Acousmatic Room Orchestration System (AROS)

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Abstract

Acousmatic Room Orchestration is an approach to design custom-made sound moods for spaces. The associated system is called AROS. Unlike other multichannel systems, AROS does not generate or reproduce pre-recorded spatial information. Instead, it generates spatiality by incorporating the acoustic characteristics of the actual space.

In an orchestra the spatial experience results from the fact that each musician plays his own part in a specific spacial location and on an instrument with a specific timbre and sound diffusion. The acoustic properties of the concert hall certainly have a great influence on the resulting sound experience as well. Based on this idea, in AROS each sound element or part of a composition has got its own speaker and distinct location within the room.

Contrary to other 3D audio systems which usually rely on a circular or spherical speaker placement, in AROS the speakers are distributed across the whole space, i.e. mounted on walls, fixed to the ceiling, put on the floor or even inside objects. The wider the speakers are spread, the greater the spatial depth becomes.

Walking through a room that is orchestrated by AROS, each distinct position is offering a different sonic perspective. It is, therefore, an ideal solution for listening applications where the listener is expected to move within the room, namely at exhibitions, fairs or in theme parks. Several projects have already incorporated this technique, such as the BMW Museum in Munich, or the Imperial War Museum in London.

Introduction

Most spatial audio applications are designed for a seated audience. In such settings the audio content can only be enjoyed to great depth in a certain area inside the venue. Furthermore, the characteristics of the room where the audio content is resounding in are not meant to have an influence on the listening experience. In many cases they are eliminated as much as possible, a cinema with highly absorbent acoustic treatment and no lighting during film playback being one example.

However, there are a great number of spatial audio applications that require the opposite approach, i.e. involving both design and architecture of the venue to bolster the listening experience. With these applications, the audience doesn't stay put but is able to move freely inside the venue. Museums and exhibitions, expo pavilions, theme parks, entrance halls of company buildings, flagship stores, spa buildings, or public places are just a few of many examples where this might be the case. Such settings require an audio system that is custom-made and seamlessly integrated into its particular space. Correspondingly, the audio content needs to be specifically designed to be played back in that particular space through its custom-made audio system.

What is a spatial experience?

First of all we have to ask ourselves, what exactly is a spatial sound experience? In short, a sound experience is non-spatial if it consists of one sound as a single point source lacking any spatial information. A sound experience is spatial if it features a sound event that has a spatial expanse, depth or distribution. There are two different reasons for this. The first category of a spatial sound experience comes about when we experience a combination of several point sources, either simultaneously or in short intervals, coming from different directions or distances (or from moving sound sources). Let us imagine an idyllic situation in a clearing of a forest - we may hear various birds singing above us, the splashing sounds of a little creek behind us, the soft rustling of the wind in the leaves all around us, and crickets in the underwoods next to us. Each single sound is coming from a certain direction, some sounds are static (e.g. the creek), some are dynamic (e.g. the birds), and others are emanating from a variety of directions and distances at the same time (e.g. the wind). In every given moment, a volatile space of sorts is defined, its borders being determined by the coordinates of those individual sounds.

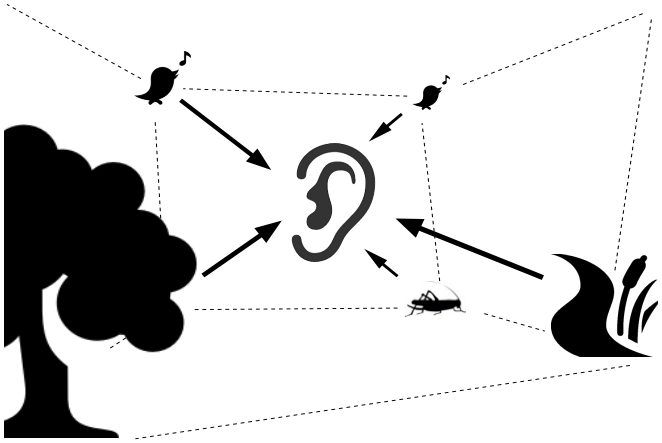

Figure 1: Several point sources together or in short intervals from different directions or distances creating a spatial sound impression (first category of a spatial sound experience)

The second category of a spatial sound experience occurs when a sound event takes place inside an architectural space. In this case, we do not only hear the sheer sound event, but

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also its acoustic reflections coming from different directions, each one characterized by a specific delay. Our listening experience is not a combination of individual point sources (as is the case in the first category), but a single point source with a certain spatial (and temporal) expanse.

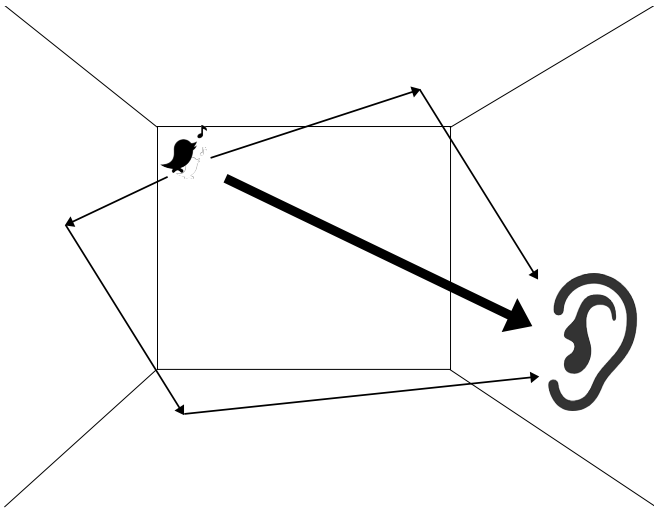

Figure 2: One point-source in an architecturally constructed space creating a spatial expanse. (second category of a spatial sound experience)

An example combining both phenomena (several point sources and acoustic reflections) is the classical orchestra. Undoubtedly, most people would describe a concert as a very spatial experience. The reason for this is easy to explain, for in an orchestra each musician is seated in a particular position in space. Each musician plays a specific part on his instrument. The individual instruments differ not only in pitch and timbre, but also in the way they emit and diffuse their sound waves. The trumpet's rather sharp timbre is directed to the front, while the horn's pretty soft timbre diffusely radiates backwards. Therefore, the sound of the trumpet comes upon the audience primarily from the direction of the instrument, the sound of the horn, on the other hand, exclusively via its reflections off the concert hall's rear wall. The combination of sounds from different directions encompassing different timbres and diffusion levels inevitably results in an extremely spatial sound experience.

The AROS principle

A similar approach is effectuated with the Acousmatic Room Orchestration System (in short, AROS). As with an orchestra, every sound or part within a composition comes from a uniquely placed speaker, hence each speaker represents its own separate channel. These speakers, also related to the instruments of an orchestra, can also be of different types, sizes and linearity.

As is the case with the orchestra, AROS unifies the different point sources and the characteristics of the actual space where they are happening. Both architecture and acoustic space are thereby fundamentally incorporated into the composition. In a sense, the room itself has now become the orchestra playing the music. In this analogy, the speaker relates to the space just like the strings relate to the body of an instrument, it is stimulated by the loudspeaker and responds back to it.

This approach opens up creative possibilities. One example would be the creation of so-called standing waves by use of certain frequencies, corresponding precisely to the spatial proportions and resulting in a unique effect that feels as if sounds were floating inside the room. Another example is the option to orchestrate different smaller sound spaces inside the venue. By doing so, different aspects or themes within the space can be worked out, creating the layout of a dramaturgy. But with this application, time itself is not the main parameter anymore when it comes to the dramaturgy. It is rather the listener, now moving freely inside the venue and, at any given point on his journey, gaining a different perspective of the sonic scenery.

Spatial orchestration is particularly essential when the sonic atmosphere is delicate and subtle, or even on the brink of perception. It allows compositional elements, such as melodies and chords, to be used in a much more subtle way – which is crucial if we are to appeal to audiences on an emotional level without distracting their attention from other content. Using sound quality and spatiality for a specific effect enables composing aural moods that add depth to the overall atmosphere inside the room, without ever becoming obtrusive. In this manner, while the sound atmospheres still retain a great impact, the listener is never annoyed or distracted by them. They rather interweave with the architecture, the objects, the lighting and overall scenography.

How does AROS work?

Unlike other 3D audio systems which usually rely on a circular or spherical speaker placement, in AROS the speakers are distributed across the entire room, mounted on walls, fixed to the ceiling, put on the floor or even inside of objects. The wider the speakers are spread out, the better the spatial depth becomes.
The parameter of physical distance is equally important as the direction or angle of a speaker. Moreover, the speakers need not point strictly towards the centre, they might deliberately be aimed at a wall to achieve a diffusion effect.

Different speaker types can be applied, ranging from directional to 360-degree speakers and featuring different frequency ranges. Some of them might be just tweeters if they merely have to render the part of some high-frequency sounds within the composition. The need for the speakers to be integrated into the architecture, in some cases even hidden away, sometimes calls for flexible solutions such as flat panel loudspeaker mounted behind walls, and also transducers inside of objects or underneath the floor might be appropriate.

Although any AROS setup is custom-made throughout, there is a standard configuration called AROS II. The sole purpose of this standard is the fact that it facilitates the exchange of work-in-progress mixes between studios (the final mixes are always created in the actual venue), and it also provides a solid setup to demonstrate AROS-mixes in a studio

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environment. AROS II features three levels of distance and height, in the smallest possible configuration.

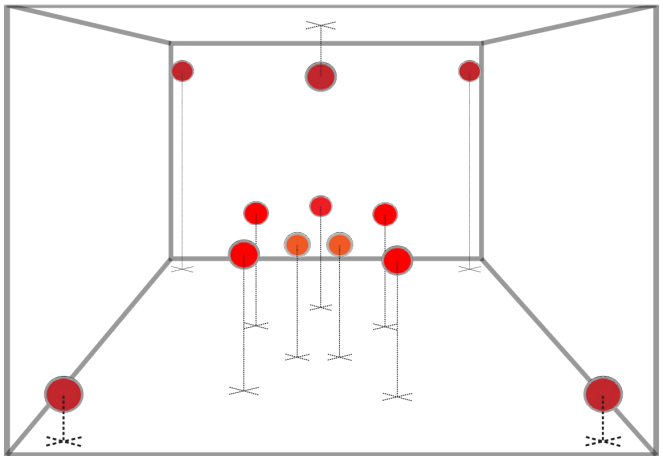

Figure 3: AROS II Standard

Distinction to other 3D audio formats

There are a number of differences between AROS and other 3D audio systems such as Dolby Surround, WFS, Auro-3D or Ambisonics. Most of the latter share the common feature that they merely simulate spatiality. This means that the sound space these systems resound in is completely decoupled from the architectural space where the listener is located. Therefore, we could also talk of some factual sound projection. The structural characteristics of the actual venue are superimposed by those of a virtual room. This relates, in the visual domain, to the projection of a movie. Here, too, you can see and imagine a space having great depth, although the screen itself is two-dimensional and flat.

The reason why 3D audio systems work this way is the development of said technologies as standards to work in listening environments such as cinemas. But not every cinema hall has got the same size and equipment. Therefore, down-mix and up-mix functions were developed to ensure compatibility with higher or lower level setups. Anyway, one goal of these efforts is to ensure a perception of equal spatiality in a large number of venues. Just as important to these systems is the fact that from each seat or position within the room, sound is perceived from the same angle or distance (and also elevation). The area designed for a more or less constant sound experience is called ‚sweet spot' and is usually a lot smaller than the size of the actual venue.

This is quite different with AROS, which is custom-made for one specific space. Therefore, there is no need for compatibility. As sounds are integrated into the architecture just like physical objects, the perception of directions and distances of particular sounds varies depending on the listeners exact position within the space. If, for example, the listener perceives a particular sound to be coming from a specific corner of the room, it is because the speaker emitting the sound is actually positioned in said corner. Its position is absolute. When walking through the venue the listener's auditory perspective is constantly changing, making him hear the same sound atmosphere differently in each specific location (just the same in the visual domain, of course, in terms of the visual perspective of architecture). Therefore, no sweet spot or ideal listening location exists, every position inside the room is unique.

In a standardized multi-channel system, however, the spatial depth is only simulated (e.g., a sense of distance is created by adding artificial reverberation). The position of any sound is relative. In a cinema, for instance, this means that a particular sound always seems to keep more or less the same distance to the listener, regardless of the listener's position inside the cinema hall (e.g., front row or rearmost row).

Here is a list of the basic differences between 3D audio systems and AROS:

Description	Most 3D Audio Systems	AROS
Loudspeaker array	circular or spherical	all over the place (walls, ceiling, floor and objects)
Different distances of speakers to the listener	no	yes
Position of sounds within the venue	relative	absolute
Spatial proximity	impossible (exception: WFS)	possible
Acoustics of venue	excluded	involved
Compatibility of mixes to different spaces	yes	no (custom-made)
Sweet spot	yes	no (the whole venue is the sweet spot)
Multiple speaker types in same system	no (exception: subwoofers)	yes

Nevertheless, other 3D audio technologies such as WFS can be integrated into AROS. This makes sense if the application calls for the ability to position sound objects anywhere in the room in realtime. It is also possible for ready-made 3D audio content in formats such as Auro-3D or Dolby Surround to be adapted for AROS.

History

AROS was invented by the Swiss company Idee und Klang in 2005.
But its underlying idea, the loudspeaker orchestra, was already established in the early 1970s by the ‚Groupe de recherches musicales' of Radio France, especially by the composer François Bayle. At that time, it was used solely in the context of electro-acoustic concerts. With the so-called Acousmonium, Bayle utilized various speakers on stage playing back the sound of a single stereo source (tape recorder). The ‚space' parameter was indeed composed beforehand and existed as part of the written score. It was performed in concert by actually misusing an analogue mixer, routing each speaker to a separate fader. The result was a live performance, but not in the classical dimension of music (notes and rhythms), but in the context of spatiality and diffusion.

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Figure 4: An Acousmonium (Loudspeaker Orchestra) by François Bayle.

AROS is based on this idea. But in contrast to the Acousmonium, each speaker is driven individually and various panning methods were implemented. And more significantly, the context is not a concert but, as mentioned before, sound atmospheres for exhibitions, pavilions, shops as well as other interesting architectural rooms, such as entrance halls, hotels, shops or public spaces.

In 2010, a stand-alone panning server called PS-1 was developed, based on the SPAT object of IRCAM. This allows to mix 128 sources to 128 outputs. The automation data of the panning can be recorded in any DAW like Pro Tools, so any production or compositional environment suitable for the project may be chosen.

Applications

The first project in which the Acousmatic Room Orchestration System was applied on a big scale was at the BMW Museum in Munich, which opened its gates in 2008. The audio design, a vital component of the museum, was part of the planning from a very early stage. The objective of the construction of the new BMW Museum was to exhibit more than just cars in a matching architecture. With its sophisticated combination of architecture, media, exhibits and an orchestrated sound atmosphere, the result rather resembles a homogeneous piece of art. The museum was equipped with 600 speakers. Each area within the partially acoustically transparent exhibition space had its very specific sound architecture. These different soundscapes of the individual rooms had to be coordinated within an overall composition. As a result, visitors would experience an overall dramaturgy when passing through the museum.

In a similar fashion AROS was integrated in places such as the Imperial War Museum in London, the State Grid Pavillon at the Expo 2010 in Shanghai, or the Museum of Future Government Services in Dubai.

Figure 5: The central space of the BMW Museum in Munich featuring about 140 loudspeakers invisibly integrated into the architecture: they are located inside the bridges, inside the columns at different levels, inside the ceiling (reflecting towards the media-walls) and underneath the cars.

Conclusion

Unlike other multichannel systems, AROS does not reproduce pre-recorded spatial information. Instead, it generates spatiality by incorporating the acoustic characteristics of the actual space. This approach allows the space to serve as the body of an instrument that is stimulated by the sound content that is played back in it. Every AROS and its corresponding sound content is custom-made to perfectly fit a specific space. Walking through a space that is orchestrated by AROS, each distinct position is offering a different sonic perspective. AROS is, therefore, an ideal solution for listening applications where the listener is expected to move within the space, namely at exhibitions, sales areas or in theme parks.

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