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An anechoic configurable hemispheric environment for spatialised sound

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An Anechoic Configurable Hemispheric Environment for Spatialised Sound

Abstract

This paper reports on the recently completed and significant upgrade of the University of Wollongong's Configurable Hemispheric Environment for Spatialised Sound (CHESS). The CHESS studio, which housed a 16 speaker hemisphere for creating spatial sound, has been converted into an anechoic chamber and a new 3D speaker system has been designed. The recent work is a continuation of a successful cross-disciplinary research activity between the Faculty of Informatics and the Faculty of Creative Arts. Also reported are new research initiatives that will be taking place in the facility.

Introduction

The original Configurable Hemispheric Environment for Spatialised Sound (CHESS) was a 3D sound environment that allowed for playback of up to 16 channels of audio using loudspeakers attached to a hemispheric framework (Schiemer, et al., 2004). It was created in 2001 as a collaborative project between the 3D audio team in Informatics, led by Ian Burnett, and staff in the sound, composition, music and production program from Creative Arts, led by Stephen Ingham.

CHESS has been the principal infrastructure used for research activities in spatial sound (Potard and Ingham, 2004). A photo of the original CHESS system, which includes a 3D loudspeaker array, is shown in Figure 1. Technology resulting from this research was used in an international symposium on sonification (ICAD 2004), and for the production of a 16-channel electroacoustic composition created collaboratively between the Faculties of Informatics and Creative Arts (Schiemer & Potard, 2004).

Figure 1. The Original CHESS facility (Schiemer, et al., 2004)

The recently upgraded facility has created an anechoic environment for spatial sound. This will enable a wealth of new research activities previously not possible with the original CHESS facility. This report will outline the design and construction of the chamber, the design of a new 3D loudspeaker array, and summarise existing and future research activities to be supported by the facility.

Creating an Anechoic Environment

for CHESS

In 2007, a team from the Faculties of Informatics, Creative Arts, and Science, led by Christian Ritz, was awarded a Research Infrastructure Block Grant (RIBG) to build the University of Wollongong's first anechoic chamber: a new anechoic home for CHESS.

Figure 2. Anechoic CHESS

A traditional anechoic chamber requires sound insulation of all 4 walls, the ceiling, and the floor. Such insulation is generally expensive, and requires installation of large wedge shaped soundproofing. The solution adopted for the new facility at the University of Wollongong is the flat-walled multi-layer technique invented by Jingfeng Xu (Xu, *et al., 2005)*. The approach uses standard building insulation material installed in multiple layers on the walls, ceiling and floor to absorb sound within the room (Xu, *et al.,* 2005).

The anechoic chamber was designed to provide 99% acoustic absorption at any one-third octave band centre frequency between 250 Hz and 10 kHz. A photo of the interior of the chamber is shown in Figure 2.

Compared to traditional wedge-based anechoic chambers, employing the design of (Xu, *et al., 2005)* resulted in significant economic savings whilst achieving similar acoustic characteristics. Similar in size to the chamber reported in (Xu, *et al., 2005)*, the anechoic facility has approximate dimensions of 4.8m in length, 3.3m in width, and 2.4m in height. An additional advantage when compared to conventional wedge based designs is the reduced sound insulation thicknesses, making the technique suitable for smaller spaces (Xu, *et al., 2005)*.

As well as the installation of sound insulation, a number of other building modifications were required. These included the design and installation of a raised floor, and modification of the air-conditioning system to eliminate noise created in the chamber from air-flow through the ducting and outlets. Whilst a number of alternative solutions were considered, the most cost-effective solution was to install a damper system. This system significantly reduced noise generation and allowed for user control to toggle the air-conditioning on/off when total silence is required (e.g. when conducting sound recording experiments).
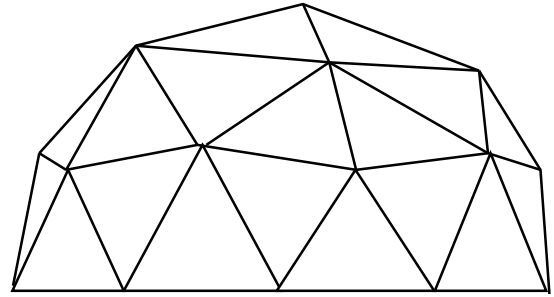

Figure 3. A 2V Geodesic dome (Landry, 2002)

New Geodesic Speaker Array

The original CHESS system consisted of a customised structure formed from six steel frames arranged to form a 'globe' (Schiemer, *et al.,* 2004) (see Figure 1). Hinged brackets allowed for attachment of loudspeakers and placement at desired azimuths and elevations. Rebuilding CHESS within the anechoic chamber required a new design due to the reduced space resulting from the sound insulation.

The new design will consist of a geodesic array built from metal tubing. The new array will use lighter (and lower cost) active studio monitors (Genelec 8020A) and will be constructed using lightweight material to ensure that it is more configurable and easier to accurately manipulate speaker positions than the original CHESS structure.

The dome design will be the upper hemisphere of a 2V Geodesic dome as illustrated in Figure 3 (Landry, 2002). The use of this dome will allow placement of loudspeakers at regular spatial positions and is particularly suited to 3D audio reproduction (Vennonen, 1995). The new CHESS speaker array will be formed from a regular decagon shaped base constructed from 10 metal tubes. The remainder of the dome will then be built from metal tubes of two different lengths and customised hinged brackets will be constructed to allow attachment of the loudspeakers at arbitrary positions on the framework.

Audio Recording and Playback System

The complete CHESS system included a user interface hosted on a Pentium 4 PC that communicated via a LAN with the 3D audio Digital Signal Processing (DSP) software and commercial audio hardware hosted on a MAC G3. The 16 channel speaker array was interfaced to the MAC G3 with audio conversion hardware (Alesis AI-3) via a Digidesign Digi-001 controlled by Pro-Tools LE. Custom 3D audio software was also developed for the original CHESS system using Max/MSP on the G3. Spatial audio reproduction was achieved using the Ambisonics approach (Malham, 2005), where the appropriate loud-

speaker signals were created using custom software implementing 4th order Ambisonics encoding (Schiemer *et al.*, 2004).

For the new facility, experiments will be conducted using both the existing control system as well as an alternative system: the MAC G3 is replaced by a dual-core Pentium D PC interfacing through a RME HDSP9652 Hammerfall DSP system to three Behringer ADA8000 pre-amps, controlled by Adobe Audition (Windows) or Ardour (Linux). The alternative system provides the advantage of increased flexibility for simultaneous multichannel recording and playback through the same system, which has been used in recent research published by the authors (Cheng, et al., 2006).

Key Research Projects to be Supported by the New Facility

Location-Based Audio Object Annotation

The new anechoic chamber will allow for new experiments into the recording and analysis of spatial sound. Authors Ritz, Burnett and Cheng have researched computationally efficient algorithms that provide event-based metadata extraction from spatial positioning information derived from multichannel speech recordings in real acoustic environments, where problems caused by room reverberation and background noise are generally hard to predict and account for (Cheng, et al., 2006). The new anechoic environment will allow for controlled experiments into the recording and annotation of spatial audio objects which are not affected by room reflections and noise signals. This will enable new scientific experiments comparing results between anechoic and reverberant recordings.

New Techniques in Recording and Playing 3D Audio

The research, design, and development of new microphone array techniques for recording 3D (spatial) sound require an anechoic environment for accurate characterisation of the array acoustic response and performance evaluations. The authors are currently developing new techniques for the recording of spatial sound using non-obtrusive array designs, distributed arrays, and arrays of directional vector sensors. The anechoic facility will also be used to study frequency response in thin film speaker material used in the Orbophone (Lock and Schiemer, 2006), a new interface for sound radiation.

Spatial (3D) Audio Coding

Authors Ritz and Burnett and their PhD student Bin Cheng have developed a new spatial audio coding technique called Spatially Squeezed Surround Audio Coding (S3AC) (Cheng, et al., 2007; Cheng, et al., 2008). This technique has been applied to the compression of multi-channel surround audio as well as Ambisonic B-format recordings, with results from perceptual listening experiments conducted in real environments having shown significant advantages over existing approaches (Cheng, et al 2007; Cheng, et al 2008). The anechoic chamber and new 3D speaker array will be used for new experiments investigating the human perception of spatial sound without interference from unwanted reflected signals. The results of these experiments will be used for developing new coding techniques that further reduce the bit rate for compressing 3D audio encoded in various signal formats.

Auditory Perception of Microtonal Music

An anechoic facility will be useful for conducting perceptual studies involving auditory perception of microtonal music (Narushima, *et al.*, 2008) by composers, performers and untrained listeners as part of a new ARC Discovery Project ARC. Two international collaborators taking part in this project will investigate harmonic structures and psychological processes involved in microtonal composition. The Sonic Arts Research Network, a research collective formed in the University of Wollongong to foster interdisciplinary research between the Faculty of Informatics and the Faculty of Creative Arts, provided funding to support these joint initiatives.

Acoustics of Ancient Architecture

The way acoustic sound is enhanced through specific material surfaces and textures is of great interest in the understanding of performance in ancient architecture, such as the Hellenistic theatre in Paphos, Cyprus, where members of the faculty have worked. The Sonic Architectures exhibition in October 2006 in the Faculty of Creative Arts Gallery was a start in exploring these issues (Wood Conroy, *et al.*, 2006). The anechoic chamber will allow the effects of different material surfaces on the acoustic properties of sound to be studied in a controlled environment. It will give researchers new insights on sound projection based on understanding how such a theatre might have sounded to audience members in ancient times.

Conclusion

The University of Wollongong's CHESS facility has been a successful collaboration between two faculties that has led to a number of research outcomes. The upgrading of CHESS to provide a new anechoic environment has produced a unique facility that will ensure many new re-

search and creative projects involving sound in all dimensions.

Acknowledgements

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