MEASUREMENT AND VISUALISATION OF ROOM RESPONSES IN LEVEL, TIME AND DIRECTION

AUTHOR

Daniel Protheroe
Marshall Day Acoustics
daniel.protheroe@marshallday.co.nz

INTRODUCTION

3D impulse response (3DIR) measurements are required to analyse a room sound field in a fully objective way: sound reflections in terms of level, time and direction.

3DIR measurements are beneficial for observing the directional distribution of early and late sound energy, comparing different seating areas, variable acoustic settings and identifying physical aspects of the room which are maybe causing undesirable reflections.

Existing 3DIR measurement systems often use expensive, proprietary or impractical hardware.

A 3DIR measurement system called IRIS has been developed which utilises a compact first order Ambisonic microphone array, a Core Sound TetraMic (Figure 5).

SYSTEM OVERVIEW

1 **3D Impulse Response Recording**
The impulse response is recorded in level, time and direction using a Core Sound TetraMic.

2 **Time and Frequency Analysis**
The recorded IRs are filtered into the desired band and segmented into a series of short time windows.

3 **Resolve Level and Direction**
Level and direction are calculated for each time window using a sound intensity technique:
$\mathbf{I} = \overline{p(t)\mathbf{u}(t)}$

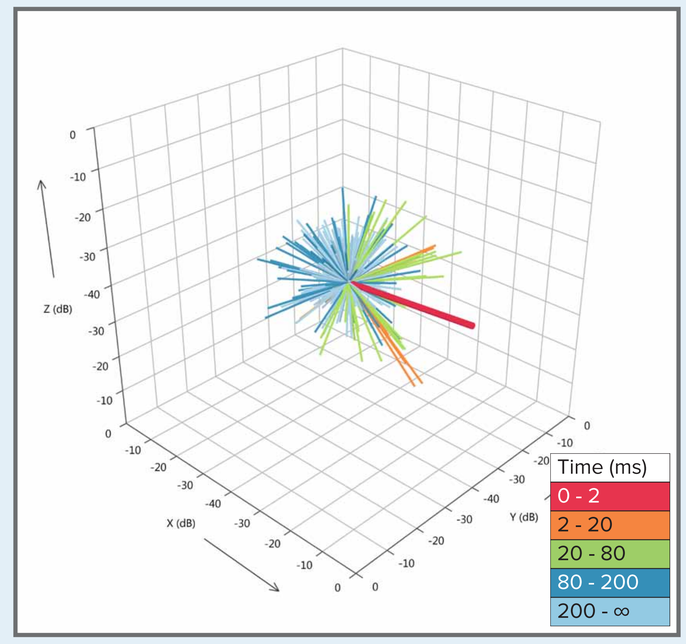


Figure 1: IRIS diagram - sound intensity vectors visualised as a hedgehog pattern.

4 **Visualisation**
The sound intensity vectors are visualised as a hedgehog pattern (Figure 1). Each line represents a sound intensity vector: the length indicates the level (dB), angle is the estimated direction of incoming energy, time of arrival is represented by colour.

AUCKLAND TOWN HALL

The IRIS measurement system was used to obtain 3D impulse responses in the Auckland Town Hall, New Zealand (Figure 2). This classical shoe box concert hall seats 1500 people across three levels.

R1 (Stalls Level) The direct sound is represented by the thicker red line. Early lateral energy is indicated by the green lines. The sound field becomes diffuse as time progresses (dark to light blue).

R2 (Circle Level) The lack of vectors behind the receiver is a result of absorption from raked padded seats and curtains along the balcony walls.

R3 (Circle Level) Position R3 is far from the source and overshadowed by the ceiling of the second balcony. The length of the direct sound vector (red) is similar to the reflections vectors, indicating a low direct to reverberant ratio. The raked seating behind R3 absorbs energy from this direction.

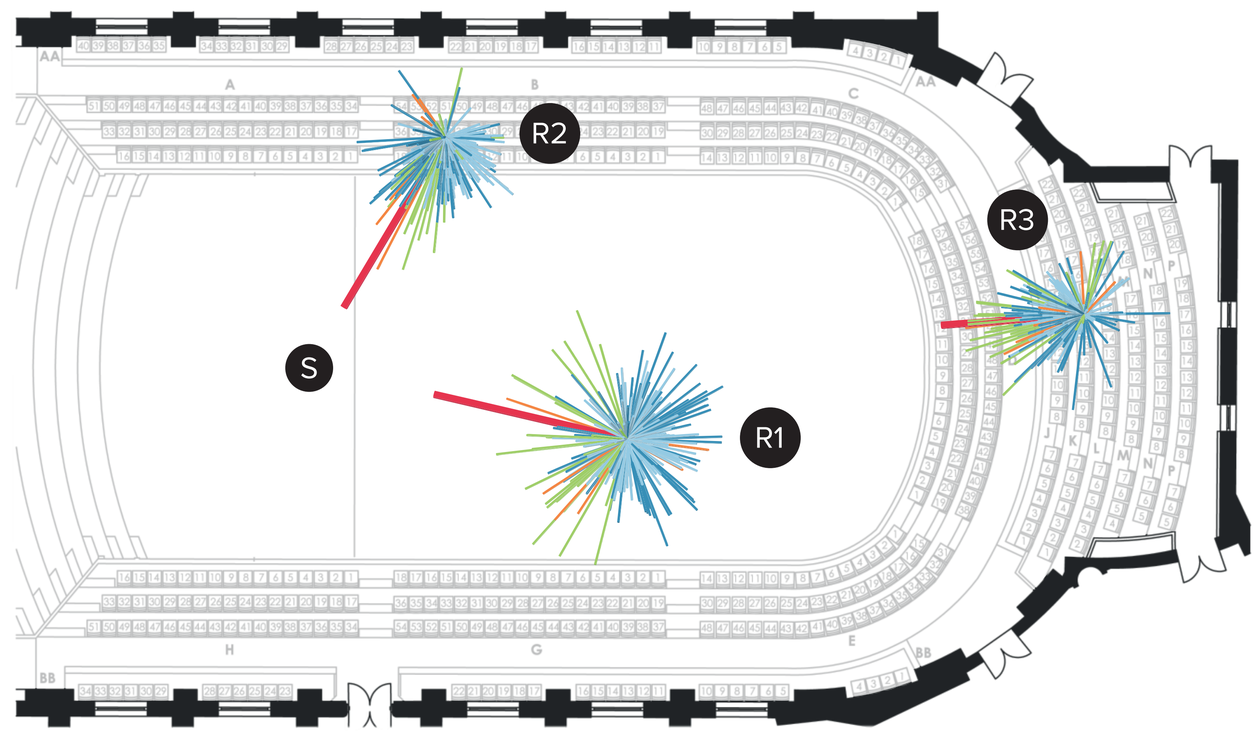


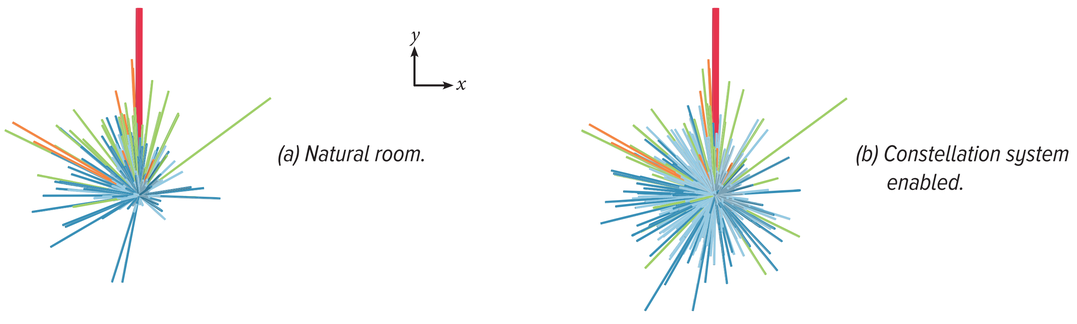
Figure 2: IRIS diagrams at three receiver positions in the Auckland Town Hall.

ASB THEATRE, AOTEA CENTRE

The ASB Theatre, in the Aotea Centre, Auckland, New Zealand, was recently refurbished. The acoustics were improved by modifications to the room and by installation of a Constellation active acoustics system by Meyer Sound.

Figure 3(a) shows the 3DIR of the room in its natural state, measured at a position in the stalls. The natural room has a short reverberation time and significant levels of early energy (green). This is suitable for speech and amplified music.

Figure 3(b) shows the same position with the Constellation system on. This is enabled for unamplified performances (opera and symphony concerts) which require more support from the room. The IRIS diagrams clearly illustrate the difference, most notably in late energy (blue).



(a) Natural room.

(b) Constellation system enabled.

Figure 3: 3DIR at a position in the ASB Theatre.

AUCKLAND MUSEUM

The Auckland War Memorial Museum contains a 200 seat fan shaped auditorium.
The 3DIR at one position is visualised in the x-y, x-z and y-z planes in Figure 4.

As expected from a fan shaped room, there is more energy arriving from the frontal and overhead directions compared to from the sides. This is most notable in the y-z view.

The ceiling is highly diffusing, and this can be seen by the even distribution of early energy (orange and green) in the top half of the x-z view.

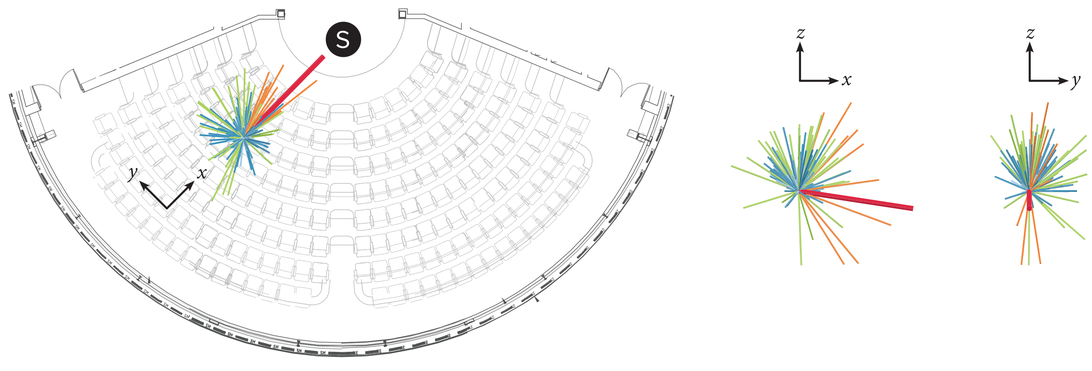


Figure 4: 3DIR at a position in the Auckland Museum auditorium visualised in the x-y, x-z and y-z planes.

ANECHOIC CHAMBER

Experiments were conducted in an anechoic chamber to assess the accuracy of the IRIS system.

The accuracy of directional estimation for horizontally arriving sounds was found to be within 7.5°.

Early lateral energy fraction measurements were found to be within one JND (0.05) of the calculated values from calibrated test arrangements.

SUMMARY

A 3D impulse response measurement system called IRIS has been developed. The system utilises a compact first order Ambisonic microphone array. The IRIS system has been validated by collecting 3D impulse responses in varied rooms, and the results appear to be strongly correlated with the respective physical environments.

MARSHALL DAY Acoustics

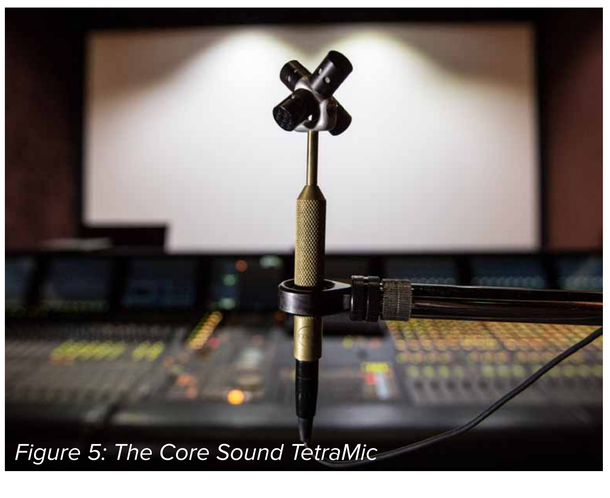


Figure 5: The Core Sound TetraMic