Wearable navigation assistance - a tool for the blind

F. van der Heijden, P.P.L. Regtien

Laboratory for Measurement and Instrumentation
Faculty of Electrical Engineering, Mathematics and Computer Science
University of Twente, P.O. box 217, 7500AE Enschede, The Netherlands
Email: F.vanderHeijden@utwente.nl; p.p.l.regtien@utwente.nl

Abstract. *This paper describes the system architecture for a navigation tool for visually impaired persons. The major parts are: a multi-sensory system (comprising stereo vision, acoustic range finding and movement sensors), a mapper, a warning system and a tactile human-machine interface. The sensory parts are described in more detail, and the first experimental results are presented.*

Keywords: Navigation tools, ultrasonic range finding, stereo vision, multimodal information system, probabilistic map building, partical filtering.

1. Introduction

About 1% of the human population is visually impaired, and amongst them about 10% is fully blind. One of the consequences of being visually impaired is the limitations in mobility. For global navigation, many tools already exist. For instance, in outdoor situations, handheld GPS systems for the blind are now available. These tools are not helpful for local navigation: local path planning and collision avoidance. The traditional tools, i.e. the guide dog and the cane, are appreciated tools, but nevertheless these tools do not adequately solve the local navigation problems. Guide dogs are not employable at a large scale (the training capacity in the Netherlands is about 100 guide dogs yearly; just enough to help about 1000 users). The cane is too restrictive.

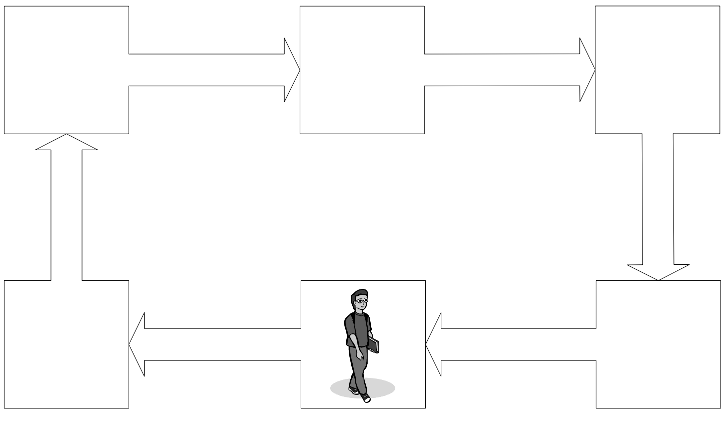

Fig. 1. The architecture of an electronic, navigational tool for the blind

The goal of this research is to develop a wearable tool that assists the blind to accomplish his <u>local</u> navigation tasks. Fig. 1 shows the architecture of the proposed tool. It consists of a sensory system controlled by the user. The primary data needed for local navigation is range data (which is not necessarily obtained from visual data alone; at this point, the type of sensors is still an open question). The mapper converts the range data into map data. The local map is the input to a warning system that transforms the map data into a form that is suitable for communication. In order to give the blind person freedom of movement, he must be able to control the focus of attention of the sensory system. For that purpose, the tool must be provided with a man-machine interface.

The machine-man interface is of great importance for the success of the tool. The three modalities that can be used are: acoustic, neurophysiologic, and tactile. From these three possibilities, the project aims at tactile interfacing. An acoustic 1D, 2D or even 3D display is an interesting option, but it interferes with the ordinary auditory information system (which is an important navigational tool for the blind). The neurophysiologic option (bionic eye), though already studied for more than two decades, is still in an immature state. Another disadvantage of both 'hearing with sound' and the bionic eye is that the learning time is long. A promising technique is the "tactile suit" developed at TNO Human Factors [1].

2. Sensor control and the sensory system

The ultimate goal of this project is to provide an electronic tool for the local navigation task of the blind. The tool must provide information about the direct surroundings of the blind to enable him to move around without collisions. We assume that, although mostly unknown, the environment does have some structure such as in an urban outdoor situation (e.g. a street), or in an indoor situation: smooth floors, now and then a doorstep, stairs, walls, door openings and all kind of objects that possibly obstruct the passage.

We start with three sensor types: stereovision, optical flow, and sonar. Preliminary research has shown that other types of sensors are also of interest, e.g. ladar, radar and infrared (detection of people and traffic). The system should be expandable such that the information from these types of sensors can be integrated easily in a later stage of the project.

Fig. 2. Sensor systems: left: dual camera system for stereo vision, worn as glasses; right: acoustic sensor system worn on top of a shoe.

Stereovision and optical flow are accomplished by an optical imaging system consisting of a dual camera system mounted in the two legs of a pair of spectacles (Fig. 2). This allows easy control on the focus of attention. The camera system must be provided by an IMU that registers the movements of the head. Preliminary experiments indicate that dense stereovision provides useful, but not always sufficient and reliable data.

Fig. 3. Dense stereo vision. The right image encodes the depth of the scene.

Figure 3 shows the disparity map obtained from a commercial stereo vision system (MEGA-DSC from Videre Design, operating at a resolution of 320x240 pixels and 30 fps). Due to the lack of texture and edgeness, large areas of the map are not reliable. In fact, only for a relative small fraction of the pixels it makes sense to calculate the depth. These pixels form the 3D anchor points of the 3D depth that makes up the surroundings of the user.

If the scene is static and the motion of the camera is known, optical flow provides enough information for 3D reconstruction. Fig. 4 shows an example of a laboratory experiment. However, as in the case of stereo, optical flow can only be calculated for a sparse set of image points. However, the surplus value of optical flow is that it – especially in combination with stereovision – facilitates collision avoidance.

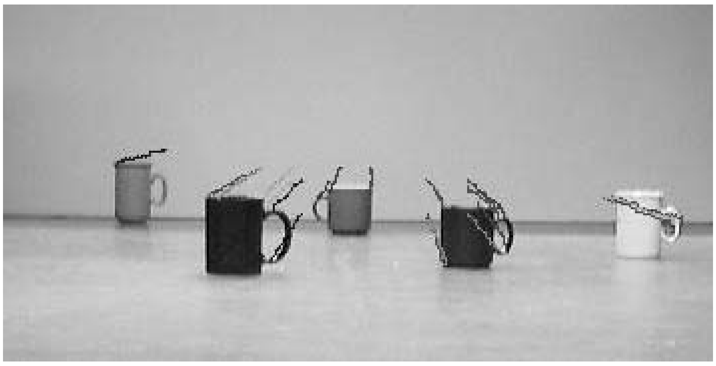

Fig. 4. Flow vectors projected in a scene

In addition to stereovision and optical flow, we propose a sonar-like sensor system consisting of an array of acoustic transducers circularly aligned and mounted on the top of a shoe (Fig. 2). This system should also be accompanied by an IMU. It is used for the registration of the movements of the shoe. The location on the shoe provides a point of view of the sensor that is suitable for the detection of a class of objects that otherwise – from another point of view – is hard to detect. During the walk the motion of the shoe implements a scanning of the space in front of the user. Some features of the gait provide information about the pose of the sensor relative to the body. Using an IMU these features can be detected and the pose of the sensor can be recalibrated.

A sonar system, consisting of a rotating transducer (or more practically, an array of transducers aligned along an arc) has its own pros and cons. The different properties between acoustic imaging and optical imaging are due to differences in the wave-material interactions. For instance, optical imaging takes advantage of the texture of the surfaces of objects. The reflections in acoustic images are often mirror-like (except at edges and corners).

The wavelength used in sonar system in open air is about 10 mm. The direct consequence of such a large wavelength is that the directivity of a single transducent is wide. Therefore, the accuracy and the resolving power of the localization will be low. A polar scan of the surroundings allows for the application of deconvolution (Fig. 5) so as to improve the resolving power.

As said before, we do not claim that these three sensors offer all the necessary information in all circumstances. The open architecture of the system, and its modularity, provides the possibility to add other sensor types at a later stage of the development.

a. b. c. d.

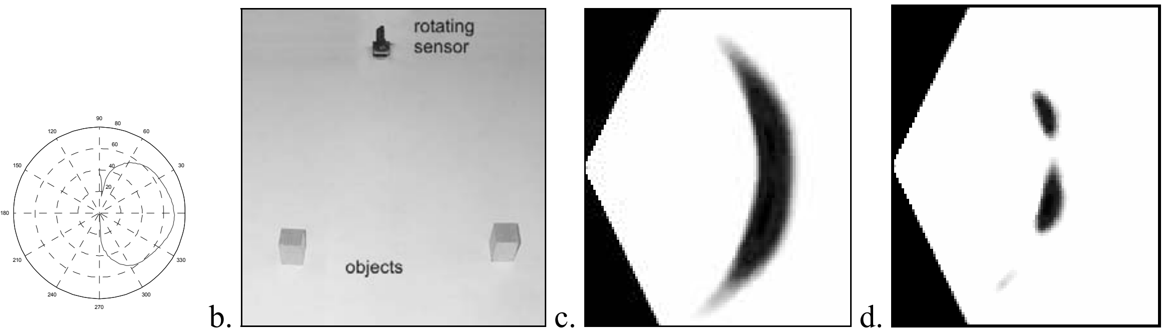

Fig. 5. Sonar system: a) Directivity plot; b) Geometrical set-up; c) Raw image;d) Deconvolved image

3. Discussion

Some electronic tools have already been proposed earlier [2-5], but their usage and applicability are limited for various reasons. The systems use only a single modality (e.g. single view vision, stereovision, or sonic). Our preliminary experiments show that a single modality does not suffice. Therefore, we propose to combine multimodal information streams (coming from different types of sensors).

A second problem is the unstable behaviour of the sensors due to the motion of the person. We propose to stabilize the system by means of inertial measurements in combination with particle filtering for map building.

A third problem is how to inform the user of the collision risks. Most systems use auditory output. This interferes with natural sounds, and thus reduces the sense of hearing: it disrupts an important navigation clue of the blind. This project aims at a tactile user interface. An interesting possibility is the tactile suit [1]. Since the information capacity of such a channel is limited, the semantic level of the provided information must be appropriate.

The fourth problem is the long training period that is needed. The current research aims at an intuitive man-machine interaction. Overall, the research will apply a user-centred design approach to realize a system that fulfils the actual needs of the blind (which is a diverse group in itself).

4. References

[1] J.B.F. van Erp, J.A. Veltman, H.A.H.C. van Veen (2003): *A Tactile Cockpit Instrument to Support Altitude Control*. Proceedings Human Factors and Ergonomic Society 47tn Annual meeting 2003

[2] S. Shovel, J. Borenstein, Y. Koren, *Auditory guidance with the Navbelt – a computerized travel aid for the blind*, IEEE Tr. SMC, Vol. 28, August 1998.

[3] J. Borenstein, I. Ulrich: *The GuideCane – A Computerized Travel Aid for the Active Guidance of Blind Pedestrians*, IEEE Int. Conf on Robotics and Automation, Albuquerque, NM, April 1997.

[4] I. Ulrich, J. Borenstein, *The GuideCane – Applying Mobile Robot Technologies to Assist the Visually Impaired*, IEEE Tr. SMC, Vol. 31, No. 2, March 2001.

[5] W. Dobelle, *Artificial Vision for the Blind by Connecting a Television Camera to the Brain*, ASAIO Journal, Vol. 46, page 3-9, 2000.