Blind-assisting Waistcoat Based on Distance-Vibration Algorithm and Sensory Substitution Principle

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Abstract. At present, there are more than 200 million people having the congenital or acquired visual disorder in the world. Blindness make the daily activities of people subjected to various restrictions, and the most prominent restriction is obstacles in walking. The traditional guide tool used by most visual impaired people for assisting the walking has the defects such as single function, inconvenience in use, poor combination with the human body, etc. Therefore, with the development and increasing mature of the wearable device and the Internet-of-things technology, a new way is searched for solving the walking problem of the blind people, and the study for combining the blind assisting device with the frontier neuroscience, wearable technology and Internet of things can make the science and technology to benefit this disadvantaged group and has positive social significance. This study utilizes the laser radar to substitute the visual organ to acquire spatial distance information around the blind people, transmits the data to the Arduino single chip microprocessor to process through the serial port, and finally controls the vibration mode on the waistcoat through the Bluetooth communication, thereby innovatively converting the radar input into the vibration mode, developing the corresponding distance-vibration algorithm, and allowing the blind people to acquire the spatial obstacle information in a motion sensing mode. Over a given adaption period, as the user’s brain learns, understands and integrates different vibration modes, the user can directly have the vision-like depth perception of the space in a sensory substitution mode on neuroscience.

1. Introduction

1.1. Background and significance of the research
According to the statistics of the World Health Organization, there are more than 200 million people having congenital or acquired visual disorder in the world. The blindness is a physical disability severely restricting the normal life and activity of people. Visual cortex in the human brain sends the processed target information into two parallel routes after receiving the input of optic nerves. The main function of ventral occipitotemporal sulcus route is to process information of an object such as shape, characteristics, color, etc. The dorsal parieto-occipital route is responsible for transmitting visual data of the object such as the location, coordinate and the like. Therefore, the blindness not only deprives people of visual experience in color and patterns, but also greatly affects the judging ability of people for the spatial shape. It means that the blind people cannot perceive the peripheral spatial
situation in a distance range that their limbs cannot touch and the traditional guide cane cannot reach. It can be concluded from medical cases of Mike May and other studies that the depth perception disorder is just a main factor causing of the walking difficulty of the blind people. Therefore, the key for assisting the walking of the blind people is to find an effective way for rebuilding the depth perception and to make people capable of receiving the information about the spatial depth.

The sensory data can be fed through a sensory channel different from the conventional ways. Various studies have already proved that the human brain can learn to extract the meaning of this kind of information stream. It is particularly valuable that the sensory substitution is a sustainable non-intrusive technique which can provide the sensory information through another channel to avoid the loss of this feeling. The application of this theory has already become a research focus of the modern biomedical engineering field.

1.2. Current situation of the development

There are various devices assisting the visual impaired people on the market at present, but they have many limitations.

The traditional guide cane is most widely used at present and is lowest in cost, but it has single function and is required to manually move and touch the ground, and its detection range is small and is only limited to a ground area about one square meter in a length range of the guide cane. The user can make judgment by touching obstacles and sidewalk for the bind around his feet, but always runs into the objects at the height of the face such as the signboard.

Guide dogs are strictly trained and know a lot of commands. They can guide the blind people to walk and can guide their owners to stop to avoid dangers when there are obstacles and turns. However, it is expensive to train and care the guide dogs, and the interference of pedestrians and unfamiliar environment may cause the attention shifting of the guide dogs. Moreover, it is inconvenient to carry the guide dogs in a lot of public places such as the train station, so the application space of the guide dogs is greatly limited.

There are also fewer electronic guide canes and smart guide instruments on the market. They can detect the road conditions in a wider range by installing a probe, sometimes including the detection of obstacles above the pavement. For example, the electronic guide cane developed by GANGANGUANGBO - the assistant professor in Akita Prefectural University and consists of an ultrasonic distance measuring circuit, a photosensitive alarming circuit, a voice recording and playing circuit and a power supply circuit. Its ultrasonic distance measuring circuit consists of an ultrasonic distance measuring module and a triggering output circuit. When ultrasonic waves encounter obstacles, an ultrasonic signal of a same frequency but different phase is returned. A receiving circuit is a phase discrimination and filter circuit and is used to filter the original signal and then compare the phase difference. A distance d from the obstacle to the blind people is in direct proportion with the phase difference ΔP, i.e. \( d = k\Delta P \). When \( \Delta P \) is greater than a threshold value, a signal output circuit is triggered to transmit an obstacle encountering signal to be directly connected to a play control input end of the voice module. After receiving the play signal, the voice module reads voice data from ROM to a DA conversion circuit, and then through a two-order filter and power amplification circuit, a prompting voice is sent to the blind people by a loudspeaker. A photosensitive resistor will drive a red LED to transmit the prompting information.

These devices can solve the problems of the detection range limitation and accuracy to certain extent, but they are expensive and still adopt the guide cane form, and are low in combination with the human body. Holding the cane to detect the road is still a limitation for the activity of the user and make them unable to free hands to perform the daily actions such as lifting bags, opening doors, fetching, etc. Furthermore, the guide cane is large in size, the voice prompting is abrupt in the public places, and the user cannot easily reach the psychological state of normal living and barrier-free life. A subsection

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2. General design of the system

The system consists of three main parts.

1. Head-wearing scanning radar

The head-wearing scanning radar is an input module of the system and is used to detect a distance of a front object of a certain angular range on the advancing path of the blind people and to judge whether the blind people should avoid the front obstacle by detecting the distance of the object in a certain range of the user. The head-wearing scanning radar is controlled by the rotation of a servo motor head to rotate so as to scan an area in front of the blind people and to transmit the measured distance data to a main control module through a communication serial port.

2. Bandage-type arm radar

The bandage-type arm radar is also an input module of the system and is a radar fixed on an arm of the user through a bandage. It is used to measure the distance and speed of side obstacles so as to judge whether the blind people has the walking danger. The bandage-type arm radar transmits the measured distance data to the main control module through the serial port communication. The main control module is used to calculate the speed.

3. Wearable vibration-type waistcoat

The wearable vibration-type waistcoat is an output module of the system and provided with a vibration module and a luminous module and makes corresponding response according to the information transmitted by Bluetooth receiving modules (1) and (2). The specific response is the dot matrix vibration of different positions and the luminance reflecting the specific information of the obstacle. The artificial touch feeling is formed through the response of the vibration and luminance and reflects the specific location of the obstacle for the wearer and reminds people surrounding the wearer.

The physical picture of this system is as shown in Fig. 1, Fig. 2 and Fig. 3. This system includes three portions stated above, i.e. the head-wearing scanning radar, the bandage-type arm radar and the vibration-type wearable waistcoat.

Figure 1. Head-wearing scanning radar
3. Software design
All functions of this system are realized by C-language embedded programming in the Arduino development environment. The system program is started by the bandage on the arm and the main control on the head-wearing module. After the program is started, Arduino controls the servomotor head in the head-wearing module to move. At the same time, the laser radar is started to scan the peripheral environment and return a real-time obstacle distance and transmit the distance data into the main control for processing through the serial port communication. The main control compares the received distance data with a distance threshold value that is inputted in advance. If the distance is less than the set threshold value, it indicates that the obstacle distance is within a dangerous range, and the main control module transmits the real-time servomotor angle and bandage distance information to the vibration-type waistcoat through the Bluetooth module.

After receiving the angle information transmitted by the Bluetooth module, the main control module of the waistcoat judges an angle range of the servomotor and reflects the real-time location of the servomotor as the location information of the obstacle to the wearer through the vibration modules that are distributed in a Sudoku form, so that the wearer can make timely response to avoid the obstacle, thereby achieving an artificial sensory effect.

4. Experiment design and result analysis
A series of experiments are designed herein to verify the feasibility and accuracy of this system. The experiment contains two parts: actual wear experiment of subjects and quantitative analysis experiment

4.1. Actual wear experiment of subjects
The thought of this experiment is as follows: select a subject to wear all devices of this system and cover the eyes of the subject with a blinder so as to simulate the walking circumstance of the blind people. Thereafter, the subject walks in an empty room with obstacles. If the subject can sense the location of the obstacles, the subject can avoid the obstacles under the eye covering condition. The experiment result shows that the subject can avoid the obstacle under the instruction of the device when walking slowly. Meanwhile, the vibration modules can well reflect the distribution of the obstacles.
4.2. Quantitative analysis experiment
To detect the accuracy of this system through data, the following experiment scheme is designed for this system: firstly, select a Sudoku drawer of 40cm*40cm, place the Sudoku drawer on an edge of a desktop to simulate the spatial distribution of obstacles, and number the drawers, wherein the nine drawers respectively correspond to numbers 1-9 from left top to right bottom. Number diagram of the Sudoku drawer is as shown in Figure 5.

![Figure 5. Number schematic diagram of Sudoku](image)

When in experiment, the head-wearing scanning radar module is arranged a same horizontal line with the Sudoku center (i.e. No. 5 drawer), and the situation under different distance threshold values is simulated by changing the distance between the radar and the drawer. If the distance between the radar and the drawer is just the set threshold value and the drawer is pulled out, the radar can detect the presence of the obstacle in the distance threshold value, and the location of the withdrawn drawer can be reflected on the waistcoat (for example, when the No. 4 drawer is pulled out, the No. 4 LED light on the corresponding position of the waistcoat will emit light). If the radar can make accurate response on each location, it can prove the accuracy and feasibility of this device.

Under such experimental concept, the writer performed two groups of reference experiments, i.e. the scanning mode reference experiment and the distance reference experiment. In each group of experiment, the scanning of 50 cycles is carried out, and the times that the radar can accurately reflect the location when each Sudoku drawer is pulled out is recorded.

4.3. Scanning mode reference experiment
The servomotor head of this system has two scanning modes, i.e. crossing scanning mode and M-shaped scanning mode. At the crossing scanning mode, the servomotor moves only on the transverse axis and longitudinal axis in one scanning cycle, and the scanning locus of the servomotor in one cycle is in a crossing shape. At the M-shaped scanning mode, the servomotor moves obliquely along an M-shaped locus in one cycle, and the scanning route in one cycle is in an overlapped shape of an M and an inverted M. The control logic of the crossing scanning is simple, and the scanning period is short,
but the scanning dead corner is large; and the M-shaped scanning is wide in scanning range and can realize a scanning range almost without dead corner just in front of the wearer, but its control logic is complicated, the needed scanning period is longer and is about three times of the crossing scanning mode. The experiment results are as shown in table 1 and table 2:

| Table 1. Crossing scanning experiment results |
|---------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| No. | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    |
| Action times | 2    | 48   | 3    | 47   | 48   | 49   | 4    | 48   | 2    |

| Table 2. M-shaped scanning experiment results |
|---------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| No. | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    |
| Action times | 46   | 48   | 47   | 50   | 49   | 46   | 48   | 48   | 49   |

It can be seen from the experiment data that under the crossing scanning mode, the radar almost has no action on four locations, i.e. 1, 3, 7 and 9 (fewer actions may be regarded as move by mistake), and the four locations are just located outside the transverse axis and longitudinal axis; and meanwhile, under the M-shaped scanning mode, the radar has accurate action at each angle, which is in line with the above analysis result.

5. Conclusion and prospect

Based on Arduino and laser radar, under the wearable concept and the concept of the sensory substitution, this study designs a vibration-type walk-assisting waistcoat for the visual impaired people such as the blind people. We analyze main walking difficulties of the blind people and try to solve these difficulties and make optimization by using technological means. This study utilizes the laser radar to substitute the visual organ to acquire spatial distance information around the blind people, transmits the data to the Arduino single chip microprocessor to process through the serial port, communication and finally controls the vibration modules on the waistcoat through the Bluetooth communication to conveys different spatial information by the different combinational vibration modes of nine dot matrix on the waistcoat. We used the luminous module and the vibration module to act together in the experiment so as to make this process visualized. We used the side radar to detect the distance and the approaching speed of the object. In this way, when the danger such as approaching of vehicles to the side of the blind people occurs in real life, the guide waistcoat can make prompting in time. The wearable device creatively allows the blind people to acquire the space and obstacle information in a motion sensory way and is convenient for the user to wear, thereby maximally reducing the limitation to the life and activity of the blind people. Based on the existing research achievements of the neuroscience, we can look forward that over a given adaption period, as the user’s brain learns, understands and integrates different vibration modes, the user can directly have the vision-like depth perception of the space in a sensory substitution mode, which greatly helping their daily walk and improving their life.

However, due to the limitation on the time and hardware materials for researching and making the prototype, the existing design can be further improved. The radar can be embedded into the wearable device in a smaller and more portable mode, and a built-in rotary scanning function rather than the servomotor driving can be adopted.

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