Real-time Dangling Objects Sensing: A Preliminary Design of Mobile Headset Ancillary Device for Visual Impaired

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***Abstract*—Blinds and severe visual impairments can utilize tactile sticks to assist their walking. However, they cannot fully understand the dangling objects in front of their walking routes. This research proposed a mobile real-time dangling objects sensing (RDOS) prototype, which is located on the cap to sense any front barrier. This device utilized cheap ultrasonic sensor to act as another complement eye for blinds to understand the front dangling objects. Meanwhile, the RDOS device can dynamically adjust the sensor's front angle that is depended on the user's body height and promote the sensing accuracy. Meanwhile, two major required algorithms, height-angle measurement and ultrasonic sensor alignment, are proposed with this prototype. The research team also integrated the RDOS device prototype with mobile Android devices by communicating with Bluetooth to record the walking route.**

I. Introduction

In recent years, the underprivileged minority has been concerned constantly. Visually impaired groups fall into this category. Initially, one of the approaches for them to understand whether they can walk around without any obstacle through a white cane. As long as the obstacles appear more than the length of their white cane, they could not make any judgment.

Fortunately, there is another way to guide the blind by using the guide dog [1]. The method of using the guide dog is that user has to know how to reach the destination and command the guide dog goes straight, turns right, or turns left. On this planned route, the guide dog is responsible for preventing any collision or fall for the owner. Therefore, the user must have good directional stability and ability to walk by assisting with his or her guide dog. However, the guide dog training is extremely difficult and the relative cost is expensive. Furthermore, the life of guide dog is shorter than human, so it is not widespread for using the guide dog.

To solve the short range, expensive and life problems, many researchers have developed electronic devices to assist the visually impaired [2], such as the NavBelt from University of Michigan Robotics Laboratory [3] and the electronic guide cane [4][5]. Most of them use ultrasonic sensors to detect obstacles to realize the environmental status. However, these devices seem a bit of large. Of course, there are the other approaches to replace the detecting sensors, for example, infrared [6]-[9], laser [10], radio-frequency identification [11]-[13], and magnetic [14]. Anyway, these researches existed some restrictions. For example, some of them can be utilized for indoor space [6][8][11]-[14].

As surveying the walking speeds for visually impaired people [15][16], Clark-Carter, et al. presents the average walking speeds for visually impaired is 1.61 m/sec [15] and Nakamura shows that the walking speeds for late blind and congenitally blind are 1.11 and 0.86 m/sec, respectively [16].

This study tries to utilize and integrate existing technologies to achieve a set of the headset ancillary device for the visually impaired. The purpose of this device is cheap, hand-free, light weighted, convenient and easy for use. Our designs are illustrated in the following sections.

II. Designs

The proposed headset ancillary device uses a single-chip microcomputer, Arduino MEGA 2560 R3, as the main body. The required electronic components include an ultrasonic sensor (HC-SR04), a relay, a servo motor (GWS Mini-STD), a Bluetooth module (HC-05), a buzzer, two light-emitting diodes (LED), and a six volt tandem cell.

The ultrasonic sensor owns a receiver and control circuit to detect whether there are obstacles ahead. The servo motors can rotate to the appropriate angle by referring to the calculated angle that is computed by the Arduino MEGA 2560 R3. To save the power consumption, a relay is attached with an additional power supply. The development tool uses Arduino Sketch v1.0.5.

Before the experiment execution, it is necessary to define several required terminologies for the ultrasonic sensor. The measuring angle, initial angle, and alignment angle are defined as α, β and θ, respectively. Meanwhile, the user's body height, the nearest detection length of ultrasonic sensor, and user-defined detection distance are defined as H, N_0 and D, respectively.

Further, the experimental steps are shown in Fig. 1 and include: (1) the user keeps the upright stand at attention, and his or her hands naturally hang; (2) the user turns on the power of this device; (3) the ultrasonic sensor rotates to the alignment angle ($\frac{\alpha}{2}+\beta$) and uses the height-angle measurement algorithm (HAMA) to calculate the H and N_0; (4) the ultrasonic sensor alignment algorithm (USAA) calculates θ that is based on the HAMA result; (5) the servo motor rotates to calculated angle, θ, via a relay control to achieve

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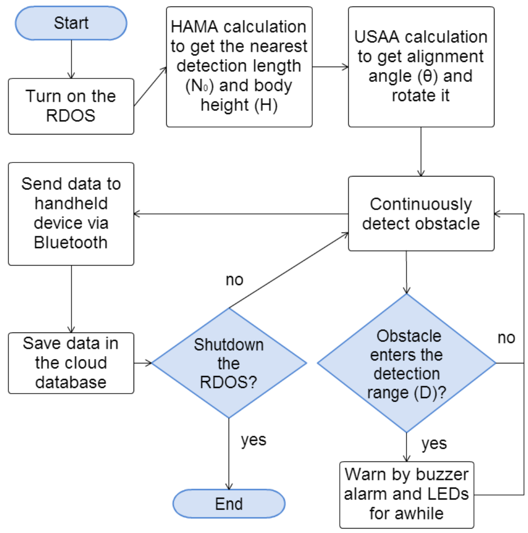

Fig. 1. Real-time dangling object sensing flowchart

power saving; (6) the device continuously detects the obstacles in front of the user with meaningful detection distance, D; (7) the sensing data sends through the Bluetooth module to a mobile device to display in graphs and stores in a cloud database for future reference; and (8) a buzzer alarm will be sounded, and two LEDs will alternatively flash red and green lights when any obstacle enters the warning range, D.

It is essential to detect the user's body height before walking by utilizing this device. Because the selected ultrasonic sensor has a measuring range of 30 degrees, which is shown in Fig. 2. Furthermore, it is possible to get inaccurate measured data from the non-slim users. To avoid these unseemly sensing problems, we set the sensor initialized angle, β, in 15 degrees.

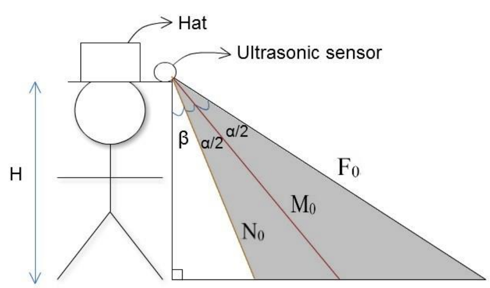

Fig. 2. Measure user's body height

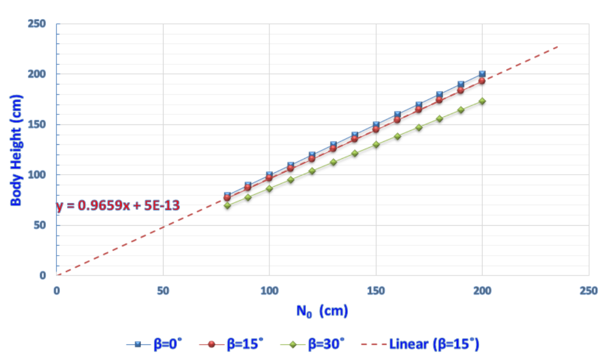

Fig. 3. Relationship between body height and nearest detection length

Figure 3 illustrates the relationship of H and N_0. The estimation formula is shown in Eq. (1). As our design said, the body height measurement will be obtained after 20 times detections of N_0.

$$\mathrm{H} \approx N_0 \cos\beta \tag{1}$$

The device will align itself by using our proposed HAMA after measured user's body height. For example, the ultrasonic sensor rotates θ angle to well align its sensing position, which is shown in Fig. 4. Because this research wants to provide a device to detect the dangling object in front of the users' walking path, it is necessary for the proposed prototype to estimate the farthest detection length (F_1). Subsequently, the F_1 can be calculated by Eq. (2).

$$\theta = \tan^{-1}\left[\frac{2\sum_{i=0}^{3} D_i}{H}\right] - (\alpha+\beta) \tag{2}$$

The USAA is used to detect obstacles in front of and above the user's waist, so this research defines to detect the dangling objects that are in the above of the height of the user's waist and briefly sets this height as the half of H. The user-defined detecting distance, D, is the sum of D_i.

Note that the users for using the commercial white canes can be divided into six ranges by the real length of the white canes: less than 150 cm, between 150 cm and 160 cm, between 160 cm and 170 cm, between 170 cm and 180 cm, and between 180 cm and 190 cm.

Figure 5 shows the relationship of the farthest detection lengths, measured body heights, and calculated rotation angles. It is necessary to note that the rotation angle, θ, is estimated as logarithmic regression analysis in order to close to the real-world status.

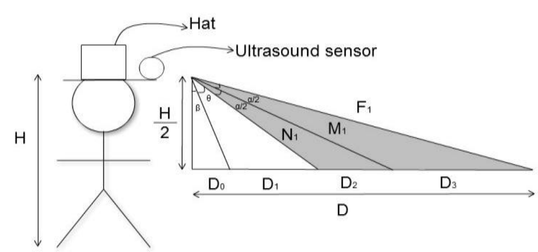

Fig. 4. Height-angle measurement algorithm schematic diagram

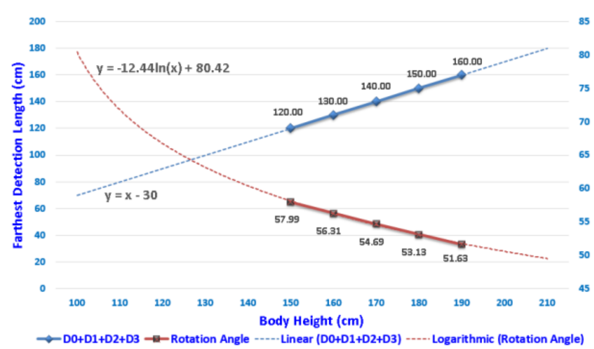

Fig. 5. Measured Body Heights and Calculated Rotation Angles

III. ALGORITHMS

Our design has three main algorithms: the HAMA, the USAA and DanglingObjectDetection. The first algorithm is depicted in Fig. 6 and its purpose to find the trusted height values. As disclosed from the practical experiences, this detection process will get some relatively exceptional values, so we have to exclude these abnormal values.

```
float HAMA (int iCountTimes) {
    fN0[20];                     // Store detected data
    RotateSensorTo(0);           // Rotate sensor to startup angle
    RotateSensorTo(BetaAngle);   // Rotate sensor to initial angle
    RotateSensorTo(AlphaAngle);  // Rotate sensor to scanning angle

    // Compute the average
    For (i=0; i< iCountTimes; i++) {
        fN0[i] = Detected N0 data from ultrasonic sensor;
        fSumOfN0 += fN0[i];
    }
    fAvgOfN0 = fSumOfN0 / iCountTimes;

    // Mark extreme data to negative
    For (i=0; i< iCountTimes; i++) {
        fDiffOfN0 = Abs(fN0[i] – fAvgOfN0);
        if (fDiffOfN0 > fThresholdOfN0)
            fN0[i] = – fN0[i];
    }

    // Remove extreme data
    iNormalCount=0;
    For (i=0; i< iCountTimes; i++) {  // Recalculate average
        If (fN0[i] >0) {
        fSumOfN0 += fN0[i];
        iNormalCount ++;
    }
    fAverageOfN0 = fSumOfN0 / iNormalCount;
    fBodyHeight = fAverageOfN0 * cos(BetaAngle);

    Return (fBodyHeight);
}
```

Fig. 6. Height-angle measurement algorithm

The second algorithm, USAA, is to align the head of ultrasonic sensor by rotating the bundled servo motor to appropriate detection angle that is shown in Fig. 7. This algorithm will use the height value which is calculated by the HAMA. The fAlphaAngle is related to the full detection angle of the ultrasonic sensor and can be obtained from the specification of the ultrasonic sensor.

```
void USAA (float fDistance) {
    RotateSensorTo(0);
    RotateSensorTo(fBetaAngle);
    fCotPara = 2* fDistance / HAMA(20);
    fThetaAngle = cot(fCotPara) – fAlphaAngle – fBetaAngle;
    RotateSensorTo(fThetaAngle);
}
```

Fig. 7. Ultrasonic sensor alignment algorithm

Relatively, the last algorithm is not so complex that the ultrasonic sensor will detect the front dangling objects once per second. It determines whether the obstacle in front of the user, and these obstacles will come to the warning range. If the obstacles enter the detection range, the designed alerts, such as LEDs and buzzer, will warn the user immediately.

IV. RESULTS

The indoor utilization of our prototype by one of the designers is shown in Fig. 8. The tester wears a cap with our integrated device. The weight is about 200 grams. The mobile power supply located on the outside of the right side of the cap and the other side is the box, including microcontroller. The leading edge of the cap is the sensing components.

This device utilizes sound wave to detect objects, so there are several restrictions on use. These limitations are listed as follows. (1) The times of measuring the user's body height; (2) a lot of external factors, such as indoor/outdoor, wind speed, ground floor, which will affect the measurement results; (3) the side clearance is required with at least the radius of user's arm length; and (4) the hat alignment is assumed as fixed and horizontal when users are moving.

During the experiment, the prototype will continuously receive the data which is detected by the HC-SR04 ultrasonic sensor. The received data is shown in Fig. 9 and then transmits to a mobile device via Bluetooth. Finally, the mobile device continuously simulates the graphical chart and also records the data to the database in the cloud-side. These data will allow users to extract the valuable information, such as obstacle locations, from the previous known routes and might probably appear on the way.

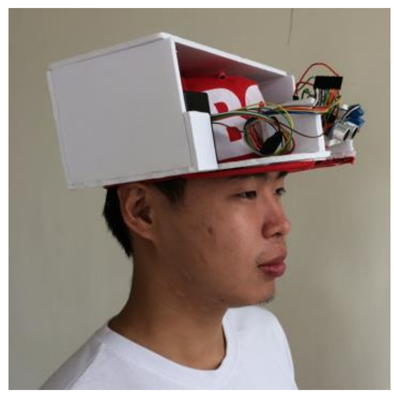

Fig. 8. System prototype

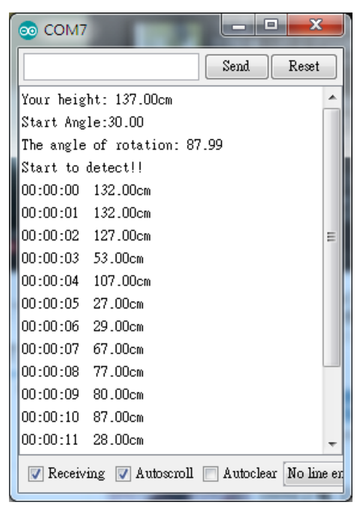

Fig. 9. A real-time sensing outcomes from Arduino console

This research assumed that the visually impaired have the same walking speeds that are calculated from the mean value of the [16] and [17]. That is, the average walking speed is approaching 1.19 m/sec. Meanwhile, our proposed device has to detect objects at approximate 1.5 meters ahead. Therefore, the prototype has to provide the subsequent response within 1.26 seconds to ensure the safety of the next step. In summary, it is reasonable and feasible for our proposed prototype to detect the front dangling objects once per second.

This study hopes to refine many details of the components in the future works. The restriction of the current use is a big problem for visual impaired. For example, the impact of wind speed should be considered, and system should adjust dynamically and let the sound waves adapt in the air speed. Furthermore, it is necessary for this system to provide a function to alert the user to alignment the cap when his or her hat is crooked, or this system had to discover possible tolerated tilt angle of the hat.

Meanwhile, this research has achieved its first step to implement a feasible prototype in the laboratory. We plan to extend its second step to cooperate with special-education school and preliminarily earned the oral grant from the principal of the Kaohsiung Municipal Renwu Special School. That is, this proposed prototype will be tested by visual impaired and continuously adjust its designs to try to satisfy the utilization habits of visual impaired. Before executing the compassionate tests, our research team has proposed the required application to human research ethics committee, and the further step will be started once the application is granted by the committee.

V. Conclusion

This research proposed an innovative design for visual impaired by utilizing the nonspecific hat. It overturns the original guidance approaches and tries to be an ancillary device for generic white cane users. By using our proposed prototyping device, the visually impaired will be allowed to walk around a more accessible space. Meanwhile, the applied scope can also be extended to the robots. That is, this device can determine whether the moving robot can walk forward or not. These research outcomes disclose that the users can easily fetch real-time traffic status by utilizing our device when they are moving.

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