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Using ambisonic technology in entertainment and design

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Using ambisonic technology in entertainment and design

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PHOTO BY ANDRE COSTANTINI

"THE ARUP RECORDING IS THE BEST RECORDING of any of my work ever. The amount of detail and accurateness in the sound is just stunning. Changing the listening position changes the experience of what I hear, just like in live performance. Listening to it, it feels like really being *in* the sounds as during the moment of performance." This was the response of Ulrich Krieger, member of Lou Reed's Metal Machine Trio, after listening to Arup's 3-D ambisonic recording of the band's 2009 New York City performance played back in Arup's Los Angeles SoundLab.

Greg Weber, Director of Production for the San Francisco Opera, used the SoundLab in Arup's San Francisco office to simulate the audience experience of a proposed new performance space located in the original San Francisco Museum of Modern Art galleries on the top floor of the War Memorial Veterans Building, directly above the Herbst Theatre. Weber says, "All artists want the perfectly designed acoustical space. Perfection comes at a very high cost. As happens with designing theatrical spaces, one reaches a point of uncertainty on where the monies which you do have will be best spent. Sadly, few of us have enough money for perfection. The Arup SoundLab focused our team on where to spend both money and time on designing the perfect space for our needs and our budget. It saved us not only on the design, but will continue to save us after the facility has opened because we will have made decisions based on our ears—not on theory or math. That is the difference one gets when working with SoundLab technology—we will have a product already aural tested and approved by our artistic team."

Across the Atlantic, in London's Trafalgar Square, Arup is commissioning the BE OPEN Sound Portal, the latest in a series of full-scale immersive sound installations in collaboration with professional artists who are creating content for these virtual environments.

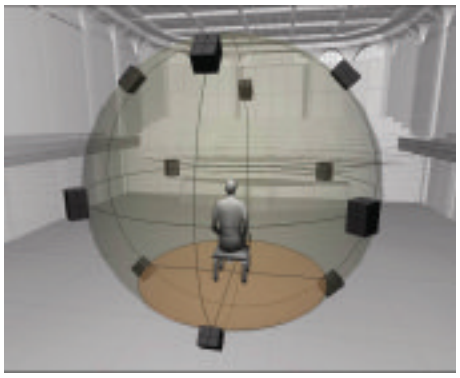
These are just three examples of commercial and artistic applications that capitalize on the use of a 3-D audio reproduction system called *ambisonics*. While ambisonic technology has been kicking around for decades in universities and audiophile listening communities, we've been pioneering and perfecting its use to simulate spatially accurate acoustic environments in the performing arts and across industry, as well as to record and reproduce music and sound art in an immersive experience.

Fundamentally, ambisonics provides the ability to reproduce or create a soundfield that is an immersive representation of an acoustic environment, existing or yet to be built. Ambisonics mimics the way that humans localize sounds in front of, behind, above, and below us. Sound-source location is defined by dividing the soundfield into spherical harmonics. The spatial resolution and number of harmonics depend upon the order of the ambisonic system. A first-order ambisonic signal (called *b-format*) can be thought of as having been encoded with three figure-of-eight microphones pointing in the X, Y, and Z directions, with a fourth omnidirectional microphone to represent overall sound-pressure level. Because figure-of-eight microphones have polarity via pressure gradient, vector information can be obtained from their signals. In the case of ambisonics, the X-Y-Z arrangement of the polar patterns can define these vectors in three dimensions. As orders increase, more harmonics appear and source direction can be defined with greater spatial resolution. Creating an ambisonic soundfield does not inherently create specific loudspeaker signals; rather, the soundfield can be decoded to a specific instance of a wide variety of 2- or 3-D loudspeaker arrays.

Ambisonic material can be generated in a number of ways:

- By recording a natural soundscape with a microphone that mimics the figure-of-eight array described above
- By panning sound sources in ambisonic space using spherical coordinates (azimuth/elevation or pitch/roll/yaw)
- Through convolution with a b-format impulse response

Within an Arup SoundLab—an acoustically isolated room devoid of external noise and its own acoustic coloration—3-D recordings are decoded and played back through a sphere consisting of 12 or more loudspeakers and additional subwoofers. Rather than using a surround-sound format, which relies on discrete signals sent to specific loudspeaker locations in a lateral relationship with the listener, this ambisonic system places loudspeakers in a sphere with either geometric or time alignment to a sweet spot, where the 3-D soundscape is created and the listener perceives.

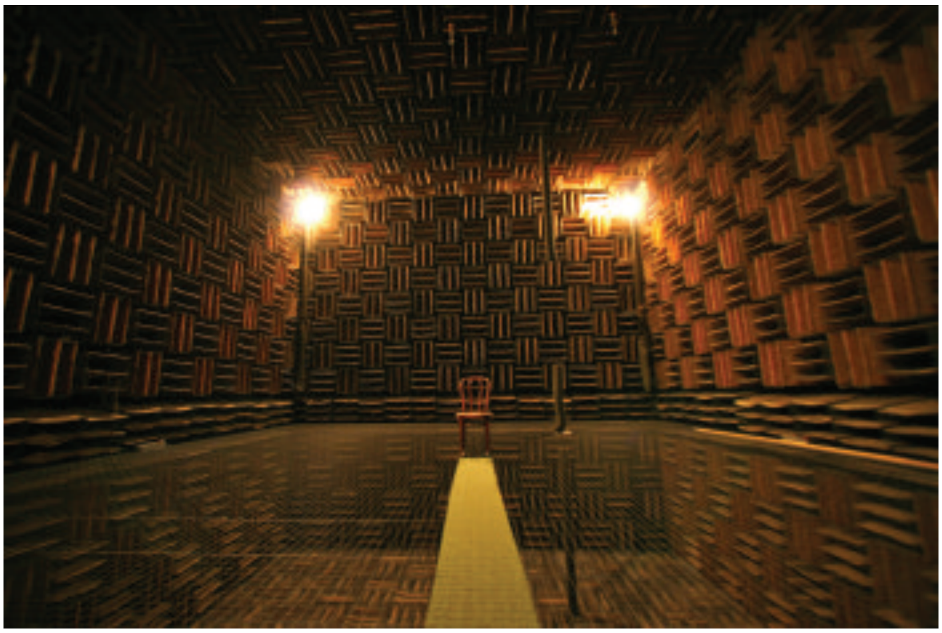


The auralization process

Just as architects can generate renderings of their newly designed spaces or lighting designers can create previsualizations of lighting for new shows, acoustic professionals can create auralizations, or 3-D renderings of the sound, for newly designed or existing spaces for their clients.

Key to the auralization process is obtaining an impulse response (IR), which can be thought of as the acoustic signature of a room or space. This signature is called the *impulse response* because it is attained by producing an acoustic impulse—a brief, broadband sound, such as a gunshot from a starter pistol—and recording the room's response, which is the sequence of sound reflections that define the room's character and reverberation. This IR is obtained in a real room by producing the impulse with an omnidirectional loudspeaker (source) that sends energy out in all directions and recording it in 3-D with an appropriate microphone (receiver). This process can also be simulated in a 3-D computer model with acoustics software such as CATT-Acoustic or Odeon. The IR must be obtained for any source and receiver combination uniquely, as it captures the timing, amplitude, and direction of the sound for each. With this process, room acoustics can be auditioned and analyzed.

In the case of a concert hall, where the source is an orchestra and the receiver is an audience member, the "impulse" would be music. In this scenario, the source material used for the process should be recorded anechoically—in a room that minimizes sound reflections or other reinforcement of particular frequencies of sound that are not true to the inherent thing being recorded. This is to avoid embedding the signature of another room in the source recording. Ideally, the recordings are taken in purpose-built anechoic chambers, which contain immense amounts of sound-absorbing treatment on the walls, ceiling, and floor (the room is entered via a tension-wire grid). Once an anechoic source is obtained, it can be virtually placed in a room by a process called *convolution*, which is a mathematical combination of



Anechoic chamber

the anechoic source and the temporal and spectral content of the impulse response. In this way, visitors to the Arup SoundLab are able to virtually and instantaneously jump from the Musikvereinssaal in Vienna to a hall currently in design and only existing in a computer model, using the same source material, maintaining near-equivalent audience seating locations, as reproduced on a fully immersive ambisonic sound system.

and relative strength as when the recording was made. When simulating the sound of a proposed new venue from its basic architectural form and materials, ambisonic systems can re-create how the virtual room's acoustic response colors your perception of a performance. In a creative setting, you are immersed in a new soundscape defined by the artist.

Seen this way, ambisonic technology is fundamentally used to generate a new space. When built into a room that is acoustically neutral and controlled, the room can effectively disappear and be replaced by an alternate environment. Ambisonic spaces then allow the listener to react intuitively and subjectively to a reproduction of any source activity, as if they are actually there.

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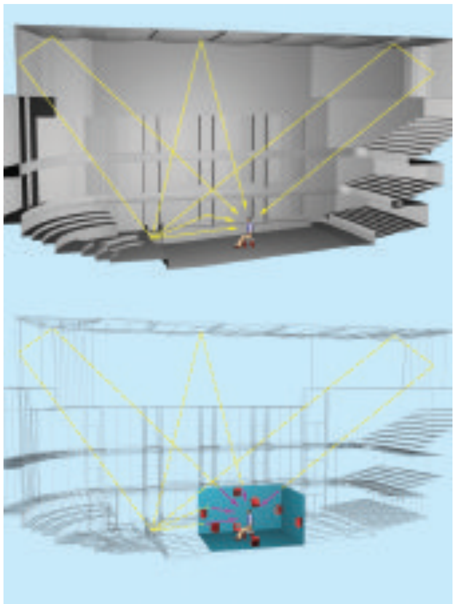
Virtualization experience

Once a recording is taken, an architectural model is rendered, or a multichannel soundtrack is generated, the space beyond the loudspeaker array becomes the representation of the chosen environment from the standpoint of the listener. Inside the ambisonic sweet spot, reflections from the stage floor arrive at your ear at the precise time and from the same direction



Design collaboration

By listening in ambisonic space rather than interpreting numbers and empirical data of acoustic analyses, designers and consultants can more readily achieve a level of communication necessary for an integrated design approach. In the dialogue between acoustic design professionals and architects, both strive to create a successful space; however, design intents often clash. Often, an architect generates the design vision of a space, from which the acoustician will perform an analysis. The two will then try to balance out the differing criteria, sometimes to the detriment of a holistic solution. However, a faithful representation of the design allows both parties to simply judge the value of how the design responds in the proper context, leaving little room for mistranslation and prejudiced viewpoints. We have found that once an architect hears their design rendered, even when entering the SoundLab with a clear agenda, they will ultimately work on modifications to seek out the result and acoustic outcomes beneficial to the project at hand.

Accuracy

Producing such simulations places significant responsibility on the professional to create faithful renderings of real physical environments. At all times, they must disclose to the client, and understand themselves, the degree of accuracy that can be achieved for a given methodology. For example, ray-tracing computational programs are very popular with professional acoustic consulting firms. However, Bengt-Inge Dalenbäck, an industry-leading developer of such software (CATT-Acoustic), states very clearly that such ray-tracing approaches are inherently limited in accuracy: "[Geometric acoustic]–based programs cannot be highly accurate, but they can be sufficiently accurate to be very useful tools in consulting. They can give say 80% of the answer with a very reasonable amount of work…" (BNAM 2010, "Engineering Principles and Techniques in Room Acoustics Prediction").

Meanwhile, anyone who has spent time in an acoustic test lab and conducting real-life field measurements understands that the dynamic response of materials in the built environment are not fully realized by simplified lab measurements. When considering the accuracy of a virtualization using ambisonic environments, an expert understanding of assumptions, real-life behaviors of materials versus laboratory data, and calculation methodologies used in computational software are crucial for assessments to be useful and productive in the design dialogue. Misunderstanding of any aspect of this can confuse clients and devalue the groundbreaking contributions such technology can avail.

PHOTO COURTESY ARUP

In London's Trafalgar Square, Arup is commissioning the BE OPEN Sound Portal, a virtual environment where artists create content for an ambisonic array.

Applications and future work

Lou Reed entered his first meeting in the New York SoundLab dismissing the likelihood of ever hearing a recording that would be true to his experience on stage. His opinion was forever altered after hearing Arup's live 3-D recordings of his performance reproduced as an exhibit entitled *Metal Machine Trio: The Creation of the Universe* in a purpose-built ambisonic listening space at the University Art Museum, California State University Long Beach. "*The Creation of the Universe* aims to introduce listeners to what Arup audiophiles refer to as a three-dimensional ambisonic spatial experience. Or, in Reed's words, 'The best . . . I've heard in my life. It's seriously exciting and very physical without hurting you.'" (Oscar Raymundo, "New Museum Exhibit Turns Lou Reed's Most Hated Album into a Work of Art," *Rolling Stone*, January 31, 2012).

The same technology enabled the San Francisco Opera to confidently make major design decisions with long-term impacts on the facility because an ambisonic system proves more accurate and realistic for listening studies, allowing for calibrated, immersive simulations. When Greg Weber and his colleagues were in Arup's San Francisco SoundLab, the Britten opera *The Turn of the Screw* was rendered in the new performance space (with proposed acoustic modifications), while another virtual band rocked in the Herbst Theatre below. Extensive testing in the War Memorial Veterans Building allowed Arup to re-create the level of sound transmission traveling from the Herbst Theatre through to the new opera space above.

These first two examples capitalize on an ambisonic system's ability to simulate the real physics of an actual space, while in Arup's BE OPEN Sound Portal installation in London, a new virtual environment is generated by the artists creating content for the loudspeakers employed in an ambisonic array.

Further cutting-edge work is underway at Arup, seeking to further explore the game-changing proposition of ambisonics. Real-time interaction is of particular interest, with spatialized sound controlled wirelessly by the sensors in a mobile device or the data output of a Microsoft Kinect. With the movement of a device or wave of a hand, the soundfield can be modulated. Ambisonics also has significant potential in the physical computing realm. Arup has been involved with the growing open-source hardware community, working to develop both new physical interfaces for artistic use and also prototypes to assist in architectural design. Arup's San Francisco office is currently investigating its application for people who have recently become blind and must train themselves to tap into their spatial recognition of sound. Similarly, a future use

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where performers can test drive a new venue design in an ambisonic space may not be far off.

Looking forward, our experience in a variety of fields and applications has shown that ambisonics can be used as a valuable design tool for new performing arts spaces and a robust platform for the reproduction of live recordings or new material. We are still in the early phases of discovering the full possibilities of ambisonics to provide immersive and accurate representations of 3-D space. ■

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Arup is a multidisciplinary engineering and consulting firm and offers acoustics, audiovisual, and theatre consulting services from 19 of its offices worldwide.