2015 Fifth International Conference on Instrumentation and Measurement, Computer, Communication and Control

Design of Attitude Sensor Acquisition System Based On STM32

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Abstract—**The main controller STM32 is applied to the attitude sensor data acquisition system, which made reduce costs and development cycles. Firstly, according to the design requirement, the frame of the attitude sensor acquisition system is described. Secondly, the hardware circuit gives a design. The key circuits are described, and include MPU6050 circuit and STM32 interface circuit. Then, Using keil software to design the STM32 driver program, using LabWindows/CVI virtual platform to write the host computer program. Finally, the MPU6050 sensor is tested and analyzed in the LabWindows/CVI virtual platform; Through many experiments, it is found that the Kalman filter is more effective to reduce the error of the sensor.**

Keywords-component; STM32; gyroscope ; kalman filter

I. INTRODUCTION

As the attitude sensor acquisition system is improved, it is very important to study the error of the gyroscope. The errors of the system include systematic and random error, and the random error is the main error source of the system[1]. The attitude sensor acquisition system model is established, and the Kalman filter algorithm is used to eliminate the random noise in the gyro error and to improve the accuracy of the measurement. The object of the process is random signal, which has outstanding performance in real time.

The design of attitude data acquisition platform based on STM32, discuss the application of Kalman filter in the acquisition system ， and based on the technology of digital signal processing, the algorithm of Kalman filter is realized.

II. SYSTEM DESIGN

A. System Framework

The attitude acquisition data includes the acceleration data and the gyro data. The acceleration sensor detects the attitude inclination angle, and can be obtained by 3-axis accelerometer. The gyroscope detecting angular velocity. At present ADI company, FREESCALE company ,ST company and InvenSense company all produce similar attitude sensor chip. This system uses MPU-6050 (InvenSense company) to test the gyroscope and acceleration data.

The system use the STM32 microcontroller (ARM Cortex-M3 kernel) as the main control processor to complete the acquisition of attitude sensor data acquisition and processing, then using RS232 serial communication to sent the attitude sensor data to the host computer. Finally, the attitude data is processed and filtered by the host computer, so the attitude sensor sampling and data processing method are analyzed.

Through the RS232 communication software platform to send commands to the STM32 microcontroller, and the attitude data from the receiving STM32 processor, processing, display and save the data, so to attitude data and processing method were analyzed and compared.

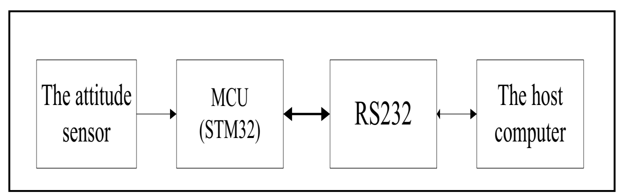

Figure 1. The system structure overview

B. Hardware Design

The system is designed based on STM32 microcontroller (ARm Cortex-M3 kernel) and MPU6050. The microcontroller can operate at a frequency of up to 72 MHz, on-chip integrated high-speed memory (256 KB of memory and 48KB of SRAM), rich enhanced awake I/O interface, greatly simplified the difficulty of engineering design. The attitude sensors (MPU6050) combine a 3-axis gyroscope and a 3-axis accelerometer on the same silicon, operating voltage of 2.4V to 3.5V. The parts feature a user-programmable gyro full-scale range of ±250 to ±2000 °/sec (dps), and a user-programmable accelerometer full-scale range of ±2g to ±16g. The device can access external magnetometers or other sensors through an auxiliary master I²C bus, allowing the devices to gather a full set of sensor data without intervention from the system processor. The attitude sensors MPU-6050 connect the control processor STM32F103RC through its I2C interface. The figure 2 gives a key part of the circuit.

978-1-4673-7723-2/15 $31.00 © 2015 IEEE
DOI 10.1109/IMCCC.2015.393

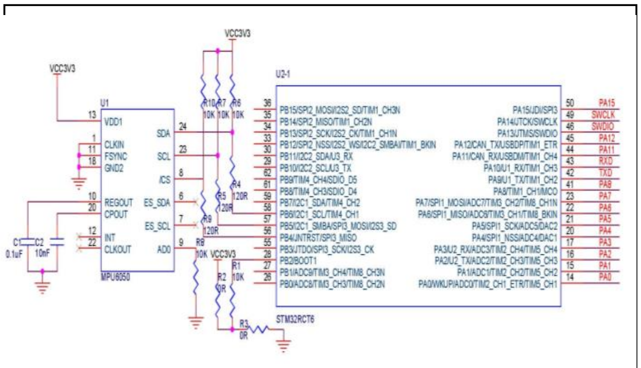

Figure 2. Schematic diagram of MPU-6050 and STM32

III. KALMAN ALGORITHM

A lot of readers have a certain understanding of the Kalman filter, here is not a detailed derivation of the kalman filter algorithm, combined with a brief description of the application[2].

- State equation:

$$X_k = A_{k-1} X_{k-1} + w_k \tag{1}$$

- Measurement equation:

$$Z_k = H_k X_k + v_k \tag{2}$$

In the above equations A and H are matrices, k is the time index; X is called the state of the system; Z is the measured output; and w and v are the noise. The variable w is called the process noise, and v is called the measurement noise.

These five equations of the Kalman filter for this problem are given as follows.

- The previous estimate of the state and the current value of the input.

$$\widetilde{X}'_k = A\widetilde{X}_{k-1} \tag{3}$$

- Calculate the a priori covariance

$$P'_k = A_k P_{k-1} A_k^T + Q_{k-1} \tag{4}$$

- The Kalman filter gain

$$K_k = P_k' H_k^T (H_k P_k' H_k^T + R_k)^{-1} \tag{5}$$

- This gain is used to refine (correct) the a priori estimate to give us the a posteriori estimates.

$$\widetilde{X}_k = \widetilde{X}'_k + K_k (Z_k - H_k \widetilde{X}'_k) \tag{6}$$

- Calculate the a posteriori covariance

$$P_k = (I - K_k H_k) P_k' \tag{7}$$

IV. MCU SOFTWARE DESIGN

STM32 takes overall system's control section, the programming uses the C language to program on the KEIL compiler realizes. The process is as follows:

STM32 complete the initialization for each module, include Serial module, IIC module, Timer, MPU6050 and PORTA module. And then, MCU program Microcontroller program to enter the circulation structure. Its main function is to receive the PC machine instructions through the RS232, and set up the operating parameters differentiating instruction. For example: Baud rate, MPU6050, Interrupt, start/stop sampling etc. After starting the interrupt, STM32 rely on an operating timer interrupt to perform sampling and sending data through RS232, sampling time defaults the 10ms.The figure 3 shows the flow chart of program.

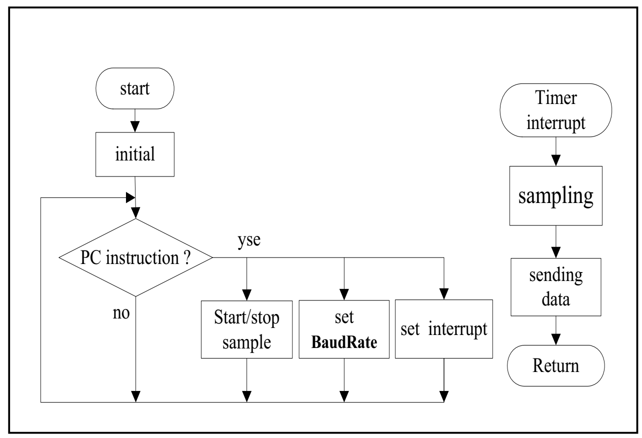

Figure 3. The flow chart of STM32 program

STMicroelectronics provides a firmware library for the ARM 32 STM32F103x series MCU. This firmware library contains a collection of routines, data structures and macros covering the features of all peripherals. Using this library saves time that would other wise be spent in coding, and reduces the application development and integration cost. Using the firmware library, the software configuration is briefly described.

A. MPU-6050

The MPU-6050 always acts as a slave to the STM32 with the SDA and SCL pins connected to the IIC-bus. After the completion of the initialization of the IIC-bus, MPU-6050 can be configured and controlled.MPU-6050 main control steps include wake up the MPU-6050, setting sample rate, configuring accelerometer and gyroscopes' full scale range. Here is configuration MPU-6050 process.

```
I2C_ByteWrite(PWR_MGMT_1,0x00);
I2C_ByteWrite(SMPLRT_DIV,0x07);
I2C_ByteWrite(GYRO_CONFIG,0x18);
I2C_ByteWrite(ACCEL_CONFIG,0x00);
```

B. RS232 serial

This design uses the STM32 serial port. Referring to the STM32F103xxx reference manual and the use of the STM32 firmware library, here gives the method of configuring the serial port under the use of the manual. The flowing is configuration RS232 process.

- Config USART1 clock

RCC_APB2PeriphClockCmd(RCC_APB2Periph_USART1 | RCC_APB2Periph_GPIOA, ENABLE);

- USART1 GPIO config

/* Configure USART1 Tx (PA.09) as alternate function push-pull */

GPIO_InitStructure.GPIO_Pin = GPIO_Pin_9;

GPIO_InitStructure.GPIO_Mode = GPIO_Mode_AF_PP;

GPIO_InitStructure.GPIO_Speed = GPIO_Speed_50MHz;

GPIO_Init(GPIOA, &GPIO_InitStructure);

/* Configure USART1 Rx (PA.10) as input floating */

GPIO_InitStructure.GPIO_Pin = GPIO_Pin_10;

GPIO_InitStructure.GPIO_Mode = GPIO_Mode_IN_FLOATING;

GPIO_Init(GPIOA, &GPIO_InitStructure);

- USART1 mode config

USART_InitStructure.USART_BaudRate = 19200;

USART_InitStructure.USART_WordLength = USART_WordLength_8b;

USART_InitStructure.USART_StopBits = USART_StopBits_1;

USART_InitStructure.USART_Parity = USART_Parity_No ;

USART_InitStructure.USART_HardwareFlowControl = USART_HardwareFlowControl_None;

USART_InitStructure.USART_Mode = USART_Mode_Rx | USART_Mode_Tx;

USART_Init(USART1, &USART_InitStructure);

USART_Cmd(USART1, ENABLE);

C. TIMER2

The STM32 TIMER2 is used in this paper. Operation of the TIMER2 has such steps: first configure TIMER2 interrupt priority, then set the TIMER2 interrupt parameters. The default interrupt period is 10 milliseconds. The part of the code is as follows:

TIM2_NVIC_Configuration();

TIM2_Configuration(Period);

The master control program includes a branch of the loop program and an interrupt service function. Branch loop program main function is to wait for the host machine instructions, such as setting a timer interrupt parameters, the start/stop sampling, set the baud rate, etc. Interrupt service routine function is to send data to the host computer.

V. PC SOFTWARE DESIGN

LabWindows/CVI is a software development environment for C programmers. LabWindows/CVI provides powerful function libraries and a comprehensive set of software tools for data acquisition, analysis, and presentation that you can use to interactively develop data acquisition and instrument control applications.In this paper, the software platform established interactive interface based on LabWindows/CVI Library, including Interface Library, Formatting and I/O Library, RS232 Library and Analysis Library[3].

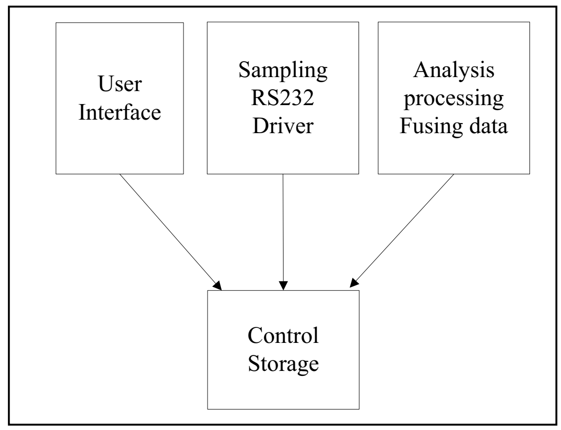

Figure 4. Software module frame

- User Interface Library

Its functions are used to create and control a graphical user interface. The functions DisplayPanel() and RunUserInterface() are used to display the main panel and run the UI. And The functions DiscardPanel() and CloseCVIRTE() are used to free resources and return. The function PlotStripChart () can plot sampling data in a strip chart control.

- RS-232 Library

Its functions are used to control multiple RS-232 ports using interrupt-driven I/O. Using this function OpenComConfig() is to Open a COM port and set port parameters. The baud rate parameter is used frequently. The baud rate of serial-port is set to be 19200bps. If the specified port is already open, and want to closes the port. CloseCom() function descript for this information. It can Read data from input queue of COM into buffer through the function ComRd(). Using ComWrt() function sends bytes from the output queue to the serial device under interrupt control without program intervention.

- Analysis Library

Its functions are used to operate on arrays to simulate and analyze large sets of numerical data quickly and efficiently.

Complete the data analysis function is the main function of FFT() and written.

This design mainly has four buttons in the main panel. When a button is pressed, the corresponding function is corresponding. When the Reset-System button is pushed on the panel, ResetSystem() function will be start. And the attitude data acquisition system will reset hardware and software, the system parameters will be rebooted. If the parameters want to be modified, press this Set-Parameters button. The callback function Set-Parameters() will respond to set Parameters include Baud Rate, Sample Rate, Parameters of MPU-6050,etc. This Start button completes the function of starting and stopping the sampling. This Start-Stop() function first response start sampling, again in response to stop sampling. This Plot button calls Char_Func() function. The sampling data Plots a waveform onto a graph control.

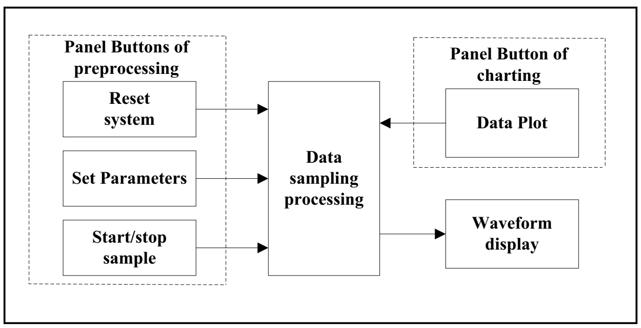

Figure 5. Software structure

VI. TEST AND ANALYSIS

The attitude change from horizontal to vertical state, and the attitude data was sampled and send to the host computer by the stm32 processor. By the LabWindows/CVI software program, we can see its results.

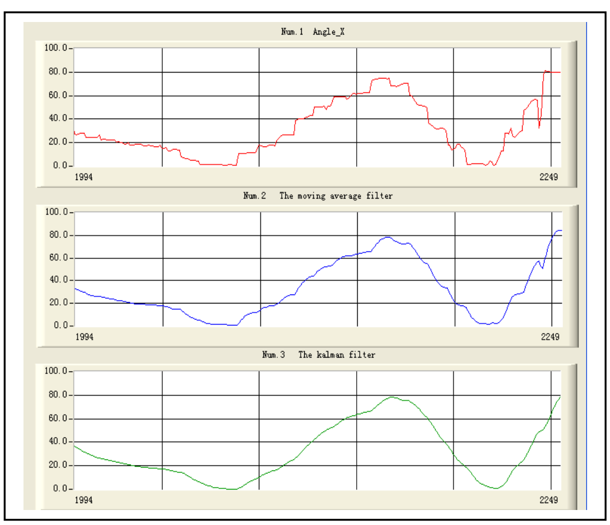

Figure 6. The waveform of the attitude data

In figure 5, the num.1 waveform chart shows that MPU-6050 does not have processed data. From the chart to see the data is not stable, and the impact of noise. The num.2 waveform chart shows that the results using sliding mean filtering. The method to realize the filtering by means of successive sampling data (N=8), effectively restrain small noise. The Num.3 waveform figures Kalman filtering, Fusing accelerometer and gyroscope data allows for attitude calculation. From the test results, it is found that the Kalman filter is more effective to eliminate the drift of the sensor, and reduce the noise of the sensor, so as to get more valuable data.

VII. SUMMARY

In this paper, the attitude data acquisition system based on STM32 processor is designed, and the key circuit of the system is described, and the STM32 and LabWindows/CVI program are written. At last, the MPU6050 sensor is tested and analyzed, and compared with the data. Through the experimental results, it can be seen that the Kalman filter is more effective to eliminate the drift of the sensor, and reduce the noise, and obtain a good effect.

ACKNOWLEDGMENT

This work is dedicated to all the teachers who have taught me a lot, especially to my supervisor, Li Jie, who has helped to work out the outline, giving me enlightening advice throughout the whole process. To him, I owe a profound debt of gratitude.

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