Many visually impaired people are familiar with facial vision [2], the ability to get a sense of what is out in the world, without vision. It is now known that this is accomplished by echolocation; people listen to the echoes of their footsteps or cane-taps off obstacles. Unfortunately, natural echolocation is hard to learn so only a few people are proficient at it.

We have created a device which makes echolocation more effective and easier to learn, while being audible only to the user. When completed the device will cause nearby objects to appear to be emitting sounds.

The echolocating person emits noises, such as footsteps. These reflect off obstacles in the world and return. Time to each echo measures distance. Each ear receives an echo slightly different in time and level. The interaural time difference, and the interaural level difference, together measure the azimuthal (left-right) angle.

Signal Processing

Ultrasonic signals can be shifted to the audible range in two ways: time stretching involves playback at a slower rate than recording; heterodyning requires multiplication by a sine wave, using the identity:

\[ \sin \theta \sin \phi = \frac{\cos(\theta - \phi) - \cos(\theta + \phi)}{2} \]

Time stretching distorts interaural time differences, and compresses the signal in linear-frequency space. This device uses heterodyning, in order to leave interaural time differences intact and enhance Doppler frequency shifts.

References

[1] Bitjoka Laurent and Takougang Noupowou Alain Christian. A sonar system modeled after spatial hearing and echolocating bats for blind mobility aid. A radar screen visualization of signals recorded from the shelf has many copies of the emission, delayed by varying amounts.

Object Discrimination

Objects have characteristic patterns of reflections (glints). These allow users to get an impression of texture, and to learn to identify objects by sound. A smooth ceiling gives primarily a single reflection, while a bookshelf has many copies of the emission, delayed by varying amounts.

Space Mapping

A radar screen visualization of signals recorded from the device with obstacles in a typical room overlaid. The device was mounted on a calibrated pivot. A range plot, as above, was produced every 5°, with range denoted radially, and sample magnitude denoted as dot size. The left microphone is shown in red, the right in green.

Interaural time (distance) and level differences are apparent. Reflections tend to be specular, so perpendicular portions of objects give strong reflections, even if not directly in the beam.