Tunnel Robot Obstacle Avoidance Control Based On Ultrasonic and Vision

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ABSTRACT: Knowing the distance information of the obstacles is good for planning process path for mobile robot. Based on ultrasonic and machine vision range finding principle, we design a mobile robot multi-sensor ranging system, the measurement of 0 ~ 200 cm distance obstacle, measurement error is less than 1%. And visual sensors of ultrasonic ranging system, collecting robot obstacle information of different azimuth, and introduces in detail the design of hardware and software of the system.
KEYWORD: ultrasonic, machine vision, obstacle, hardware and software

1 INTRODUCTION

1.1 *Overview.*

In real-time obstacle avoidance and path planning process for autonomous mobile robot, the robot relies on accessing to information in the external environment, sensing the presence of obstacles, and measuring the distance to the obstacle. Currently, the robot obstacle avoidance and distance measuring sensors are with infrared, ultrasound, laser and vision sensor. Most systems use a single ultrasonic sensor for Information collection, but because of the presence of ultrasonic sensors measure the problem of blind spots, ranging range is generally between 30 ~ 300 cm. The design considering the advantages and disadvantages of each program, use visual sensors and Ultrasonic sensors in obstacle avoidance control. Because vision can be more truly reflect the situation, it can make up some ultrasonic sensor disadvantages, in closing measurement.

1.2 *System Block.*

This design, FIG0, bases on STMicroelectronics Cortex-M4 architecture chips STM32F407ZET6. There are three ultrasonic modules front, left and right for preliminary obstacle detection, image sensor for accurate positioning. Once the obstacle detected, open OV7670 module, take an image of the main tunnel road, transfering data to image processing chip, and planning mobile trajectory based on the relevant image. Relevant traffic information cache into SRAM and convey to master PC through Wife module. Interactive interface to display the main action of the robot is estimated, and the initial teaching process.

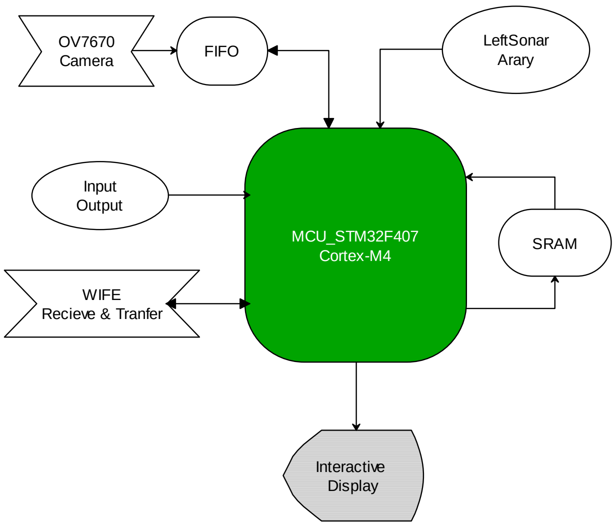

FIG0: System Block

2 SYSTEM DESIGN

2.1 *Hardware Design.*

STM32F407ZET6 Core System: STM32F407Zet6 is a high-performance ARM® Cortex ™ M4 microcontroller. It integrates innovative peripherals, 168 MHz operating frequency, in addition, with Ethernet MAC and camera interfaces for CMOS sensors. 32-bit Flash MCU with floating-point unit (FPU), and memory protection unit (MPU) with digital signal processing (DSP), improved application security.

Standard and advanced communication; I2C, SPI, FSMC interfaces.

Ultrasonic Acquisition: The acquisition system is mainly composed of three HC-SR04 ultrasonic ranging modules FIG1. Using the TRIG IO port triggers ranging, the least 10us high trigger signal. Module automatically sends eight clocks 40khz square wave, once detects whether a signal signal returned by ECHO IO port outputs a high level. The high pulse width of echo signal is proportional to the measured distance. Thus it can calculate the distance, the farthest range of 4m recent range of 2cm, measure angle of 15 degrees. Control module timing chart FIG2 follows.

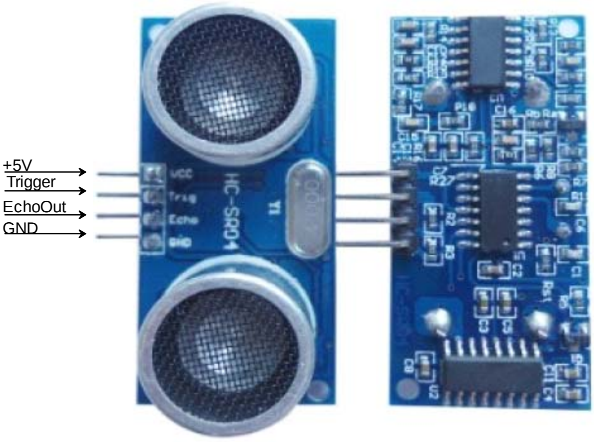

FIG1: Ultrasonic Ranging Modules

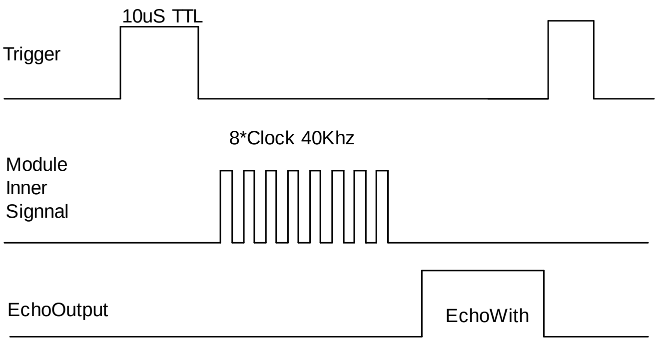

FIG2: Module Control Timing chart

Radio: Taking into account the power supply for the mobile robot battery, so two NRF24L01 modules in FIG3, which is based on an open global 2.4Ghz ISM band license-free use, the maximum operating speed 2Mbps, efficient GFSK modulation, built-in hardware CRC error detection and multipoint communication address control, anti-interference ability, low power 1.9 - 3.6V work, standby mode state 22uA, power-down mode is 900nA. It especially suits in industrial control applications. The modules convert wireless data into SPI, transfer chart FIG4 data then transfer to MCU. So use SPI1, SPI2 Interface, as is show in FIG5.

FIG3: NRF24L01 modules

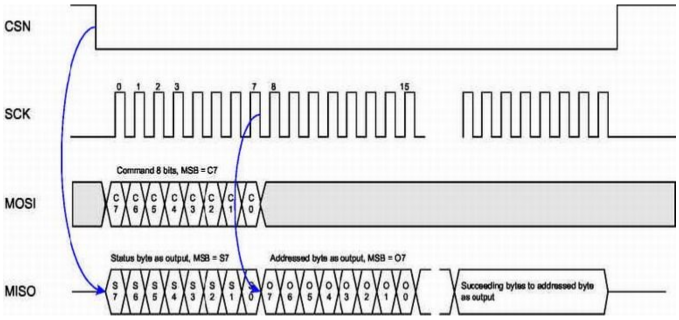

FIG4: SPI Transfer Chart

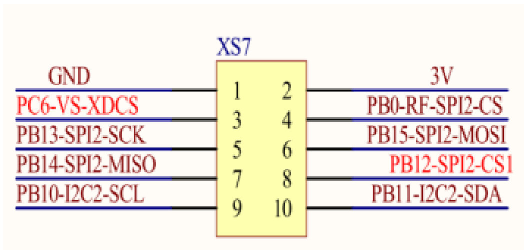

FIG5: SPI Interface Circuit

Image acquisition: Image acquisition mainly uses OV7670 image acquisition module FIG6. OV7670, high sensitivity and low voltage image sensing chip, is suitable for embedded applications. The module VGA images can reach up to 30 frames per sec, completely control image quality, format and data transmit. All image processing functions includes gamma curves, white balance, hue and so on, through SCCB programming interface. Camera module comes with a FIFO chip for temporarily storing image data, so you can easily obtain image data. Only a MCU, you can use the camera module.

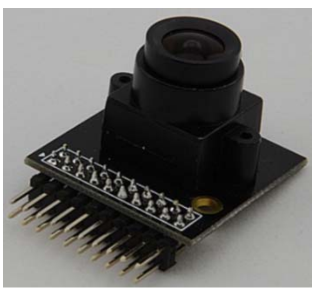

FIG6: Image Acquisition Module

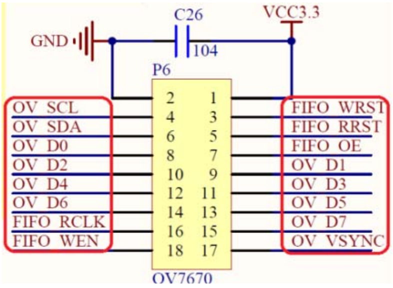

FIG7: OV7670 Module Interface Circuit

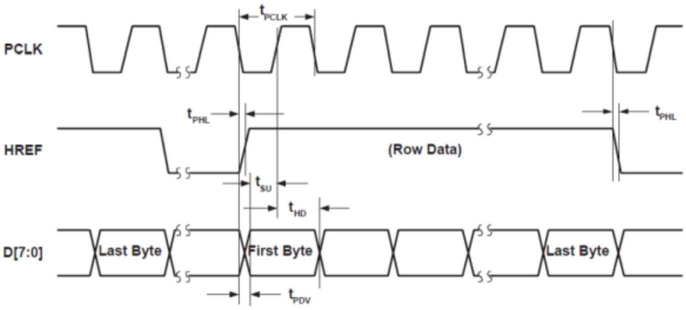

FIG8: Horizontal Timing Diagram

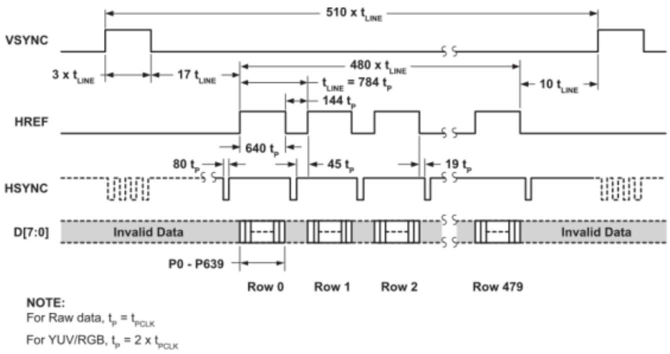

FIG9: VGA Frame Timing

OV7670 image data output (via D [7: 0]) under the control of PCLK, VSYNC and HREF/ HSYNC as is shown in FIG8. RGB565 data format output process is shown in FIG9 VGA Frame Timing. Design needs STM32 microcontroller IO port act as SSCB control bus and control read and write data from FIFO, the interface circuit as in FIG7. STM32F407ZET6 controls each frame transmitted data into FIFO.

The design is composed of 1M byte capacity SRAM chip produced by ISSI, IS62WV51216. STM32F407ZET6 FSMC controller interface controls IS62WV51216 write and read as a buffer circuit FIG10, A [0:18] to FMSC_A [0:18], D [0:15] to FSMC_D [0:15], UB to FSMC_NBL1, LB to FSMC_NBL0, OE to FSMC_OE, WE to FSMC_WE, CS to FSMC_NE3.

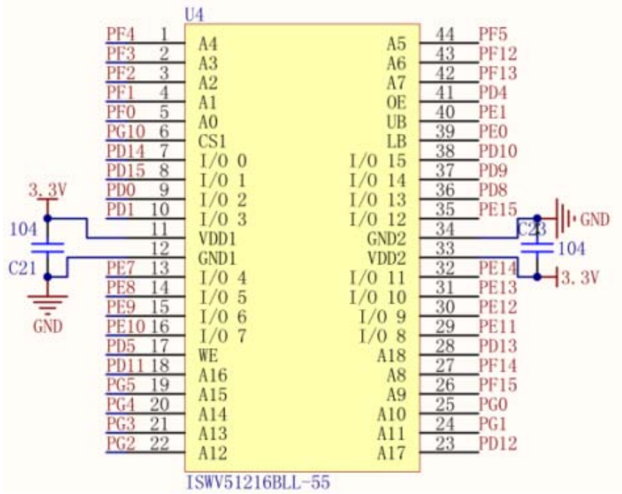

FIG10: FSMC Control SRAM IS62WV51216 Circuit

2.2 *Software Design.*

The software design structure of the control system are as FIG11:

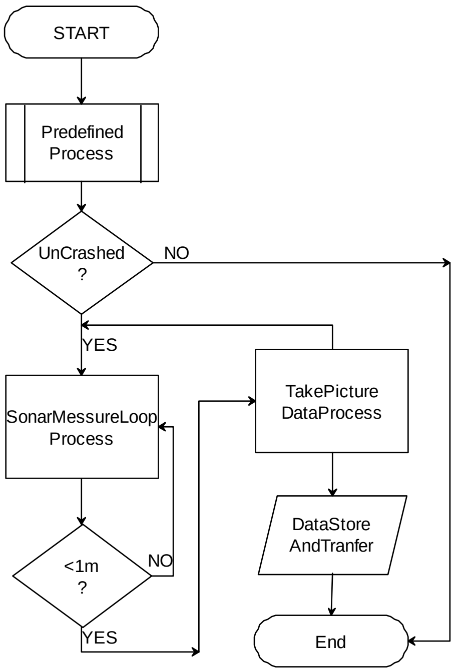

FIG11: Software Design Structure

1: Ultrasonic Ranging by using echo sounder, emission transducers emit acoustic pulses. Reflected sound waves is received by the receiving transducer touch an obstacle. According to the time difference calculate obstacle distance. According to the relationship between Distance and speed of sound, represented as s = 1/2 ct. TIM2 generates an ultrasonic trigger in every 1S. TIM3 capture echo level width .This is the ultrasonic detection subroutine shown in FIG12.

2: Visual detection subroutine, once distance is less than 1M trigger the camera take pictures. Image data is processed by STM32F407ZET6 to plan advance path do as follow FIG13.

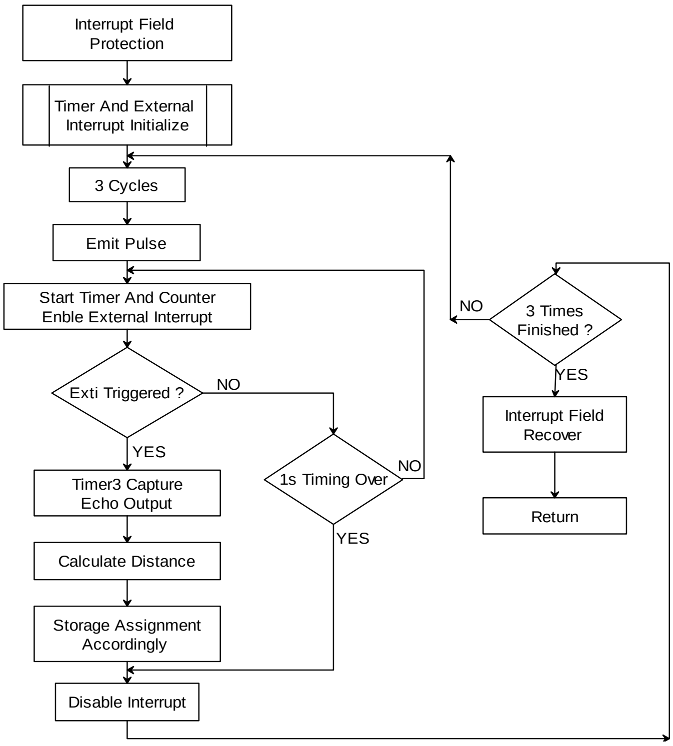

FIG12: Ultrasonic Detection Subroutine

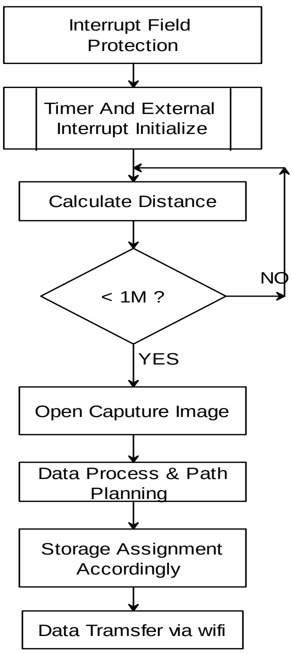

FIG13: Visual Detection Subroutine

3: At the time of MCU data processing, data was transferred through wireless to PC.PC also does image data process and path plan to ensure the current path corrected that improve the efficiency of obstacle avoidance.

4: Input and output are mainly used to prevent a crash in case of emergency.

5: Test result Table 1. The robot can tell apart three different directions measurement tasks and avoid obstacle from 0 ~ 200 cm. The error is less than 1%.

Table 1: Test Result

Target cm	Measuring cm	Error %	Target cm	Measuring cm	Error %
5	5. 05	1. 00	50	50. 47	0. 94
10	9.91	0. 90	75	75. 71	0. 95
15	15. 12	0. 80	100	100. 98	0. 98
20	20. 18	0. 90	150	151. 40	0. 93
25	24. 78	0. 88	200	201. 90	0. 95

3 SUMMARY

This paper discussed a low-cost, low-power, high-performance mobile robot ranging obstacle avoidance system. A Multi-sensor system with ultrasonic and vision sensor, effectively solved the problem of a single defective sensor ranging system measuring blind; and used three groups of sensors fitted in three different positions of the robot, the robot can tell apart three different directions measurement tasks and avoid obstacle from 0 ~ 200 cm. The error is less than 1%. Thus this system can adapt to various situations in the avoidance of the tunnel.

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