Modernization of the device for assisting visually impaired people for positioning in space

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Abstract. **The article discusses the modernization of a device that helps visually impaired people to detect obstacles such as "step up" and "step down".**

The article presents a structural diagram of a modernized device, an updated element base, a new design, as well as expanded functionality.

Instead of two HCSR-04 ultrasonic sensors, two JSN-SR04T ultrasonic sensors with a transmitter and a receiver combined in one housing with a working distance of up to 4.5 m were used as sources of information about obstacles in the upgraded device. Sensor signal processing was now performed using the Arduino Nano platform. Signals about the presence of obstacles, their type and distance to them were output to one vibration motor. The upgraded device was powered not from one 9V battery, but from one high-capacity NCR18650B battery with a charging board.

A smartphone can be connected to the upgraded device via a wireless communication module, on the screen of which programmed information about a person's movements can be displayed. In addition, you can make some changes to the software settings using your smartphone.

The structurally modernized device is made in the form of a conventional walking stick, and the replacement of the ultrasonic sensors with the JSN-SR04T made it possible to mark the sensors in the handle and the rubber tip of the cane, making their presence less noticeable to others. The weight of the finished device was 490 g with a cane height of 83 cm.

Testing this device on a limited set of conditions showed the validity of the chosen research direction. During the experiments, such a drawback was found as the appearance of false alarms when moving in an apartment on the carpet when an obstacle of the "step down" type is detected. When walking on laminate and linoleum, there were no false positives.

Key words: visually impaired people, obstacle, positioning in space, microcontroller, smartphone, cane.

I. Introduction

The World Health Organization [1] estimates that about 1.3 billion people in the world live with some form of visual impairment.

Most people with visual impairments are in the age group over 50.

With regard to distance vision, mild visual impairments are observed in 188.5 million people, from moderate to severe - in 217 million, while 36 million people are affected by blindness. When it comes to near vision, 826 million people live with this kind of visual impairment.

With the growth and aging of the population, there will be an increased risk that more people will develop visual impairment.

II. Problem setting

Advances in microelectronics and measuring transducers have made it possible to create a number of devices to make it easier for visually impaired people to navigate in space.

Today, there are such tools for helping visually impaired people as WeWALK electronic cane (Fig. 1), Robin smart assistant, SunuBand smart bracelet, eSight 3 glasses, Amigo cane, SmartCane cane, LaserCane cane.

Fig. 1. WeWALK smart cane

The peculiarity of these devices is their functioning as some additions to the "white cane", which is a mandatory attribute of blind people. The lasers or vision systems used in these devices only expand the capabilities of the "white cane", but make the owners of such devices very noticeable among other people.

At the same time, visually impaired people are extremely sensitive to the fact that others notice their physical disabilities associated with poor vision. For this reason, one of the

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primary tasks in the development of a device to help visually impaired people is the invisibility of such a device to others.

The results of the development of such a device by a team of teachers and students of the Moscow Polytechnic University are presented in the publications [2-6].

A prototype aid device is shown in Figure 2.

Fig. 2. Photos of a prototype aid device

For use in the prototype of the assistance device, the HC-SR04 sensor was chosen as the most optimal sensor in terms of price/quality ratio. This is an ultrasonic sensor with a separate emitter and receiver, which has an operating range from 2 to 400 cm.

First of all, we are talking about the development of a device for helping visually impaired people. Such people are able to distinguish large details of the surrounding world (for example, doors, windows, cars, etc.). However, at the same time, they cannot discern things such as small holes, steps leading up or down, curbs and similar obstacles. In this case, they are forced to use a white cane, which leads to increased attention from others. However, in most cases, an ordinary person does not even know how much a person with such visual impairments wants the people around him not to notice these problems.

The prototype did not meet the requirements of stealth. The weight of the prototype was also significant - 0.88 kg with a battery, which required the use of an additional shoulder strap for extended wear.

The next version of the help device was developed on the basis of a conventional cane (Fig. 3), but also two HCSR-04 ultrasonic transducers were used as measuring transducers in this device, which also made this version noticeable to others.

Fig. 3. Second variant of help device

Thus, the requirement of being invisible to others in this device remained unfulfilled.

III. Discussion

Visually impaired people confidently distinguish between doorways, windows, apartment furnishings, other people, pets, as well as means of public and individual transport. The main problem for visually impaired people is the timely detection and recognition of such obstacles as thresholds in the house, stairs, curbs, stones, pits and cliff edges. It is not necessary for them to use a white cane, but these obstacles that are not noticed in time can cause injury to a person.

Thus, the upgraded device should retain the functions of detecting an obstacle, determining its type and distance to it, while observing the requirements of being invisible to others.

Instead of two HCSR-04 ultrasonic sensors, two JSN-SR04T type ultrasonic sensors with a transmitter and a receiver combined in one housing with a working distance of up to 4.5 m were used as sources of information about obstacles in the upgraded device.

Replacing the ultrasonic transducers with the JSN-SR04T made it possible to mark the transducers in the handle and rubber tip of the cane, making them less visible to others.

The block diagram of the upgraded device is shown in Figure 4.

The core of the device is the Arduino Nano hardware platform, which significantly reduced the size of the device.

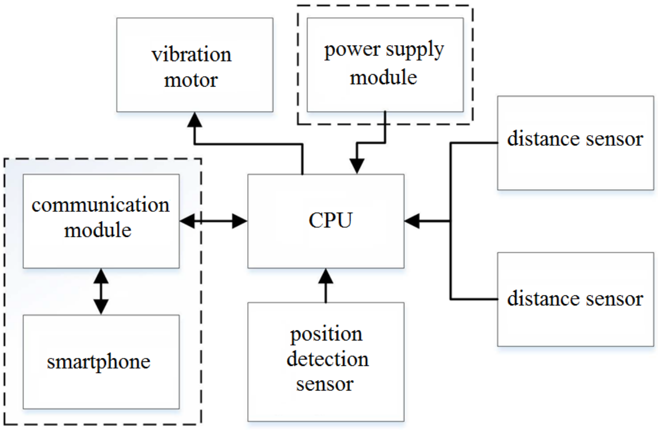

Fig. 4. Block diagram of the device

The algorithm of the device operation can be described as follows:

- power turns on, the device is initialized and the main program starts;
- initially, the "step up" obstacle sensor (Fig. 5) is interrogated, and its signal is compared with the threshold value for the near range (Fig. 6) set by the software, the interrogation occurs only if the cane is in working position;
- if the sensor signal is higher than the threshold value, power is supplied to the vibration motor with a frequency of 5 Hz and a pulse-width modulation (PWM) value corresponding to the near range, the PWM value sets the vibration amplitude.

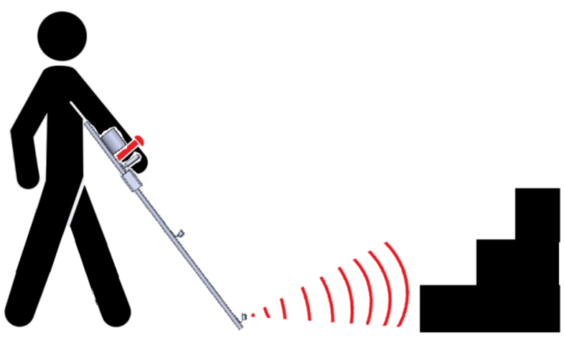

Fig. 5. "Step up" obstacle detection

The near range of obstacle detection is the distance interval from 25 centimeters (since the sensor has a dead zone) to the reference point (in the program and application, this variable is called "dist1"). The reference point can be located in the range from 30 to 200 centimeters.

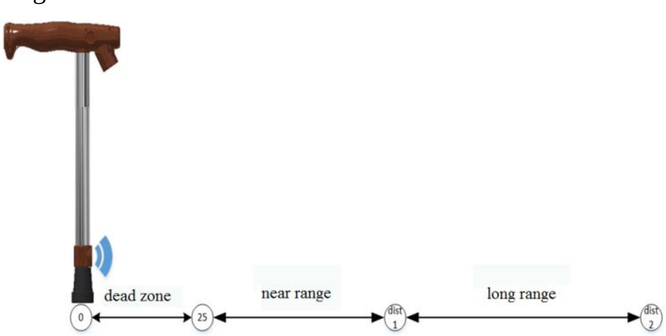

Fig. 6. Near and far range to "step up" obstacles

The far range of obstacle detection is the distance from the reference point (variable "dist1") to the maximum recognition distance (variable "dist2"). The maximum distance can be from 100 to 300 centimeters.

If there is no "step up" obstacle in the near range, then it is searched for in the far range.

When you press button 1 on the handle of the cane, information is displayed on the smartphone in accordance with the application interface (Fig. 7).

Fig. 7. Application interface

If there is no "step up" obstacle, the program proceeds to search for an obstacle of the "step down" type (Fig. 8). At the same time, the sensor located in the upper part of the cane is interrogated, and its output signal is compared with a threshold value set in the software;

If the signal of the upper sensor is higher than the threshold value, a constant voltage is applied to the vibration motor for 500 ms.

Then the pressing of button 2 is checked and, if it was pressed, the programmed information (location, time, pedometer) is sent to the smartphone.

After 20 seconds, the program loops.

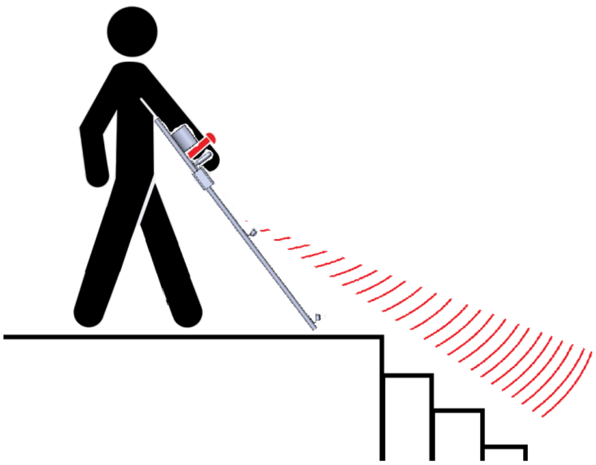

Fig. 8. "Step down" obstacle detection

The upgraded device was powered not from one 9V battery, but from one high-capacity NCR18650B battery with a charging board.

A photo of a completely finished device is shown in Figure 9.

Fig. 9. Photo of the finished device

The use of a high-capacity NCR18650B battery made it possible to increase the continuous operation time of the device with the flashlight on to 5 hours and 40 minutes, and with the flashlight off to 9 hours.

It is important to note the presence of a micro-USB connector on the device, which makes it possible to connect an external portable 5-volt charger and continue using the cane even if the internal battery is discharged.

The mass of the finished device was 490 g. The length of the cane is 83 cm.

An essential feature of the device is that the detection of an obstacle, its recognition and measurement of the distance to the obstacle occur while walking and do not require stopping or any trial movements.

Tests of the upgraded device, carried out inside the building, confirmed the effectiveness of the proposed solutions, but at the same time revealed such a drawback as the appearance of false alarms when moving in an apartment on a carpet when an obstacle of the "step down" type is detected. False positives ranged from 20% to 80%. When walking on laminate and linoleum, there were no false positives.

The upgraded device practically does not differ from a standard cane.

IV. Conclusion

In the process of modernization, the following solutions were proposed and implemented:

- in order to reduce the weight and dimensions, the Arduino Uno hardware platform was replaced with the Arduino Nano hardware platform;
- two JSN-SR04T ultrasonic sensors with a transmitter and a receiver combined in one housing with a working distance of up to 4.5 m were used as sources of information about obstacles instead of two HCSR-04 ultrasonic sensors;
- the use of JSN-SR04T ultrasonic transducers made it possible to place them in the handle and the tip of the cane;
- signals about the presence of obstacles, their type and distance to them were output to one vibration motor;
- wireless connection of the smartphone made it possible to display programmed information on its screen, as well as set the distance to an obstacle of the “step up” type;
- the upgraded device was powered not by a single 9V battery, but by a single high-capacity NCR18650B battery with a charging board, which significantly increased the operating time of the device, and also allowed you to recharge the battery without removing it from the cane.

The upgraded device is almost indistinguishable from a standard walking stick, which makes it almost invisible to others.

As a result of tests of the upgraded device, its operability was confirmed. At the same time, the following directions for further improving its characteristics were identified:

- due to the fact that the JSN-SR04T ultrasonic transducers has a wider directional pattern than the HCSR-04 ultrasonic sensors, it is necessary to conduct additional research on the possibility of false positives of the "step up" sensor from small road surface irregularities;
- it is necessary to conduct serious experimental studies of the operation of the device for different materials of reflecting surfaces, as well as for obstacles of different shapes and sizes;
- to increase the moisture protection of the device, it is planned to analyze the possibility of using a sensor of the US40-25A type made in a hermetic aluminum housing;
- increase the computing power of the device core to solve more complex problems related to complex obstacles.

All proposed changes are currently under development.

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