Dynamic Sound Localization

Amir A. Handzel and P.S. Krishnaprasad

Problem

- What binaural dynamic cues are available to the human sound localization system?
- How do they break the notorious circle (tori*cones) of confusion?
- Derive a localization algorithm for a mobile robot based on these principles.

Background

Humans rely on several cues to infer the location of a sound source:

- Binaural information due to diffraction (mostly) about the head -- comparison of sound amplitude and phase between ears (IPD,ILD).
- Direction dependent spectral filtering by Pinna (external ear) and canal.
- Echoes and reverberations from environment for range estimation.
- Dynamic (binaural) information due to rotation of head relative to source -- shown experimentally but, so far, not understood theoretically.

Mathematical Analysis and Results

•Sound pressure at ear is a complex function of frequency (amplitude and phase), governed by Helmholtz eqn. (for time harmonic source).

• Solution for spherical head is expansion in Zonal Spherical Harmonics (ZSH) which are invariant under SO(2) rotations.

•Interaural functions (IPD,ILD) have same symmetry: can statically localize source only up to rotations about interaural axis.

•Polar (horizontal) rotations act by derivation of amplitude and phase as so(2) representation.

•Comparison of derivatives of amplitude and phase at each ear give IPD' and ILD'. <u>They break the confusion symmetry by generating different flow on ILD-IPD plane for different source locations!</u> (Fig. 1)

Localization Algorithm:

1. Define metric between four interaural localization functions (ILD,IPD,ILD',IPD') for source and test directions.

2. Choose test direction for which metric has minimum (zero).

Dynamic (derivatives) information gives unique global minimum -- no confusion. (Fig 2-3)

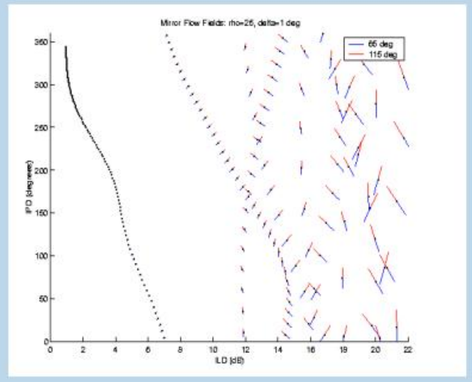

Figure 1

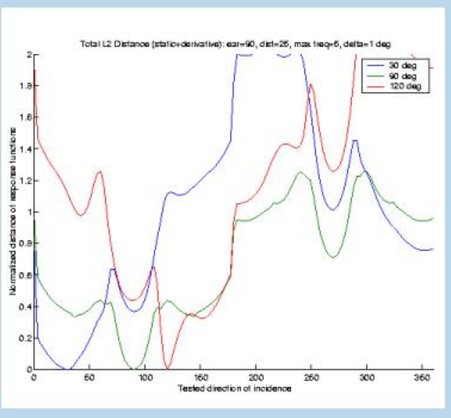

Figure 2

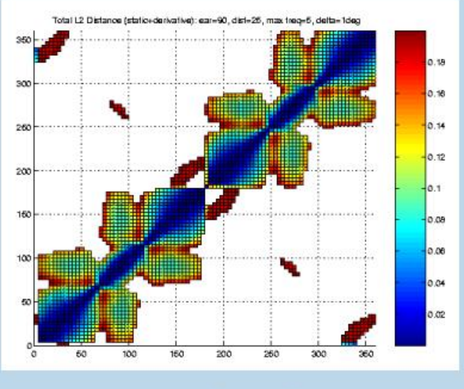

Figure 3