Remote Guidance for the Blind - A Proposed Teleassistance System and Navigation Trials

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Abstract — **The paper presents initial research on the system for remote guidance of the blind. The concept is based on the idea that a blind pedestrian can be aided by spoken instructions from an operator who receives a video stream from a camera carried by the visually impaired user. An early prototype utilizing two laptop PCs and a wireless internet connection is used in orientation and mobility trials, which aim to measure the potential usefulness of the system and discover possible problems with user-operator communication or device design. Test results show a quantitative performance increase when traveling with a remote guide: 15-50% speed increase and nearly halved times of navigational tasks; however, the main success is the engendered feeling of safety when assisted and the enthusiasm with which the concept was welcomed by blind trial participants.**

Keywords — **assistance, blind, remote guidance, visually impaired**

I. INTRODUCTION

Vision loss is a serious impairment that deprives a human of approx. 80–90% perceptual abilities and has a detrimental effect on professional, social and personal quality of life. The European Union surveys report that 4 out of every 1000 Europeans are blind or suffer from serious visual disability. This number increases yearly due to the aging demographic.

In earlier studies [1], the authors have conducted questionnaires among the blind asking to indicate the main barriers in their everyday activities. The three following ones were pointed out (ranked according to their importance):

1. Lack of the means for safe and independent mobility (e.g., obstacle detection and early warning),
2. Limited capability to navigate in the surrounding environment (route planning and following, identification of whereabouts),
3. Difficulties in access to visual or text information (e.g. road signs, bus numbers) and handling of devices (e.g. cellular phones, vending machines).

Overcoming the first two barriers can only partially be achieved by means of the so called primary aids, i.e. the white cane or a guide dog. Much research effort has also been devoted to development of electronic travel aids (ETA) that implement different versions of sensory substitution concepts to compensate for the lost vision [2]. Unfortunately, these devices have not found any widespread acceptance among the blind. The causes include high costs, poor reliability and lack of comfort in using such devices. On the other hand, it is clear that no single device can match the comprehensive help offered by a sighted guide. Obviously, for different reasons, this solution is not always possible or accepted by a blind person and often deepens the feeling of being a social burden.

A compromise concept would be a system that is capable of delivering the sighted guide assistance remotely – i.e. by building a so called teleassintance link. The current and upcoming ICTs (Information and Telecommunications Technologies) offer platforms for implementing such systems.

A. *Existing teleassitance systems*

To the authors' best knowledge, the first reported system for remote guidance of the blind, was the system developed at the Brunel University, UK [3]. Three ICT technologies were combined to offer the teleassistance functionality; namely, GPS (Global Positioning System), GIS (Geographic Information System) and video/voice transmission over the 3G mobile network. The system [3] comprises of two units. The mobile unit that is carried by the blind user and a stationary PC based unit. The mobile unit is equipped with a portable camera and an audio headset. The stationary unit, operated by the sighted guide, runs an application displaying what the camera carried on the blind person's chest sees [4]. Video, voice and other data is transmitted over the 3G communication network. The authors have noted successful remote navigated walks of the blind individuals within the campus precinct [3]. However, no commercial deployment of the system was reported.

Although few recent scientific publications in this narrow field can be found, a number of companies are working on very similar commercial projects. One has been announced by a French company Ives Interactivity Video & Systemes [5]. The device called Visio.assistant is now in the phase of preindustrial tests using WiFi. In that solution the webcamera and the wireless transmitter are mounted in a case resembling hand hair dryer.

Another system worthy of mentioning is MicroLook, awarded two medals on the 2007 Brussels Innova fair. This system is under development by a Polish company Design-Innovation-Integration [6]. MicroLook differs from the earlier designs by integrating a webcamera with a headset and a mobile telephone platform. The project is at the stage of a prototype under tests.

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B. The Electronic Travel Aid

For a number of years, the author's group in the Medical Electronics Division of the Technical University of Lodz has been working on a project aimed at development of a prototype ETA system for the blind. The system utilizes stereoscopic cameras for 3D scene reconstruction [1,7]. Each obstacle that is segmented out from the scene is associated with a unique sound code that warns the blind. Headphones are used for playing the sounds. A special sound lateralization technique implementing the Head Related Transfer Functions (HRTF) is used for "auditory 3D display" of the obstacles [8]. The system module that is currently under tests provides micro-navigation functionality. It is supported by a Symbian OS based smartphone playing the role of the auditory assistant of the blind. Ordinary phone functions are speech synthesized and new software procedures are provided, e.g. internet browser (via RSS feeds), voice-recording, and recognition of colours [9].

Our current goal is to couple the earlier developed system modules i.e. micro-navigation with the macro-navigation functionality, which will be offered by the remote assistant, GPS and digital maps of the urban terrain. In this work we report an initial study of the remote guidance system that underwent preliminarily indoor testing.

II. Experimental Setup and Procedures

A. Early prototype

A decision was made to make the first prototype functional and easily modifiable, without limiting the system to a restrictive platform or a transmission protocol. The easiest way was to do that was to operate on a PC platform and use existing wireless technology for development and trial purposes.

The prototype of the guidance system is composed of two notebook computers - one carried by a blind person in a specially constructed, ventilated backpack, the other operated by the guide.

An earphone and microphone headset, and a USB-camera are connected to the notebook PC carried by the blind user. The earphones used are of the "open-air" type in order not to block environmental sounds. The camera is mounted on the chest of the blind person. The initial considered mounting location was on the visually impaired person's head; however, the first trials showed that it was an inconvenient solution both for the operator and the blind user. First, natural movements of the guided person's head provided the operator with erroneous information about the walking direction. Second, instructions from the operator interfered with the way the blind user wanted to move his head in order to hear the sounds of the environment. Despite the usefulness of the operator being able to remotely "look around", due to the aforementioned inconveniences the chest-camera was opted for. A blind participant wearing the prototype is shown if Figure 1.

Fig. 1. A blind trial participant wearing the early prototype, which provides communication with and streams video to a remote guide.

The other notebook is operated by the guide, who remotely aids the visually impaired person. A link is established over the Internet using wireless cards and a dedicated wireless router with a maximum range of about 200m. The relay of audio and video was performed by the freeware Skype program. This was an initial temporary solution for the early prototype, as a dedicated program for audio and video streaming is being tested in parallel.

B. Trial rationale and goals

Having prepared the early prototype, our goals were to test what problems may arise in further development of the system, study the intricacies of user-operator communication, as well as to develop procedures for quantitative review of the system. Among the analyzed aspects were the influence of video quality and delay on the operator's job, what information is necessary to be passed on between the user and the operator, and how does guided and unguided travel and orientation compare.

C. User-Operator communication

Prior to the experiments the operator clarified the commands he would use for navigation, some were relatively obvious, but some required a short explanation. The list of the commands used is presented below:

- "left/right 90°" – turn by a quarter of a circle while standing in place
- "half left/right" – turn by 45°
- "slightly left/right" – turn by 15°, if moving, continue moving in that direction
- "forward" – clear path ahead for at least 2m
- "obstacle on the left/right, keep left/right to walk around it" – nearby obstacle and directions for easiest avoidance
- "step left/right" – take a single step perpendicular to the direction of travel, if moving continue to

"Slightly left/right" proved to be very practical directions for keeping the guided person on the right track. "Step left/right" seemed good for avoiding small obstacles; however, participants preferred to just be warned of the presence and position of an obstacle.

D. Trial description

Three blind volunteers took part in the trials – all male, ages 25-45, two blind since birth, and one for the last 17 years. Two had temporarily successful retina transplantations, which unfortunately regressed leaving them with partial light sensitivity (they were thus blindfolded for the tests). Each of the participants was asked to travel three multi-segment paths and locate a doorway in the corridor.

The multisegment-paths were designated in a 7 by 12 meter hallway. Four cardboard obstacles were deployed at random along the paths and were moved around between each travel attempt, to prevent the participants from memorizing obstacle locations and using them for orientation. One of the experimenters accompanied the blind volunteers at all times, should a surprising or dangerous situation arise. Every blind volunteer used his long cane during the tests.

Each path was completed in four different "modes":

a) *unguided walk* – the participants were told path information only, for example: 10 steps ahead, then turn right and make 6 steps, then make 5 steps and so on. Prior to the tests the number of steps was adjusted to each participant's stride length. In case a participant forgot the route the experimenter reminded him, but nothing else. This run served as a reference, simulating a path known from memory, but with possible unexpected obstacles along the way.

b) *remote guidance without path information* – the blind participant wore the headset, the chest-camera and the backpack with the laptop. The operator provided remote guidance on the base of a real-time video transmission. However, he did not provide precise information about the path (number of steps) and only estimated the participant's position from the video feed.

c) *remote guidance with path information* – as in the previous mode, the blind volunteers were guided by the remote operator. This time however, the operator provided them with precise information concerning the path (i.e. the exact number of steps to take).

d) *walk with a human guide* – in this reference run a visually disabled person held a guide's hand who led their way along the precisely defined path. The speed of walking was dictated by the blind participant.

At the end of each trial run the blind participant was asked to point to where he thought the start of the path was located. This was to test whether focusing on the remote guidance influenced the person's orientation skills.

The door-finding task was a more realistic test. The participants were requested to find the sixth doorway on the right in a university corridor. Cardboard obstacles along the route made the task more difficult. Simple as it may appear, all of the participants failed to find the target door with their first attempt due to losing count. This test was subdivided into three categories: unguided, remote guided, and a reference guided run.

E. Data collection

A wide angle camera automatically took pictures of the trials every 2 seconds. A sample photo is presented in Figure 2. Bright markers on the participants' pant legs allowed quick, half-automated position plotting. The results were interpolated in order to graph the subject's positions with a resolution of one second. Using this technique it was possible to accurately record, time-stamp and measure all the traversed trial paths. The perceived starting point direction was also marked for each trial.

At the end of the experiment, each participant completed a short survey providing feedback about the proposed system, his communication with the operator, and expectations from the developed device.

TABLE 1: Results from one of the trial paths and the door locating task

	Walked distance [m]			**Path wavering* [m]**			**Path/Task completion time [s]**			**Average Speed [m/s] *normalized*****			**Error in locating the starting point**		
Participant	**MM**	**RP**	**JM**	**MM**	**RP**	**JM**	**MM**	**RP**	**JM**	**MM**	**RP**	**JM**	**MM**	**RP**	**JM**
Path 1 (reference, help of a human guide)	27,0	27,0	27,0	-	-	-	55	38	30	0,49	0,71	0,69	45°	90°	Unable to guess
Path 1 (unguided, path information only)	25,1	22,0	30,0	4,0	9,4	3,9	92	82	82	0,27 ***1,00***	0,27 ***1,00***	0,37 ***1,00***	100°	135°	45°
Path 1 (remote guidance, no path information)	21,7	22,2	22,6	10,0	8,1	8,6	69	55	60	0,31 ***1,15***	0,40 ***1,50***	0,44 ***1,19***	55°	45°	55°
Path 1 (remote guidance with path information)	22,1	23,4	24,5	5,1	9,8	7,5	63	60	58	0,35 ***1,30***	0,39 ***1,45***	0,42 ***1,42***	45°	45°	45°
Door locating task (reference)	20,0	20,0	20,0	-	-	-	30	36	30	-	-	-	-	-	-
Door locating task (unguided)	22,5	39,9	22,2	-	-	-	60	66	94	-	-	-	-	-	-
Door locating task (remote guidance)	21,2	40,1	20,7	-	-	-	34	36	38	-	-	-	-	-	-

*sum of distances from 5 key path points, **normalized to unguided trial speed

Fig. 2 Navigational trials were automatically recorded. Markings on the participants' pant legs and on the floor allowed precise path reconstruction.

III. Trial Results and Analysis

A. *Performance review*

Comparing the performance between the three participants is difficult as the etiology of their blindness and mobility skills are disparate. The results provided in Fig. 3 and Table 1 are the most representative of the group. Figure 3 shows superimposed trial attempts for one path by a single participant. Due to space constrains Table 1 shows data only for one of the three test paths.

The detailed trial data shows that the help of a remote guide is a significant improvement over traveling unguided. It is still far from assistance of a human guide present on site, but the average travel speeds were 20-50% better then when traversing the paths unguided.

The large path wavering when under remote guidance shows that the operator is not always able to precisely estimate the position of the assisted person. This is improved when he can provide a-priori instructions about the distances in the paths.

Contrary to their expectations, the blind participants retained better orientation when using the remote guide, then when walking unguided or with a human guide, as they were able to more precisely guess their starting point.

The task of locating the correct door was failed by all three participants on the first attempt. The successful unguided attempt was on average two times slower than when assisted by a remote guide.

B. *Operator Conclusions*

The camera in use had a relatively restricted angle of view of around 50^o, which is very narrow compared to human vision (up to 180^o). A fish-eye lens would be far handier for obtaining bearings, especially when remotely guiding the user across a street. This has yet to be solved.

It also transpired during the trials, that it is far more effective to inform the guided person about a nearby obstacle and let him pass the obstacle alone than trying to maneuver him precisely, e.g. with "step left/right" commands. The operator simply instructs: "obstacle on left, a doorway on half right". It requires less effort from both the operator and the blind pedestrian, is more concise and yields better results. After all, the ultimate goal of the system is to complement and not replace the way the blind travel.

C. *Survey results*

The measurements were followed by a short questionnaire, which revealed some important points for improving the system. All the respondents expressed great excitement about the project. They professed that if the device comes into being, they would use it on daily basis to travel with more confidence and explore new areas. They conceded that the presence of the operator voice engendered a feeling of safety, which the ETA [1] all of them had contact with previously could not compare to.

The surveyed participants expressed a general reluctance to hold any extra items such as an electronic compass or a camera, and under no circumstance would they relinquish their canes.

Their three primary predicaments that need to be addressed are as follows:

a) finding a set of traffic lights to safely cross a pedestrian-crossing
b) finding the button to activate a green light on a pedestrian-crossing
c) looking for a quiet street and being guided across it. Traversing a pedestrian-crossing with no traffic lights is the most risky task.

All of which would be solved by the developed system.

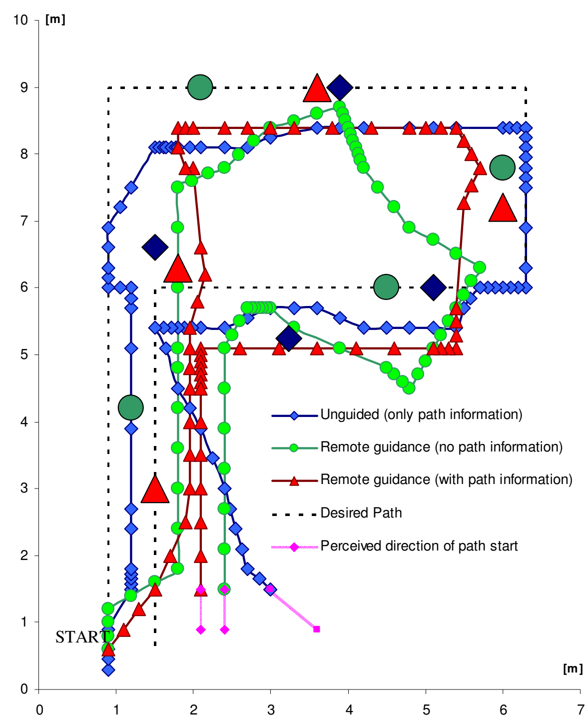

Fig. 3. Superposed recorded walking paths for a blind participants' trials. Each path point corresponds to the subject's position at 1s intervals. Large icons represent obstacles that were randomly repositioned between trials.

IV. Present and Future Work

A. GPS navigation

The inclusion of a GPS receiver to enhance the system's functionality is already in the pipeline. The availability of a very precise map enables the visualization of sidewalks, lawns, the outlines of buildings, stairs, traffic lights, zebra crossings, bus and tram stops which are very helpful landmarks for the blind. Even though the accuracy of commonly used GPS receivers falls short of the precision required to track the exact position of a pedestrian, it still will be of great aid to the operator, and through that to the blind user. Furthermore, an electronic compass would be of great help to the operator, allowing him to observe the assisted client's orientation.

B. Adjustable video quality

The tests revealed the necessity to enhance the quality of the video stream to the operator, or if that fails, change the parameters of the video transmission on demand, prioritizing either smooth frame rate or high resolution. The participants broached the issue of reading signs, numbers and names in halls and corridors, the numbers of approaching trams or buses. This can be accomplished by capturing a high resolution video sequence where the frame rate and latency are of secondary importance. On the other hand, crossing streets or moving on busy pavements necessitates a high frame rate and good response that compromises the resolution. These parameters should be regulated by the remote operator according to the needs of a situation.

C. Target platform

The early prototype solution using a notebook PC is of course too bulky to be applied in the final device. The target system will be compact and light enough for it to be concealed into a small handbag or waist-pouch.

The target platform has yet to be decided upon. There are several devices considered, all with their pros and cons. Mobile phones have the advantage of being a ready made, and relatively cheap technology; however they lack in computational power and video quality. Small palm-top or flybook computers are an expensive solution, but one that meets all the demands. The last considered technology are powerful microcontrollers, which would require the design of a custom circuit board and casing.

The current solution of using Wi-Fi is practical only for indoor prototype testing. The final device will provide communication with the operator either through existing 3G mobile phone channels, or will be using the quickly developing Wi-Max technology.

Interviews with the blind volunteers showed that the size and appearance of any electronic travel aid is of great importance to them. Our target device must be small enough to fit in a pocket or a light shoulder bag. It cannot be overly exposed, as almost half of the interviewed blind users have experienced cell-phone or mp3-player theft at some point of their lives.

V. Conclusions

The trial results and the questionnaire following the tests show that the provision of this "electronic vision", albeit in its infancy, could elevate both the physical and psychological comfort of the blind. The operator's presence engenders a strong feeling of safety. Should an unexpected event occur, a blind user of the system can always count on immediate assistance. For some blind people an insurmountable mental block prevents them from even considering going outside their homes alone.

Objective test results show that a blind person assisted by a remote guide walks faster, at a steadier pace and is able to more easily navigate inside a building. The trials provided valuable experience to the designers concerning future requirements from the target platform and the communication channel. The authors feel strongly encouraged by the positive feedback from the participants about the significance of their research.

Another concept worth considering is that the operators themselves could be disabled individuals. Confined to a wheelchair, they could find employment in aiding the blind.

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