

Impact case study (REF3b)

Institution: University of Derby
Unit of Assessment: UoA 15
Title of case study: Improved Spatial Audio from Ambisonic Surround Sound Software

1. Summary of the impact (indicative maximum 100 words)

The reduction of spatial variation in the quality of reproduced sound within a defined space using varied loudspeaker placements is a significant challenge for sound engineers. Dr Bruce Wiggins has conducted research into encoding, decoding and processing algorithms using Ambisonics, a system based around full-sphere sound reproduction. The outcomes of the research have been made accessible to the wider community by the creation of a suite of software plug-ins (WigWare), a production workflow, and associated teaching materials which can enable commercial audio workstations to benefit from Ambisonics. There are numerous recorded instances of successful use.

2. Underpinning research (indicative maximum 500 words)

Ambisonics, pioneered in the 1980's by Michael Gerzon, is a kernel-based 3D surround sound system. The encoding (recording or panning) of the audio is separated from the decoding (or rendering) of the audio to speaker feeds. This means that the system can be rendered to any number of speakers in almost any position in 3D space, as long as the positions of the speakers are known. Moreover, Ambisonics is a system optimised around a number of psycho-acoustic criteria which, when implemented, reduce the variability of audio no matter what speaker arrangement is used for reproduction. This allows for a 'mix once' system where subsequent remixing is not necessary when replayed over different loudspeaker systems. The research work carried out began by giving a thorough treatise on Ambisonic theory, specifying the relationship and conversions from and to other surround systems, which led to work quantifying and optimising the system using measured Head Related Transfer Function (HRTF) data and the more standard energy and velocity vector analysis. These complex multiple input, multiple output system were then optimised using a modified heuristic Tabu search algorithm with multiple defined fitness functions (Wiggins 2003, 2004). This was necessary as, up to this point (2003), there was no known or published method of generating Ambisonic decoder coefficients for irregular speakers arrays. This included the standard 5 speaker array as specified by the International Telecommunication Union (ITU-R BS 775); the standard matrix pseudo-inverse approach gave results that were psycho-acoustically sub-optimal as the matrices in question became ill-conditioned. Work carried out by Gerzon just before his death in 1995 on this subject was shown to lead to sub-optimal results (Wiggins 2003). This research solved that problem. Subsequent work concentrated on the encoding side of Ambisonics, giving new insight in the performance of Ambisonic, 3D microphones with respect to near-field effects (distance cues), and how these could be handled in terms of decoding to loudspeaker arrays (Wiggins, 2009). Concurrently, work based on both the use of Ambisonic mixing tools in the context of music production and digital audio workstations allowed for the wider community to utilise the outputs of this research in the form of software Virtual Studio Technology (VST) plug-ins which implemented encoding, decoding and 3D reverb effects for up to 24 loudspeakers for 1st, 2nd, 3rd and 4th order Ambisonic systems. Note here that the order is an indication of the number of channels used in the encoding $[(N+1)^2]$ where N is the order, with higher channel counts resulting in better spatial acuity. This software, named WigWare, first released in November 2005, has evolved to take in further work based on proximity effect, near-field compensation and speaker compensation. This arises from the distance of both the encoded, or recorded source, and the speakers used to replay the audio. To disseminate the work, 'screencasts' documenting how to set up and use the software research outputs in an example Digital Audio Workstation (DAW) have been made publicly available (using Reaper as the DAW – <http://reaper.fm>). This work has led to a number of invited presentations, at DAFx 2012, Institute of Acoustics Reproduced Sound 2012 and Birmingham University and involvement with the BBC R&D Audio Research Partnership.

The principle investigator was Bruce Wiggins who enrolled as a PhD student at the University of Derby in 1999, completing in 2004. The supervisors were Iain Paterson-Stephens and Professor Richard Thorn with contributing work by Dr Stuart Berry and Dr Valerie Lowndes (all staff at the University of Derby)

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3. References to the research (indicative maximum of six references)

The main key outputs related to the work are:

Wiggins, B. Paterson-Stephens, I., Lowndes, V., Berry, S. (2003) The Design and Optimisation of Surround Sound Decoders Using Heuristic Methods. Proceedings of UKSim 2003, Conference of the UK Simulation Society p.106-114.

<http://tinyurl.com/BruceImpact5> (Best Quality 1 of 3)

Wiggins, B. (2004), An Investigation into the Real-time Manipulation and Control of Three-dimensional Sound Fields, PhD thesis, University of Derby, Derby, UK.

<http://tinyurl.com/BruceImpact4> (Best Quality 2 of 3)

Wiggins, B. (2007) The Generation of Panning Laws for Irregular Speaker Arrays Using Heuristic Methods. Proceedings of the 31st International AES conference, London, UK.

<http://tinyurl.com/BruceImpact3> (Best Quality 3 of 3)

Wiggins, B. (2008) Has Ambisonics Come of Age? Reproduced Sound 24 - Proceedings of the Institute of Acoustics, Vol 30. Pt 6.

<http://tinyurl.com/BruceImpact2>

Wiggins, B., Spenceley, T. (2009) Distance coding and performance of the mark 5 and st350 SoundField microphones and their suitability for Ambisonic reproduction. Reproduced Sound 25 – Proceeding of the Institute of Acoustics, Vol 31, Pt 4.

<http://tinyurl.com/BruceImpact1>

4. Details of the impact (indicative maximum 750 words)

After completing the PhD it became apparent that although there were a number of researchers working on Ambisonics, it was extremely difficult to utilise the published work for Audio Production and live events. Ambisonics was not implemented in any commercial music production software, meaning practitioners could not utilise the benefits of the system. To this end, a number of VST software plug-ins were created (November 2005) which implemented the encoding and decoding algorithms necessary for 1st and 2nd order Ambisonics. These plug-ins could be loaded into VST compliant DAWs allowing existing workflows to be leveraged with minimal changes. The plug-ins were improved and augmented, including graphical user interfaces, 3D reverberation, distance filtering/proximity effects and up to 4th order operation, to incorporate new research from the UoA. They have been consistently updated and expanded with bespoke decoders created for new projects. Both the software and a publicly available set of instructional videos are available at www.BruceWiggins.co.uk. The software has been used in a number of projects in both academia (from Undergraduate to PhD level work) and in industry with the public being exposed to the outputs of the system internationally.

The reputation of the University's work in spatial audio technology led to an approach by Funktion One, designers of high quality sound reinforcement equipment, who were looking to implement spatial audio in large, live outdoor events. The WigWare software was used to process live audio, with extra software created to allow for frequency dependent panning effects. This joint project led to a measured benefit of lower noise levels off-site, and more enveloping audio on-site compared to other stages controlled in a standard stereo-based manner. The software is now a feature of Funktion One live events, known as the Funktion One Experimental Soundfield, with the system featured at the Glade Festival every year since 2006, and at the Glastonbury Festival on the Glade and Sprit of 71 stages from 2008. The latter included a live version of Tubular Bells processed by the WigWare software in 2011. In an article interviewing Anslem Guise, one of the founding members of the Glade Festival (Tpi, 2012) he openly praises the system "*My highlights this year were the Meteor and I would say Origin this year was incredible,*" commented Guise. "*The decor from Artescape in Cape Town combined with the lighting and of course the amazing Ambisonic sound from Funktion-One really was another level.*" John Newsham (from Funktion One) is quoted in the same article "*The Ambisonic system runs in Audio Mulch on a laptop with Bruce Wiggins' Wigware Ambisonic VST plug-ins and an Echo soundcard. Bruce has developed second order Ambisonic VST panners which are capable of delivering some stunning pan effects,*" (Tpi 2012).

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The research is also utilised by computer games company, Codemasters, who have pioneered the use of real-time Ambisonic encoding and decoding in their Playstation 3, Xbox 360 and PC games. They have been using the WigWare suite of Ambisonic plug-ins in order to create pre-mixed Ambisonic audio for use in their games including Colin McCrae DiRT2 (reported by VGChartz as 1.68M sales) and the 2011 BAFTA winning Formula 1 2010 game (2.3M sales reported by Trade paper MCV on 17th May 2011). The use of pre-mixed audio has allowed for full 3D scenes to be constructed, mixed, and stored using just four channels of audio, yet still allows them the flexibility of re-orienting the entire sound field using just a few multiply and add operations per sample. Different speaker layouts in the decoding are then easily added post mix. This has allowed an increase in the complexity and amount of audio content in the game as the storage of the 3D scene is much more efficient. It is thought that the steerable pre-mixed audio, i.e. premixed audio that can still take into account which way the camera is facing on decoding, was a world first in computer games, thus allowing significantly more audio content to be included on the DVD used to distribute Xbox games.

The BBC's Audio R & D department have been using the research as part of a wider project looking into future high definition audio formats. Research Engineers from BBC's audio team visited Derby in 2011 in order to discuss Ambisonics implementation issues and production workflow. They also attended our Sounds in Space event the same year where Wiggins presented a live demonstration comparing 1st, 2nd and 3rd order Ambisonics using the Wigware software. This, along with the research has "*helped members of our team to understand Ambisonics processing and how it sounds, allowing us to explore the area more effectively in our own research.*" With the team also using Wigware plug-ins, along with a number of web-based animations Wiggins generated visualising the differences between Ambisonic orders, to demonstrate Ambisonics as a surround format to colleagues at the BBC; this has informed decisions on the direction of research at the company. Also, the BBC have "*used your [Wiggins'] papers ([2004] thesis and 31st AES conference) in developing an understanding of issues for irregular loudspeaker layout decoding processes, and used it to build some of our own algorithms in MATLAB for 3D irregular decoding*". The BBC's work in this area has been reported on TV and the web, with a screenshot of the WigWare web site appearing on BBC Click (18m.50s on 13-08-2011 episode, BBC, 2011).

Further afield, the Museum of Jurassic Technology in Los Angeles (<http://mjt.org/>) has a small 14 seat cinema theatre where they are working on a 3D, stereoscopic, motion picture that was shot in the Republic of Georgia (2011). The audio was recorded with a B-format Ambisonic microphone and an accompanying Ambisonic Music Track has been produced using the WigWare plug-ins. The founder of the Museum, and the user of the research was awarded the MacArthur Fellowship (nicknamed the Genius Grant) in 2001.

Examples of the impact of the work on live and recorded music production are numerous. Work at Blumlein Records in Germany not only releases recordings using the WigWare tools, but also advocates their use in magazine articles and on the internet regarding surround audio production; "*Mixing took place in Ambisonic B-Format. I used Bruce Wiggins' Ambisonic panner to place every M/S decoded channel at its position within an octagon and WigWare's 5.1 decoder to map the B-Format to my ITU 5.1 monitoring environment. When editing the session alongside the composer, Oliver [Korte] was amazed by the precise localisation of every sound source around us. Quite an achievement considering the – in Ambisonic terms – irregular placement of the loudspeakers.*" (Levine, 2011). A surround DVD released in February 2013 entitled Oliver Korte: Elemente is a typical example of work produced using the software (AllMusic. 2013) with reviews available, in German, at Korte-oliver.de. (2013). One such review states "...it is included on DVD in a breath-taking 5.1-surround version...". On Tuesday 3rd July 2012, Bob Beldon's Animation band performed tracks from the Transparent Heart album which was performed in live 8 speaker Ambisonics using the WigWare software to provide Ambisonic reverberation in real time. A review of the evening stated "*Coupled to Ambisonic's pioneering live surround sound set up that was manipulated live by its creator Serafino DiRosario... the immersive audiovisuals only served to heighten the intense feelings at the heart of Beldon's visionary urban jazz aesthetic.*" (Flynn, 2012).

A number of researchers are utilising the research worldwide, such as at Queensland University of Technology in Australia where the Wigware software is used to provide live panning and decoding in the production of a Theatrical work with 3D audio (Wilkinson, 2013). A recent PhD student at Queen Mary's University London used the software in a project with the BBC (Morrell et

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al, 2012) in order to create a hybrid 3D audio rendering system combined with surround vision. In addition, a composer, orchestra conductor and researcher at the University for the Creative Arts is utilising the software in their PhD in music (Abrás, 2013). Wiggins also generated the irregular Ambisonic decoder coefficients used in the CSound Ambisonic Decoder op-code (Furse et al. 2008). This computer programming language for sound has been downloaded more than 310,000 times since January 2008 (source: Sourceforge.net).

5. Sources to corroborate the impact (indicative maximum of 10 references)

Abrás, J. 2013. *www.juanmanuelabras.com*. [online] Available at: <http://www.juanmanuelabras.com/> [Accessed: 18 Oct 2013].

AllMusic. 2013. *Oliver Korte: Elemente - Various Artists | Release Credits | AllMusic*. [online] Available at: <http://www.allmusic.com/album/release/oliver-korte-elemente-mr0003887094/credits> [Accessed: 18 Oct 2013]

BBC, 2011. *BBC Click Episode 13-08-2011* [online] Available at: <http://www.bbc.co.uk/programmes/b013pdnf>, still image found here <http://twitpic.com/65ana6> [Accessed: 18 Oct 2013]

Flynn, M. 2012. *Jazz breaking news: Bob Belden's Animation Dive Into The Dark Side Of Manhattan*. [online] Available at: <http://www.jazzwisemagazine.com/news-mainmenu-139/69-2012/12416-jazz-breaking-news-bob-beldens-animation-dive-into-the-dark-side-of-manhattan> [Accessed: 18 Oct 2013].

Furse, R., Wiggins, B., Adriaensen, F. and Groner, S. 2008. *bformdec1*. [online] Available at: <http://www.csounds.com/manual/html/bformdec1.html> [Accessed: 18 Oct 2013].

Korte-oliver.de. 2013. *[korte-oliver.de] Prof. Dr. Oliver Korte: Komponist und Musiktheoretiker: Presse zur CD/DVD "Elemente"*. [online] Available at: <http://www.korte-oliver.de/werke/kritiken/kritiken-view/presse-zur-cddvd-elemente/> [Accessed: 18 Oct 2013].

Levine, A. (2011) *Rediscovering Ambisonics, Resolution (Audio for Broadcast, Post, Recording and Multimedia Production)*, pp47-48 V10.3 April 2011

Morrell, M., Baume, C., Reiss, J. *Vambu Sound: A Mixed Technique 4-D Reproduction System with a Heightened Frontal Localisation Area. Spatial Audio In Today's 3d World - AES 25th Uk Conference, Universtiy of York, 2012*

TPI. 2012. *Electronic Wonderland*. [online] Available at: http://www.tpimagazine.com/production-profiles/1589162/electronic_wonderland.html [Accessed: 18 Oct 2013]

Wilkinson, J. 2013. *Notes on Creating a Sound Play*. [online] Available at: <http://ambisonicsinthetopend1945.wordpress.com/> [Accessed: 18 Oct 2013].