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An Improved Multifunctional Intelligent Guide Crutch Based on STM32

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Abstract: In order to facilitate the walk of the blind, the design of the multifunctional intelligent guide crutch for the blind based on STM32 is proposed, and hardware and software system was also completed. The guide crutch had functions such as voice timekeeping, emergency call, obstacle detection, and road area water detection and down step detection. The switch between each function was achieved by buttons set in system so as to make the design more humanized. With the final detection, the guide crutch parameters, such as the functions and technical indictor, meet the design requirements, and can offer a trip way of safe and convenient.
Keywords: Guide crutch; STM32; multi-sensor; PSD; voice broadcasting.

1. INTRODUCTION

China is the country with the blindest people in the world, with about 7 million blind people, accounting for 18% of the world's total blind people. Their actions are very inconvenient due to their vision. In most cases, blind people can only rely on guide dogs and guide crutch. Because training guide dogs take a long time and a high cost, more people choose guide crutch. The traditional guide crutch achieves a relatively simple function, and can only touch obstacles and blind roads at the foot. There are also many new types of intelligent guide sticks. A new electronic guide stick was released at the All-Japan Blind Welfare Society held in Akita, Japan in May 2010. It was developed by Gang, an associate professor at Akita Prefectural University in Japan, which allowed users to feel obstacles at the height of the face, avoiding objects such as signs on the height of the face [1].

The traditional guide crutch is far from meeting the needs of the blind. Although the intelligent guide crutch has been improved, it still has limitations such as insufficient functions [2]. By visiting blind friends, it is generally reflected that the current guide crutch is difficult to judge the situation of road area water and descending steps or stairs. In view of this situation, an intelligent guide crutch based on multi-sensor fusion was designed. On the basis of the current intelligent guide crutch, a variety of environmental condition detection functions were added, which could help the blind to fully perceive the surroundings without the help of others.

2. OVERALL DESIGN AND SYSTEM IMPLEMENTATION

The composition of the multi-sensor fusion intelligent guide crutch was shown in Figure 1. With the STM32 microcontroller as the core, in addition to the traditional detection function, by adding other sensors, the road area water and the descending step detection were realized.

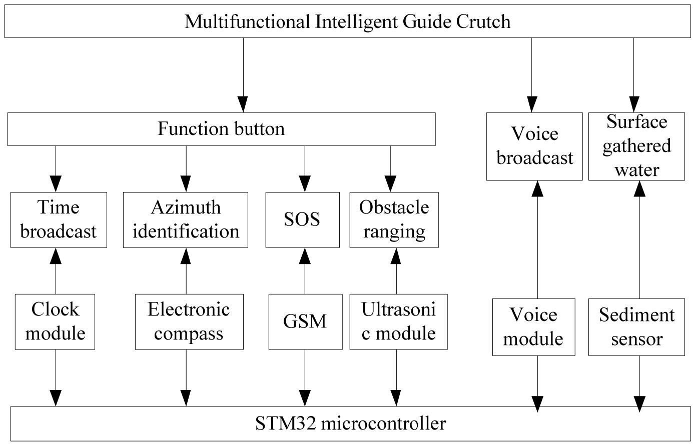

Fig 1. System structure diagram

2.1 Surface gathered water detection

After the rain, in some rural roads, or in the case of urban road construction, the road surface tended to have more water, which would cause inconvenience to the blind people, and even dangerous situations might arise. The common method for detecting water was to use bimetal. When the bimetal was immersed in water, the resistance would be generated. The size was related to the spacing and area of the bimetal. The advantage was that the structure was simple, but the bimetal would oxidize for a long time, affecting the detection precision.

In order to overcome this shortcoming, this paper adopted the method of capacitance measurement. Since the relative dielectric constant of water was much larger than that of air, the parameters such as the depth of water could be obtained by testing the change of rectangular plate capacitance. The formula for calculating the plate capacitance was as shown in the following equation.

$$C = \varepsilon \times S / d \tag{1}$$

Where, when the area S and the spacing d are constant, C is determined by the relative dielectric constant ε. In the actual production, the NE555 time-base oscillating circuit was used. When the water depth changed, the output frequency of the circuit changed. According to the variation, the water depth could be known. In addition, the guide crutch was often inclined during use, and the depth of the water in the oblique direction was measured, instead of the vertical depth, and the inclination sensor was used for correction to obtain the vertical depth of the guide crutch into the water.

2.2 Down step detection

When the blind person walked out, he often encountered the descending steps of the road surface. The traditional guide blinds could make a certain degree of prejudgment to the descending steps, but the warning time was short, due to the walking inertia, which would cause different degrees of danger. The descending step belonged to the downward mutation, and it was necessary to use a sensor with a certain height to tilt down to detect, and the ultrasonic ranging technology could not judge. In response to this problem, it was found that the PSD (position sensitive detector) ranging was a scattering ranging, and the measurement of the inclined surface can be realized.

PSD ranging uses the principle of geometric triangulation. The method is to align the laser with the emitting lens and then illuminate the object to be measured. The light scattered on the surface of the object is concentrated by the receiving lens onto the high-resolution photo detecting device to form a scattered spot. The center position of the spot is determined by the distance between the sensor and the surface of the object being measured, and the sensor output signal is related to the center position of the spot [3].

PSD is a PN junction capable of generating a photoelectric effect on the surface layer, and respectively corresponding two sets of electrodes and common poles are drawn, as shown in Fig.2.

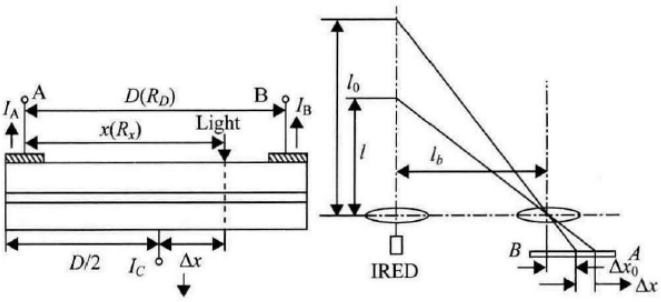

Fig 2. PSD structure and ranging principle

On the PSD element, the distance from the electrode A to the electrode B is D, and the internal resistance is RD. When the incident light is received, the distance from the beam position to the electrode A is x, and the corresponding resistance value is Rx. When the incident spot is constant, then at the electrodes A and B, a corresponding current is generated which is related to the pitch of the incident point to the corresponding electrode.

In order to make the ranging range wider and the sensitivity higher, the center of the PSD was not aligned with infinity, but was aligned with the intermediate distance l0. It can be seen from the geometric relationship that the PSD at this time had actually been shifted by an offsetΔx0.

$$\Delta x_0 = l_b f / l_0 \tag{2}$$

Where, f was the focal length of the ranging receiving lens, lb was the spacing between the transmitting and receiving lenses. According to the PSD characteristics, when the measured distance is l

$$I_A \propto \frac{D}{2} + \Delta x = \frac{D}{2} + \left(\frac{l_b f}{l} - \Delta x_0 \right) \tag{3}$$

$$I_B \propto \frac{D}{2} - \Delta x = \frac{D}{2} - \left(\frac{l_b f}{l} - \Delta x_0 \right) \tag{4}$$

The ratio of the output signal is related to the measured distance l.

$$P_l = \frac{I_A}{I_B} = \frac{\frac{D}{2} + \left(\frac{l_b f}{l} - \Delta x_0 \right)}{\frac{D}{2} - \left(\frac{l_b f}{l} - \Delta x_0 \right)} \tag{5}$$

$$\frac{1}{l} - \frac{1}{l_0} = \frac{D}{2 l_b f} \frac{P_l - 1}{P_l + 1} \tag{6}$$

When the ranging structure was determined, f, lb, and D were constants,

$$M = D/2 l_b f \tag{7}$$

Then there were:

$$\frac{1}{l} - \frac{1}{l_0} = M \frac{P_l - 1}{P_l + 1} \tag{8}$$

Formula (8) represented the correlation between the ratio Pl of the output current and l, so it was not necessary to determine the current value of each point, and the parameter l of the measured object could be completely obtained from Pl. Pl is the ratio of A and B currents. It is very difficult to divide in the actual circuit, so logarithmic compression can be performed on IA and IB, and then subtracted, as shown in Fig.3.

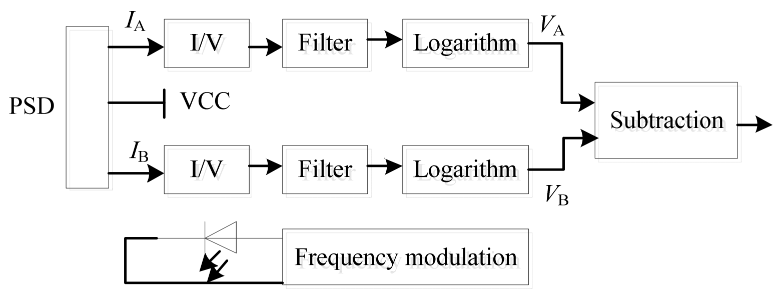

Fig 3. PSD signal processing circuit

In Fig.3, the signal processing circuit included two parts of the transmitting circuit and the receiving circuit [5]. The transmitting circuit adopted a frequency modulation system, and a modulation system with a frequency of about 700Hz was used according to the frequency selection characteristics of the laser transmitting tube and the PSD receiving device. The system transmitted a pulsed optical signal of 700Hz for approximately 100ms.

In the receiving circuit, the PSD two-terminal photocurrent was subjected to current-voltage conversion, filter amplification and logarithmic compression through two identical sets of circuits, and then subtracted, an output signal related to the ratio Pl was obtained.

In the design and production, it was noted that the transmitting part had interference to the receiving part. When the distance was long, the interference signal would be larger than the useful signal, so that the circuit cannot work normally, and space isolation and circuit shielding were required [6]. In addition, although the magnification before logarithmic compression had no effect on the circuit output, the circuit cannot be saturated.

The specific method for solving the signal interference was that the transmitting and receiving circuit boards were independent, the circuit board adopted the electromagnetic compatibility anti-interference design, and the large-area copper was grounded, and the anti-interference effect was obvious. At the same time, the transmitting and receiving boards were shielded by an aluminum box, and the outgoing leads were shielded. In the experiment, the transmission and reception were powered by their respective batteries, and the interference was greatly reduced, but the system cost was increased.

2.3 Program algorithm implementation

In the program design, it mainly included the collection of various sensor signals, the synthesis of speech and the generation of vibration reminder signals. The following mainly described the PSD ranging. The output value of the PSD signal processing circuit was VA-VB, which was related to Pl, that is, to the distance. Through A/D conversion, the distance could be calculated by formula in the MCU, but it was more troublesome. The simple and quick method was to use the look-up table method to measure the relationship between distance and VA-VB in advance, and stored it in the form of a table in the microcontroller. When the guide crutch was used, the distance was obtained by looking up the table.

When judging whether there was a descending step, the front and back measurement comparison method was used. The previous measurement result was the reference. If the latter measurement result was greater than the previous threshold, it was considered that there was a descending step in front, and the threshold value must be determined experimentally. The program flow chart was shown in Fig.4.

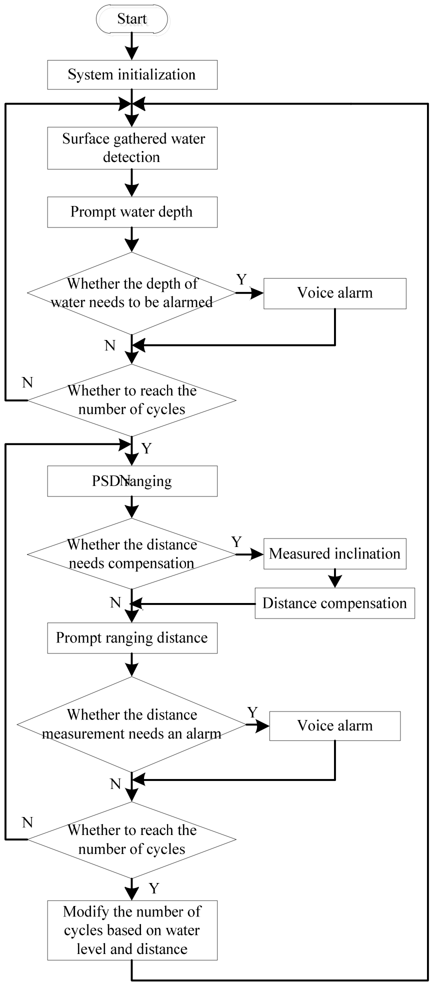

Fig 4. Program flow chart

3. EXPERIMENTAL RESULTS AND ANALYSIS

3.1 Surface gathered water detection experiment

The experiment was carried out with two samples of clean water and muddy turbid water. The actual water depth was calibrated with a stainless steel scale. The specific results are shown in Table 1.

Table 1. Clean water and dirty water test results

Clean water			Dirty water		
Actual depth /mm	Measuring depth /mm	error /%	Actual depth /mm	Measuring depth /mm	error /%
10	10.6	6.0	10	10.8	8.0
20	21.0	5.0	20	18.5	-4.5
50	48.2	-3.6	50	48.0	-4.0
100	103.0	3.0	100	103.5	3.5
200	196.0	-4.0	200	194.0	-3.0

The measurement results of the above two kinds of water show that the sensor can be adapted to the measurement of water with different cleanliness and relative dielectric constant under the condition of double structure and comparative measurement. However, the error of the depth measurement was large, and there were two reasons for the analysis. First, the actual depth was determined by the visual method. Due to the wetting effect of the water on the scale, the actual depth of the measurement itself may have a certain error. Second, the sensor capacitance was shallower than the shallow depth. At this time, the circuit distribution capacitance changes, the ambient temperature effect cannot be ignored. For the blind to detect the water in front of the road, the author believes that the error is still acceptable.

3.2 PSD ranging

In the indoor situation, the sensor was facing the wall, the distance measurement error test, the ranging error was within 4%, but for the general use of blind navigation, it was considered acceptable. The specific results were shown in Table 2.

Table 2. PSD ranging result

Vertical test			Tilt 45^o test		
Actual distance /cm	Measuring distance /cm	error /%	Actual distance /cm	Measuring distance /cm	error /%
100	102	2.0	100	103	3.0
120	124	2.3	120	115	-4.2
150	145	-3.3	150	143	-4.7
200	207	3.5	200	211	5.5
250	242	-3.2			

Since the PSD sensor needs to be slanted downward when detecting the descending step, experiments were carried out with common outdoor cement floors and asphalt roads. In the experiment, it was found that when the angle between the sensor and the ground was between 90oand 42o, it can be effectively measured, but the distance and accuracy of the distance measurement will be reduced to some extent. For example, when the sensor was irradiated and the ground was at an angle of 45o, the maximum distance was 2m, and the error was about 5.5%. The reason for the error is that in the case of oblique shooting, the reflected light intensity is lowered, the signal-to-noise ratio is lowered, and the measurement range and accuracy are affected. However, for the general purpose of blind navigation, it is considered acceptable. The measurement results of the PSD sensor at a tilt of 45o are shown in Table 2.

4. CONCLUSION

Aiming at the inconvenience of the blind people's real life activities, a technical scheme of intelligent guide crutch is given. Based on the advantages of the current intelligent guiding cane, other environmental detection functions are added to help the blind people to travel safely and return to society. This paper mainly introduces the PSD sensor to detect the descending step. After calculation and experiment, it can judge the descending step with height greater than 8 cm, and the warning distance is about lm. PSD ranging has certain requirements on the reflector material and emission angle due to the influence of the scattered light intensity. In the future, we will continue to optimize circuits and program algorithms, reduce the requirements for reflectors, further improve detection performance, improve detection sensitivity, and increase warning distance. It is expected to greatly facilitate the travel of blind people.

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