Research at the University of York into 3–Dimensional Ambisonic Sound Systems for Recording and Computer Music

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The **Music Technology Group** at the **University of York** has been involved in **Ambisonic** technology since the very beginning. Our interest was stimulated by the fact that since an essentially unlimited number of sounds, at any number of different positions, can be encoded within the same four **B format** channels, complex manipulations of large numbers of signals can be accomplished with relatively simple algorithms, a feature which is impractical or unavailable in other systems.

It was this feature in particular that lead us recently to mount a large research effort into the application of **Ambisonic** technology to computer music, although we had over the years constructed various analog devices and been involved in a number of **Ambisonic** recordings, mostly with the **"Music From York"** label. In the last eighteen months, the research has been moving rapidly from theoretical studies and small scale prototype systems to full scale practical usage. In the the course of this work, a considerable amount of practical experience has built up. Needless to say, this process is still continuing and will do so for the foreseeable future.

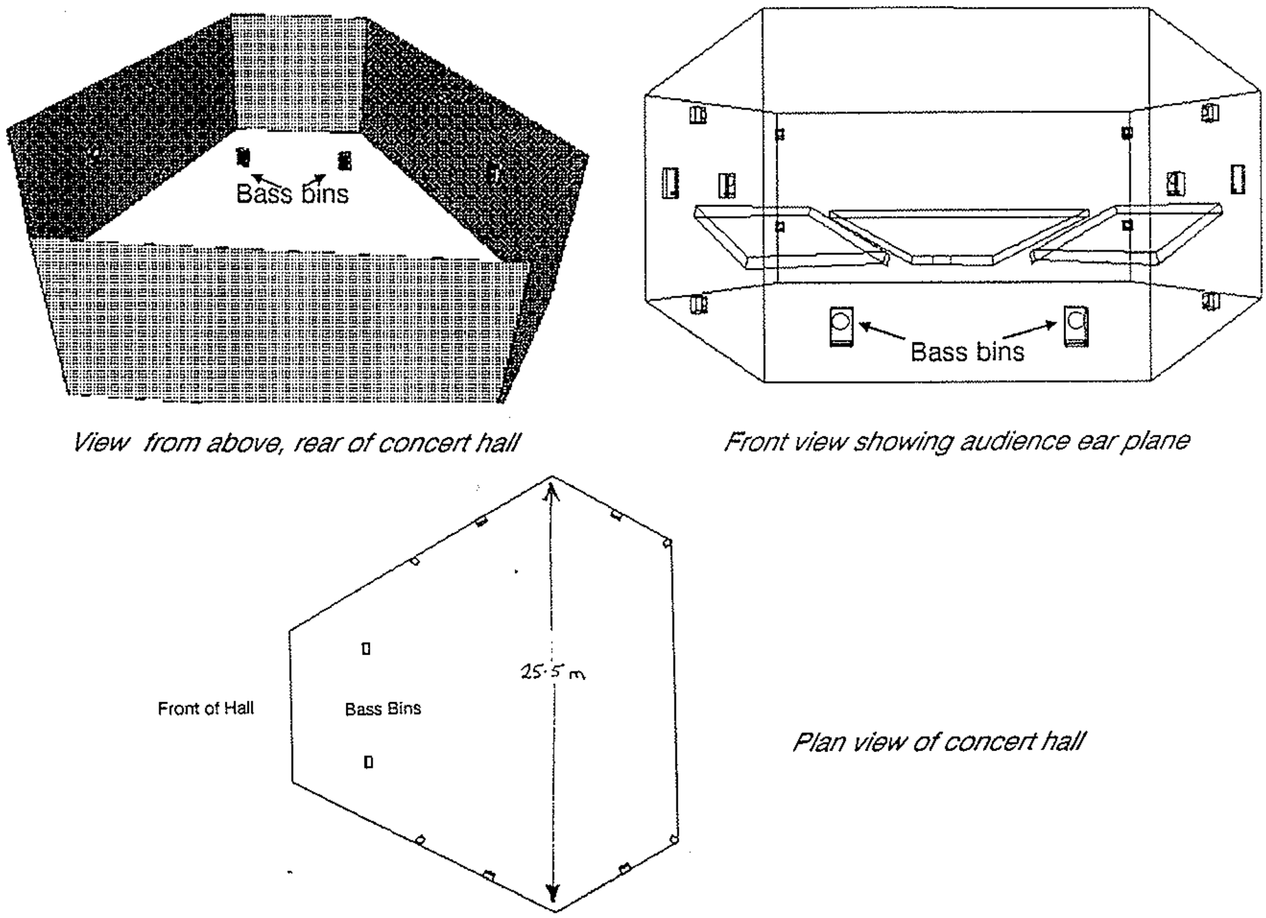
At the time of our report to the **International Computer Music Conference** (ICMC) in September 1990 we had used the system in a number of smaller concerts with some success. Since then, however, we have had our first really major use of the system with the **Music Departments'** major multi–media production, **"Electric Zodiac"**. This was the 1990 edition of our annual "Practical Project" series and the first to be run by members of the **Music Technology Group.** It was intended from start to make Ambisonic sound projection a major feature of this production so work was commenced to upgrade the **programmable speaker decoder** which we demonstrated at **ICMC 1990** in order to double its maximum capability of 4 speaker pairs to eight. This enabled us to use twelve main speaker clusters in our concert hall, together with bass bins and some 'fill–in' speakers (see fig. 1).

Speaker decoders for **with height (3–D) Ambisonic** sound projection currently rely on a decoding theory which requires the speakers to be arranged in diametrically opposed pairs, at equal distances from a central point and evenly disposed on the surface of the sphere. We soon discovered what happens if the disposition is too uneven. With the practical limitations we had in our concert hall, there was an insufficient height component. The software which drives the decoder attempts to compensate for this by driving the speakers which have some height harder. Unfortunately, when there is a greater than two to one spread between speaker positions, this simply results in the sounds being louder in some directions than others. A temporary solution was provided by exaggerating the height of the speaker pairs in the input to the decoder program. This corrected the loudness variations, at the expense of a more diffuse image when sounds move above or below the audience.

In the short term this approach will be replaced by a more subtle one, where the shape of the soundfield will be altered prior to applying the decoding equations. In the longer term, a more flexible approach to the design of the decoding equations is being sought, without the limitation of requiring diametrically opposed pairs of speakers. However, this is not a trivial task, since one of the main reasons for introducing the concept of diametrically opposed pairs into decoder theory was to simplify the problem to the point where it can be handled by relatively low–level matrix manipulations. We suspect that rather than develop a mathematical formula which would attempt to simply calculate the required speaker feed signals, the answer may lie in the use of some form of iterative optimisation algorithm. Our success in the use of low amplitude fill–in speakers to correct an anomaly in the front image (caused by the difference in acoustic response of the forward speaker positions) lends credence to this approach, since this was essentially a human driven optimisation, not explicitly allowed for in the existing theory.

The mention of differences in acoustic response brings us to another lesson learnt during the course of this and other productions; it is very important that listeners get a similar response from all speakers, but particularly from the members of any one pair. Whilst the variation in loudness for differing listening positions translates into a relatively benign warping of the perceived soundfield, which reasonably closely follows what would happen in a natural soundfield, differences in frequency responses and patterns of early reflections can cause unnatural changes and disruptions of perceived directionality. This dictates a need to carefully align the speakers so that, for instance, as large a proportion of the audience as possible is sitting in matching portions of their radiation patterns.

The number of composers who are using Ambisonics, either on the **Composers' Desktop Project** digital workstation using the **"SurroundSound"** program, or using more conventional, analog equipment with in our studio, is growing all the time. Apart from the author, we could mention **Richard Orton** and **Tony Myatt,** staff members in the **Music Department, Cathy Lane,** an ex-Music Technology student, **Tony Hood,** who is doing a D. Phil. in composition at **York** and who has put much effort into extending and refining **SurroundSound**, and **Ambrose Field,** a second year music undergraduate at **York.**



View from above, rear of concert hall

Front view showing audience ear plane

Plan view of concert hall

Fig 1: Speaker layout for the 'Electric Zodiac' concert

On the soundfield manipulation side, we are currently putting much effort into developing a real_time, fully digital soundfield processing unit with Midi control capability (fig. 2). This uses a low cost DSP board, originally developed by our **Computer Science** department, which is based on a 40MHz TMS320C25. The built in Midi links are used for dumping program code to the DSP during development work and for controlling the board, if necessary, during operation. We have added four channels of A to D and D to A conversion, which can run up to 48KHz sampling rate (16 bit) and the ability to transfer audio data directly to and from an Atari ST computer so that it can be linked to the **CDP** environment. The implementation of the simpler manipulations (rotate, tumble, tilt, etc.) are proceeding well and and we hope soon to be able to report progress on some of the more esoteric frequency dependent effects such as spectral spreading and true distance cueing. The development of this device is a vital in our progress towards an integrated sound performance environment in which **Ambisonic** sound diffusion is used either on its own or in combination with other, more conventional diffusion techniques such as used by **Dennis Smalley** of the **University of East Anglia** or the members of **BEAST (Birmingham Electro-Acoustic Sound Theatre),** with whom we are in the process of a series of exchange concerts.

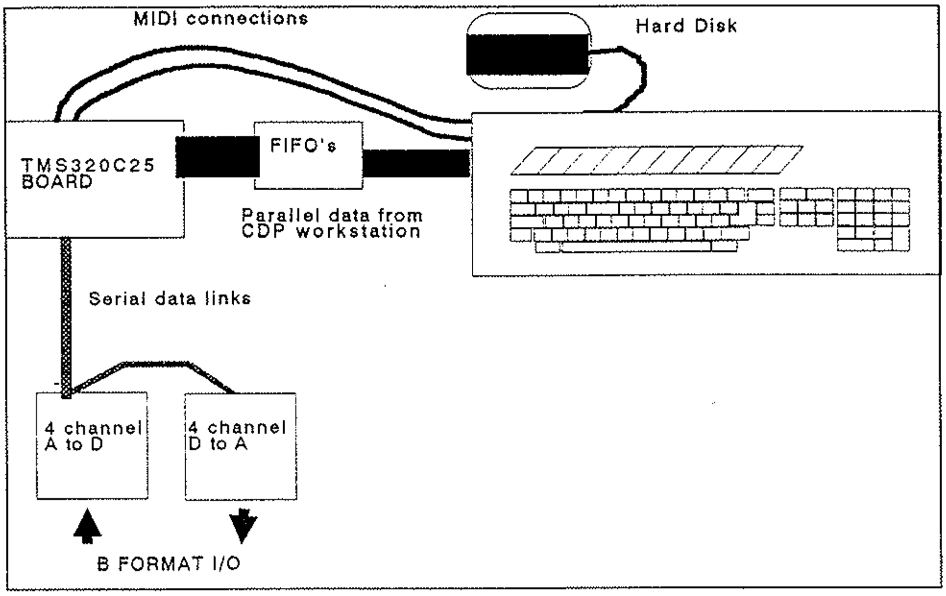


Fig 2: Fully digital Ambisonic processor

The Music Department at York currently has operational the following items of Ambisonic gear:

Commercial

Audio Design Pan-Rotate Unit

AMS Soundfield mic with custom built control unit including a **UHJ encoder** and digitally controlled B format gain control

Minim and Integrex horizontal only **decoders**

Custom Built

Twin **Hemipans** (3-D pan pots)

Mirror control

Programmable soundfield controller (processes either a four channel B format signal input or four mono inputs and produces a B format output with multiple transformations - tumble, tilt, rotate, zoom etc. - using digitally controlled analog circuitry)

16 speaker fully programmable **Periphonic (3-D) decoder**

YORK MUSIC TECHNOLOGY GROUP

The **Music Technology Group** at **York University** is a co-operative venture of the **Departments of Music and Electronics.** On the teaching side, there is a intensive one year **Masters** course in **Music Technology** which has been running since 1987 and from Autumn 1992 we are starting a three **undergraduate** course in **Music Technology.** (More details from the Music Technology Admissions Officer at the above address). There is also a very active **research** programme involving both **musical** and **technical** topics..

York MUSIC TECHNOLOGY GROUP

Music Technology Group Research Topics

As well as our work in **Ambisonics**, the **Music Technology Group** (MTG) and the **Signal Processing Research Group** (SPRG) at **York** are actively engaged in research into many different audio and music topics. These include ***E–Scape***, object oriented sonic composition and performance environment (MTG), ***Midigrid***, a computer based performance/composition system (MTG), ***Midas***, a very high performance, multiple DSP environment for sound synthesis and processing which is essentially continuously upgradeable (by adding extra or new DSP 'nodes') (MTG), ***Soundimation***, an intergrated audio and video composition system (MTG) ***Binaural Signal Processing***, for various purposes including the enhancement of speech (SPRG/MTG), ***Speech Parameter Extraction*** for text–to–speech synthesis and MIDI control (SPRG), and ***Lifestyle Enhancement Aids for the Disabled*** based on music or audio processing (MTG/SPRG).

Useful Reading

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3) GERZON, M.A. "Ambisonics Part two: Studio Techniques" STUDIO SOUND, August 1975. pp. 24 – 30.

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8) GERZON, M.A. "Surround Sound Decoders" in 7 parts. WIRELESS WORLD 1977

9) GERZON, M.A. "Design of Ambisonic Decoders for Multi Speaker Surround Sound" Presented at the 58th AES CONVENTION, New York, 4 November 1977.

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11) FARRAR, K. "Soundfield Microphone" Part Two. WIRELESS WORLD, November 1979 pp. 99–103

12) MALHAM D.G. "Digitally Programmable Soundfield Controller" STUDIO SOUND, Vol 26 No 2 p. 75, 1984.

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16) GERZON, M "Periphony: With Height Sound Reproduction" Journal of the Audio Engineering Society, Vol 21, No.1 Jan/Feb 1973. pp. 2–10

17) MALHAM D.G. "Ambisonics – A technique for low cost, high precision, three dimensional sound diffusion", ICMC Glasgow 1990 Proceedings, pp. 118–120

18) O'MODHRAIN, SILE "Surroundsound, A B format Soundfield processing program for the Composers' Desktop Project Soundfile system", ICMC Glasgow 1990 Proceedings, pp. 121–123

19) MALHAM, D.G. "Progress in the Application of Ambisonic 3–Dimensional Sound–Diffusion Systems to Computer Music" ICMC Montreal 1991 Proceedings, pp. 467–470.

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