IRIS

White Paper:

An introduction to 3D acoustics

Future acoustics now

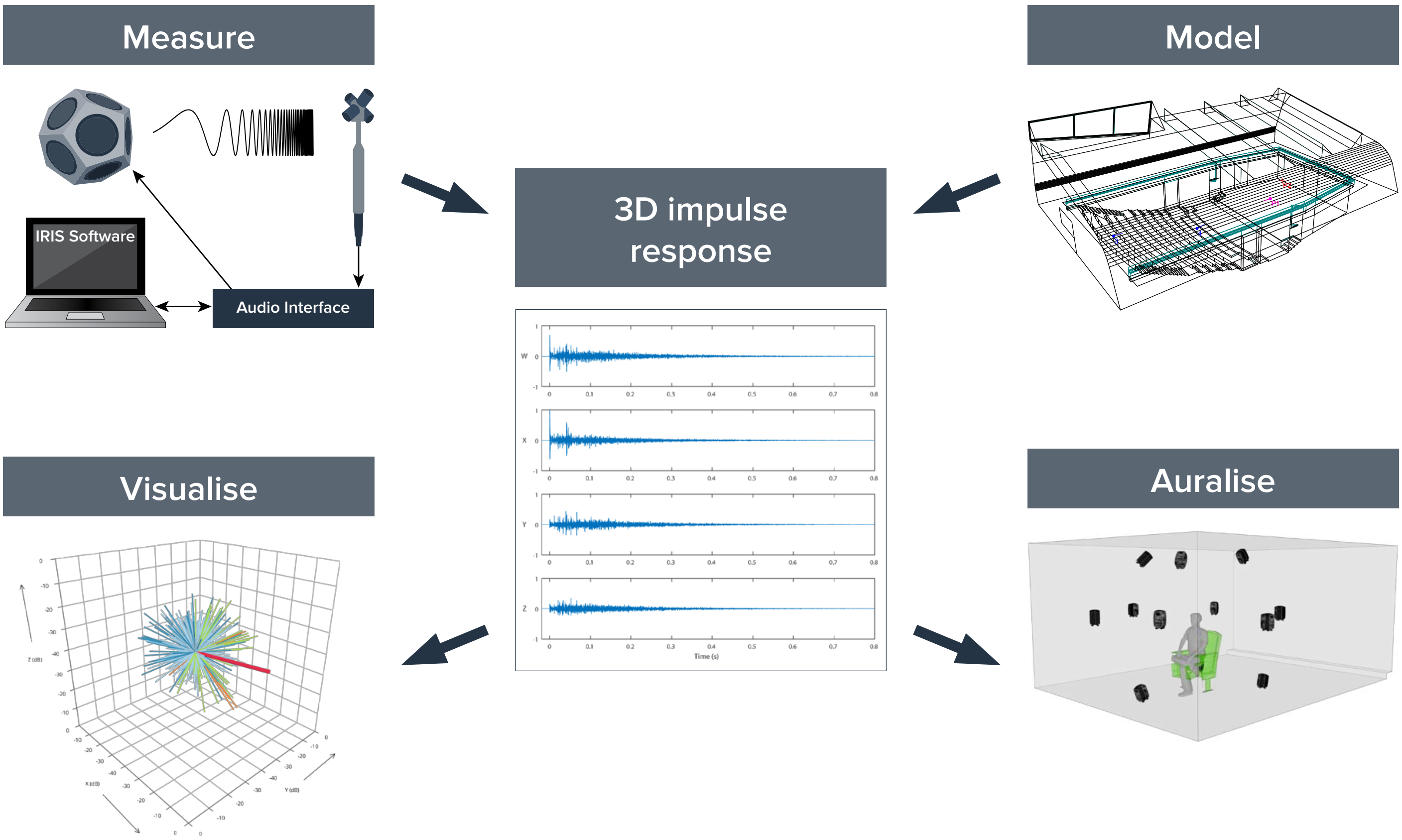
Two-dimensional plans were once considered the standard in architecture and engineering, but in recent years 3D computer modelling and visualisation have become an essential part of modern building design. As well as providing for better coordination within the design team, 3D modelling enables the execution of designs that are more complex than what would otherwise have been attempted. Meanwhile, 3D visualisations and 'walk-throughs' allow clients and other stakeholders to experience a design and more fully participate in the design process.

The same is true for acoustics. Expanding acoustic analysis and design into three dimensions enables more complex analysis and provides tools to enable architectural visualisations to be supplemented with realistic auralisations.

Three dimensional analysis and prediction has been utilised in acoustic prediction software for some time. Ray tracing algorithms are able to provide directional information through reflection arrival and spatial decay plots, and a further advantage is gained by using software programs to create 3D impulse responses.

However, until recently, on-site acoustic measurements have generally been limited to time and level information (with some consideration of lateral components in performance venues). This information is usually more limited than what can be provided by computer modelling during the design phase. By utilising new advancements, the 3D sound field can now be measured as a 3D impulse response. These measurements from the physical space can then be directly related to the outputs from the computer model.

The intent of this guide is to provide acousticians with an introduction to 3D audio and to demonstrate the gains that can be achieved when 3D impulse response measurement, modelling, visualisation and auralisation are connected.

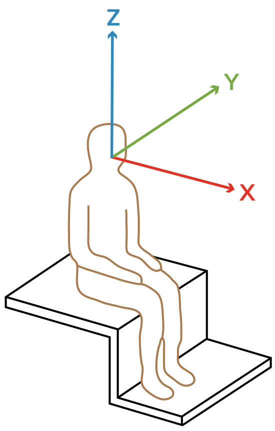


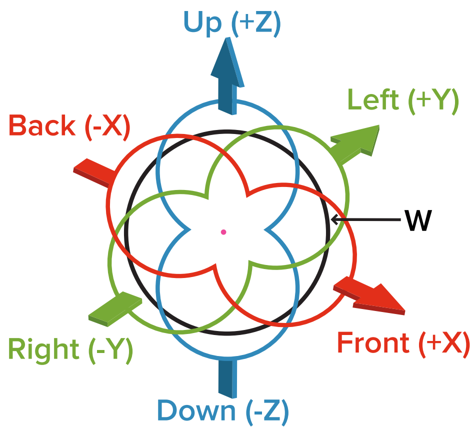
3D impulse response

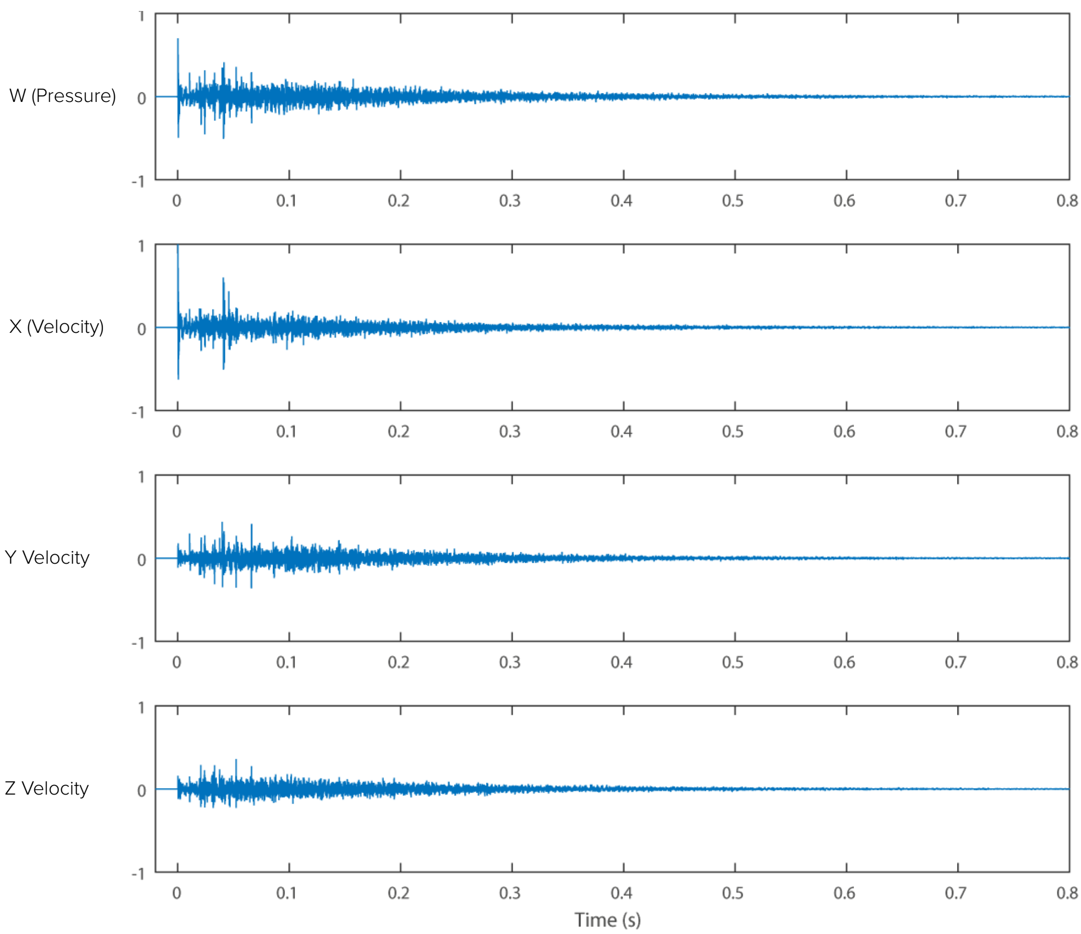
An impulse response represents the excitation of a room by an impulsive source, historically generated using a starter pistol or balloon burst. A 3D impulse response contains directional information, in addition to the time and level information contained in a traditional omnidirectional impulse response.

The use of a common 3D impulse response format is the key to enabling integration and connection between different 3D acoustic tools. The format that has been adopted by practical acoustic applications, as well as most virtual reality (VR) applications, is first order Ambisonics, also known as 'B-format'.

B-format can be stored in a four-channel wav file. Sound pressure (omni) is carried on one channel. The other channels contain particle velocity in the X, Y and Z directions (i.e. equivalent to the output from a figure-eight microphone aligned in these directions).

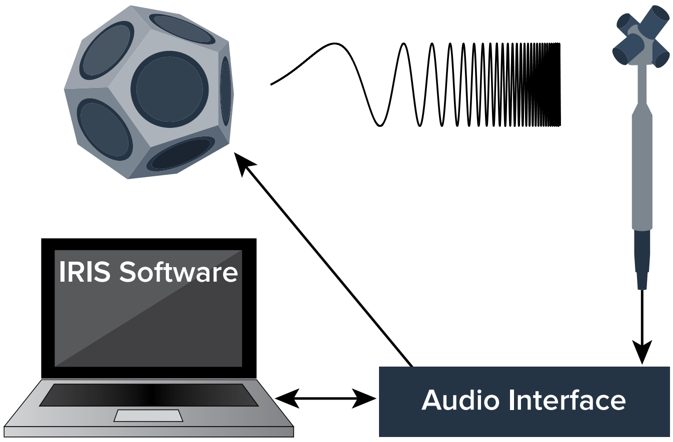






Measure

A 3D impulse response is captured in a similar way to an omnidirectional impulse response, but using a microphone array that is able to detect the direction of the arriving sound.



The IRIS measurement system utilises a compact four-headed (tetrahedral) microphone array – the Core Sound TetraMic. The four signals are carried through a single multi-core cable.

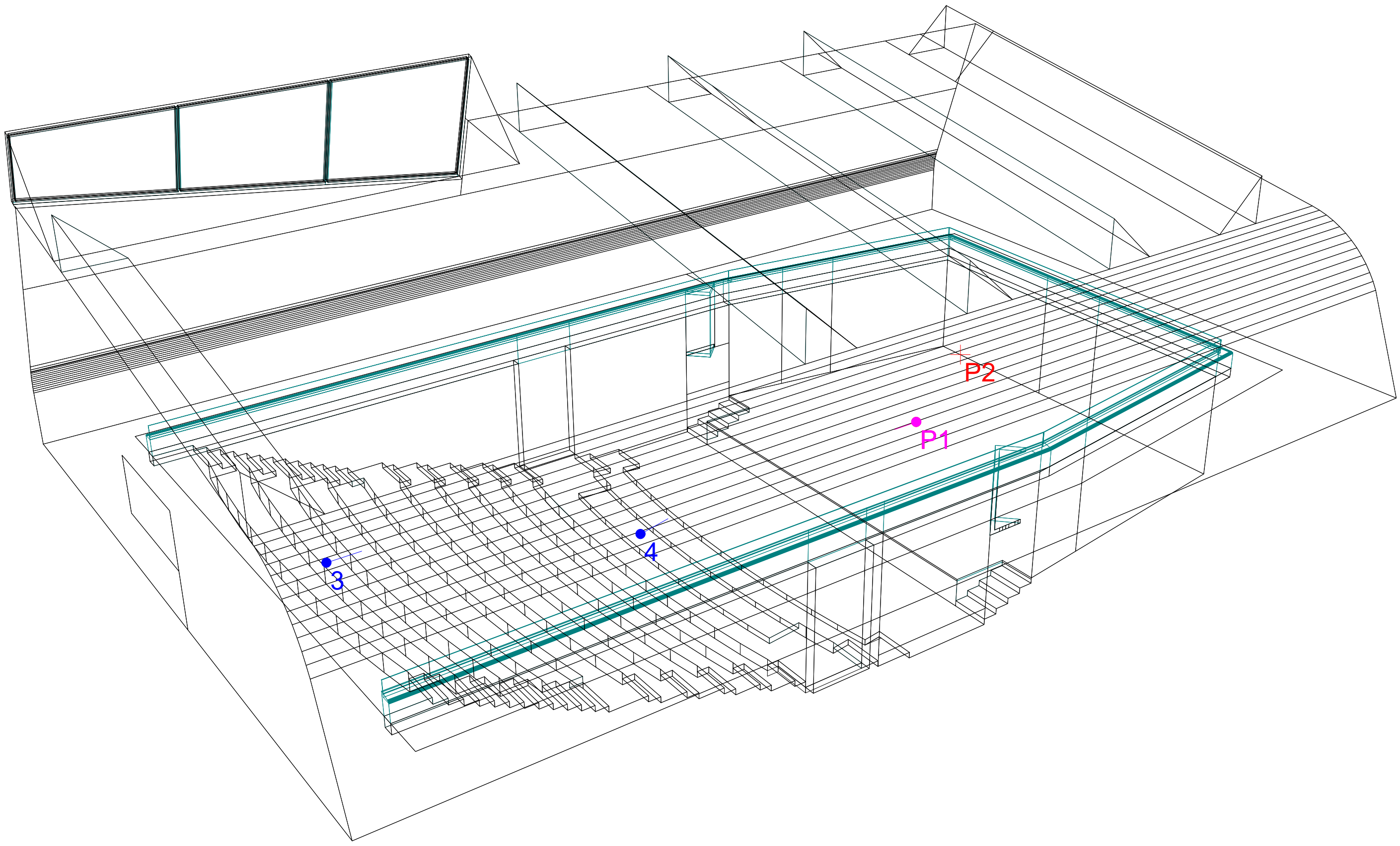
A loudspeaker is used as the sound source and the impulse response is measured using the swept sine method, which provides excellent noise and distortion rejection. For room acoustic measurements adhering to ISO 3382-1, a dodecahedron loudspeaker is used. The swept sine signal can also be played back through an installed loudspeaker system for measuring the performance of that system. If auralisation is the end goal, studio monitors or similar can be used to provide a flatter frequency response with directional characteristics that are similar to natural sources.

Above: IRIS measurement of a lecture theatre

Model

B-format 3D impulse responses can also be generated by room acoustics prediction software programs, such as Odeon, CATT-Acoustic and EASE. These can be utilised and analysed in the same manner as captured impulse responses.

Comparing modelled B-format impulse responses with responses measured in the physical space can provide additional insight into the performance of the room and help improve modelling accuracy.



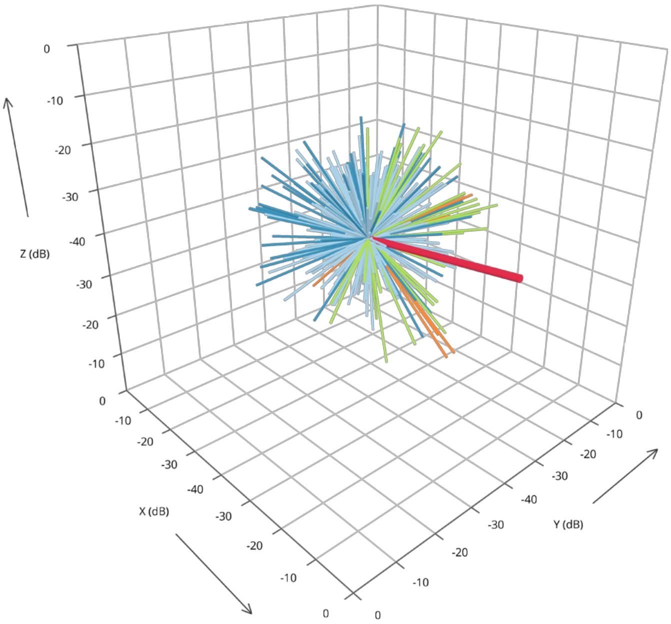
Above: An acoustic model (Odeon) used to generate 3D impulse responses

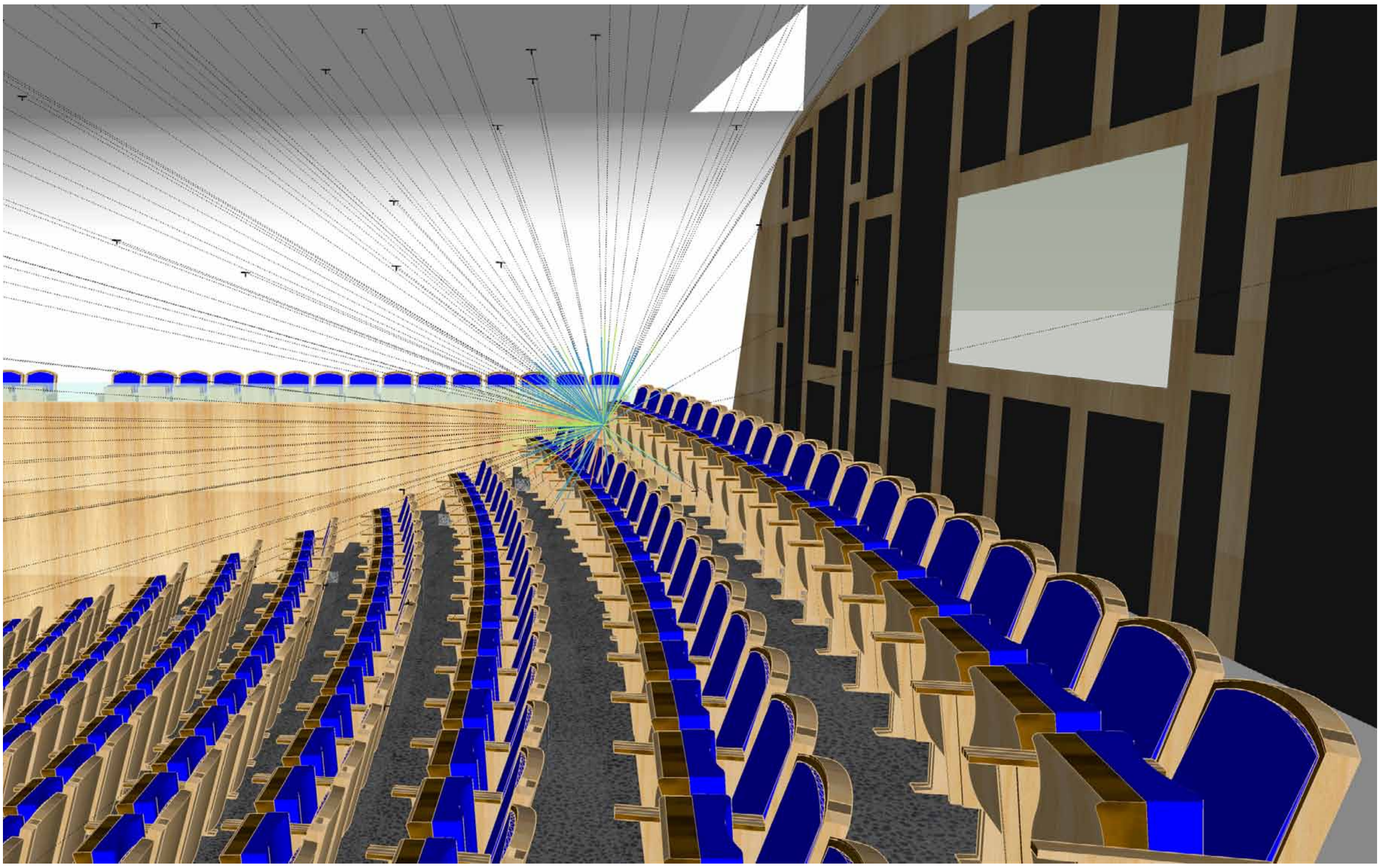
Visualise

A B-format impulse response is difficult to interpret in its raw wav file form. To gain a clearer picture of how sound is behaving in a space, the impulse response is best viewed in a visual form. IRIS generates a visualisation of the 3D impulse response data as an 'IRIS plot'.

The IRIS plot is a 3D colour-coded representation of arriving sound energy displayed as rays. Length indicates level, angle is the ray direction and colour represents the time of arrival. The IRIS software allows interactive 3D rotation and zoom of the plot.

IRIS plots can be used to provide a 'sketch' of the acoustic performance of the room or analysed in detail to observe the direction of reflections. These representations can be imported into architectural models to enable plots to be directly related to features of the room.





Above: An IRIS plot within SketchUp, using the 'extend rays' feature

Auralise

Virtual reality (VR) is rapidly becoming the industry's preferred method for introducing architectural designs to clients. VR provides an experience of the design that is second-to-none. To produce an accurate and fully immersive environment, it is critical to create a realistic 3D sound field to accompany the architectural visualisation.

The B-format impulse response captured by IRIS can be used to create a 3D auralisation. This is done by convolving the B-format impulse response with an anechoic recording.

Modern computer processing power enables convolution to be done in real-time, enabling the processing of live or dynamically changing audio. Many audio recording programs can host 'convolution reverb' plugins that can convolve multi-channel audio with minimal delay. For example, plug-ins such as Voxengo Pristine Space or SIR2 can be hosted within software packages such as REAPER or Cycling '74 Max.

Recreating the 3D soundfield requires 'decoding' of the B-format signal into the appropriate audio feeds. For example, a decoder might provide a binaural feed for headphones or a multi-channel feed for a loudspeaker array in an auralisation room. Decoders can be integrated into playback software and this is becoming more common. For example, binaural decoding is provided within YouTube for playback of videos with B-format audio.

Above: A VR auralisation room

Conclusion

The move towards 3D audio opens up a new world for acousticians. Knowing the direction of reflections can provide new insight into the performance of rooms and reproduction of true surround sound adds a level of realism to auralisations that is not possible in stereo.

This introduction is intended to highlight the unique advantages 3D audio technology offers to acoustic practice with an emphasis on how 3D measurement, modelling, visualisation and auralisation can be connected using a common file type (B-format).

If you have questions about the practicalities of using 3D audio and the application of this technology in your situation please contact **daniel.protheroe@marshallday.co.nz** or **malcolm.dunn@marshallday.co.nz**.

More information about the IRIS 3D acoustic measurement system, including practical case studies, is available at **iris.co.nz**.