

Design of Smart Blind Crutch System Based on Arduino

Wei Li¹, Yue Wang²

¹Sino-British College, University of Shanghai for Science and Technology, Shanghai, 200031, China

²Institute of Electronic Science and Technology, Xiamen University, Xiamen, Fujian, 361102, China

Abstract: *The blind used traditional blind crutch to walk on the blind track in the past. With the increase of the blind and the increase of the complexity of the situation of the road, the simple blind crutch cannot give enough security to the blind. The blind crutch needs improvement in active obstacle avoidance and night safety to meet the demand. In this paper, a smart blind crutch is designed. The ultrasonic ranging sensor, laser ranging sensor, color sensor, photosensitive resistance, buzzer and vibrator are linked together with Arduino microcontrollers to realize obstacle avoidance reminder, blind lane and traffic light recognition, glowing when the light is dim, which are integrated into blind crutch to facilitate the travel of the blind. The tests show that the blind crutch is accurate in reminding obstacles in front, accurate in recognizing blind lanes and ground traffic lights, and sensitive in luminous induction at night. Compared to the traditional blind crutch, the travel safety of the blind is more guaranteed especially at night. This smart blind crutch also provides referenced for smart blind crutch.*

Keywords: *Smart Blind Crutch; Arduino; The Blind*

1. Introduction

In 2015, it is estimated that 253 million people have visual impairment worldwide. Of these person, 36 million were blind and a further 217 million had moderate to severe visual impairment (MSVI). It is predicted that the number of the blindness will increase to 115 million in 2050.[1] As the number of these vulnerable groups, so does our attention to them. What's more, the situation of the road become more complex. For instance, the appearance of the shared bikes and the allowance of parking the shared bikes on the sidewalk make it more difficult to cross the sidewalk. In some cities, most of the sidewalks even do not have the blind track. The increase of the blind will force the government to attach importance to these phenomena. The emergence of many microcontrollers makes it easy to design smart products to help these people. When the blind people walk on the sidewalk, they usually use a common crutch to beat the ground repeatedly to avoid obstacles in front of the them. However, this way often has limited scope and cannot timely remind passers-by and vehicles to avoid. Now some smart blind crutches have appeared to solve these problems. These smart blind crutches are mostly at a single angle, but obstacles can appear at multiple angles. In addition, current smart blind crutch cannot remind the blind when the traffic light is red. For these phenomena, we designed a smart blind crutch. It can sense the obstacle of the obstacles of three directions by using a laser sensor and two ultrasonic sensors, which can solve the problem of sensing a single direction. The smart blind can sense the color of the ground. It can sense the traffic lights on the ground and remind the blind. It also has LEDs which will open automatically in the dark environment. The designed blind crutch has been made a real product and tested. The test data shows that the blind crutch can give the blind the remind accurately.

2. Overall system design

This smart blind crutch uses two Arduino microcontrollers as the core of the control system as shown in Figure 1. The Arduino nano microcontroller controls four modules the laser sensor module, optical sensor module, alarm module and ultrasonic sensor module. The other microcontroller Arduino uno controls the color sensor module and another alarm module. Choosing two microcontrollers is to make the blind crutch sense the situation more sensitive.

Figure 2 is the structure of the blind crutch and the real product designed. The whole crutch takes the strong material which has low density (Carbon composite fiber material). There is a power switch at the handle, and the handle has spiral texture to increase grip comfort and friction for the blind to hold for a

long time. Laser ranging module, the ultrasonic ranging module and color sensor module are mounted near the bottom of the blind crutch. In the middle of the blind crutch, there is a box to store the microcontrollers, power module and LED. The optical sensor module is mounted out of the box.

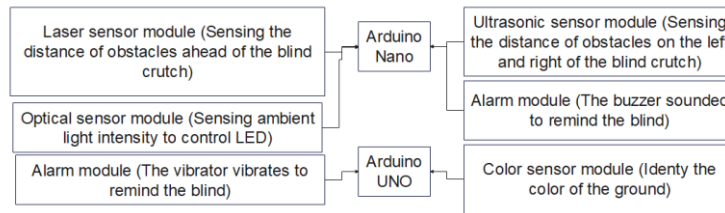


Figure 1: The main design of the blind crutch

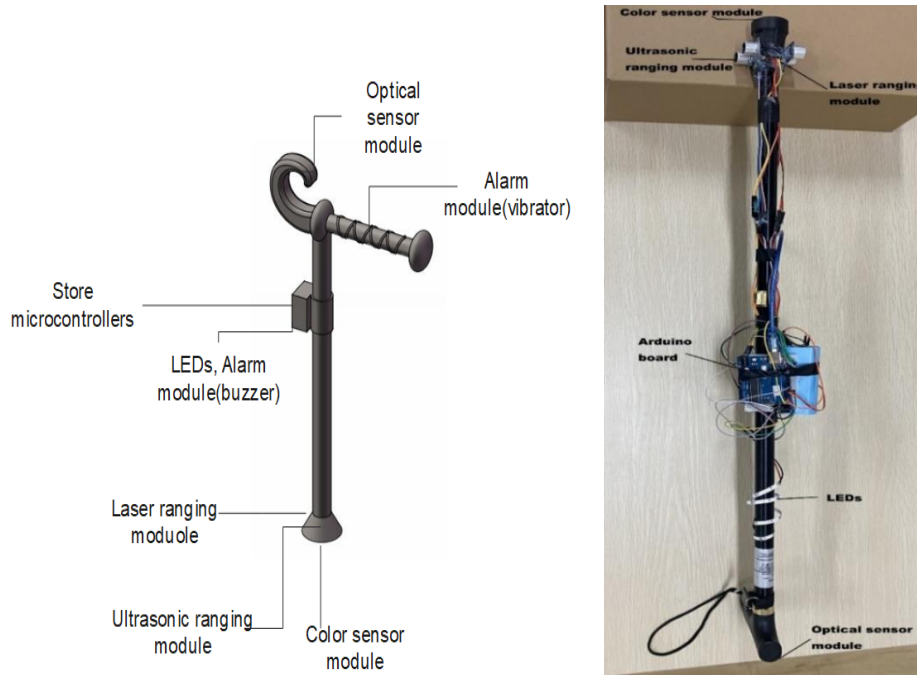


Figure 2: The basic structure of the blind crutch (left), The picture of real product (Right)

3. The main functional modules of the system design

3.1. Laser ranging module

The main electronic component of laser ranging module is VL53L0X. The laser it emits is safe to eye and completely invisible and it has high accuracy and low power consumption in a low price. VL53L0X takes 940nm vertical cavity surface-emitting laser to emit the laser and the laser bounces off an obstacle and is picked up by the VL53L0X, which measures how long the laser travels through the air to get the distance. The formula of the distance is shown below.

$$Distance = \frac{Time * Velocity\ of\ light}{2} \tag{1}$$

3.2. Ultrasonic ranging module

Ultrasonic ranging module choose HC-SR04 to measure the obstacles in the left side or right side of the blind crutch. This electronic component can provide the non-contact distance sensing function of 2cm to 400cm and the distance measuring accuracy can reach up to 3mm. It needs at least 10us high level signal to work normal that IO port named TRIG trigger ranging. It will automatically send eight 40kHz square waves and automatically detect whether there is a signal returned. If there is a signal returned, IO port named ECHO output a high level. The duration of the high level is the time from transmission to return of the ultrasonic wave. [2] The formula of the distance is shown below.

$$Distacne = \frac{Duration * Velocity of sound}{2} \quad (2)$$

3.3. Optical sensor module

Optical sensor module consists of a light dependent resistor and a common resistor. Light dependent resistor is made of semiconducting materials such as cadmium sulfide or cadmium selenide. The working principle is based on the internal photoelectric effect. The intensity of the light increase, the resistance of the light dependent resistor will decrease. When the intensity of ambient light decrease, the microcontroller read the voltage change and give the pin of LED a 5v voltage to lit LED to remind pedestrians and vehicles to avoid.

3.4. Alarm module

Alarm module is designed to remind the blind to be careful. The blind crutch has two alarm modules. One of them chooses buzzer to remind the blind. The other one chooses vibrator. The reason of choosing two kinds of alarm modules is to distinguish the reminds.

The active buzzer is chosen in this module. The active buzzer consists of a vibrator and passive buzzer, which is convenient that it can makes sound when connected to a DC power source. The buzzer will ring once when there is an obstacle in front of you and twice when there is an obstacle on the left or right side to remind the blind.

The vibrator is mounted near the handle. The vibrator has a plastic outer shell and a tiny DC motor inside to drive the eccentric wheel. There is a control circuit out of the vibrator. When the microcontroller sends a 'vibration' signal to this module, the control circuit is switched on. There is an eccentric wheel on the motor shaft. In the process of motor rotation, the center particle of the eccentric wheel is not at the center of the motor. The motor is in a state of constant loss of balance, and vibration is caused by inertia. [3]

3.5. Color sensor module

Color sensor module consists an electronic component, TCS34725. The principle of this color sensor is that it measures the brightness of the red component, the green component, the blue component and the whole component respectively through four kinds of silicon photodiodes and outputs the brightness of each component in the form of numbers.[4] Then calibrate the numbers to 255: 255: 255 and get RGB of the object. TCS34725 has high sensitivity, wide dynamic range and infrared shading filter so that it can also have a high accuracy when the conditions of light change or it pass through attenuating materials. The distance of work for color recognition is about 3mm to 10mm. [5] There are four ports used in this module on TCS34725. This module is used to identify the color on the ground to help the blind if they are on the blind tracks or the traffic lights are red as shown in Figure 3.



Figure 3: Detection object of color sensor. Traffic lights on the ground (left), the blind tracks (right)

4. Control algorithm

The system uses C language for programming, and uses Arduino IDE to write and compile system codes. Arduino IDE

Figure 4 is the simple control flow chart. First, the power module is turned on and the two microcontrollers are initialized. Arduino UNO controls color sensor to sense the color on the ground. If the color is yellow, the vibrator will vibrate once and if the color is red, the vibrator will vibrate all the time until the color sensed is not red. And Arduino Nano controls the ranging module and optical sensor module. First it senses the distance of obstacles ahead. If the distance is less than 20cm, the

microcontroller will control buzzer to sound once. Next, it will sense the obstacles in the left side or right side, if the distance is less than 10cm, the buzzer will sound twice. When the intensity of ambient light decreases to a certain extent, microcontroller will control LED on. The microcontrollers and the sensors work in this loop until the power module is off.

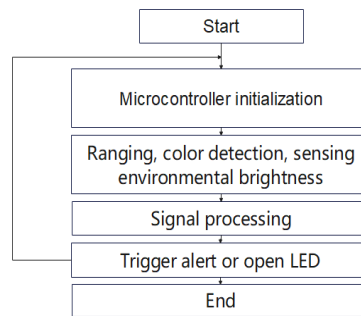


Figure 4: Simple control flow chart

5. Results and discussion

5.1. Detection range tests

The laser the sensor is mounted 5cm above the ground to avoid the impact of some small stones or potholes on the ground. HC-SR04 is mounted on the left and right sides of the blind crutch and are 5cm above the ground, between 7.5 and 15 degrees horizontal as its sensing angle is no more than 15 degrees.

In the test, add the obstacles in front of the sensors as shown in Figure 5. Record the measured distance and actual distance in Table 1. As Table 1 shown, for two ranging modules, the unit of the distance measured by laser ranging is millimeter. The errors of two ranging module are about the same and are acceptable. Change the types of the obstacles and in different environments, find that if there is some dirt or drop of water on the laser emission hole or laser receiving hole, it cannot range the distance accurately. For ultrasonic ranging, when the body area of obstacle is less than about 0.4m², the surface of the obstacles is enough smooth like glass, the error of the actual distance and the measured distance is obvious. [6]

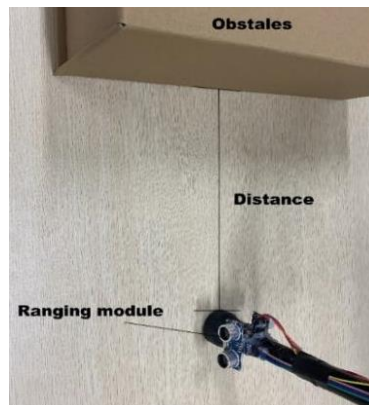


Figure 5: Test ranging module

Table 1: The data in the test

Actual distance	Measured distance (Laser ranging)	Error	Measured distance (Ultrasonic ranging)	Error
5cm	5.5cm	9.1%	55mm	9.1%
10cm	9.68cm	-3.3%	103mm	3.0%
15cm	14.65cm	2.3%	155mm	3.2%
20cm	19.67cm	1.7%	204mm	2.0%
25cm	24.75cm	1.0%	257mm	2.7%
30cm	29.55cm	1.5%	310mm	3.2%
35cm	34.25cm	2.2%	361mm	3.0%
40cm	39.08cm	2.4%	411mm	2.7%

5.2. Color discrimination

It's very complex as one red color in different perspectives, RGB is different. What's more, some dirt and the abrasion of the blind tracks and the traffic lights will affect the numbers of RGB. So, after the test, choosing a range of RGB to identify the color is better. According to the color map shown in Figure 6, the area that's circled is the range used. The detail range is shown in Table 2. According to the test, most of the red color that may be color of the traffic light can be identify by color sensor.

In the test and calibration, put different objects on the ground and use blind crutch to touch them. Record the RGB data if in the range of Table 2. Find that the face of the objects affect the RGB data obviously. However the range we set is enough large, so this effect can be ignored. The results are acceptable.

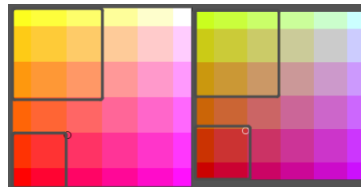


Figure 6: Area of the color map. R=255(left), R=204(right)

Table 2: The table of the ideal range of RGB of two areas

	R	G	B
Yellow area	204-255	153-255	102-255
Red area	204-255	0-51	0-51

5.3. Vibrator and buzzer remind the user

The vibrator vibrates once when the RGB is out of the range of yellow area. The vibrator vibrates all the time when the RGB is in the range of red area. The buzzer sound once when the distance from the front obstacles within 20cm, and sound twice when the distance from the left or right sides obstacles within 15cm.

5.4. LEDs are turned on automatically in dark environment

The light dependent resistor is mounted at the top of the blind crutch. In the dark environment, the LEDs are turned on automatically. When the light falls on the light dependent resistor, the LEDs close. The light dependent resistor should be far away from the LEDs to avoid LEDs blinks.

In the test, choose indoor and outdoor two environments to test. Change the intensity of the light in different environments and test whether the LED will turn on in relatively dark conditions.

5.5. Overall results

Doing the tests described above and record data in Table 3. From Table 3, the success rate up to 98%. The results are acceptable. It shows that this smart blind crutch can help the blind to avoid the obstacles and increase the security at night.

Table 3: The test of the smart blind crutch

Test	Test times	Response set	Numbers of success
Distance of obstacles ahead is less than 20cm	100	The buzzer sound once	98
Distance of obstacles in the left side or the right side is less than 15cm	100	The buzzer sound twice	98
The color of the ground is not yellow or red	100	The vibrator vibrates once	99
The color of the ground is red	100	The vibrator vibrates all the time	99
The environment is dark	100	The LEDs open automatically	100

5.6. Discussion

The smart blind crutch can help the blind avoid obstacles. But as the limitation of the color sensor, it can only identify the color of the ground as working distance of work for color recognition is too short.

The blind crutch can identify the color on the ground to remind the blind to be careful though the color sensor cannot identify the objects are traffic lights or other things that have the same color. Use image identification to identify the traffic light and the blind tracks is better than using color recognition. However, it needs a camera with high pixels. It will increase the cost and need a better microcontroller. The sensors chosen in this smart blind crutch are more suitable. With the development of the technology, the smart blind crutch will combine the laser radar and the camera which have been used on the cars to help the blind to avoid the obstacles and even can identify the objects and tell the blind what's the obstacles.

6. Conclusion

In present study, a smart blind crutch-based Arduino microcontroller, combined with color sensor, laser sensor, ultrasonic sensor, optical sensor was designed to facilitate the travel of the blind. The microcontrollers control the alarm module whether the alarm module alerts the blind according to the distance measured by ranging modules. LEDs on the blind crutch will open automatically when the environment is dark. Through the test, the success rate of function realization is up to 98%. It verifies that the safety of the blind will be greatly guaranteed by using smart blind crutch. The modules of this smart blind crutch will give the reference to the other smart products for the blind.

References

- [1] P. Ackland, S. Resnikoff, R. Bourne, "World blindness and visual impairment: despite many successes, the problem is growing," *Community Eye Health*. vol.30, no.100, pp.71-73, Sep. 2017.
- [2] Y. E. Song, X. Y. Zhang, C. G. Wang, H. N. Lin, "Design of Intelligent Blind Guide Stick Based on STM32," *Chinese Journal of Electron Devices*. vol.43, no.5, pp.1181-1184, Oct. 2020.
- [3] Y. J. Zou, "Design and implementation of smart phone navigation interactive system based on vibration feedback," *Jilin University*. 2016.
- [4] G. S. Cheng. "Color sensor," *Technology of sensor*. no. 6, 1992.
- [5] Z. Y. Li, "Design and Programming of Carrying Robot based on Arduino Technology (II) -- Application of color sensor and servo motor" *Journal of Capital Normal University (Natural Science Edition)*. no.5, pp.1-3, 2018.
- [6] S. F. Yuan, R. Y. Zhang, C. Liu, Y. P. Wang, "Design of intelligent guide rod based on Arduino," *Science and Technology & Innovation*. vol.37, no.5, pp.61-65, 2021.