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Experiments in binaural audio for telepresence

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Background

One area of telepresence research that has had less, though increasing, analysis is that pertaining to the audio aspects of presence, particularly with regard to the remote detection of real world sounds. If telepresence can be considered as the physical sensation of being elsewhere, whether within a virtual, or real environment then addressing the sensation that provides audio information, whether virtual or real should be a worthwhile endeavour in order to enhance the sense of presence.

Audio for Telepresence

With the audio sensation, in humans having two ears, (binaural) then sound signals can be detected round corners, through walls, whilst asleep and in particular from behind. The action is then to direct the gaze to the region of interest in order to make an assessment. "Ears tell eyes where to look."[1] Additionally ears provide though the spectral mix of sound reflections, information about the form of a particular auditory space, its dimensions, height and qualitative information about the surfaces that generate those reflections. [2]

There is a distinguished history of investigation into the precise nature of how humans hear and localise sounds, and this knowledge provides a base upon which to create a telepresence experience[3] [4]. Some of the mechanisms involved include the existence of two ears having asymmetrical cartilage reflectors, the pinnae, attached in opposition onto a movable, flesh-covered bony spherical container, the head. The use of the pinnae has been shown to significantly aid localisation particularly when using sounds having a wide frequency range.[5] Two opposed microphones at human head width on a movable structure, in conjunction with the individual spectral modifications introduced by the pinna can give a form of hearing transducer suitable for binaural detection.

An attempt to include a sound capability in order to investigate localisation using a mechatronic approach for telepresence was created (see Figure 1) by Harrison [6]. Figure 1 shows a steered electromechanical platform having binocular cameras and capable of pan, tilt, and roll and had in addition a pair of pinnae and miniature microphones added at the ear analogue positions in order to mimic binaural hearing[7].

The structure was then slaved to a head tracker and a VR headset having a binaural capability as shown in Figure 2. This attempted to investigate whether there was an enhancement to the sensation of telepresence by the addition of the audio sensation.

The particular test used was to investigate whether a sound emanating to one side of a remote telepresence structure could be detected by the user in such a way that they could rotate the remote head and look at it. This required closing off the remote binocular cameras and then noting the position of the head. A series of 12 clock face positions was laid out within an anechoic chamber and the remote "head" driven via a VR headset and tracker until the sound was located, and the position recorded. This brief test showed that the addition of a sense of hearing did give the ability to detect sounds that were behind and the results were strongest with the person from whom the ears were moulded. The increase in the sense of presence was also noted by the users. A brief result of one of the tests is given in Figure 3.

These tests showed that the addition of the head motion and the pinnae gave particular advantage when it came to detecting sounds that are actually in front of the remote head but are perceived as being behind, known as "front-to-back" confusions.

However a key limitation was that since the electromechanical structure had been designed to be controlled by stepper motors the vibration of these motors permeated the remote microphones and generated motor noise within the microphones. However once the binocular camera pair were reintroduced with the VR headset in order to simulate the human stereoscopic vision capability then there was an increased sense of presence felt in the remote environment, and this provided a base from which a further test platform to enhance telepresence could be produced.

The research objective for the second audio structure was two fold, 1 to attempt to use low audio noise DC motors instead of the steppers used in the previous development and additionally 2, to investigate if the phenomenon of "supernormality"[8]. Accordingly the author put together a second structure using lower noise dc motors, improved quality microphones and using a more flexible mechanical structure in order that ear separation distance in particular could be increased.

An annotated diagram of the second structure is shown in Figure 4. This has additionally a perspex baffle intended to mimic the frequency dependant audio shadowing effect of the human head,[9] as well as higher quality microphones and amplifiers. Some preliminary results of this testing are shown in Figure 5 which illustrates the ability to localise at up to 4 x the head diameter and without vision, though using the binocular vision capability in the final two tests as a check. The angle of error is shown which illustrates a trend towards an improvement in the ability to localise a particular broadband sound. Although the reduced noise of the motors could still be detected and this mitigated somewhat against the sensation of the remote presence, the trend in the data would appear to suggests a somewhat greater ability to localise at greater head width.

Summary

The potential to enhance a real remote presence experience by using audio has been touched on here though the subject offers tremendous potential. It is necessary to have an understanding of human hearing mechanisms in order to construct such a system and this must be tied into the binocular vision capability since the real world sense of presence involves multimodal interactions of these senses, and others.

There is some experimental evidence presented here that, using localisation angle, or how closely the head can point towards a sound, it is possible to augment the presence experience by the addition of a binaural capability. It is clearly possible to tele-rotate the remote head in order to locate a sound and hence for the vision sense to enable further decisions, for example “fight or flight”. There has been a brief account here of some of the systems that have been used to explore the sense of presence and future work aims to improve this further, and to include haptics.

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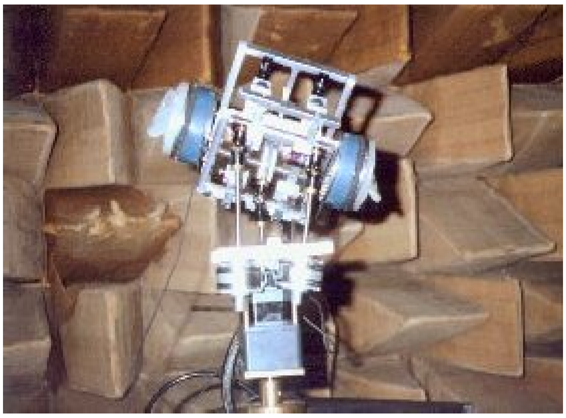
Figures



Remote presence head in Anechoic chamber Figure 1

Figure 2 The author with VR Headset and position tracker

	R	***E***	***P***		***A***	***Z***	***I***	***M***	***U***	***T***	***H***		
A		1	2	3	4	5	6	7	8	9	10	11	12
C	1	.	.										
T	2	.	.										
	3				..								
A	4					.							
Z	5					.							
I	6						.	.					
M	7							..					
U	8								.				
T	9									.			
H	10										.		
	11											.	.
	12												.

Figure 3 Pinnae mounted + head motion

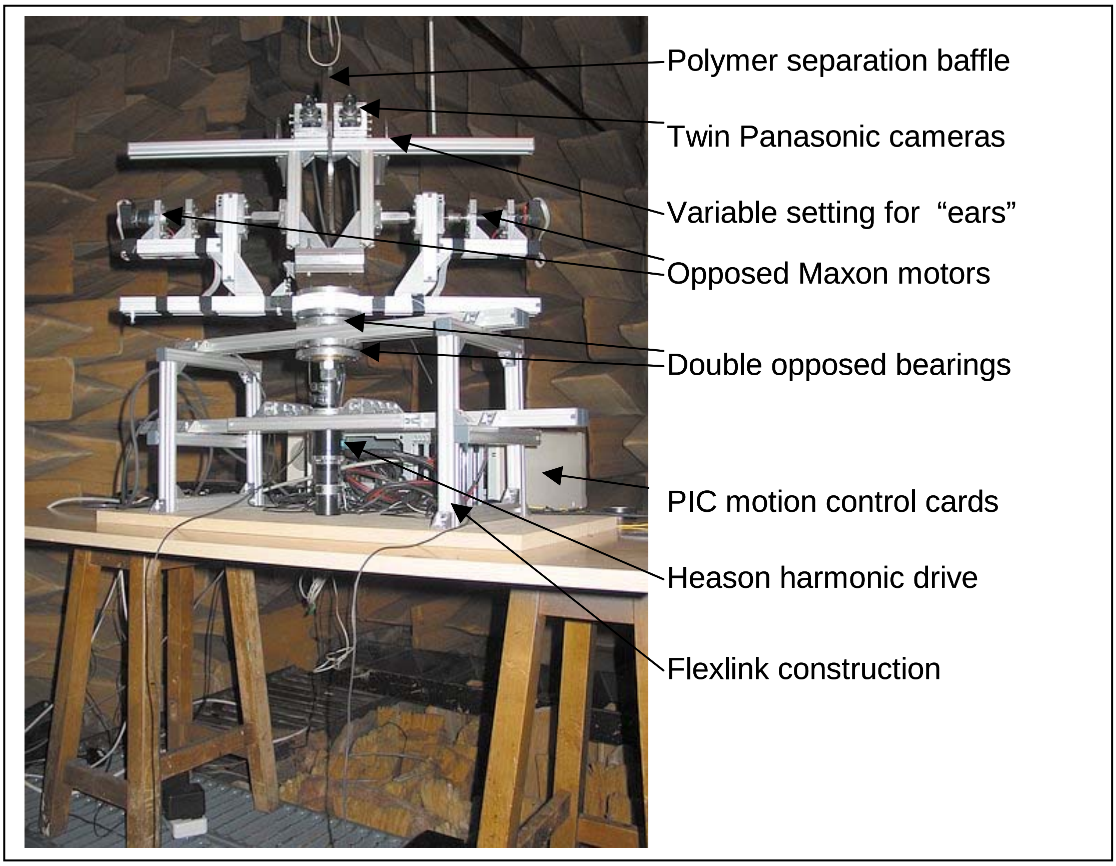


Figure 4 Improved Audio test structure in Anechoic Chamber

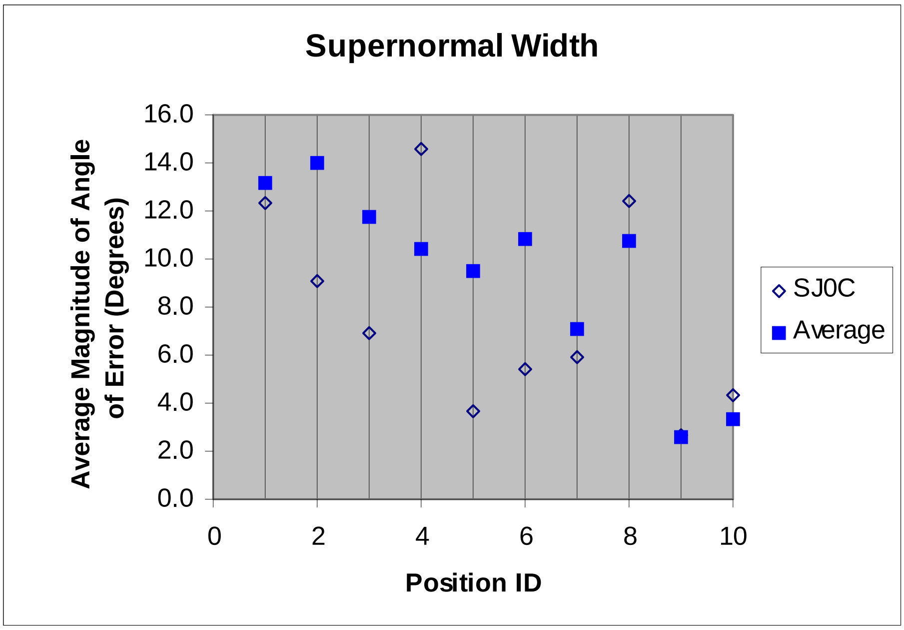


Figure 5 Sample user data for 4 varying head widths