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An electronic traveler aid for the blind using multiple range sensors

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Abstract: This paper presents a novel electronic travel aid, called iSONIC, which can help a visually impaired person walk around more safely. Attached to a conventional white cane, the iSONIC detects obstacles at head-height that cannot be covered by a traditional cane and gives warnings in the forms of vibration or sound to avoid dangerous situations. We developed an algorithm to restrict the sensing range to reduce confusing and unnecessary detections and a method to remove the sensing errors due to the impact of ground tapping. In addition to obstacle detection, the iSONIC give information of object color and the environmental brightness when the user wants to know.

Keywords: electronic travel aids, blind people, range sensor

Classification: Ultrasonic electronics

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1 Introduction

Most of the blind or partially sighted people use white cane or guide dog to assist walking. The conventional white cane is the most successful and widely used. However, the white cane scans only a small area ahead of the user and

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cannot detect obstacles especially at head-height, which could cause severe damage. The guide dogs are very helpful for the blind but require extensive training. In addition, caring for the dogs appropriately is not easy for the blind.

In order to address these limitations, Electronic Travel Aids (ETAs) have been developed [1, 2, 3, 4, 5]. Detecting an obstacle using a cane is limited within the area in which it can reach. Use of sensors greatly extends the range of obstacle detection in ETAs for the blind and partially sighted people. Typically, An ETA uses a laser or ultrasonic beam which is emitted in certain direction in space. The beam is reflected from objects that it confronts. A matching sensor detects the reflected beam and determines the distance and shape of the object based on the time difference between emitting and receiving the beam.

In this paper, we introduce a new electronic travel aid for the blind, called iSONIC, which can detect obstacles using multiple range sensors and informs the user via tactile and aural feedback. Attached to a conventional white cane (Fig. 1), it senses obstacles in front of the upper body, which cannot be covered by a conventional cane.

There are three main contributions to enhance the previous devices, which are as follows; the development of an algorithm to restrict the sensing range to detect obstacles only in the forward moving direction using a ultrasonic sensor, a gyro sensor and an inclinometer, the development of a method to eliminate impact errors caused by tapping the ground based on a filtering method, and providing functions to sense the colors of objects and the brightness of surroundings using a color sensor.

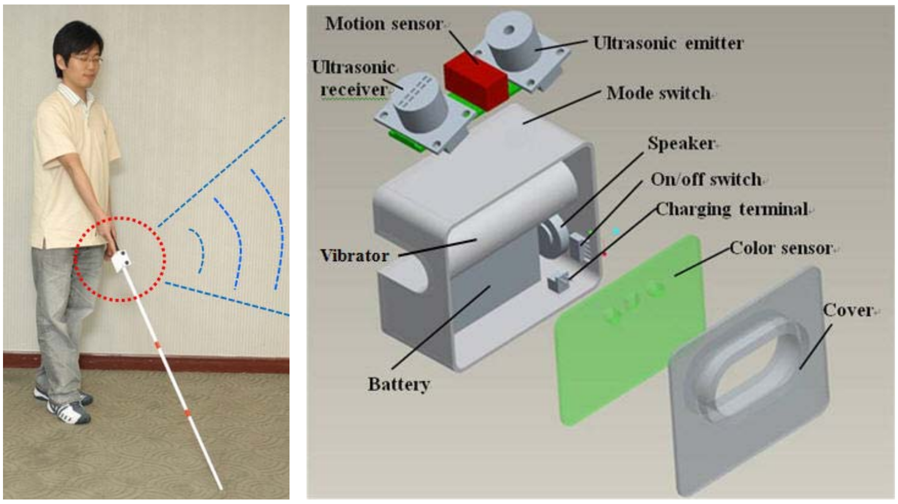

Fig. 1. iSONIC: a new electric travel aid for the blind

2 iSONIC : a new electronic travel aid

We introduce a new electronic travel aid to enhance the function to detect obstacles and to sense object's color information and the environmental

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brightness. The iSONIC consists of an ultrasonic sensor to detect obstacles; a gyro sensor and inclinometer to limit detection range; a color sensor to detect the colors of objects; a brightness sensor to detect the brightness of surroundings; a micro-processor and electric circuits to process sensing data; a vibrator to warn of the existence of an obstacle (Fig. 1). The size of the iSONIC is 70 mm x 42 mm x 62 mm and weight is around 130 g.

2.1 Limit the detection range

The ultrasonic sensor is used to detect obstacles at head height along the travel path ahead of the user. Typically, blind people still sweep the cane in order to scan obstacles on the ground. The sweeping motion leads the wide angle detection causing confusing and unnecessary measurements at both left and right position of cane. For instance, the ultrasonic sensor may detect obstacles which is far from the centerline of the user's travel path and would not block the user's forward motion.

In order to determine both extremities and ignore the measurements, the rate gyro is installed near the sensor (Fig. 2). By integrating the angular velocity with respect to time, the angle of the cane is calculated. The inclinometer is used in order to reset the accumulated integration error by measuring the absolute angle from the direction of the gravity. The inclinometer has quite large response time, so the reset is made when the gyro value does not change for more than 0.4 second. iSONIC discards the measurements around the left and right positions to limit the detection range.

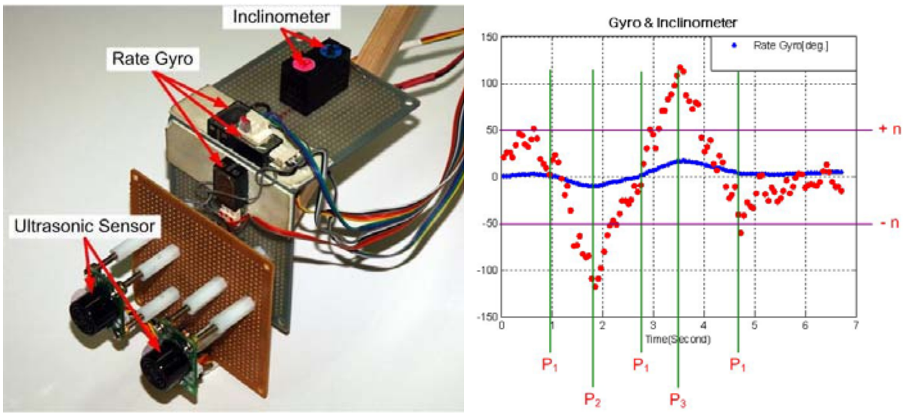

Fig. 2. Detection both left and right positions to limit the detection range. P1 is the middle position, P2 is the most left position, P3 is the most right position, n is the pre-set value.

2.2 Remove the error due to tapping the ground

Practical difficulty arises when the ultrasonic sensor is used for the cane. The user frequently taps the ground or an obstacle with the cane and the impact causes an incorrect measurement of the range due to the sensing mechanism of the ultrasonic range sensor. Fig. 3 shows the raw data from the ultrasonic

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sensor and the filtered result. As the cane sweeps, the distance varies from 110 cm to 160 cm. However, during the course of ten sweeps, five incorrect measurements are made due to the impacts.

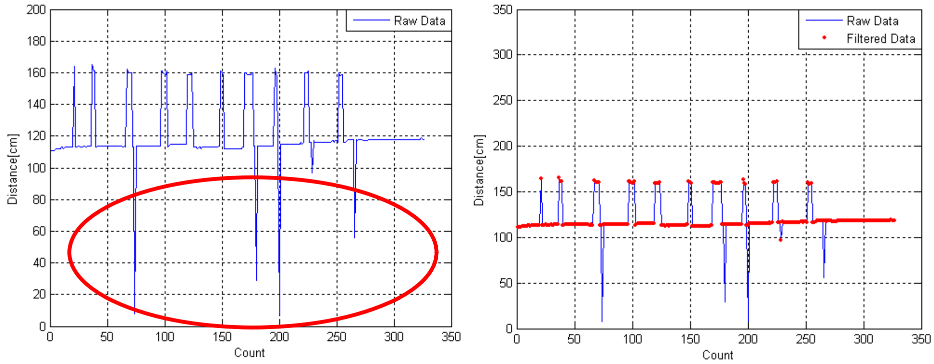

Fig. 3. Compensation of impact disturbance

In order to remove this impact disturbance, a simple moving average filter is used as follows:

$$S_{avg}(i) = \sum_{j=i-N+1}^{i} \frac{S(j)}{N} \tag{1}$$

If $\quad s_{avg}(i) - s(i) > 40$

Then $\quad s_{filtered}(i) = s(i-1)$

Else $\quad s_{filtered}(i) = s(i)$

For our implementation, the value of N is set as 5 based on experiments in various environments including wood, brick, and clay floors.

With three axes accelerometers and three axes rate gyros, the relative 3D movement can be estimated, which is described in this subsection.

The orientation of an object in 3D is described with the Euler angles (Roll, Pitch, Yaw) and their relation to the angular velocities in three perpendicular axes is represented in the following equation:

$$\frac{d}{dt}\begin{bmatrix}\phi \\ \theta \\ \varphi\end{bmatrix} = \begin{bmatrix} 1 & \sin\phi\tan\theta & \cos\phi\tan\theta \\ 0 & \cos\phi & -\sin\phi \\ 0 & \dfrac{\sin\phi}{\cos\theta} & \dfrac{\cos\phi}{\cos\theta}\end{bmatrix}\begin{bmatrix}\omega_x \\ \omega_y \\ \omega_z\end{bmatrix} \tag{2}$$

where ϕ, θ, φ are the roll, pitch and yaw angles respectively and ω_x, ω_y, ω_z are measured angular velocities in the x, y, z coordinates using the rate gyros.

Three accelerometers are attached perpendicularly to each other and each measure the acceleration in sensor coordinates. The acceleration in global coordinates A_g is calculated from the following equation.

$$A_g = C_s^g A_s - G \tag{3}$$

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where C_s^g is the directional cosine matrix, A_s is the acceleration vector in sensor coordinates, and G is the gravity matrix.

We calculated position vector A_g by integrating with respect to time twice the acceleration vector in (3).

2.3 Sensing color and brightness information

The iSONIC has extra features to sense the colors of objects and the environmental brightness, which have been requested from the blind for their daily life. The color sensing is implemented using a color light-to-frequency converter. Colors are correctly identified as RGB (Red, Green, and Blue) values. However, it is not easy to separate various colors based on RGB values. Instead, a representative value will be much more understandable to the user. So, we converted RGB values to HLS (Hue, Lightness and Saturation) values in order to represent the colors appropriately. Lightness and Saturation values are used to differentiate white, black, and grey color from other colors. The Hue value is then used to select the corresponding representative color. Red, Yellow, Green, Violet and Blue are selected based on a user survey. When the user pushes the color sensing button, the iSONIC informs the user of the result by the synthesized voice. The brightness is measured using a CdS (cadmium sulfide) photo resistor. As with the color sensing, a synthesized voice was used to inform the user of the brightness.

3 Usability evaluation

To evaluate the usability of the iSONIC, we have defined evaluation items. Evaluation items have 3 categories: availability, convenience, and maintenance. In the availability category, we have selected 7 types of criteria such as necessity, easy of control, reliability, propriety of feedback, easy of learning, error prevention, and error recovery.

According to the result, the most evaluators can easily learn to use the device. They said all functions of the iSONIC have moderate reliability but they wanted to improve the accuracy to detect obstacle. For the tactile and audio feedback, they were satisfied. And they sometimes pressed wrong button by mistake but they were able to overcome the problem quickly and easily. Some of evaluators felt weight unbalance due to attaching the iSONIC onto the white cane. And subjects think that there is no noise in the device.

We realized that size and weight of the device are still problems for the blind even though we have tried to reduce the size and weight. The evaluation result shows that the users want smaller and lighter one. The iSONIC is easy to carry. But the durability of the device is not good enough. Some of subjects have a difficulty in attaching and detaching the device on the white cane. And, as a final comment, most of the evaluators would like to buy the iSONIC when it becomes available commercially.

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4 Conclusion

This paper presents a new ETA, iSONIC, to help the visually impaired person to move about more safely. Using an ultrasonic sensor, the iSONIC detects obstacles at head-height that could cause serious damage to the human face and brain. It allows the blind to avoid dangerous situations by warning system through vibration and voice.

To enhance the obstacle detection, we have developed two functions: neglecting unnecessary range reading due to sweeping motions and the sensor's wide beam coverage based on a rate gyro and an inclinometer, and removing impact errors due to tapping the ground using a moving average filter. In addition to the obstacle detection, the device can read information of object colors and environmental brightness.

The device was selected as the subject of a government supported model implementation. To put the device to practical use, more development is needed for reliability and convenience. Designs to protect the sensors and processors from impact, to improve the battery charge, to improve attaching onto and detaching form the cane are all necessary for the commercialization. Additional functions may include detecting stair ways or steps and adding GPS for navigation.

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