Open Access

Nora Loepthien*, Tanja Jehnichen, Josephine Hauser, Benjamin Schullcke and Knut Möller

Development of a low-cost senor based aid for visually impaired people

DOI 10.1515/cdbme-2016-0158

Abstract: The aim of the project is the development of an aid for blind or visually impaired people, considering economic aspects as well as easy adaptability to various daily situations. Distance sensors were attached to a walking frame (rollator) to detect the distance to obstacles. The information from the sensors is transmitted to the user via tactile feedback. This is realized with a number of vibration motors which were located at the upper belly area of the subject. To test the functionality of the aid to the blind, a testing track with obstacles has been passed through by a number of volunteers. While passing the track five times the needed time to pass through, as well as the number of collisions, were noticed. The results showed a decline in the average time needed to pass though the testing track. This indicates a learning process of the operator to interpret the signals given by the tactile feedback.

Keywords: aid to the blind; low-cost; sensor based.

1 Introduction

In Germany, about 645,000 people have sight disorders or are blind [1]. Various aids exist to improve their environmental perception, such as guide dogs or white canes. However, these have serious disadvantages or are quite expensive. The white cane, for example, is the most common device. It is one of the cheapest aids and easy to use and to obtain. However, it is not possible to detect any objects above the hip and one hand is permanently holding the cane, making it unsuitable for elderly people who need additional support to maintain balance or stability while walking [2].

The second generally known aid is the guide dog. High training and running expenses, pet allergies and the work that comes with a dog might prevent many blind people from using a guide dog, especially elderly.

As a result of the democratic change the elderly population will grow. There are various diseases that affect particularly elderly people in their vision. An aid to the blind that meets the needs of an elderly user is needed to ensure a safe participation in daily life.

The objective of this work is to demonstrate how common rollators can be enhanced with low-cost hardware to support elderly people with sight disorders. This should give the possibility to hold on to something and provides a more secure feeling for the user. Therefore, a rollator was equipped with a sensor system, measuring the distance to obstacles in surrounding environment. As Johnson and Higgs did in their work [3], a vibrotactile feedback system, realized with vibration motors, was used to pass environmental information to the user. This enables the users to still use their hearing sense to observe the surroundings [4]. In order to ensure high safety for the user, the system needs to be able to prevent collisions with objects in all relevant heights. The goal is to regain more independence and a save feeling for many blind people when they are outside of well-known surroundings by using the aid.

2 Methods

2.1 Control unit

Arduino is an open-source physical computing platform, consisting of a microcontroller with several I/O ports and a software component. To control the sensors and the vibration motors an Arduino Uno board is used. This type consists of 14 digital in and outputs operating at 5 V. Furthermore, there are six inputs for analogue voltage. This enables to directly connect five sensors and corresponding motors to the Arduino board.

The Arduino Uno embeds a microcontroller, providing a software to analyse the distance of an object and to control the sensors and vibration motors.

***Corresponding author: Nora Loepthien,** Institute of Technical Medicine, Furtwangen University, VS-Schwenningen, E-mail: nora.loepthien@hs-furtwangen.de
Tanja Jehnichen, Josephine Hauser, Benjamin Schullcke and Knut Möller: Institute of Technical Medicine, Furtwangen University, VS-Schwenningen

2.2 Ultrasound sensor

The principal feasibility is demonstrated using the HC-sr04 ultrasound sensor (SRF-04, Devantech Limited, England). The measuring angle of this device is 30°, which enables a good coverage with only few sensors, a distances range between 2 and 400 cm, with an accuracy of tree millimetres is considered as appropriate for the application. The power supply for the sensor is 5 V DC, making it directly applicable in combination with an Arduino Uno board. To detect an object, the HC-sr04 sends out an ultrasound impulse which is reflected by an object and then received back by the sensor. With the measured time between sending and receiving the signal, the distance d can be calculated:

$$d = \frac{t/2}{344\frac{m}{s}}$$

with t being the time between sending and receiving of the ultrasound pulse. The time t is measured with the internal timer of the microcontroller of the Arduino Uno platform. In the application one measuring interval is set to 0.02 s, resulting in 50 measurements per second.

2.3 Vibration motors

Vibration motors are used to transmit the information collected by the sensors to the user. The used mini vibration motors operate within an operating voltage of 2.2 V DC–3.6 V DC, thus they can be used with the Arduino Uno board without an extra power supply.

Different types of vibrations were used to signalize the distance to an object. At a distance <80 cm the corresponding motor vibrates for one second with a break of 0.02 s. As an object enters the 50 cm radius, the vibration is two seconds long with a 0.02 s break between them. Permanent vibration is used for obstacles with a distance <20 cm from the user. Each motor exclusively reacts to the linked sensor.

2.4 Complete setup

The developed aid for the blind consists of five sensors and five vibration motors. In the software each motor is directly linked to one specific sensor. The sensors are attached to a walking chair with a special developed fixture. This basic structure enables stable measured data. Three sensors are facing forward and two are additionally covering some parts of the sides (see Figure 1). The vibration motors are situated corresponding to the sensors at the

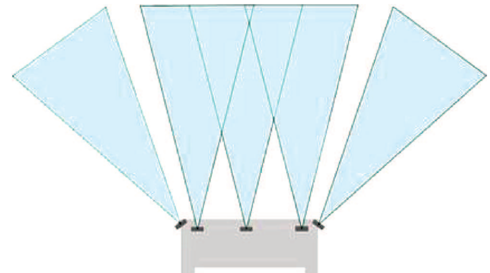

Figure 1: Top view of the walker with the registration area of the sensors.

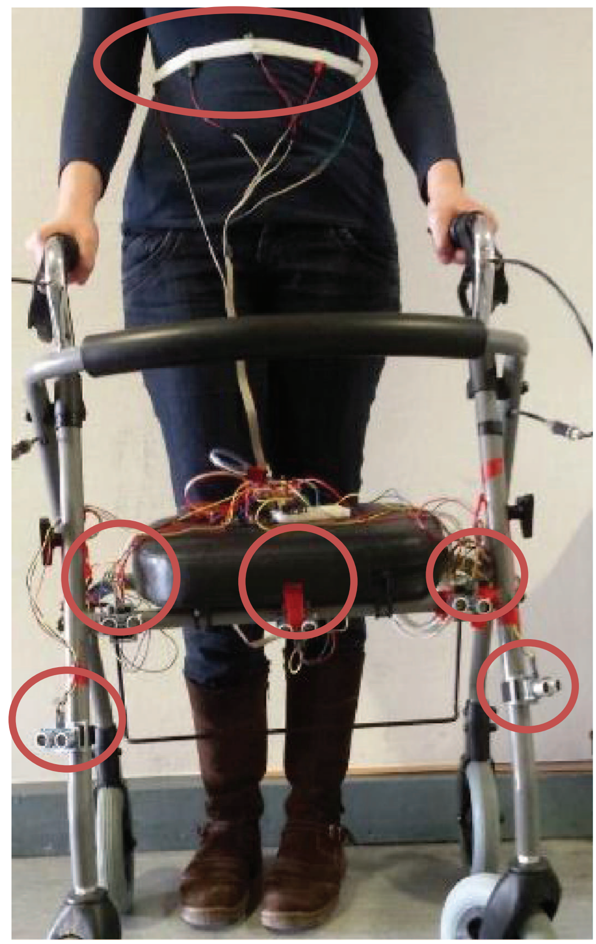

Figure 2: Complete set up of the aid for the blind; walker with the sensors and the attached vibration motors.

upper belly area (see Figure 2). The first and fifth motor are each facing lateral, the third is in a medial position and the second and fourth are in between, which leaves a gap of approximately 10 cm between the motors. The measurements of the perception of the waist by van Erp [5] suggests, that the number of motors could be increased to enable a more accurate transmission of the information. To supply the Arduino Uno board with power, a nine-volt battery was used.

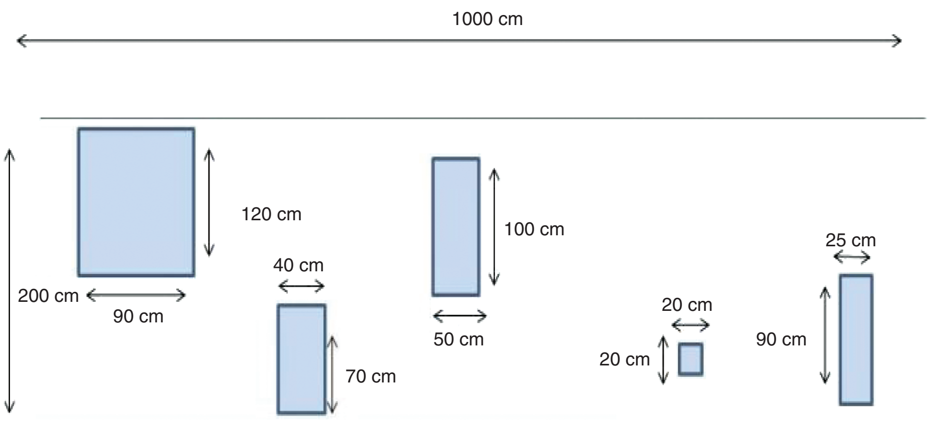

Figure 3: Set up of the testing track.

2.5 Experimental setup and study protocol

On a testing track with a length of 10 m, five obstacles of different sizes were positioned (see Figure 3). All the objects were made out of cardboard and about 70 cm high. 18 volunteers (10 males, average age of 23.06 years) had to pass the test track.

All volunteers did not have any sight disorder. Therefore, all had to wear a blindfold. The test persons had not seen the track beforehand. Each test person had to pass the testing track five times. For the first four trails the track has not been changed. The constellation of the objects has been changed on the fifth test to see, if the test persons had learned how to use the aid for the blind. For every test the time and number of collisions was taken.

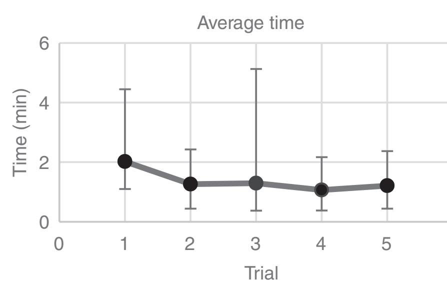

Figure 4: Average time per test: Track remained unchanged for the first four trials. Last trial was performed with changed position of obstacles.

Table 1: Average rate of collision per test divided in female and male test persons.

Test	1	2	3	4	5	Ø
Male	1.200	0.300	0.900	0.500	0.700	0.720
Variance	1.398	0.483	1.853	0.707	1.059	1.196
Female	1.750	1.250	0.875	1.000	0.875	1.150
Variance	1.389	1.669	0.991	0.926	0.835	1.189

3 Results

Figure 4 depicts the volunteers average time for to the different test numbers. The average time needed to pass though the test track for the first time was 2.02 min. The second time the test persons needed 1.26 min, the third time 1.29 min and the fourth time 1.06 min. When the arrangement of the obstacles changed, a slight increase of the average time occurred with 1.21 min. As shown in the diagram the average time decreases. The variance from the second, fourth and fifth tests gets smaller in comparison to the first one. The high variance of the third test is caused by one single volunteer.

The average collision rate of male and female test persons is depicted in Table 1. Female volunteers have a slightly higher rate. In the first test the collision rate was the highest, but no clear reduction can be seen.

4 Discussion

Between the various test persons there are considerably differences in the needed time and number of collisions.

The decrease of the average time and variance after the first run through suggests a learning effect. During the first test the test persons quickly get used to the functionality of the aid for the blind. However, because all the participating test persons were in their early twenties, it is not clear how this test result can be transferred to elderly users. The learning time might take considerably longer. There is also a chance that the number of vibration motors overstrains elderly users. To get more specific predictions more test with people who have sight disorders and a wider range of ages are necessary.

The majority of test persons showed difficulties passing through narrow points. Most test persons were overstrained by the numerous vibration motors that signalised an object. It seemed to be difficult to give priority to one or two of the vibration motors if all five are alarming the user. To avoid that many or all vibration motors are activated at the same time, the range of the side sensors has to be decreased. To be able to react in time, the sensors in running direction have to alarm the user way ahead of an object. The sensors that detect objects on the side of the walker only need to alarm the user if they are running at the risk of scratching them.

Some of the test persons thought that a more accurate distinction of the distances would make the orientation for the user easier. It is questionable if a more distinctive differentiation makes it easier to locate an object or if it overstrains the user. The differences of the breaks between vibrations would get less noticeable and therefore the distinction more difficult. Maybe the number of differentiations can be increased as the user gets more secure with the aid of the blind and has a better feeling for the vibrations and their meaning.

To enable the user to react to different situations, there needs to be a collection of programs to select from. For example, there needs to be a program for situations that only enables a slower movement with many objects close-by. In crowds it is important, that the sensors do not react too far in advance. On the other hand, to enable a fast walking speed the sensors have to react at an earlier stage to give the user enough time to react to obstacles.

To reach the aim of a whole body protection there have to be more sensors in different angles to recognise objects in different highs. The testing showed that a sensor based aid for the blind can work. However, there are a lot of improvements, alterations and enhancements that need to take place, before a safely daily use for people with sight disorders is possible.

Author's Statement
Research funding: This work was supported by the Bundesministerium für Bildung und Forschung BMBF under grant 01PL11008 (TREFFER). Conflict of interest: Authors state no conflict of interest. Informed consent: Informed consent has been obtained from all individuals included in this study. Ethical approval: The research related to human use complies with all the relevant national regulations, institutional policies and was performed in accordance with the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent committee.

References

[1] Knauer C, Pfeiffer N. Erblindung in Deutschland - heute und in 2030. s.l.: Springer-Verlag; 2006.
[2] Möller K, Möller J, Arras KO, Bach M, Schumann S, Guttmann J. Enhanced perception for visually impaired people evaluated in a real time setting. In: Dössel O, Schlegel WC, editors. World Congress on Medical Physics and Biomedical Engineering. Munich, Germany: Springer; 2009;25/4. p. 283–6.
[3] Johnson LA, Higgins CM. A navigation aid for the blind using tactile-visual sensory substitution. Conf Proc IEEE Eng Med Biol Soc. 2006;1:6289–92.
[4] Dakopoulos D, Bourbakis NG. Wearable obstacle avoidance electronic travel aids for blind: a survey. Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on; 2010;40.
[5] Van Erp JBF. Vibrotactile spatial acuity on the torso: effects of location and timing parameters. In: Eurohaptics Conference, 2005 and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems, 2005. World Haptics 2005. First Joint; 2005. p. 80–5.