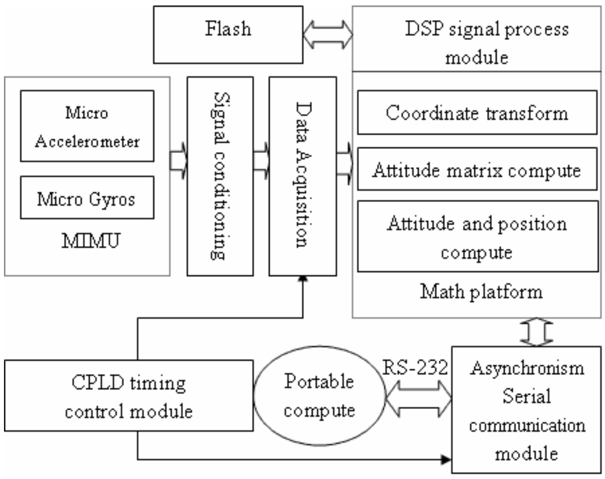

Fig. 3 The hardware sketch of MIMS

2.4. Software design of MIMS

According to the above working principle of MIMS, the whole software sketch of MIMS is shown in Fig. 4. Since the GyroChip™ Horizon gyroscope do not have enough accuracy to measure the rate of earth rotation, it is neglected during computing. Where, the subscript b denotes that the parameter is in the carrier coordinate, and the subscript *r* denotes that the parameter is in the reference coordinate. Then all the information demanded by MIMS can been computed by using the speed strapdown inertial navigation algorithm, Fig.5 shows the flow of the program computation, herein, we don't discuss it in detail.

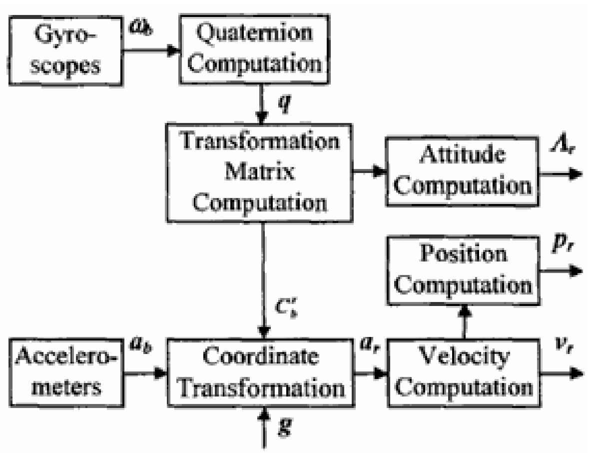

Fig. 4 The software sketch of MIMS

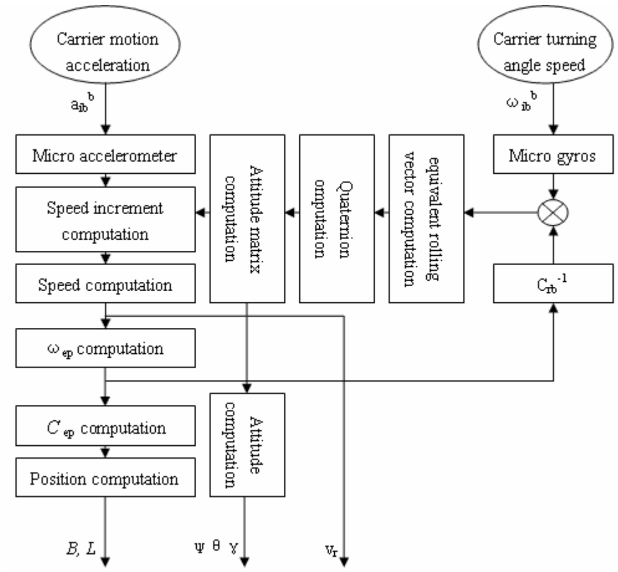

Fig. 5 Software implementation flow of MIMS

3 Experiment of MIMS

In order to prove the validity of MIMS, we have done many experiments of the attitude computation by using the three-dimensions multi-function speed and position swivel table, Fig. 6 is the experiment scene of testing attitude angle, Fig.7 is the displaying interface of the attitude angle (including roll, pitch and yaw) deduced through attitude conversion matrix by Runge–Kutta algorithm, Tab.1 are the comparison results between swivel table running attitude angle and the Attitude angle tested by MIMS. In the Tab. 1, the coloum ψ, θ ,and γ individually denotes the yaw, pitch, and the roll angle of the running swivel table, and the coloum ψ_t, θ_t, and γ_t individually denotes the yaw, pitch, and the roll angle tested by the MIMS, the unit of the attitude angle is deg.

From the Tab. 1, we can see the max difference between the relevant ψ and ψ_t is 1.79 deg, the max difference between the relevant θ and θ_t is 1.71 deg, and the max difference between the relevant γ and γ_t is 1.74 deg, all of them are less than 2 deg, it shows MIMS can availably work, meanwhile, and tells us that the precision of MIMS is lower than the traditional inertial measurement systet.

Fig. 6 The experiment scene

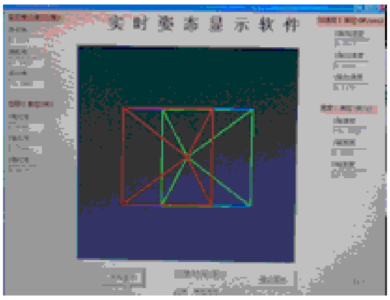

Fig.7 The displaying interface

Tab.1 Composition of the attitude angle

Swivel table running Attitude angle /deg			Attitude angle tested by the MIMS /deg		
ψ	θ	γ	ψ_t	θ_t	γ_t
90	90	90	89.63	91.05	88.98
180	180	180	178.89	180.37	181.25
360	360	360	361.35	361.09	359.31
720	720	720	718.28	719.02	721.74
1080	1080	1080	1081.71	1081.45	1080.98
1440	1440	1440	1440.59	1438.29	1439.01
1800	1800	1800	1801.35	1800.84	1799.02
90	360	540	88.21	359.09	541.27
180	1080	1440	180.67	1081.51	1439.83
720	90	360	719.02	91.71	361.45

4. Conclusion

By using the micro accelerometer and micro gyros, and treating DSP chip as the navigation computer, and adopting the classical navigation algorithm, a kind of micro speed strapdown inertial navigation system is designed from its total framework, the hardware framework and the software framework in this paper, finally the validity of MIMS is proved by the experiments, it provides the direct engineering experience for further researching the project application of MIMS.

References

[1] J. Liu, The testing and measurement technology research of space-time position of Micro rate strapdown Inertial Measurement Unit, Doctor Paper of The Beijing institute of Technology, 2001.

[2] J Barton, A Lynch, S Bellis, etal. An inertial measurement unit (IMU) for an autonomous wireless sensor network. Electronics Packaging Technology Conference, 2004, pp. 586-589.

[3] Donato Cardarelli. An integrated MEMS inertial measurement unit, IEEE0-7803-7251-4/02. 2002. pp.314-319

[4] B.S. Davis, Using low-cost MEMS accelerometers and gyroscopes as strapdown IMUs on rolling projects, IEEE0-7803-4330-1, 1998,pp. 594–601.

[5] H. Dong and W. Zhang. Micro inertial measurement system from China.IEEE Instrumentation & Measurement Magazine 2002(3),pp. 16–19.