International Conference

Sound Field Control

Guildford, UK
July 18–20, 2016

CONFERENCE REPORT

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Sound Field Control, a term coined for the first AES conference on the topic held three years ago, has been increasingly associated with a field of work concerned with the active management of acoustic sound fields. It is not Spatial Audio, although it crosses over in to that field, as some aspects of sound field control can involve manipulating and rendering sounds to deliver a particular spatial effect. Potential uses of the technology include the creation of independent sound zones, active control of noise, personal communication systems, electroacoustic manipulation of room acoustics, and replication of complex spatial sound fields using multichannel audio systems. Application areas include automotive audio, telecommunications, consumer entertainment systems, portable devices, aircraft interiors, virtual reality, live music and professional audio, concert halls, cinemas, museums, and other public venues.

For its second international conference on the topic, SFC 2016, AES returned to the University of Surrey in Guildford, UK, from 18–20 July, where some 90 people from all over the world gathered on some of the hottest days of the year to learn about the latest developments and to network with their colleagues. Many attendees had been present at the first conference in 2013. Conference cochair Filippo Maria Fazi opened the event by saying that SFC 2016 was going to be even better than the last one, with two and a half days of papers, workshops, and demonstrations. Cochair Philip Jackson added to Filippo's welcome, saying that it was important to remain connected in the global research community, especially considering the divisive forces currently at work in the world. He thanked everyone on the committee, and backed up by some photos from a safari trip to Kenya he showed that he expected the conference would be fast, fun, scary, and indeed exotic.

INTRODUCTORY KEYNOTE

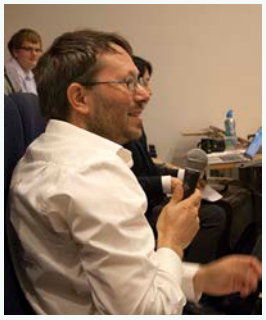
Professor Philip Nelson was introduced by Fazi as a "scientific superstar" in the UK, leading the Executive Group of Research Councils UK, and still an active academic at the Institute of Sound and Vibration Research, University of Southampton.

Nelson's talk was a whistle-stop "incomplete history" of sound field control, according to his own introduction. Until scientific endeavor began, he said, GDP growth had been almost nonexistent, but since then it has averaged some 2% per year and doubled living standards in 30 years. "If it weren't for Edison, we'd all be watching TV in the dark," he suggested.

At the same time as Edison (around 1877), Lord Rayleigh was doing the first experiments on sound field control, being interested in the synchronization of anti-sound to sound, using a pair of tuning forks. At MIT in the 1940s, Norbert Wiener had been interested in an automatic gunfire control problem, first characterizing acoustic signals as received, desired and error, a common approach today. He designed specific filters to process and extract the relevant components. In 1953 Olson and May worked on a sound reducer in a head rest, then Atal and Schroeder were the first to work on crosstalk canceled stereo in 1966. During the 70s Gerzon and others developed Ambisonics, a means of representing spatial sound fields. Nelson's own group had worked for many years on the active control of aircraft cabin noise, with Steve Elliott having developed a rapidly converging filter for canceling noise in car cabins that became standard fit on Honda Accords in 2013. Headphone noise canceling, he said, is widely used today.

Conference cochair Filippo Fazi introduces the first keynote.

Philip Nelson provides a short history of sound field control.



Conference cochair, Philip Jackson

The main dilemma of sound field control, said Nelson, is that you can do it at low frequencies but it gets much harder at high frequencies and over a large area. You can usually control a sound field within a well defined volume, though. In questions, the issue of designing a sound field for a desired human experience was raised by Eric Hamdan, as well as how to ensure that high sound quality is achieved.

SOUND ZONES

During a first paper session on sound zones, two presentations dealt with the topic of how to create personal sound zones around listeners. Philip Coleman and Philip Jackson described planarity-based sound field optimization for multilistener spatial audio, after which Philippe-Aubert Gauthier went into generalized singular value decomposition for personalized audio using a loudspeaker array. After lunch, Markus Christoph and Matthias Kronlachner described a method designed to improve personal sound zones by individual delay compensation. Qiaoxi Zhu and his colleagues then went on to look at robust personal audio reproduction based on acoustic transfer function modeling.

Papers cochair Søren Bech chairs the first session on sound zones.

ULTRASONIC TWEEZERS AND TRACTOR BEAMS

In a fascinating invited talk during the afternoon, Bruce Drinkwater showed how it's possible using ultrasonic transducer arrays to create pressure (gradient) "tweezers," vortices and the like, to trap objects and move them around. The sound pressure levels needed are rather high, even to hold relatively small objects, but he showed how very light balls could be held and moved in the air using such systems. The challenge seems to be how to deal with moving larger objects, and if the sound concerned were to be moved into the audio frequency range it would probably have to be deafeningly loud. Nonetheless it is a remarkable field of investigation that has the "wow" factor.

Ultrasonic tweezers and tractor beams are the theme for Bruce Drinkwater.

Papers cochair Jung-Woo Choi poses a question.

SPONSOR TALK

Eric Hamdan spoke on behalf of conference sponsor Comhear, which works closely with the University of California at San Diego (UCSD). Hamdan explained the company's aim and business model, describing the beam-forming technology that is at the heart of development, and a 360° sound projector. The 4DX immersive audio system delivers personal near-field audio in movie theaters.

Eric Hamdan speaks on behalf of sponsor Comhear.

CREATIVE APPLICATIONS OF SOUND FIELD CONTROL

In recent years there have been significant advances in sound field control technologies. Some of these technologies provide engineering solutions to everyday problems, however, a significant proportion will only be fully exploited when they are adopted by creative practitioners. In this workshop the panel members motivated a wide discussion on creative applications of sound field control technology, the barriers that might currently be limiting its application, and future routes to support and encourage cre-

Gavin Kearney chairs the first workshop.

From left, Peter Lennox, Tony Myatt, Eric Hamdan, and Bruce Wiggins during the first workshop on the topic of creative applications of sound field control.

ative exploitation. Chaired by Gavin Kearney, panelists Peter Lennox, Eric Hamdan, Bruce Wiggins, and Tony Myatt, discussed whether the artist needs to have a significant level of technical knowledge to be able to use sound field control tools. Hamdan suggested that creative practitioners need to be able to experience the sophisticated tools available in order to feel familiar with them. Having an accessible user interface as part of the workflow is key. Myatt, who termed himself a "spatial audio producer," said that in much of his work he'd had to cobble together pieces of technology as a standardized workflow because complex spatial audio production does not exist yet. According to Wiggins, at the moment there are so many ways you can go wrong in this field. Sometimes it's necessary to switch digital audio workstations (DAWs) in order to use the required tools. Peter Lennox suggested that a lot of people don't really want to know the technical details, but it would help to clarify the terms used. A visual metaphor doesn't always translate to the audio world.

A number of panel members would have liked to see more venues and artists willing to experiment with sophisticated spatial sound production, but most PA companies won't even consider it without expert facilitation. VR headsets, on the other hand, are an excellent environment for sandbox experiments, suggested Hamdan. Wiggins, on the other hand, would like to see software from the big players moving away from 2 channel and 5.1.

Filippo Fazi suggested that a lot of the discussion so far had assumed that sound field control meant spatial audio, but what about multizone audio? Lennox felt that navigable sound fields, which could only be experienced by exploring them, held a lot of potential. Philip Jackson said it was worth considering that sound quality might be less important than convenience and usability, however Jung-Woo Choi noted that quality contributes to sound zone performance rating.

HIGH-ORDER AMBISONICS & MODE MATCHING TECHNIQUES

In the last paper session of the day, three presenters dealt with topics related to high-order ambisonics, a method of representing sound fields using spherical harmonics. In MPEG-H terminology this has been termed "scene-based" representation.

Ferdinando Olivieri, presented for the authors, described the efficient compression and transportation of scene-based audio for television broadcast, which is essentially the high-order ambisonic (HOA) mode of the MPEG-H spatial audio coding and transmission system aimed at next-generation broadcasting systems. He suggested that HOA is widely used for manipulation of scenes in virtual reality contexts, for example, as it makes the transformation and rotation of scenes quite straightforward.

Jorge Trevino discussed presenting spatial sound to moving listeners using HOA, and finally Bruce Wiggins explained AmbiFreeVerb 2, a 3D ambisonic reverb with spatial warping and variable scattering.

SOUND FIELD PERFORMANCE

A buffet dinner in the Performing Arts building preceded the replay of "'Longinye Swamp Sequence"—soundfields from Amboseli National Park, with an introductory talk by Tony Myatt. The production was based on spatial sound ambiences recorded from a roving vehicle in the wilds of Africa. Replayed over a large number of loudspeakers in a circular array in the large recording studio, the sequence gave an immersive feeling of involvement in these outdoor wildlife scenes.

Delegates enjoy some networking on the first evening.

Tony Myatt explains the Longinye Swamp Sequence performance during the first evening in the PATS Studio.

Steven van de Paar explains the psychoacoustics of reverberation during his keynote on Tuesday.

TUESDAY KEYNOTE

In an opening keynote on the second day, which emphasized psychoacoustics, Steven van de Paar reviewed the effects of reverberation on auditory perception. Source segregation in reverberant mixtures turns out to be a major engineering challenge, he explained, it being very hard to tell from a cochleagram, for example, that there are two speakers in a mix. Grouping of signal components is they key, using things like common onset, pitch, modulation, and location to identify the component sources in a mixture.

Steven spoke of the occlusion principle, explaining that if we remove those parts of a time–frequency plot that cause masking of one signal by another it is still relatively easy to understand each stream. So we seem to be able to extract enough information about each stream despite the occlusion. With reverberation, though, this doesn't work so well. The reverberant energy is often higher than the direct sound, but the precedence effect is still powerful in the presence of reverberation. He described a means of trying to capture direct and reverberant spatial characteristics of a scene and reproduce the relevant parts in a reproduction room so that the results sounded the same as the original. It involved reproducing and optimizing the most perceptually important parameters of the content.

Perceptual dereverberation was also mentioned, using an example of speech reproduction in a reverberant room. Speech preprocessing was used to enhance intelligibility, showing that it was possible to remove quite a lot of direct sound the room using time-variant filtering and a perceptual model, once the reverberant field has been energized.

PSYCHOACOUSTICS

Sungyoung Kim kicked off the first paper session on psychoacoustics with a paper on height loudspeaker position and its influence on listeners' hedonic responses. Hyun Kook Lee followed with his discussion of perceptually motivated 3D diffuse field upmixing, designed to extract information from non-3D material to feed additional height loudspeakers in 3D setups. Continuing the discussion of reproduction with height, Gavin Kearney described the perception of auditory height in individualized and non-individualized crosstalk cancellation. Finally Michael Kohnen looked into dynamic crosstalk cancellation with and without compensation of early reflections.


Michael Kohnen on dynamic crosstalk cancellation

POSTERS AND DEMONSTRATIONS

A short session before lunch provided an opportunity for the presenters of demonstrations and posters to introduce their material. Each had a couple of minutes to enthuse the audience about what they'd be showing in the extended lunch session to follow.

Delegates were assigned to different tour groups, which would circulate round the demonstrations in order to give everyone a chance to hear the various offerings, some of which were designed for only one person at a time to experience. Others could have their lunch or discuss the posters while not visiting demonstrations.

Posters included one by Glenn Dickins on the validation of sound field duplication for device testing, a discussion of performance prediction of contrast control methods for sound zones by Martin Møller and Martin Olsen, an investigation of the significance of loudspeaker nonlinearities for personal sound zones by Xiaohui Ma, and a performance comparison of filters for personal audio reproduction by Homin Ryu.

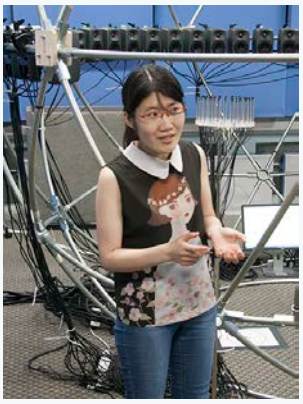
Among the fascinating demonstrations was an opportunity for delegates to try Bruce Drinkwater's portable implementation of an ultrasonic levitator, which required the careful balancing of little polystyrene balls in the tractor beam, after which the device could be moved around and even held upside down while the ball remained suspended in mid air.

The demonstrations also included various implementations of beam-forming and sound zones, such as Angelo Farina's spherical source with 32 loudspeakers that could throw a sound image successfully in specific directions so that it appeared to come from a nearby wall. Marcos Simón Gálvez showed a loudspeaker array for binaural and personal audio reproduction that adapted to the listener position, while Dylan Menzies showed a listener-position-adaptive object-based stereo reproduction system. There were


The assembled company outside the Austin Pearce Building at the University of Surrey

Phil Coleman and Jordan Cheer, workshops and demonstrations co-chairs, introduce the offerings.

also a number of demonstrations involving crosstalk processing, such as for headrest sound reproduction and phantom image elevation over headphones.



Qiaoxi Zhu explains planarity-based sound field control.

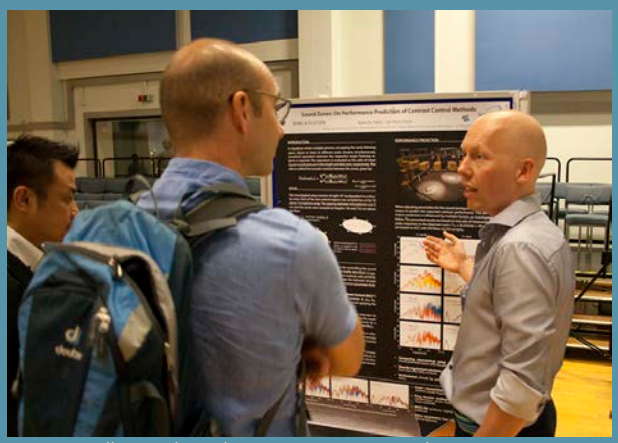
SOUND FIELD CONTROL THEORIES

An intensive afternoon of paper presentations followed, with both sessions on the broad theme of sound field control theories. Starting off the proceedings was Falk-Martin Hoffmann discussing sound field control using hemi-cylindrical loudspeakers arrays. He was followed directly by Steve Elliott talking about crosstalk cancellation and equalization for headrest sound reproduction, and then by Andreas Franck on the comparison of listener-centric sound field reproduction methods in a convex optimization framework. Finishing up the first session Mark Poletti looked at time domain description of spatial modes of 2D and 3D free space Greens functions.

After a break, the second session started with a presentation by Shoichi Koyama on source-location-informed sound field recording and reproduction, considering generalization to arrays of arbitrary geometry. Wan-Ho Cho explained sound source modeling and synthesis by the equivalent source method for reproducing spatial radiation characteristics, and Marcos Simón Gálvez discussed listener-adaptive filtering strategies for personal audio reproduction over loudspeaker arrays. Finally Glenn Dickins, all the way from Australia, spoke on the applicability of sound field techniques for larger audience entertainment.

CONFERENCE DINNER

A dinner at the Guildford Cathedral Refectory had been much enjoyed at the previous conference, so it was with much pleasure that the assembled company returned to the venue for a meal on Tuesday evening. Guildford Cathedral is one of the most modern cathedrals in the country, having been built out of brick during the 20th century, finally completed in about 1960. It stands on the same hill as the university, and its refectory, although modest in style, produces high-quality cooking that everyone enjoyed very much. The meal provided an opportunity for everyone to reconnect with old friends and make new ones.



Martin Møller explains his poster to interested visitors.

Bruce Drinkwater demonstrates the ultrasonic tractor beam.

Hyun Kook Lee shows Philip Jackson his height-effect demo.

Philip Coleman demonstrates the Surrey Sound Sphere.

Guildford Cathedral Refectory provides an enjoyable venue for the conference dinner on Tuesday night.

Gary Elko explains differential microphone arrays.

WEDNESDAY KEYNOTE

Beginning Wednesday morning, Gary Elko of mh acoustics gave an informative keynote talk on the ins and outs of differential microphone arrays. A frequency-independent beam pattern, he said, offers the most directional gain for a given number of microphones. Such arrays, though, can be more sensitive to sensor noise, wind noise, and handling noise than conventional microphones.

The specifications of differential microphone arrays are often discussed in terms of white noise gain (WNG), which is the output power due to unit variance white noise at the sensors. Thus a WNG of –10 dB would represent a microphone with a lower signal-to-noise ratio than any individual microphone in the array. With microphone arrays higher than third order the WNG becomes hard to manage, said Gary. His company's Eigenmike has pressure microphones on a rigid sphere and gives almost infinite control over the beam patterns, offering HOA up to 4th order.

MICROPHONE ARRAYS FOR SOUND FIELD CAPTURING

In a paper session immediately following Gary's keynote, three papers on microphone arrays were offered. The first, presented by Gary's colleague Jens Meyer, looked at a qualitative analysis of the frequency dependencies in ambisonics decoding related to spherical microphone array recording. This was followed in short order by a paper from Bryan Martin and his colleagues from Montreal, presented by Sungyoung Kim, on microphone arrays for vertical imaging and 3D capture of acoustic instruments. In similar vein, Francis Boland's presentation dealt with a comparison of ambisonic microphones.

LINKING SOUND FIELD CAPTURE TO SOUND FIELD REPRODUCTION

The second workshop of the conference—chaired by Philip Coleman—Jens Meyer, Hyun Kook Lee, Glenn Dickins, and Angelo Farina discussed how to link sound field capture to sound field reproduction. Lee explained that there is a gap between the scientific physical modeling of sound fields and the way that recording engineers actually work. Some hybrid of the two worlds can be beneficial. Farina suggested that for broadcasters, something like the Eigenmike is really treated just like an ordinary microphone that can be steered (rather as the Calrec Soundfield microphone was treated by many). However, we need to find ways of going beyond that, he proposed. Young people watch things on the web using headphones and streaming is the norm, bandwidth being the only limitation. This is the present reality of broadcasting, which opens up new possibilities.

The second workshop panel—from left, Jens Meyer, Hyun Kook Lee, Glenn Dickins, and Angelo Farina—deals with linking capture to reproduction.

There was some discussion of whether the exact capture and reproduction of sound fields is really the aim of most real world content production. We need to provide the tools to manipulate content and to extract and repurpose elements of it, the panelists proposed. Yet again it was pointed out that sound field control is not only spatial audio. When it comes to creating a good experience for listeners, we can't make scientific excuses such as "there's a bit of combing at high frequencies" said Dickins.

A game engine is the model of where we should be concentrating our efforts, Dickins proposed. However these are not currently employing sophisticated sound field control to the extent they could. Angelo Farina said that original content is always artificially manipulated so why not use the complex technology developed for video games?

EMERGING TRANSDUCERS AND APPLICATIONS WITH ARRAY TRANSDUCERS

In a final papers session Eric Hamdan began by introducing the bridging of near and far acoustic fields with a hybrid system approach to improved dimensionality in multilistener spaces. Angelo Farina went on to discuss the measuring of spatial MIMO impulse responses in rooms employing spherical transducer arrays, and subsequently Jung-Woo Choi presented a self-configurable wireless audio system with user tracking ability. Finally Gema Pinero explored the reshaping of room impulse responses over wireless acoustic networks.

Angelo Farina spoke on MIMO impulse responses.

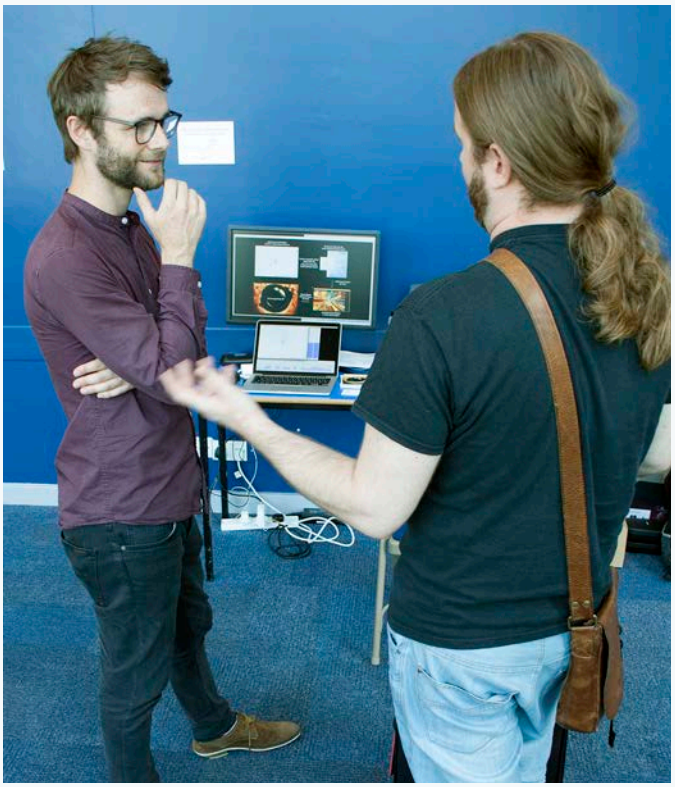
CONCLUDING REMARKS

Wrapping up a successful conference, Filippo Fazi proposed that it was still rather unclear what is meant by sound field control, however he praised the

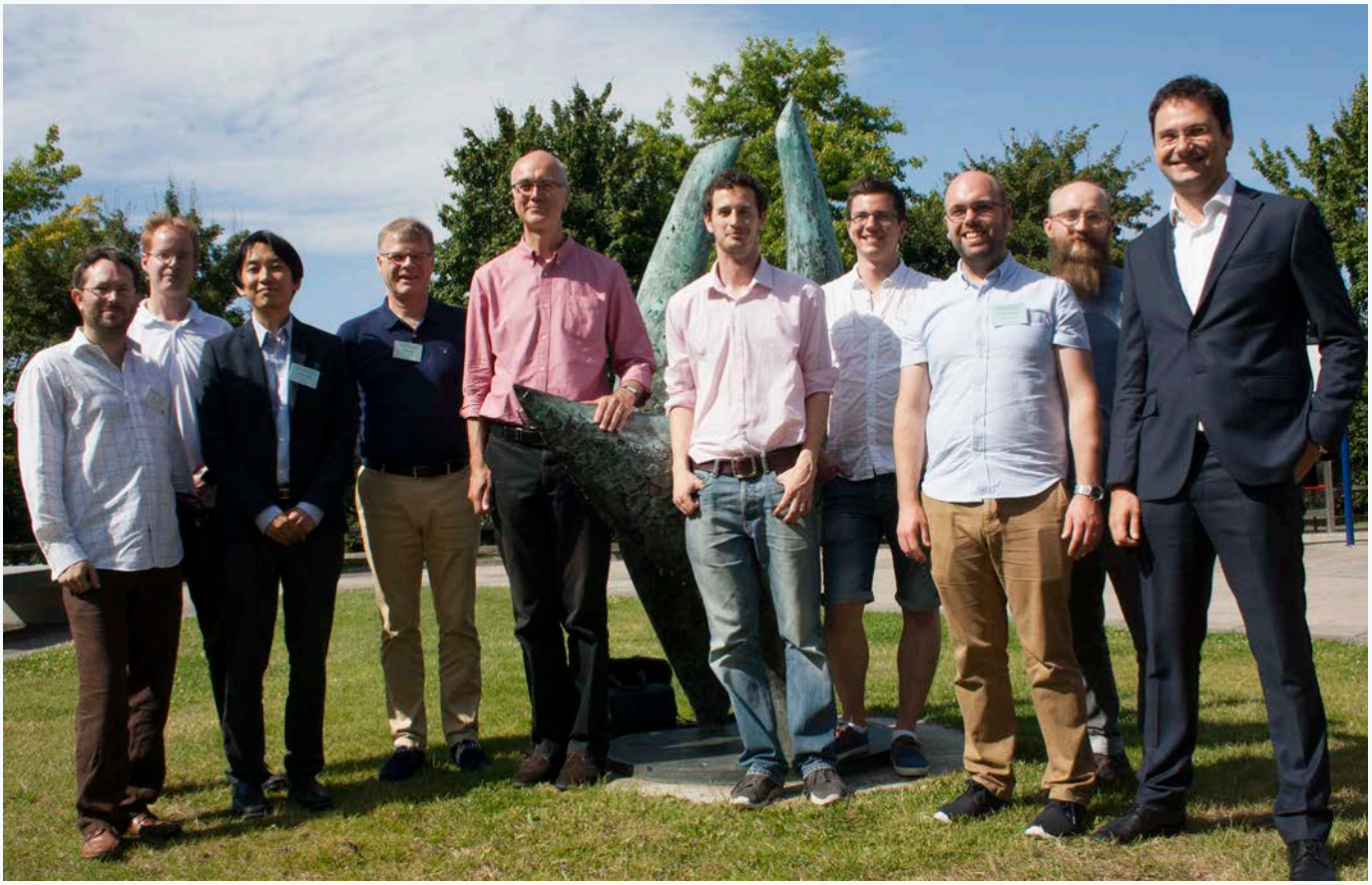
Farina's spherical microphone array demonstrated to a small group.

high quality of papers and was very pleased that there had been a lot of demonstrations to show how some of these things sound in practice. Philip Jackson asked for a show of hands to gauge interest in running another similar event in a few years time and there was an enthusiastic response. All this suggested that the second Sound Field Control conference had been an enjoyable and rewarding meeting, hopefully to be repeated once everyone involved has recovered their organizational energy and enthusiasm.

Editor's note: the papers presented at this conference can be obtained from http://www.aes.org/publications/conferences/



Chris Pike from BBC R&D gives a demo of a 3D VR production on the last day of the conference.



The conference committee: from left, Philip Jackson, Russell Mason, Jung-Woo Choi, Søren Bech, Francis Rumsey, Jon Francombe, Chris Hummersone, Philip Coleman, Jordan Cheer, and Filippo Fazi