Assessment on Design of a Talking Distance Measuring Wheel for the Visually Impaired Students

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Abstract. *This research proposed to design and create a prototype of an inexpensive talking measuring wheel for individuals who are visually impaired. By providing Brailles display and pronouncing the distance travelled, the proposed device helps educate the visually impaired to understand the concept of distance and measurement. To achieve this, an Arduino Uno R3 micro-controller is utilized to detect wheel's movement via Rotary-Encoder Arduino. Once the distance value has been obtained, the audio module selects an appropriate pre-recorded MP3 audio file to decode, informing the user of the distance travelled in two supported languages: Thai and English. The proposed device has been evaluated by 32 sighted and 12 visually impaired volunteers who extensively used the device and provided scores in seven aspects: appropriateness of the narration, suitability of the body weight, appropriateness of the keypad positions, suitable size for elementary school students, suitable for the sighted and the visually impaired, Suitable for the grip, and accuracy. The device received overall satisfactory scores, and due to its relatively low cost, is well-suited for individuals with low income.*

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Keywords:

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1. Introduction

A visually impaired person is one who suffers different degrees of vision loss, ranging from low vision to complete blindness. Lacking the ability to sense the surrounding through sight, visually impaired individuals rely heavily on alternative senses in understanding the world. Many past works have developed apparatus that aids the visually impaired in a variety of everyday tasks, such as Brailles print, smart street signs, talking color identifiers [1], obstacle-warning glasses [2], and a talking device of weight and height [3]. One of the biggest limitations for the visually impaired is the inability to visualize distance, making traversing a fixed given amount of distance difficult. Teaching young children with visual impairment to understand the concept of distance and measurement is even more challenging. Understanding distance is crucial in performing such daily tasks as navigating the city.

After having inquired teachers and students at the Northern School for the Blind under the Patronage of the Queen [4] in Chiang Mai Province, Thailand, we found that teachers have been teaching the concept of distance by letting students take steps in a straight line and then relating the number of steps taken to an approximate distance. Such an approach, while being simple and easily understood by children, still lacks precision. Motivated by this problem, our work aims to develop a precise distance measuring wheel suitable for visually impaired students. Such a device can be used both in the classroom as an instructional material and in everyday life, enabling the visually impaired to perform simple measuring tasks with ease.

2. Design and Implementation

This section consists of four subsections: the conceptual design, the design of hardware components, the circuit diagram of the proposed device, and the design of the software components.

2.1 Conceptual Implementation

The design of our proposed device is shown in Fig. 1. The diagram includes multiple blocks, each of which represents a key component in our device. The component blocks are as follows:

- Block A is a wheel [5] where each revolution measures a specific distance.
- Block B is a rotary encoder, a type of sensor used to determine the magnitude of rotation.
- Block C is a microcontroller. The microcontroller takes in pulse clock values read from the rotary encoder and converts it into distance value.
- Block D is a Listen switch [6]. When pressed, the device announces the distance value out loud.
- Block E is an audio module used to play pre-recorded voice files in MP3 format.
- Block F is an amplifier used to amplify playback voice sent from the audio module to the speaker.
- Block G is the speaker.

2.2 Design of hardware components

The model of our proposed distance measuring wheel in side view is described in Fig. 2-3. The hardware components consist of a handle, a trundle wheel (10 cm in diameter), a control box, an on-off switch, listen and reset buttons, and a speaker.

2.3 Design of circuit diagram of the proposed device

Fig. 4 shows the connectivity between components in the device's circuit. The circuit is powered by a 9VDC power supply. When powered on, the power supply powers the control system via Arduino Uno R3 [7]. The microcontroller provides 5V to the rotary-encoder Arduino [8].

3. Section Headline

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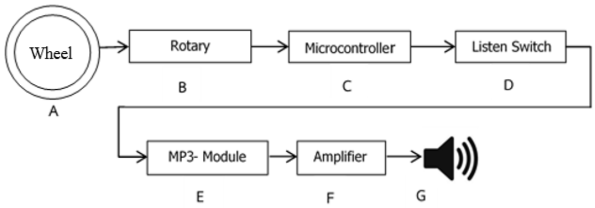

Fig. 1: The conceptual design diagram of the proposed device

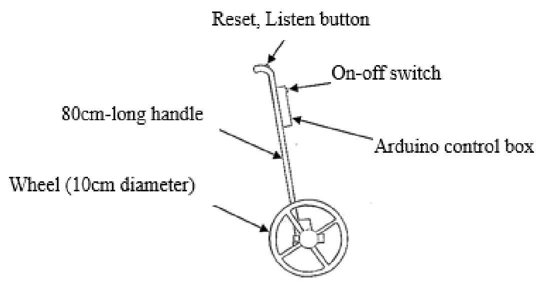

Fig. 2: The model from right side view

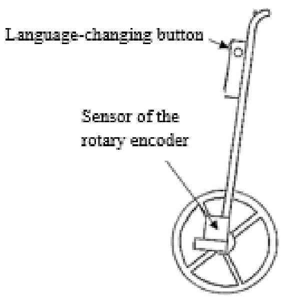

Fig. 3: The model from left side view

The rotary encoder is able to measure the physical movement of the measuring wheel both in forward direction via pin A and in backward direction via pin B. It converts perceived physical motion into an electric signal and sends it to the controller via pin P2-P3. The received value is then used to retrieve appropriate voice file from WTV020M01 audio module [9] via pin P5-P8 of the Arduino board. When the user holds the listen button, the audio signal is sent to the speaker via pin +SDK and –SDK [10]. To perform a new measurement, the user can press the reset button to clear the distance value. Lastly, all circuit components are assembled into a complete package as shown in Fig. 5 - 7.

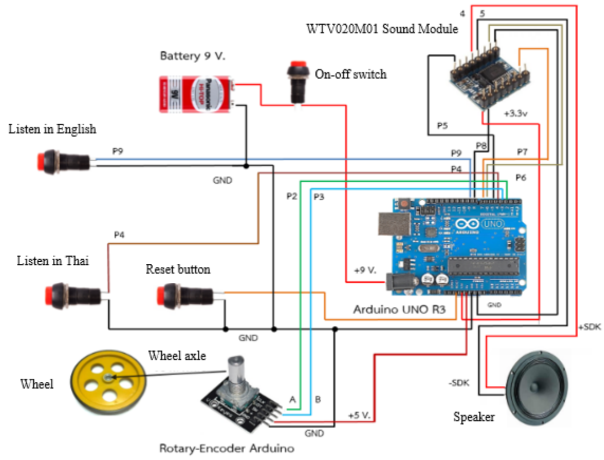

Fig. 4: Circuit diagram of proposed device

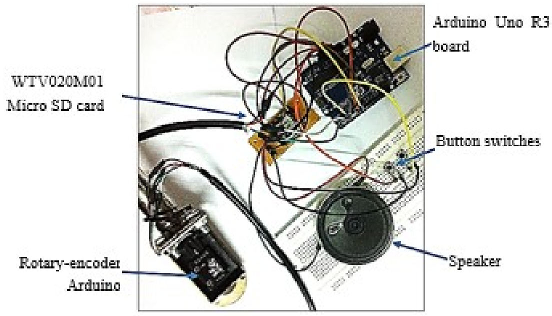

Fig. 5: The test on the control circuit

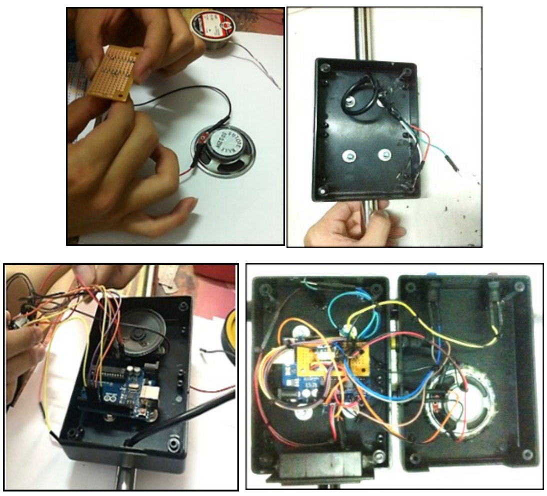

Fig. 6: The assembly of control circuits into a package

2.4. The design of software components

Fig. 8 shows the flowchart of our controller software. (1) Relevant modules are declared. (2) Check the status of the wheel. If the wheel stops, proceed to process voice signal. (3) Check the status of the button. If the button is pressed, go back to step one, otherwise stop. Within the loop, when the listen button is pressed, compute the distance value stored in the encoderPos variable (encoderPos x 1.5151515 cm/100), convert the numerical value to speech digit-by-digit with added delay of 800 milliseconds.

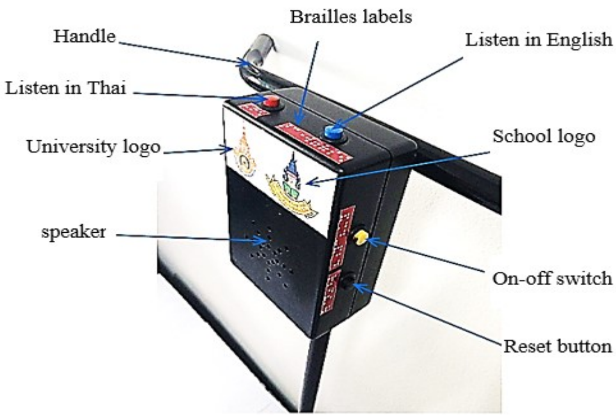

Fig. 7: Complete package of the control box

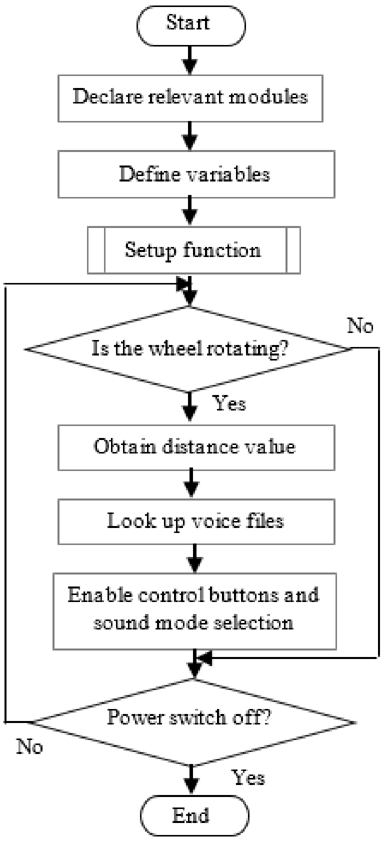

Fig. 8: Flowchart of the control software

3. Experimental results

The proposed device was first tested in an ideal environment where the measuring path is straight, with smooth ground surface and no obstacles. We measured at five different distances from 1 to 5 meters, 35 times each. We also tested at longer distance from 10 to 100 meters. As shown in Fig. 9, the record was compared against a standard commercial measuring tape as ground truth. The precision and errors are plotted and reported in Fig. 10.

A) Comparing measured distance against a standard measuring tape B) End position of the measuring wheel

Fig. 9: Experiment in the ideal environment

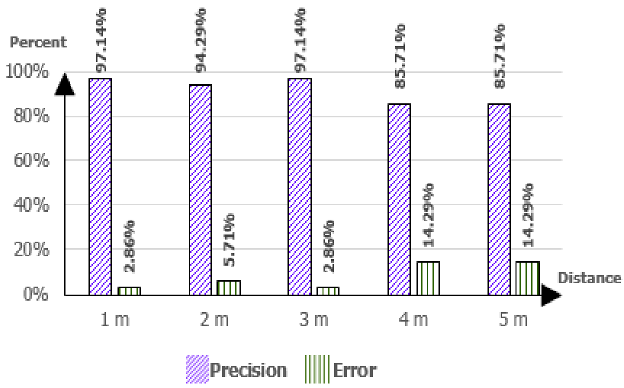

Fig. 10: Measurement precision and error from checking the proposed device against a standard measuring tape

Apart from the simulated test, the device has also been given to 32 sighted and 12 visually impaired volunteers who are students at the Northern School for the Blind under the Patronage of the Queen [4], Chiang Mai Province for extensive testing as shown in Fig. 11. The tests were carried out through actual users and satisfaction questionnaires, the device was assessed in seven aspects as follows:

(1) appropriateness of the narration
(2) suitability of the body weight
(3) appropriateness of the keypad positions
(4) suitable size for elementary school students
(5) suitable for the sighted and the visually impaired
(6) suitable for the grip
(7) accuracy

Fig. 11: the photographs of the tests during the testing by both sighted and visually impaired volunteers.

Fig. 12 shows the questionnaire results grouped by sighted and visually impaired participants. Among the sighted people, the device scores 83.59% in the aspect of narration appropriateness, 81.25% in the suitability of body weight, 87.50% in the appropriateness of keypad positions, 84.73% in the suitable size for elementary school students, 87.50% in the suitability for the sighted and the visually impaired, 87.50% in the suitability for the grip, and 90.23% in the accuracy.

In contrast, among the visually impaired students, the device scores 87.50% in the aspect of narration appropriateness, 85.42% in the suitability of body weight, 70.83% in the appropriateness of keypad positions, 87.50% in the suitable size for elementary school students, 87.50% in the suitability for the sighted and the visually impaired, 87.50% in the suitability for the sighted and the visually impaired, 79.16% in the suitability for the grip, and 92.70% in the accuracy. From the results, our proposed device received positive and satisfactory feedback in all aspects and there was no significant distinction between the sighted and visually impaired. [5], [11-12] have been reviewed to compare regarding the cost of the proposed device that showed great achievement with relatively low cost.

4. Conclusions

This research developed an affordable talking distance measuring wheel for visually impaired students that can be used as a learning aid in classroom, enabling the students to make measurements with high precision. Our device supports Thai language. The construction is lightweight, portable and safe to use. Rotary-Encoder sensor was utilized to accurately measure degree of rotation. The proposed device has been tested by average sighted people as well as visually impaired students. The test participants gave overall positive and satisfactory feedback regarding the appropriateness of design, accuracy, usability and pricing of the device. In addition, due to its low cost, the device is affordable among individuals with low income.

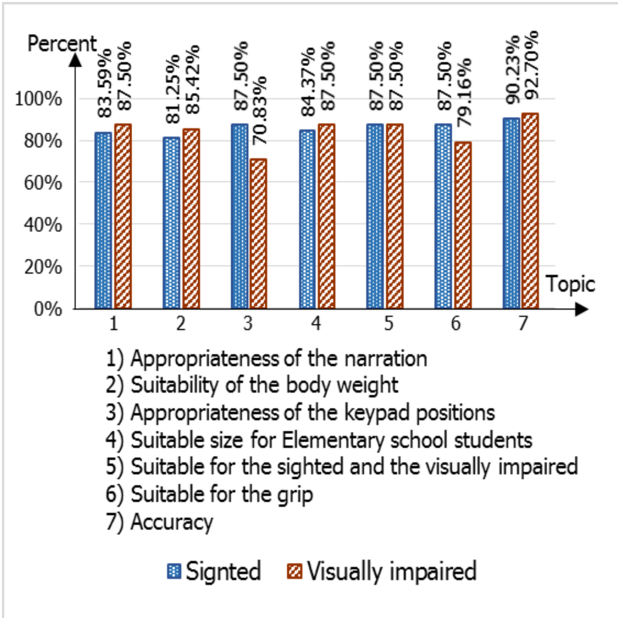

Fig. 12: Comparison of questionnaire scores from the sighted and the visually impaired participants

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Biography

Upady Hatthasin currently works in the Department of Computer Engineering, Faculty of Engineering, Rajamangala University of Technology Lanna (RMUTL), Chiang Mai, Thailand.