

Design of Embedded Processor Based Omni-Directional Mobile Platform with Ultrasonic Obstacle Avoidance

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Abstract – According to the complex and unstructured industrial environment and the requirements of obstacle avoidance, this paper built a Omni-directional mobile platform based on stm32 embedded processor. The platform was integrated with the infrared sensor, ultrasonic sensor and radio components. Based on the correction method, feedback-time method and oblique installation, this paper proposed a non-parallel and multi-angle installation method for ultrasonic sensors. The new installation method can achieve a high-precision control and awide-angle of obstacle avoidance in a complex environment.

Keywords – Ultrasonic Sensor, Obstacle Avoidance, Oblique Installation, Correction Method.

I. INTRODUCTION

With rapid development of industrial robots and the urgent needs from the industry, the technology of industrial mobile robot is more and more concerned by the society. Mobile robots have the capability to move around in their environment and are not fixed to one physical location. Mobile robots can be autonomous which means they are capable of navigating an uncontrolled environment without the need for physical or electro-mechanical guidance devices. Alternatively, mobile robots can rely on guidance devices that allow them to travel a pre-defined navigation route in relatively controlled space[1]. So real-time obstacle avoidance is a basic function for mobile robots. With the advantage of large measuring range, intense directivity and convenient installation, Ultrasonic ranging, as a non-contact measurement method, has been widely used in positioning and environment modeling occasions.

This paper focuses on the high-precision control and better obstacle avoidance under the difficult and complex industrial situations. The variables such as temperature and humidity factors and the industrial environment have an effect on the ultrasonic sensor performance. To optimize this problem, three kinds of methods are put forward and have achieved good results.

II. CONTROL SYSTEM FOR MOBILE PLATFORMS

As shown in Fig.1, the mobile platform control system consists of six modules: control module, sensor module, wireless module, motor module, display module and power supply module. STM32F103 is selected to be the processor, which supports SPI, I2C, USART, USB, CAN and other interfaces .

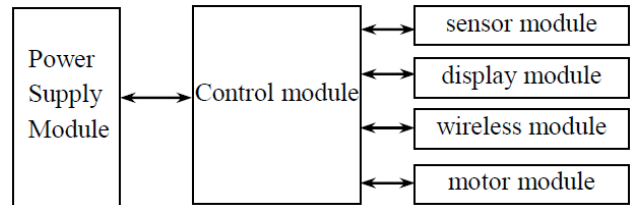


Fig.1. Mobile platform control system

When the mobile platform works, processor gets information from the ultrasonic sensor and sends driving and control signal through the brushless DC motor drive to control the speed and steering for the obstacle avoidance. Simultaneously, with the use of infrared sensors, processor achieves tracking function by detecting the predetermined trajectory.

III. ULTRASONIC RANGING PRINCIPLE

Ultrasonic ranging principle, as shown in Fig. 2, is to use ultrasound in the air velocity as the known and measure the time(Δt) when sound waves reach obstacles and reflect back, then calculate the actual distance[2].

Let T be the current ambient temperature. The speed of sound is wrote in following manner

$$c = 331.4 \times \sqrt{1 + T/273}$$

and the distance formula

$$S = \Delta t \times v$$

This paper uses HC-SR04 as the Ultrasonic module. The basic working principle as follow: (1)Using GPIO port named Trig trigger the ranging by giving 20us high level, and the piezoelectric wafer start work; (2)Module sends 8 groups 40Khz high-frequency square wave, which reaches obstacles and reflect back; (3)When the acoustic signal is returned, GPIO port named Echo will remains high level for some time, which can be used to calculate the distance.

HC-SR04 module has an effective range between 20mm to 4000mm. The measurement accuracy is up to 1mm and the measurable angles is within 15 °.

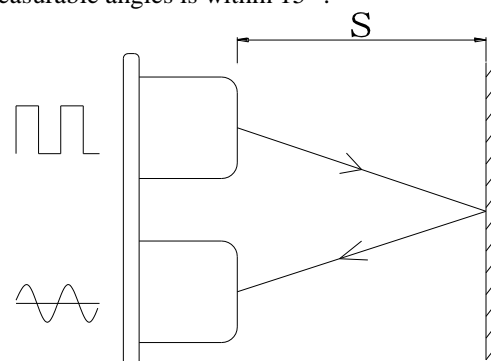


Fig.2. Mobile platform control system

IV. RANGING FACTOR AND OPTIMIZATION

A. Installation method design

Section A describes a new installation method to increase the detectable angles. Since the ultrasonic sensor is based on the acoustic wave, it has wave's characteristics, like reflection. Reflection is the change in direction of a wave front at an interface between two different media so that the wave front returns into the medium from which it originated. This phenomenon may lead that the signal sent by the ultrasonic transmitter is reflected so large angle that can not be received. Fig.3(a) shows that the angle can be detected. Fig. 3(b) points the angle that can't be detect.

To solve this problem, some mobile platforms install a plurality of ultrasonic sensors in parallel to platform body, which increases measuring range[3-4].But it fails to increase the angle detected by the ultrasonic sensor .This paper presents a non-parallel and multi-angle installation method, which installs some ultrasonic sensors by a certain angle. The proposed method expands detectable angle effectively. As shown in Fig.4.

In this paper, three ultrasonic sensors work on a cooperation mode. Every ultrasonic sensor's detectable angle only reaches 15° . To determine the mounting angle β , graphics computing method is proposed. As shown in Fig.5. In the Fig.5(a), the dark part of circle is the tilt angle that an ultrasonic sensor can detect. Three ultrasonic sensors installed by a selected angle β can detect the tilt angle like Fig.5(b). To eliminate the dead zone areas, blank part in Fig.5, according to the graphics computing method, when taking $\beta = 30^\circ$, the tilt angle reaching 45° will be continuous and integral. As shown in Fig.5(c).

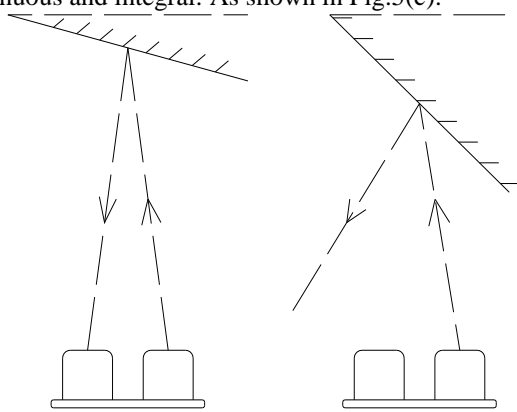


Fig.3. Ultrasonic wave Failure angle

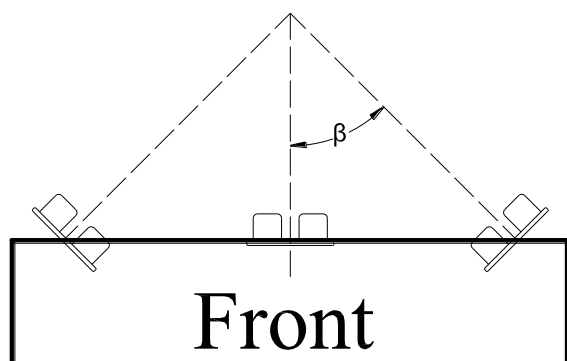


Fig.4. Mobile platform control system

B. Environmental Factors and Improvement

Propagation velocity of ultrasound waves will be affected by the density of air. The higher density is, the faster sound propagates. The density of air: $\rho = 1.293 \times (p/P_s) * (273.15/T)$, wherein p is the actual pressure, P_s is standard atmospheric pressure, T is the absolute temperature. This shows that the temperature effect on ultrasonic ranging system, which can not be ignored. Therefore, in order to improve the accuracy, different ambient temperatures need to be considered.

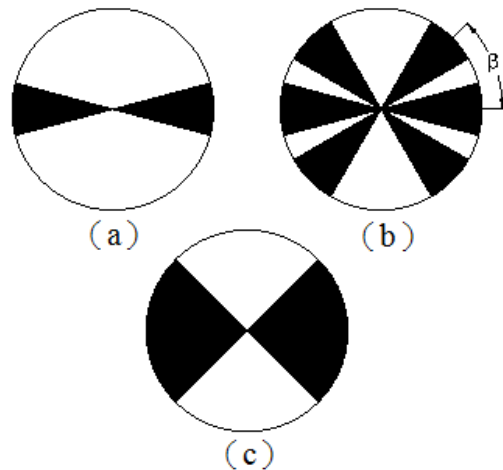


Fig.5. Detecting angle schematic

Many systems of ultrasonic ranging use a digital temperature sensor DS18B20 to give temperature compensation[5-7]. However, due to the limited accuracy of DS18B20 and its own deviation, improvement of the systems' accuracy is limited. Du etc proposed a correction method by introducing a test channel to ensure the sound velocity [8]. The ultrasonic sensor mounted on a metal shutter at the front of 100mm is placed inside the mobile platform. As shown in Fig.6.

When the mobile platform works, the measurement module of sound velocity starts in every 10 minutes. Then using the formula: $S = \Delta t \times v$ calculates the sound velocity of the current temperature and stores in the processor waiting for calling by.

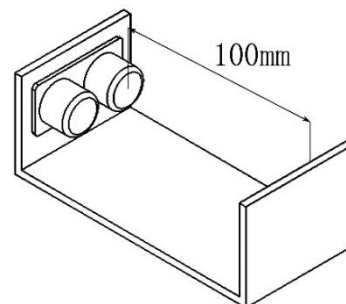


Fig.6. Installation for correction method

C. Timer optimization

Section C analyzed the influence factors through the principle of ultrasonic sensor and the distance formula: $S = \Delta t \times v$. It shows that another ranging accuracy factor is the Δt , which is time calculated by processor through timing the high level of IO port Echo.

The general-purpose timers are used in this paper, which consist of a 16-bit auto-reload counter driven by programmable prescaler [9]. To improve timing accuracy, setting TIM_Time Base->Str.TIM_Prescaler=0. So that the theoretical resolution can reach 0.04mm. And during programming, operating register TIM2-> CR1, TIM2-> CNT and GPIOC-> IDR directly Accelerate the operation speed of processor. So as to achieve the purpose of improving the timing accuracy.

V. EXPERIMENTS

A. Mobile platform avoidance test

For the use of non-parallel installation method and avoidance algorithm, the experiment demonstrates a greater result than a parallel installation method. As shown in Fig. 7.

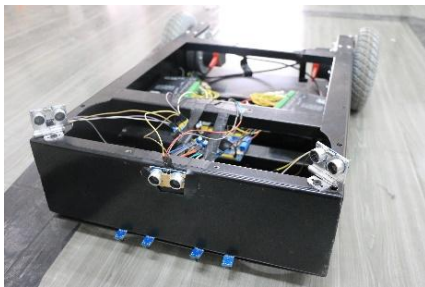


Fig.7. Mobile platform avoidance test

B. Mobile platform tracking test

Mobile platform can smoothly follow the track pre-built on the ground with Four infrared sensors. As shown in Fig. 8.



Fig.8. Mobile platform tracking test

VI. CONCLUSION

This paper introduced the embedded mobile platform with an ultrasonic obstacle avoidance system. In order to improve the measurement accuracy and avoidance breadth, the paper proposed a non-parallel and multi-angle installation method and the correction method and optimized algorithms are used. Experiments show that, after the implementation of these measures, to some extent, the ranging accuracy and obstacle avoidance capability have improved.

REFERENCES

[1] WANG Li-yang, CHEN ming, "Survey of vision—based approach to simultaneous localization and mapping", Application Research of Computers., vol.27 Aug.2010.

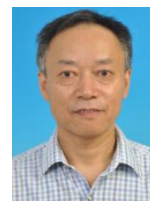
- [2] LU Xiao-long, HU Jun-hui."An ultrasonic driving principle using friction reduction", Sensors & Actuators A: Physical.,vol.199,2013.
- [3] REN Ya-nan, JIA Rui-qing, HE Jian-tian "Research on obstacle avoidance system of mobile robot based on ultrasonic sensor", China Measurement& Test., vol.38, May, 2012.
- [4] Medina-Santiago,A;Camas-Anzueto,JL;Vazquez-Feijoo, JA;Hernandez-de Leon, HR; Mota-Grajales, R "Neural Control System in Obstacle Avoidance in Mobile Robots Using Ultrasonic Sensors", Journal Of Applied Research And Technology.,vol12,2014
- [5] HONG Wei-peng, YU Jie-cheng. "Design of ultrasonic distance-measuring system using temperature compensation methods", Journal of Chemical and Pharmaceutical Research., vol.6, 2014.
- [6] Huang, Y. S.,Young,M. S."An Accurate Ultrasonic Distance Measurement System with Self Temperature Compensation", Instrumentation Science and Technology., vol.37,2009
- [7] Canali Claudio, De CiccoGiorgio, Morten Bruno, Prudenziati Maria, TaroniAndrea, "A Temperature Compensated Ultrasonic Sensor Operating in Air for Distance and Proximity Measurements", Industrial Electronics, IEEE Transactions On.,vol.4,1982
- [8] DU li, ZHANG Jian-jun, "Study and Realization of Ultrasonic Ranging Technology Improvement Method",Journal Of Beijing Polytechnic College.,vol.14,jan.2015
- [9] Milecki, Andrzej, and Pittner, Grzegorz, "Design of 32-Bit Washing Machine Controller", Solid State Phenomena., 220-221(2015).

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