Abstract — In this paper we present Panoptes, a new device for collecting and relating spatial data through an auditory interface. The main objective of this device is to make navigation easier for the visually impaired. The design consists of a handheld device containing an ultrasonic sensor, a gyroscope, a signal processing chip and a power source. Various elements of the design were simulated and the results show that the device, in concert with the natural capabilities of the human brain, allowed the user to process and use the information to navigate.

Index Terms — Aural Interfaces, Sensory Mapping, Signal Processing, Non-sight Navigation

I. INTRODUCTION

THE objective of this project is to make a university campus more accessible to the visually-impaired. On the Br, Inc. chose to focus specifically on the navigation of campus. Important design constraints included user safety, and assumed constraints included indoor and outdoor functionality, which means that the device must work inside and outside buildings. Key design criteria included minimized cost and obtrusiveness and maximized reliability and enhancement of navigation. Existing solutions to the problem ranged from primitive, like the guide cane, to highly experimental with a lack broad adoption in the blind community. Our solution brings previously experimental techniques into practical use at a reasonable cost. This solution will be demonstrated using a computer simulation and a practical demonstration of gyroscope motion analysis.

II. CONCEPTUAL DESIGN/METHODOLOGY

A. Overall Design

In conceptual terms, the Panoptes device measures the position of environmental objects in terms of range and the angle of the object in relation to the user with several sensors. The device then uses the angle and distance information to create a virtual sound source at the detected positions. It outputs this sound so that humans' natural binaural capabilities are utilized to place the sound in the sound space. Distance is related by volume while angle is related by binaural amplitude and time differences.

The operation of the device involves manually, repeatedly sweeping the device across the area which the user wishes to "see". An ultrasonic sensor measures range while a gyroscope measures the instantaneous angle. This information is analyzed, and the virtual sound space is played back to the user using headphones. The device is powered by a 9V battery.

Figure 1: A 3D model of the Panoptes device

B. Major Components

The Panoptes device can be divided into two conceptual components: sensing and aural interfacing. We will subsequently refer to the audio interfacing process as auralization, similar to visualization, but with sound. Functional components include the range sensor, the position sensor, the digital signal processor chip, the supporting circuitry, the power source and enclosure, as shown in Fig. 2.

Figure 2: The physical and conceptual components
III. DETAILED DESIGN

A. Sensing

Distance sensing is done using an ultrasonic sensor manufactured by MaxBotix. This inexpensive sensor provides a continuous distance measurement at 20Hz, with a range of 0-6.5m. Output is calibrated at 40mV/cm. This will give us 1cm resolution at the full 6.5m.

Angular position is found using a gyroscope rotation about the z-axis, manufactured by Analog Devices. This single axis gyro will tell us the angular velocity that the user's hand is rotating with, and the change from negative to positive velocity will indicate the end point of a sweep. By integrating the angular velocity over time, angular position can be found.

In order to accurately model the distance of an object at an arbitrary angle, both the motion analysis and distance measurement need to be synchronized.

![Figure 3: A radial scan of an area using an Ultrasonic sensor](image)

B. Aural Interface

Auralization transforms measured angle and distance information into sound. The process is conceptualized as positioning a single pink noise point source in a virtual auditory space. The user perceives the location of the sound via their natural stereo hearing capabilities. Note this is distinct from generating a "sound field" that informs the user of multiple points simultaneously.

![Figure 4: Auralization signal flow](image)

The angle of the virtual sound is simulated by selecting a head-related transfer function (HRTF) that results in the appropriate binaural timing and level differences when applied to the pink noise source.

The distance of the virtual sound is simulated by attenuating the pink noise source proportional to the measured distance at the previously used angle. This corresponds to how sound levels are perceived in real environments.

IV. DISCUSSION

On the Br, Inc. did not have the opportunity to assemble a prototype; however it did test each of the components individually to judge whether the hardware could perform the task expected of it. An ultrasonic sensor was affixed to a servo motor to simulate angular movement, and it provided accurate distances. A gyroscope was attached to a wand and it was able to determine the angular position of the wand accurately throughout a full sweep. A computer simulation of the auralization process was made and listeners were able to understand where the sound source originated.

There are several components in the design that On the Br. Inc. would like to improve upon in future revisions of this design. Range sensor accuracy over the required range and in different operating conditions and environments are somewhat limited due to the use of a single sensor type. Future revisions might include the use of a laser rangefinder in a hybrid configuration with the ultrasonic sensor. The mechanism for determining position in space may be improved by the addition of an accelerometer, again in a hybrid configuration with the gyroscope.

Improvements should be made to the auralization process by reviewing feedback from the users. Feedback may change the sound that is used as an auditory cue—perhaps a pulse is more effective than pink noise in a real life situation. Feedback from users is also an important factor when looking at the other aspects of the design. Considerations like weight, size, power source and form factor could well be changed in future iterations of the device.

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REFERENCES
