A remote guidance system for blind and visually impaired people via vibrotactile haptic feedback

S. Scheggi, A. Talarico, D. Prattichizzo

***Abstract*— Trained guide dogs and canes provide the visually impaired with the highest degree of independence; however, they are very limited in guiding the user towards a specific desired location, especially in an unknown environment. The assistance of other people represents a feasible solution, but it does not improve the idea of autonomous guidance and privacy. In this paper we present a remote guidance system which provides the visually impaired with haptic directional cues, useful for navigating in unknown environments. The blind user is equipped with a pair of camera glasses, two vibrotactile bracelets and a cane which is used to avoid potential obstacles. The video captured by the camera glasses is streamed to a remote operator who can properly navigate the impaired person by activating the vibrotactile stimulations. The proposed approach has been validated on a group of blind subjects in an indoor scenario. Results revealed the effectiveness of the proposed strategy for the guidance of visually impaired in unknown environments.**

I. INTRODUCTION

Visually impaired people encounter many difficulties in living an autonomous life, due to the reduced capability to perceive the surrounding environment. In particular, navigation and orientation seem to be very challenging when moving in unknown domains. Trained guide dogs and canes are useful for collision avoidance and obstacle warning but they do not provide directional information to guide visually impaired toward a desired location. Assistive devices represent considerable solutions in improving the quality of life for subjects with impairments. The development of mobility aids for the blind represents a challenging task. The nature of blindness requires that assistive technologies provide location and situational awareness, displaying this information effectively and when needed.

Fig. 1. *System overview.* The visually impaired (1) is guided by a remote operator (2) via two vibrotactile bracelets (3). A pair of camera glasses (4) streams the view of the blind user to the remote operator so that he can properly guide the subject to the desired location.

Remote guidance systems have been recently developed in literature. The aim is to blend the information provided by assistive technologies with the computational capabilities of a human operator. In [1], the authors developed a remote guidance system where the visually impaired was equipped with a digital camera, a GPS receiver and a headset. Internet and GSM connections transmitted video/audio information and GPS data between the remote operator and the user. Using audio communication, the operator navigated the blind toward a desired location and warned him about possible obstacles. Similar systems were developed in [2], [3], [4], for visually impaired pedestrians and in [5] combining GPS technology with RFID for indoor pre-localization. All the aforementioned researches did not use haptic as a possible mean of communication.

Haptic stimuli for blind navigation have been proposed in [6]. The proposed indoor localization system relied on Bluetooth communication and provided surrounding environment information by means of vibrotactile stimuli displayed to the chest and to the shoulders of the user. In [7], a comparison of different vibrotactile devices for guiding visually impaired individuals was proposed. The authors evaluated different vibration temporization and intensities. In [8], the authors developed an electronic bracelet which provided vibrations when an obstacle was close to the user. The vibration magnitude was directly proportional to the obstacle distance. A similar haptic policy was developed in [9] for the navigation of blind in virtual reality scenarios. Recently, vibrotactile stimuli for cooperative human-robot navigation were proposed in [10]. None of the aforementioned works proposed a remote guidance system which provided the impaired user with haptic directional cues.

Some issues are involved in the remote guidance systems described above. For example, GPS localization may suffer of accuracy issues and indoor signal reception. According to [11], [12], headset used to transmit audio messages may

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The research leading to these results has received funding from the European Union Seventh Framework Programme FP7/2007-2013 under grant agreement n. 601165 of the project “WEARHAP - WEARable HAPtics for humans and robots”.

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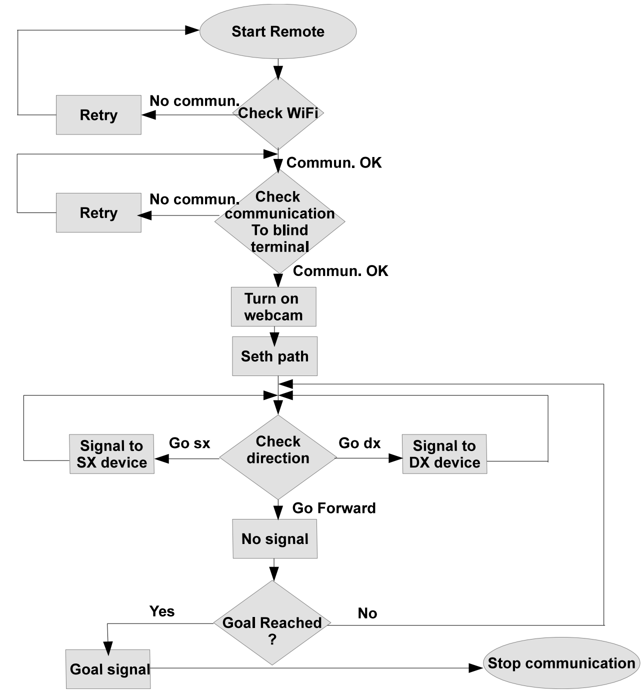

Fig. 2. *System scheme.* The remote operator guides the visually impaired user according to the depicted operations.

distort and mask sounds in the environment which are necessary for obstacle avoidance. Assistive devices should not impair any sense. Hearing is the most grown sense for blind and it should not be masked by assistive devices.

Based on these observations, we focused on developing a remote guidance system for visual impaired which could be as less invasive as possible. With the term *invasiveness* we consider both the additional equipment needed by the blind to increase his/her mobility and the amount of stimuli sent to the user. In the proposed system, the blind is equipped with a pair of camera glasses, two vibrotactile bracelets and a cane which is used to avoid potential obstacles. Note that the proposed vibrotactile devices do not substitute the cane or the guiding dog for obstacle avoidance; they represent additive devices which provide directional information in order to properly reach the desired location.

The paper is organized as follows. Section II contains an overview of the proposed system. Experimental results, involving a group of blind, are reported in Section III. Finally, in Section IV some conclusions are drawn and future directions of research are outlined.

II. SYSTEM OVERVIEW

The proposed system, which is patent pending[1], is depicted in Fig. 1. Two agents are involved in the system: a blind user and a remote operator. The visually impaired is provided with a pair of camera glasses and a pair of vibrotactile bracelets. The camera glasses stream the video to the remote operator. The operator remotely guides the visually impaired via vibrotactile feedback displayed by the haptic bracelets.

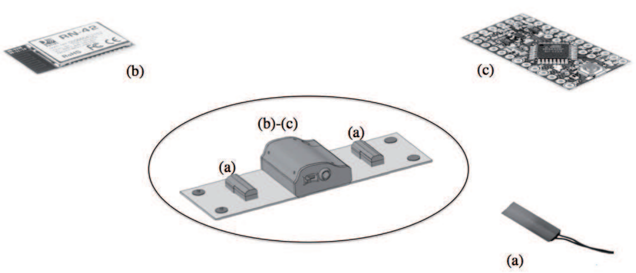

Fig. 3. *Haptic bracelet.* The vibrotactile bracelet is equipped with two vibrating motors (a), an RN42 Bluetooth module (b) connected to an Arduino mini pro 3.3 V and Atmega 328 controller (c). The Li-Ion battery is included in the box containing (b) and (c).

As depicted in Figure 1, camera glasses and bracelets are interfaced with a portable computer. The camera glasses are connected to the laptop via USB while the laptop communicates with the bracelets using the Bluetooth communication protocol. The video captured by the camera glasses is streamed to the remote operator via Skype. The remote operator can activate the bracelets using an input device (i.e. keyboard, joystick, joypad, etc ...). The directional signals are transmitted to the blind using the TCP/IP communication protocol. Fig. 2 reports the flow chart of the proposed system.

Each haptic bracelet is composed by two cylindrical vibromotors which are independently controlled using the Bluetooth communication protocol and generate vibratory signals used to warn the user (see Fig. 3). Studies have demonstrated that vibration is best on hairy skin due to skin thickness and nerve depth, and that vibrotactile stimuli are best detected in bony areas [13]. In particular, wrists and spine are generally preferred for detecting vibrations, with arms next in line [14]. Movement can decrease detection rate and increases response time of particular body parts. For example, walking affects lower body sites the most [14]. The effect of movement on vibrotactile sensitivity has been also investigated in [15]. Following these considerations, the subject wears one vibrotactile bracelet on each arm in order to maximize the stimuli separation while keeping the discrimination process as intuitive as possible. The communication is realized with an RN42 Bluetooth module connected to an Arduino mini pro 3.3 V with a baud rate of 9600. The vibrating motors are placed into two fabric pockets on the external surface of the bracelet, with shafts aligned with the elbow bone. The bracelet guarantees about 4 hours of battery life with one motor always turned on. Each bracelet weights about 80 g.

Previous pilot studies revealed that the proposed haptic bracelets are able to successfully provide directional cues to older adults. Since the perception of the cutaneous stimulation decreases with the age, the proposed vibrotactile devices can be used to successfully provide navigation hints to visually impaired people. In particular, studies on the effects of aging in the sense of touch [16] have revealed that vibration threshold is the most rapidly affected by age and it is maximal after the age of 65 years.

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[1] Deposit number PI2014A000016 of 21 February, 2014.

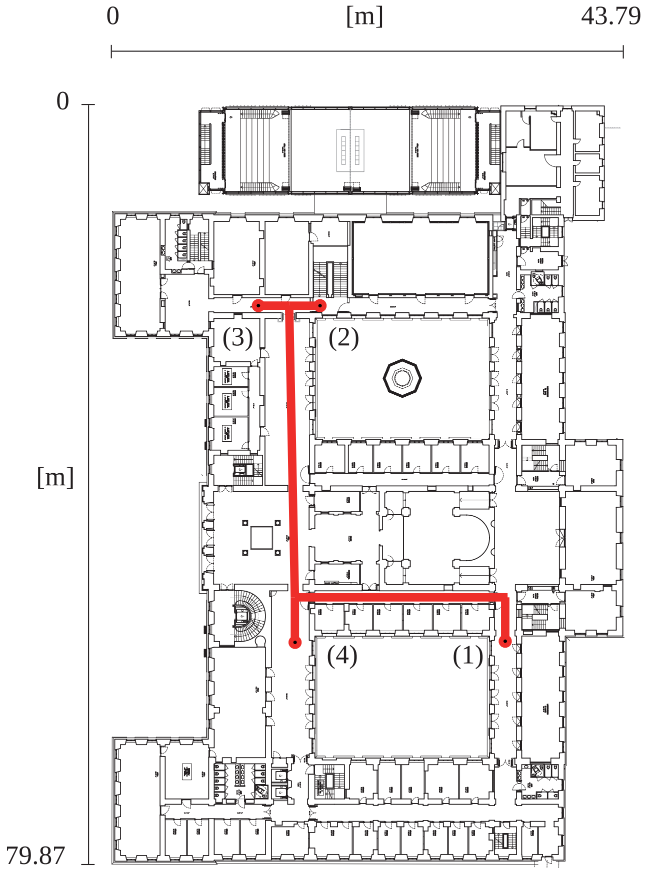

Fig. 4. *Experimental scenario.* The users were remotely guided from the initial location (1) to the final ones (2) (3) (4).

III. EXPERIMENTAL VALIDATION

A. Subjects

The proposed guidance system was tested on 10 blind subjects: six males and four females. The age range was $26 - 65$ (mean 48.5 and standard deviation 16.96). None of them had previous experiences with vibrotactile interfaces.

B. Methods

The experimental validation was conducted in an indoor environment, completely unknown to all blind users. Each subject had to move from a starting location toward a final one; three different paths were proposed (see Fig. 4).

In order to maximize the vibrotactile perception and minimize the *aftereffect* problem (vibration effects usually persist after the end of the stimulation), a periodic vibrational pattern with period of 0.4 s was displayed. In particular, when the stimuli needed to be displayed to the user, the two motors of each bracelet were alternatively activated for 0.2 s.

At an early stage of development, different stimuli indicating a smooth or a sharp turn were proposed to the subjects; however, the users preferred to have a single stimulus (left or right) which only indicates the direction to go along. In particular, they preferred to have a vibrotactile signal with fixed amplitude and frequency rather than signals obtained by modulating such parameters.

Statement number	*Statement formulation*
1	It was easy to use the vibrotactile system.
2	I did not feel hampered by the remote guidance system.
3	I did not feel hampered by the sounds made by the actuators of the vibrating bracelet.
4	I was relying more on the vibrations then on the sounds made by the vibrating bracelet.
5	It was easy to feel the vibrations made by the vibrating bracelet.
6	I felt comfortable in using the proposed system.
7	I felt safe in using the proposed system.
8	At the end of the experiment I did not feel tired.
9	I would wear the vibrating bracelet in public.
10	The vibrating bracelet helped me a lot in reaching the target point.

TABLE I

QUESTIONNAIRE PROPOSED TO THE BLIND USERS AT THE END OF THE EXPERIMENTS.

Note that the proposed system is able to only provide directional indications, without giving an accurate guidance along the trajectory. The motivation is because blind users preferred to freely move and explore the surrounding environment, instead of being constrained to move along a predefined path.

In order to evaluate the users experience, a questionnaire using bipolar Likert-type seven-point scales was proposed to the subjects at the end of the experiments. The questionnaire consisted of 10 questions (see Table I) and considered the comfort in using the proposed system and its level of informativeness in reporting the navigation information. An answer of 7 meant a "*very high comfort*" of the system while an answer of 1 meant a "*very low comfort*".

C. Results

A positive users response was returned at the end of the experiments. According to the proposed questionnaire, the mean value related to the perceived comfort was 6.2857, while it was 6 for the questions related to the informativeness of the system.

In Table II, the three different outcomes for the proposed paths are reported. All users were able to easily reach the final destination point in a acceptable time.

Useful informations were returned at the end of the experiments; the camera should be located in such a way to maximize the vision stability along the path, allowing the user to feel free in head moving. For instance, a smart

Path	*Path success percentage [%]*	*Average travel time [s]*
(1)-(2)	100	138.333
(1)-(3)	100	140.66
(1)-(4)	100	62.66

TABLE II

SUCCESS PERCENTAGE AND MEAN TIMES IN THE THREE DIFFERENT PATHS.

positioning could be on a chest. As already underlined, the users preferred to receive a single stimulus just to correct their walking direction rather than to be assisted along the whole path. In this way, possible risks of misunderstanding the haptic signals are reduced.

IV. CONCLUSIONS AND FUTURE WORK

The proposed remote guidance system proved to be an effective assistive system for visually impaired. According to their experiences, the system is considered instrumental to aid blind and visually impaired people and ease their mobility.

In future works, the stabilization of the video streamed to the operator will be taken into account. We also plan to validate the proposed device with a larger number of subjects. Experimental tests will be held in large, outdoor, crowded and noisy environments. In this regard, solutions which manage the luminosity changes will be implemented. Finally, future versions of the system could take into account the possibility to combine the assistance provided by the remote operator with automatic algorithms that localize the user and/or recognize possible obstacles.

V. ACKNOWLEDGEMENT

The authors would like to thank all the visually impaired volunteers of the I.Ri.Fo.R. onlus (Istituto per la Ricerca, la Formazione e la Riabilitazione) of the Department of Siena for their participation in this study to assess usability of the system.

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