2nd International Symposium on Ambisonics and Spherical Acoustics, IRCAM, Paris, May 6-7, 2010

Perceptual Evaluation of a Circularly Symmetric Microphone Array for Panoramic Recording of Audio

Enzo De Sena, Hüseyin Hacıhabiboğlu and Zoran Cvetković
Centre for Digital Signal Processing Research (CDSPR), King's College London

The localisation performances of three multi-channel systems are studied through a formal listening test. Second-order Ambisonics is compared with two circularly symmetric microphone array systems: Johnston's perceptual sound field reconstruction scheme [1] and its modification which we recently proposed [2,3]. It is found that the employed second-order Ambisonics decoder renders auditory images that are contracted around the mid-point between the two frontal loudspeakers and that our recently proposed system delivers a more uniform localisation performance.

Considered Multi-Channel Systems

- Perceptual sound field reconstruction systems

Circular array of five microphones situated at vertices of a regular pentagon in the horizontal plane. Reproduction using five loudspeakers in the same regular configuration. Each microphone drives the corresponding loudspeaker.

- Johnston/Lam version

The microphone directivity has the primary lobe down by 3 dB at 72° and down to effectively zero at 144°. The diameter of the array is 31 cm. [1]

- Recently proposed version (TI pan)

The microphone directivity design is established within the framework of time-intensity stereophony [2]. The diameter is set so as to deliver more "natural" and mutually consistent ILD and ITD cues [3].

- Second-order Ambisonics

The B-Format signals are encoded via the Furse-Malham 2nd-order coefficients (FMH-Format) and decoded using the in-phase coefficients. The CDP Multi-Channel software toolkit available at [4] has been used. The employed loudspeaker layout is pentagon.

Figure 1 - The test setup

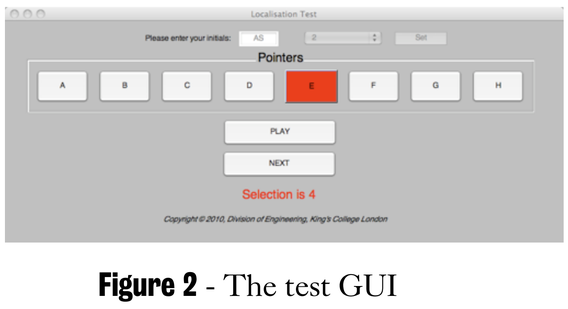


Figure 2 - The test GUI

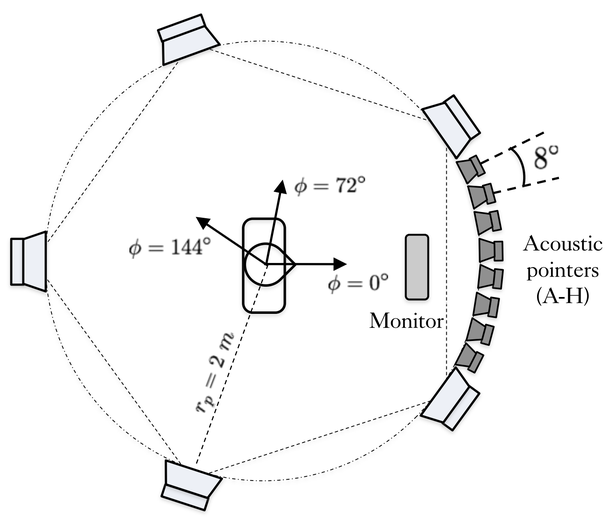


Figure 3 - The test setup diagram

Listening Test Setup

- Audio booth with walls and ceiling almost completely absorbent. $T_{60} = 230ms$
- Room dimensions: W = 4.5 m, L = 6 m and H = 2.2 m.
- Six subjects (5 males and 1 female).
- Subjects positioned in the centre of the loudspeaker array.
- Three different seating orientations - see Figure 3.

Methodology and Stimuli

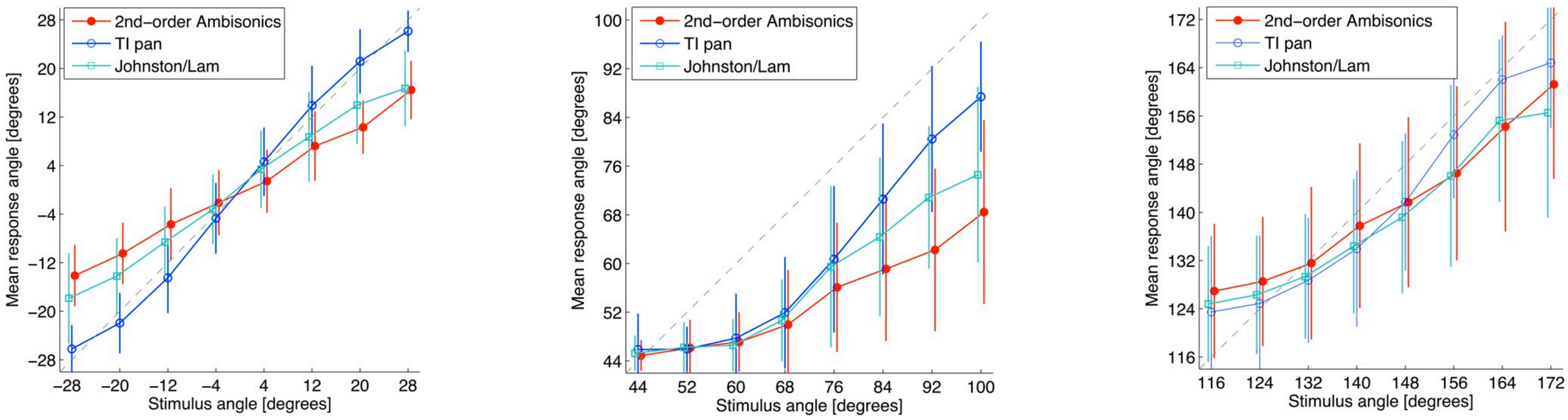
- **Stimulus**: White Gaussian noise of 100 ms duration tapered with a Tukey window (30% taper-to-constant ratio).
- For each of the 3 systems, the microphone recordings were simulated for 8 different directions corresponding to the directions of the acoustic pointers - see Figure 3 (free field).
- **The subjects' task was to listen to the five-channel system stimuli and respond by listening to and selecting the acoustic pointer which is closest to the perceived direction of the auditory image.**
- At each seating direction, each system-direction pair was repeated 15 times and with fully randomised presentation order (total 1080 trials per subject).

Results

✓ Front-looking orientation (Figure 4a)
- ✓ 2nd-order Ambisonics, the average responses lie within ≈ (−15°,15°)
- ✓ TI pan system provides more uniform subjective localisation performance.
- ✓ Johnston/Lam performs better than Ambisonics but worse than TI pan.

✓ Side-looking orientation (Figure 4b)
- ✓ Between 44° and 68° the performance of all the systems perform equally bad, possibly due to the sparsity of the surround system and the poor localisation accuracy of the auditory system for side angles.
- ✓ Beyond 68° TI pan delivers the best performance.

✓ Back-looking orientation (Figure 4c)
- ✓ The above observations hold for this orientation too.



(a) Front-looking orientation, φ = 0°.

(b) Side-looking orientation, φ = 72°.

(c) Back-looking orientation, φ = 144°.

Figure 4 - Mean response angles for the three listening positions. The error bars show the ±σ intervals. Ideally the response angle should be equal to the stimulus angle (bisecting line).

References

[1] J.Johnston and Y.Lam,"Perceptual soundfield reconstruction," AES 109 Convention - Preprint # 5202, Los Angeles, USA, September 2000.

[2] H. Hacıhabiboglu, E. De Sena, and Z. Cvetkovic, "Design of a circular microphone array for panoramic audio recording and reproduction: Microphone directivity," AES 128 Convention - Preprint # 8063, London, UK, May 2010 (to be presented).

[3] E. De Sena, H. Hacıhabiboglu, and Z. Cvetkovic, "Design of a circular microphone array for panoramic audio recording and reproduction: Array radius," AES 128 Convention - Preprint # 8064, London, UK, May 2010 (to be presented).

[4] CDP Multi-Channel Toolkit [Online]. Available:http://people.bath.ac.uk/masrwd/mctools.html

Acknowledgments

This work is supported by the Engineering and Physical Sciences Research Council (EPSRC) Research Grant EP/F001142/1 "Perceptual Sound Field Reconstruction and Coherent Emulation".