TUGS – The Tactile User Guidance System

A Novel Interface for Digital Information Transference

Olinkha Gustafson-Pearce, Professor Eric Billett and Dr. Franjo Cecelja
Department of Design and Systems Engineering, Brunel University, Uxbridge, U.K.

Keywords: Navigation aid, tactile interface, blind, visually impaired.

Abstract

The Electronic System and Information Technology Research Group at Brunel University has designed a multifaceted navigation system for blind and visually impaired pedestrians. The primary operation of the system mimics the advantages of an informed sighted guide by using Global Positioning Systems and remote (sighted on the user) video cameras as navigational sensors. The information generated is streamed to a central control centre. This allows the system to operate in a fully automatic or operator assisted mode dependent on the users requirements. Initially the system used an audio link to transfer information to the user, however this has proved problematic. Clear unimpeded access to ambient sound is vital for visually impaired and blind pedestrians, both for efficient wayfinding and safety. Any system which has a continuing dialogue with the user, for example, navigational instructions received through an audio link, interferes with the users ability to process ambient sounds. To solve this problem a novel Tactile User Guidance System (TUGS) with vibrating actuators, has been designed and experimentally tested.

In this paper we present the design and experimental verification of TUGS with both visually impaired and sighted users. Although we have taken the visually impaired user as the 'worst case scenario' a practical ability to transfer information through the tactile sense has considerable value to other groups who may find themselves in restricted or overloaded visual or audio situations. These groups include; front line responders in the emergency services, railroad workers, pilots and remote vehicle operators.

1. Introduction

There are currently a number of navigation aids for blind and visually impaired pedestrians that use Global Positioning Systems (GPS). The majority of GPS systems are carried by the user and use an audio, natural language interface. There are projects[1] which employ commercially available cell phones which have GPS devices built into the system. Other projects are also attempting to find alternative audio methods to transfer location, wayfinding or navigation information[2,3]. Systems which require an audio feedback to the user or have a continuing dialogue, for example, navigational instructions received through an audio link, interfere with the users ability to process ambient sounds. These local sounds are important for the pedestrian since they can convey warnings, such as the approach of a vehicle, as well as location and bearing information, the sound of rain on a rooftop or the sound of a generator, etc.. Even in tightly controlled situations problems exist with information transference using natural language[4]. Language is highly subjective and therefore open to misinterpretation. Often, clarification of the message is required and an audio system of information transference may not be the most appropriate for messages that need to be quickly given or responded to.

Also available as navigation aids are various tactile devices. These include, tactile maps[5] which tend to be difficult to carry and interpret, and various other tactile units such as the *UltraCane*[6]. Most of these devices require a significant level of concentration by the user in order to process the information given.

To overcome some of the problems associated with these aids, the Electronic System and Information Technology Research Group at Brunel University has designed an innovative multifaceted navigation system for blind and visually impaired pedestrians. A GPS unit and video cameras are positioned on the user and act as navigational sensors. The information generated is streamed to a central control station and an operator acts as a remote sighted guide for the pedestrian. There is also a facility for the system to operate in an automatic mode using specifically designed software thus allowing the system to operate in a fully automatic or operator assisted mode, dependent on the users requirements. Initially the system used a two-way audio interface to transfer information between the control centre and the user, however this proved problematic in trials. It was found that the user often had to pause in order to receive and understand the information or instructions, and the user was unhappy at the reduction in his ability to process ambient sounds.

In this paper we present the design and experimental verification of the efficiency of a novel Tactile User Guidance System (TUGS) which is an interface for transferring low order and warning information to the user. It forms part of the users interface. These two systems, audio and tactile, work in a complementary manner and it is the user who selects between the two.

2. The Design of TUGS

2.1. User Requirements

In the process of ambulatory progression through the environment, vision plays a major role in our ability to decode the available information. For the visually impaired and blind pedestrian, the ability to decode and process information from the available navigational systems is one of the major difficulties. The problem is one of information overload; the user has too much information centred on too few sensory channels. Visual channels are either unusable or severely reduced. Audio transference of data means that the hearing is overloaded and therefore essential input is compromised if further use is made of this channel to disseminate information. This leaves the haptic and tactile senses, which are underused.

In order to specify user requirements for navigational systems, extensive interviews were conducted with a visually impaired individual and then those observations were further enhanced by attending forums specifically orientated towards navigation for visually impaired pedestrians. A questionnaire was designed to further elucidate the major problems experienced[7]**.** The responses from this research gave clear requirements from the user:

- The information dissemination devices had to be hidden or as unobtrusive as possible.
- The devices should not impede on senses that were already working to full capacity.
- The interface should be easy to use.
- The devices should not constrict movement and should leave the hands free.

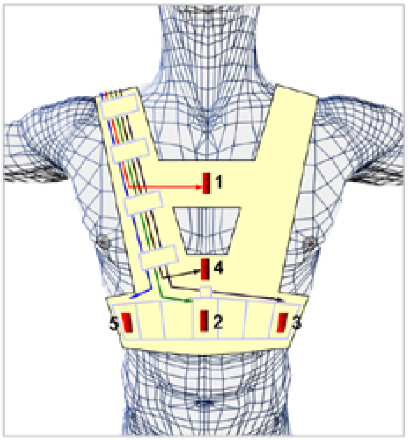
- Many blind and visually impaired individuals were either suffering from diabetes or age related issues which compromised the tactile or haptic senses in the extremities (hands, feet) therefore the interface should not be Braille or similar.

2.2. Design

The design for a secondary interface, which could give simple information to the user, and be linked into the multifaceted Brunel GPS Navigation system, evolved. This system became TUGS and consisted of miniature vibrating actuators located on the body of the user. The navigational protocols have been separated into a base and high order structure. Base instructions are made up of the simple or low order information contained within the navigational protocols. These comprise of directional instructions, 'stop' warning information and may also be set for other information of a digital nature. The high order information is still transferred through the audio channel and consists of information that is more appropriate for natural language such as that relating to correct item identification (buses, shopping, signage etc.) and is constantly available for conversational assurance should the user experience difficulty or require further assistance.

The first trials were with a variety of sighted individuals and used two actuators located left and right of the front mid-frame of the user (waistline). The team sought to ascertain the veracity of the principle of effective data transference through this system. The user was told that they would receive a signal and that they should respond in a 'natural' manner. No directional instructions were given to the volunteers. It was found that in all cases the volunteers moved towards the signal, signal right, user moved right, signal left, user moved left.

The number of actuators was then increased to five. In order to keep the navigational protocols fluid until defined in further trials, a test rig was designed which allowed easy movement of the actuators (see picture 1). The rig took the form of a harness, which is worn under the outer layer of clothing but over lightweight underwear. The actuators are small and lightweight and when further research is concluded, a form of apparel appropriate to the user will be employed. The eventual design of this garment will conform to requirements for wearable computers outlined in literature on the subject[8] and also by the needs of the user.



Picture 1.
Test rig showing actuator placement for TUGS

3.1. Experimental Verification of TUGS

The first formal trials of the system were carried out with three subjects, two sighted and one visually impaired. The trials were videotaped and questionnaires were completed by the volunteers at the conclusion of each phase of the trial. The trials were done at Brunel University, Uxbridge. The two sighted volunteers were female; one aged 18 and one aged 59. The visually impaired individual was male, aged 56 and used a long cane as his usual mobility aid. These trials were in three stages which were performed in one session taking, on average, two hours.

The first stage introduced the volunteer to the system, placed the system on the individual and asked them to respond in a 'natural' manner to the signal. They all moved towards the signal on the left/right actuator (5 & 3, picture 1) and spoke up/down to the up/down activation of the relevant actuators (1& 2, picture 1). For the central activator (4, picture 1) the command was given that this signal represented stop. Further definitions of the signals were given to the volunteers in terms of signal timing. A short signal represented bear to the right/left; a long signal represented turn to the right/left. A short signal on the up/down actuator represented a warning of up/down occurrence in the environment (stairs, escalator etc.) and a long signal represented go up/down. The stop signal had no moderation and meant stop immediately. Chart below:

Chart 1: Navigational Protocols for TUGS

Actuator	Signal	Meaning
Left	short	bear left
Left	long	turn left
Right	short	bear right
Right	long	turn right
Up	short	warning of occurrence (up)
Up	long	go up (stairs)
Down	short	warning of occurrence (down)
Down	long	go down (stairs)
Stop	long	stop

It is felt that further modulation of the signal (signal length and/or strength) and the ability to use other forms of actuators giving different forms of the signal ('tingle' electronic actuators, 'prod' air pocket actuators) are possible. However at this stage of the research the establishment of the principle of accurate transference of simple digital messages was the aim.

The second phase of this set of trials saw the volunteers walk a prescribed route around a public walkway, which was a grassed and paved outside area. The route took about ten minutes to negotiate and the TUGS signals were frequent. Approximately fifty TUGS signals were given to each volunteer. Non of the subjects were familiar with the location and had no pre-knowledge of the route.

At this stage of the trial two of the subjects made no mistakes in interpreting the signal. One subject did register several errors. This was the 18 year old female. She did not initially receive or respond to the signal, which had to be given several times before she responded. In the interview after the trial it was realised that she was wearing a loose top garment and that the weather on that day was windy. These two factors had confused the signal and on the part of the route which was particularly exposed, she had trouble separating the signal from movement in her clothing. In the interviews with all the subjects after this stage they all reported that TUGS was comfortable to wear and for the other two subjects, that the signals were easy to understand.

The third part of these trials involved a task. This was for the subject to navigate their way through the campus to the library, find a book on a shelf in an office in the library complex and then return to the test centre. The route included stairs, concrete paths, and gravel areas. The subjects were unaware of the task. The expected time for completion of this task was about twenty-five minutes. Again the TUGS signals were frequent and exceeded one hundred and fifty separate signals. The team wished to discover which parts of the task were possible to complete using TUGS and which parts required the subject to have a verbal dialogue or interaction with the control centre. Having rectified the clothing issue for the youngest volunteer, the subjects had no difficulty negotiating the route to the library. No errors were made in interpreting and acting on the actuator signals. The subjects moved through crowded areas, negotiated the library entrance area and arrived at the internal library office without any problems. Voice interaction was required to locate the buzzer for access to the office. The subjects were then guided to the bookshelf using TUGS. Voice interaction was required to identify the book. The subjects then returned to the test centre by a different route, again without error.

The results were extremely similar for all subjects. There was no measurable difference, in the time it took to complete the route or the accuracy of the ambulatory progression, between the sighted volunteers and the visually impaired subject. The visually impaired subject required more ‘bearing’ signals than the sighted subjects, in order to navigate safely around obstacles such as trash cans and people. In the post trial interviews all subjects found TUGS comfortable and the signals easy to interpret.

Picture 2.
Visually impaired volunteer wearing TUGS

3.2. Analysis of results

The examination of the subjects’ written questionnaire and analysis of the videotapes indicated to the researchers two key issues:

- The volunteers reactions to actuator signals would appear to become instinctive after a very short period of using the system. By the time that the second stage of the trial was about half way through the sighted subjects were responding to signals without attention and were actively looking around the test area. The visually impaired individual reported in his questionnaire that he was comfortable with the signals and was paying more attention to feedback from his cane. This mobility aid was still his prime source of discovering hazards, however due to TUGS ability to guide him around obstacles he had no encounters with such items, but it was still useful in terms of kerb edges and change of terrain information. For all subjects, at this stage, there was no measurable time delay between the signal being given and their response. This instinctive reaction continued throughout the remainder of the trial.

- The researchers feel that there is an interesting area highlighted by these trials and that is that there is a correlation between the 3D aspects of the environment and the ability to transfer information onto a 3D interface (the cutis covering of the body, skin). If this is correct then the complimentary nature of the system will allow further actuators to be placed on the body relevant to locations in the physical world. All of the subjects reported no loss of mobility due to the placing of the actuators and no interference with usual ambulatory progression.

These trials formed the pilot stage of the experiments and we are currently undertaking further trials to test the hypothesis raised by these limited trials.

4. TUGS in the future

In interviews with visually impaired individuals, a prime concern for them was the desire not to stand out from 'normal' pedestrians due to outlandish looking equipment. This concern has a very practical basis. To look 'strange' potentially could make one vulnerable. This might be particularly significant if one is carrying a device that resembles a laptop computer[9]. Safety, security and comfort of the user, both from the information transferred and how the device was worn and perceived, was fundamental to the design of the Brunel system. The audio component is very small and uses standard speaker technology. TUGS is worn under the clothing and since it is virtually soundless it is therefore invisible to the average observer. The camera, processing and GPS part of the equipment does not require physical interaction from the user for operational function so it can be carried in a backpack with the cameras, which are small web cams and look like buttons, mounted on the straps. This leaves the hands free for safety and other tasks. A cameo from a typical journey in the future might consist of the standard base order commands, left, right, bear left, bear right etc. but should the operator at the control centre identify an approaching hazard that the user is unaware of, would give the 'stop' signal. The user, receiving this message, stops and waits for the operator to issue further spoken information. Another scenario has the user in a supermarket. TUGS can get the user to the correct shelf for the product the user wishes to purchase but spoken commands may be required to home in to the actual item. The complete system is also designed to be a complimentary aid to the users preferred form of navigation or mobility aid, which might be a cane or guide dog.

In this paper we have presented the design and experimental verification of TUGS with both visually impaired and sighted users. Although we have taken the visually impaired user as the 'worst case scenario' a practical ability to transfer information through the tactile sense has considerable value to other groups who may find themselves in restricted or overloaded visual or audio situations. These groups include front line responders in the emergency services, railroad workers, pilots and remote vehicle operators. It is also an appropriate method of transferring information if the user has different language abilities to the core language in use in the environment.

5. Conclusion

Although the work with TUGS is still in the early stages, the results so far have been extremely positive. The users found the interface comfortable to wear and the information content easily understandable. There was a very short learning curve in the use of the system (average under ten minutes). The observations of the researchers and analysis of the questionnaires indicate that there is an ability to process and correlate the 3D environment (the physical world) and the 3D cutis covering of our bodies and that this correlation can be exploited. The sensory connection between the cutis covering and the brain, which is so efficient at locating an event on, or to, the body can be utilised in the transference of simple navigational (locations and directions) information. Our research also indicates that this transference of information would appear to be processed extremely quickly and the trials imply an instinctive reaction to navigational information that is transferred in this manner. Further trials are currently underway to verify this finding and to develop appropriate navigational protocols for this innovative interface.

References

1. Information on GPS navigation system using cell phone at: http://www.calit2net/research/labs/features/09-13-04_blair.html

2. **The Sonic Pathfinder.** http://www.users.bigpond.net.au/heyes/pa/pf_blerb.html

3. Information on the Bat cane at: http://www.batforblind.co.nz/

4. **Hutchins, Edwin** (1995) Cognition in the Wild. Massachusetts Institute of Technology. USA

5. Information on tactile maps at: http://www.cnib.ca/eng/publications/pamphlets/gis_maps.htm

6. Information on the UltraCane at: http://www.soundforesight.co.uk/ultracane_demonstrator.htm

7. **Gustafson-Pearce, Olinkha, Billett, Eric, Cecelja, Franjo.** Perceptual Impact of Environmental Factors in Sighted and Visually Impaired Individuals. This paper has been accepted for publication in the British Journal of Visual Impairment. Sage Publications Ltd.

8. **Barfield, W., Mann, S., Baird, K., Gemperle, F., Kasabach, C., Stivoric, J., Bauer, M., Martin, R., Cho.G.** (2001) Computational Clothing and Accessories in Fundamentals of Wearable Computers and Augmented Reality. Lawrence Erlbaum Associates, Inc. New Jersey. p.471-509

9. Information on the BrailleNote GPS system at: http://www.pulsedata.com/Products/Notetakers/BrailleNoteGPS.asp

Papers relating to the Brunel GPS System include:

Garaj, V. Jirawimut, R., Ptasinski, P., Cecelja, F., Balachandran, W. (2003) A system for remote sighted guidance of visually impaired pedestrians. The British Journal of Visual Impairment. Volume 21, No. 2

Jirawimut, R., Ptasinski, P., Garaj, V., Cecelja, F., Balachandran, W. (2003) A Method for Dead Reckoning Parameter Correction in Pedestrian Navigation System. IEEE Transactions on Instrumentation and Measurement. Vol 52, No. 1

Ptasinski, P., Cecelja, F., Balachandran, W. (2002) Altitude Aiding for GPS Systems using Elevation Map Datasets. The Journal of Navigation Vol. 55, 451-462. UK

TUGS – The Tactile User Guidance System. Include 2005, Include 2005 conference. The Royal College of Art, London

Jirawimut, R., Prakoonwit, S. Cecelja, F. Balachandran. W. (2002) Visual Odometer for Pedestrian Navigation. IEEE Instrumentation and Measurements Technology Conference 2002, Anchorage, Alaska

Garaj, V. (2001) The Brunel Navigation System for Blind*:* Determination of the Appropriate Position to Mount the External GPS Antenna on the User's Body. Institute of Navigation GPS 2000, Salt Lake City, Utah, USA

For further information about TUGS please visit out website at: www.brunel.ac.uk/tugs