New Zealand Acoustics

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Features

Regulars

Cover Image: Hagley Park, late afternoon, Christchurch, New Zealand.

Source: commons.wikimedia.org/wiki/File:HagleyPark02_gobeirne.jpg

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From the President and Editor

From the President

Dear Members,

This weekend my Grandma will turn 100 years old. I know this has nothing whatsoever to do with acoustics – other than the fact she'll beat Leo Beranek to that particular milestone by a mere 10 months! – but I felt it was worth mentioning, whatever the occasion!

The other BIG news since my last message (which was, admittedly, some time ago) is that the Christchurch Town Hall is going to be saved! The decision was made on August 29 to fully restore the historic building at a cost of $127m, and in fact Mayor Bob Parker stated that he believes the Town Hall is more representative of the Christchurch community than Christchurch Cathedral.

There is a lovely video interview with architect Sir Miles Warren on the TVNZ website, in which the passionate response of the community to saving the entire facility is mentioned. It's certainly a very powerful comment on how acoustics can win the hearts and minds of the people.

Now, despite my ranting and raving on this topic in the last couple of issues, I can't really claim that I had anything to do with the Town Hall being saved. I like to think in my heart of hearts, however, that the decision makers either read or heard about the seething displeasure of the ASNZ community, and this was what pushed it over the line. Any letters of support on this would be welcome.

To society matters: I'd like to offer a quick update on the proposed

Continued Professional Development scheme. You will have seen the draft proposal in early July and I'd like to thank those of you who responded with support and criticism. Since that time, a number of the key council members

Publication Dates and Deadlines

New Zealand Acoustics is published quarterly in March, June, September, and December.

The Deadline for material for inclusion in the journal is 1st of each publication month, although long articles should ideally be received at least 2 weeks prior to this.

who are involved in the project have been frightfully busy with work they get paid to do (I know… priorities right?), so things haven't progressed far since then.

We are planning at least one council meeting this side of Christmas and CPD will be at the very top of the agenda. So stay tuned for the final draft of the scheme proposal, which will incorporate a number of your most excellent comments.

In the meantime though, please do keep making a record of any and all CPD you engage in, because come July 2015, it will all count towards your Membership. If you have any queries, please email me directly.

Summer is just around the corner, and with it, the dreaded curse of the environmental acoustician – cicadas! I hope all your sound level meter measurements incorporate octave or third-octave band data, so you can wipe away the effect of the nasty critters in post-processing.

For those of you with noise loggers… well it ain't so easy unless you have a passive filter to pop over the microphone. I've measured daytime noise levels down country where the effect of cicada noise on the equivalent A-weighted level was 17 decibels!

One final note, our next Acoustical Society conference will be held in almost exactly one year from now, and will be held in Christchurch. It will be a week or so after Inter-Noise 2014 which is in Melbourne, and I hope that we can lure some international delegates across the ditch to experience the beautiful South Island. I also hope to see as many of you there as possible. Stay tuned for details in the New Year.

This will probably be the last issue of the journal for the year. In which case, I hope you have a happy and safe Christmas and New Year!

Yours faithfully,

James Whitlock

Editor's Ramble

Dear Readers,

Welcome to another issue of Acoustics NZ. It is with great satisfaction that I can bring to you 3 new peer-reviewed articles, all from New Zealand acousticians.

Out first paper is from the Acoustics Group at the University of Canterbury and describes the use of a 'tranquillity' measure for green spaces in Christchurch. This now has special relevance for the "Healthy Christchurch" initiative currently being promoted by the Canterbury District Health Board.

The second article is a mathematical analysis of an unusual kind; Mark Poletti shows the basis of the logo of our Society, arising directly from a particular solution of the wave propagation equation.

The final contribution is from a group at The University of Auckland, who have been developing ultrasound-based equipment for assisting the blind. The AUDEO device uses inaudible (to the outside observer) sound to generate an audible (to the visually-impaired user) signal for detecting obstructions.

This issue is again likely to appear later than originally intended, as I keep saying to anyone who listens to me complain 'life keeps getting in the way of my life"; a range of family and friend associated crises seem to appear every time I sit down to edit.

One factor that I may not have considered are my work habits. As I prepare the journal, I usually play some music in the background (Duran Duran at the moment), as I often do when working at a computer. However, today I came across a study stating that this may be reducing my efficiency and accuracy. Work from the UK shows that listening to music can impair tasks that require concentration. A recently published paper notes that playing music you like can lift your mood and increase your arousal — if you listen to it before getting down to work. But it serves as a distraction from cognitively demanding tasks, so I guess that it editing is tough work! (N. Perham & H. Currie, (2014) "Does listening to preferred music improve reading comprehension performance?" Cognitive Psychology, DOI: 10.1002/acp.2994).

Also of interest, our calendar of events, and of course in this issue we return to our regular acoustic-themed crossword.

All the best,

John Cater ¶

The purpose of the ICA is to promote international development and collaboration in all fields of acoustics including research, development, education, and standardisation.

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September 2013

Dear Member Society, Dear International Affiliate

By October 1st 2013 the new board, which was elected in the General Assembly in Montreal, takes over the business in the International Commission for Acoustics. At that date the presidency goes from Michael Vorländer to Marion Burgess.

We are very grateful for the valuable contributions of all board members during the last term 2010-2013. In particular we like to thank all of the retiring board members for their support of the ICA over several terms: Samir Gerges, Charles Schmid, Sonoko Kuwano, Adriano Alippi, Philippe Blanc-Benon, Eugeniucz Kozaczka.

The members of the new board are Marion Burgess – President, Jing Tian – Vice President, Michael Vorländer – Past President, Mike Stinson - Secretary General, Antonio Perez-Lopez – Treasurer, Júlio A. Cordioli (Brazil), Dorte Hammershøi (Denmark), Bertrand Dubus (France), Roberto Pompoli (Italy), Kohei Yamamoto (Japan), Jeong-Guon Ih (Korea), Grazyna Grelowska (Poland), Monika Rychtarikova (Slovakia), Yiu Lam (UK), Mark Hamilton (USA). The board will further be amended by the representatives of the Affiliate Members and by Christopher Rooke (Chile) considering his relationship with ICA 2016.

The main event of 2013 was the 21st ICA congress in Montreal, Canada. ICA can be very proud of the big success. Warm thanks go to Mike Stinson and Luc Mongeau and their team!

We are looking forward to working for the ICA on the way to the 22nd congress in Buenos Aires. In the next three years the ICA board will work on the items discussed in Montreal as listed in the board meeting minutes. You will receive information on next actions in due time.

With best wishes,

Aachen, Michael Vorländer, President ICA 2010-2013
Canberra Marion Burgess, President ICA 2013-2016

Tranquillity in the City: A Preliminary Assessment in Christchurch

John Pearse, Greg Watts and Wan Yin Lim

Acoustics Research Group, Department of Mechanical Engineering, University of Canterbury

An original refereed contribution to New Zealand Acoustics

Abstract

This paper describes a preliminary evaluation of tranquillity in four contrasting parks in Christchurch. A prediction tool for tranquillity which has been successfully used elsewhere was employed for this purpose. Results show a wide range of tranquillity ratings. A park located near a motorway had the lowest tranquillity rating though a square in the CBD was predicted to have only slightly higher levels on this measure. Factors that had affected tranquillity ratings are considered together with suggestions for remedial measures.

Introduction

Tranquillity is defined as quality of calmness one experiences in nature and being away from manmade disturbance. Tranquil surroundings can lead to better psychological and physical restoration of people living in the urban environment. This is consistent with Kaplan's Attention Restoration Theory suggesting natural restorative environments has the ability to help people recover from sensory overload from everyday urban life (Kaplan,1995). Tranquillity is to be found in natural outdoor environments where man-made noise is at a low level though natural sounds can be at a relatively high level. Numerous studies have shown a link between such environments and stress reduction, longevity, pain relief and even how the brain processes auditory signals (Ulrich et al, 1991; Takano et al, 2002; Grahn and Stigsdotter, 2003; Lechtzin et al, 2010, Hunter et al, 2010). In addition tranquil spaces have been demonstrated to promote better health outcomes. In one landmark study it was found that patients whose windows face a natural environment appeared to have a faster recovery compared to patients whose windows were facing brick walls (Ulrich, 1984). Other studies also suggest that natural environments lower the chances of increased stress level. Prison research results show that inmates located in cells with window views of nature exhibit fewer stress symptoms (Moore, 1982). Tranquil and natural environment also help lead to positive mental states with reduced feeling of anger in subjects compared to those who were exposed to urban environment (Hartig, 2003).

For maximum benefit it is likely that tranquil environments should be accessed regularly i.e. as part of the working day. This can cause conflicts for urban dwellers due to the pace of living and many time constraints. It is no surprise therefore that easy access to such environments in the city should be an important consideration for city planners and especially for a city badged as the "Garden City".

But how tranquil are the open green spaces in the city? Can they be considered tranquil and therefore "restorative"? A method is required to provide an audit of tranquillity in green open spaces so failings can be identified, mitigation measures suggested and new spaces designed with tranquillity in mind.

Background

Previous studies have involved the investigation of the environmental factors which influence the perceived tranquillity of a place. Statistically significant factors that have been identified are the noise level (L_{Aeq} or L_{Amax}) and the percentage of natural and contextual features in the visual scene. The results of the full details of the original studies are given by Pheasant et al. (2008) and the updated formula relating these factors was reported recently as TRAPT (Tranquillity Rating Prediction Tool) (Pheasant et al., 2010) is given by:

$$TR = 9.68 + 0.041\ NCF - 0.146\ L_{day} + MF \qquad (1)$$

Where TR is the tranquillity rating on a 0 to 10 rating scale. NCF is the percentage of natural and contextual features and L_{day} is the equivalent constant A-weighted level (averaged over 7am to 7pm) of man-made noise . Contextual features include listed buildings, religious and historic buildings, landmarks, monuments and elements of the landscape, such as traditional farm buildings, that directly contribute to the visual context of the natural environment. It can be argued that when present, these visually cultural and contextual elements are as fundamental to the construction of 'tranquil space' as are strictly natural features. The moderating factor MF is added to the equation to take account of further factors such as the presence of litter and graffiti that will depress the rating and water sounds that are likely to improve the ratings. This factor is unlikely to be large and it was demonstrated that the presence of litter depressed the rating by one scale point (Watts et al, 2010). The effects of water sounds are the subject of further research . The prediction tool for the tranquillity rating TRAPT was used in previous studies to assess the tranquillity in urban green open spaces and the countryside then the predictions were validated using a questionnaire survey of visitors (Watts et al, 2013, Watts and Pheasant, 2013).

In some extreme cases, the predicted value of TR goes negative due to the linear regression technique used to relate these variables. In these cases, the calculated value is set to zero. Where TR > 10 then values are set to 10.

Figure 1 shows the relation between L_{day} and TR for 3 levels of NCF (0, 50 and 100%). Where there are no natural or contextual features (NCF = 0%) it can be observed that TR reaches zero at the relatively low noise level of 66 dB(A) but where NCF is 100% it is reached at the much higher level of 94 dB(A). This graphically demonstrates the importance for tranquillity of the natural components of the visual scene. For example a 50% increase in NCF is predicted to raise TR by approximately 2 scale points while decreasing noise level L_{Aeq} by 14 dB(A) changes TR by approximately the same amount. These trade-offs can be used to identify suitable measures to improve tranquillity.

Methodology

Four contrasting parks that are located in different areas of Christchurch were selected. These were chosen to reflect differences in adjacent major road traffic conditions and surrounding land use. The survey was carried out in summer 2010 (pre-earthquake). The four green spaces were:

1. Leslie Park that is located in a mixed suburban and industrial area alongside the Main South Road carrying a traffic flow of 14,200 per 18hr day.
2. Fendalton Park, located near a housing area and adjacent to Fendalton Road carrying a flow of 29,980/18hr day.
3. Marylands Reserve that is located next to Christchurch Southern Motorway in an industrial/ commercial area. The 18hr traffic flow was 23,100.
4. Latimer Square located in Christchurch CBD with traffic flows of 12,330 & 9,891 on the two adjacent major roads.

The approach was to identify the most likely tranquil

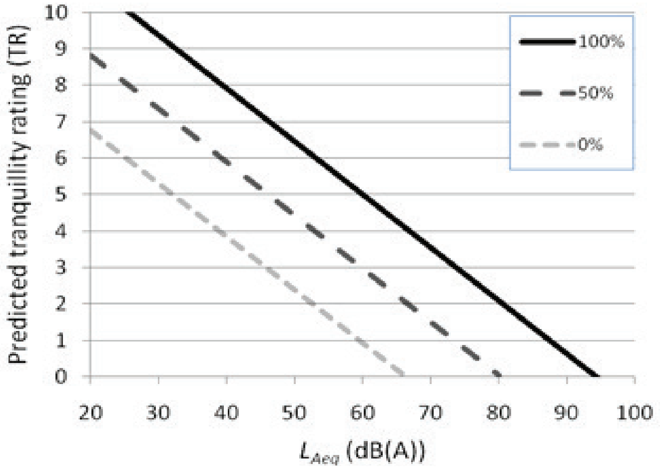

Figure 1: Linear variation of TR with L_{day} at 3 levels of NCF (0, 50 and 100%).

and non-tranquil spaces in three contrasting parks and greens and calculate the Tranquillity Rating using:

- Spot readings of A-weighted sound pressure levels
- Noise predictions based on the UK traffic noise prediction model CRTN
- Photographic survey of the percentage of natural and contextual features

Spot Readings

During the photographic surveys spot readings of the A-weighted sound pressure level were taken of background noise levels that were dominated by traffic noise. Periods of significant natural sounds were excluded from the noise sampling (e.g. bird song) as were human voices and the noise from any other mechanical sounds judged to be of only a transient nature (if present) e.g. noise from chain saw for tree surgery. The readings taken over a few minutes were used to locate the quietest and nosiest locations within the green space and later to provide a rough check on the calculation of road traffic noise levels (see below). GPS co-ordinates were recorded using a hand held device (Garmin eTrex HC) at these locations.

Noise Predictions

Since the dominant noise source at each site was road traffic noise, predictions were carried out at the sites using CRTN (Calculation of Road Traffic Noise – Department of Transport and Welsh Office, 1988). This method predicts the 18 hour L_{A10} value from 0600 to 2400 hours. Classified traffic counts were obtained from the Christchurch City Council and distances to the nearest road, road surface type and speed limit were obtained from recorded site information. It was found that at all sites the road surface was essentially level with a bituminous wearing course. Using these predicted values the L_{day} was then obtained from the conversion formulae (DEFRA,2006):

For non-motorways:

$$L_{day} = 0.95\ L_{A10,18h} + 1.44\ \text{dB} \qquad (2)$$

For motorways:

$$L_{day} = 0.98\ L_{A10,18h} + 0.09\ \text{dB} \qquad (3)$$

Note that in other countries where CRTN is not the preferred prediction method other validated traffic noise models can be used to obtain L_{day}. Where noise from other transportation modes are dominant the L_{day} value can be calculated using the appropriate prediction model.

Photographic Survey

Having identified the quietest and noisiest areas from the relevant noise maps and spot readings, the percentage of natural and contextual features was determined using a camera giving a field of view of approximately 51 degrees in the horizontal plane on a normal (non-zoom) setting. Seven contiguous pictures were taken at a height of 1.5m (close to the average standing eye height of adults in the UK) to give an approximate field of view of 360 degrees. These pictures were pasted into Microsoft PowerPoint and analysed using a 10 x 10 grid placed over the images to determine the percentage of natural and contextual features.

Figure 2: A view from the most tranquil location at Leslie Park with overlain grid for calculating NCF.

In all cases the quietest areas also had the highest percentage of natural features so according to the prediction tool this would also be the most tranquil.

Results

An example of how the 10x10 grid is used for assessing NCF is shown in Figure 1. The sky is excluded in the calculation and for each direction the number of squares containing more than 50% of buildings or other man-made structures is counted (N_{mi}). If the total number of squares more than 50% filled is N_{ti} then the NCF in that direction NCF_i is given by: $100(N_{ti} - N_{mi})/N_{ti}$. The value of NCF is then obtained by taking the average over D directions:

$$NCF = 100 / D \sum_{(i=1)}^{D} (N_{ti} - N_{mi}) / N_{ti} \qquad (4)$$

Using formula (1) the tranquillity rating at the most tranquil and least tranquil areas at each location was calculated. Table 1 summarises the results.

It can be seen that the least tranquil parts of each park were predicted to have a rating of 2 or under while the most tranquil areas ranged from 5.9 at Fendalton Park to Marylands reserve at 4.8.

Table 1: Predicted tranquillity ratings at the four study locations

Location (approximate area in hectares)	Co-ordinates	L_{day}	NCF	TR	
Fendalton Park (4.5 ha)	Most tranquil	-43.520898,172.59272	43.4	63.5	5.9
	Least tranquil	-43.518878,172.59245	68.0	55.2	2.0
Marylands Reserve (4.6 ha)	Most tranquil	-43.544350,172.588130	58.0	88.5	4.8
	Least tranquil	-43.54585,172.58558	73.6	60.3	1.4
Leslie Park (2 ha)	Most tranquil	-43.54409,172.508375	47.9	70.3	5.6
	Least tranquil	-43.545460,172.508538	67.8	41.3	1.5
Latimer Square* (2 ha)	Most tranquil	-43.53097,172.642663	56.0	83.4	4.9
	Least tranquil	-43.529982,172.643118	66.8	49.9	2.0

*Due to earthquake damage this square is currently being redeveloped

Discussion and Conclusions

To give an indication of acceptable and non-acceptable levels of the tranquillity rating it is suggested that based on previous experience that the following provisional guidelines should apply (Watts et al., 2009):

<5 unacceptable

5.0 – 5.9 just acceptable

6.0 – 6.9 fairly good

7.0 – 7.9 good

≥ 8.0 excellent

If these descriptors apply then from Table 1 it can be seen that the most tranquil sites in Fendalton Park and Leslie Park fall in the "just acceptable" category. However at Marylands Reserve and Latimer Square failed to reach acceptable levels of tranquillity.

To obtain acceptable levels of tranquillity where currently TR< 5.0 it will be necessary to consider:

(a) Reducing transportation noise

(b) Increasing the percentage of natural features

In most cases it will be most cost effective to concentrate efforts on producing tranquil areas away from noise sources and in the middle of areas with trees, shrubs and flower beds. Local screening of the noise sources is possible e.g. use of walled gardens and noise screening at source can be affected by purpose built noise barriers or better still a decorative wall (e.g. a serpentine wall with climbers). Diversion of heavy traffic and the use of low noise road pavements are further possibilities.

Latimer Square is relatively small at only 2 hectares and had two major roads on its boundaries. This has resulted in high levels of noise even in the middle of the park (L_{day} =56 dB(A)). Increasing the percentage of natural features close to 100% would be achievable and this is predicted to increase the tranquillity rating to 5.6 which is an acceptable level. Further increases would result from a traffic management scheme which reduced traffic on the boundary roads or by introducing a water feature to distract attention away from the traffic noise and provide a measure of masking. Natural sounding water features have been shown to improve tranquillity where background traffic is present though the exact benefit has yet to be quantified (Watts et al, 2009). Note that the "Green Frame" planned for the reconstructed Christchurch presents an excellent opportunity to create accessible quality tranquil spaces.

In the case of Marylands Reserve the TR would increase to 5.3 if NCF was increased to approximately 100%. As tyre/road noise is likely to be dominant on this high speed section of road further increases could be obtained by replacing the road surface material with a low noise option. This might result in a reduction of 5 dB(A) and in this case the tranquillity rating would rise further to 6.0 which would be classified as "fairly good". A further viable option would be the construction of a noise barrier adjacent to the carriageway which would be expected to result in a similar increase in tranquillity.

In conclusion this study has shown that it is possible to achieve acceptable levels of tranquillity in urban open spaces

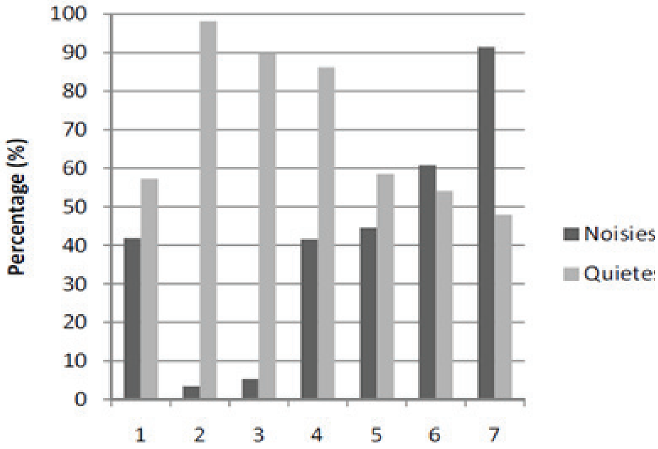

Figure 3: Variation in NCF at Leslie Park with direction of view (i = 1 to 7).

in Christchurch which are relatively densely populated area. In two cases of the four cases examined remedial treatments would be necessary to reach acceptable levels. A brief review of the literature has demonstrated the importance of tranquil spaces and some cities have enacted policy designed to enable easy access to such places. For example in New York, PLAN NYC, the sustainability agenda for the eastern US concrete jungle, includes a proposal to ensure that all New Yorkers live within a 10-minute walk of a park (Schwartz, 2011). The "High Line" in West Side Manhattan is an excellent example of how NYC authorities prompted by citizen action have risen to the challenge transforming a disused 1.6 km section of railway freight line in a derelict area to provide a linear park abundant with wild flowers, shrubs and trees and a "must see" for the city's many visitors (Figure 4).

Figure 4: Section of the popular "High Line" in NYC cutting through the old industrial Meatpacking District showing laminar flow water feature and mixed wild grasses.

The wider implications of this work are that it provides a yardstick for measuring open space performance in terms of restorative value, which can ultimately be used to prioritise amenity resources more effectively. Positive results can be employed to promote the health benefits of these spaces.

"Healthy Christchurch" is an initiative that seeks to improve the health and well being of Christchurch's residents in a number of ways and an indicator of the quality of restorative spaces should prove useful. Lesser results can be used as a spur to improve factors that affect tranquillity and thereby improve benefits to local users and visitors alike. Further work could include a more extensive audit of a larger number of open spaces based on these initial surveys and local needs. The use of a questionnaire survey to gather visitors' views on benefits, negative aspects and access problems is a useful extension that would compliment this novel approach. Finally the tranquillity prediction tool TRAPT could be used to design new spaces where tranquillity is sought e.g. as part of Christchurch City redevelopment.

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Focused Sound Sources and the Acoustical Society of New Zealand Logo

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An original refereed contribution to New Zealand Acoustics

Abstract

This paper demonstrates that the logo of the New Zealand Acoustical Society has a sound physical basis. The logo shows concentric circles with a discontinuity between the right and left hemispheres. If the logo were a sound field, these discontinuities would represent amplitude inversions. This behaviour occurs in sound fields containing focused sources, where circular wavefronts converge on a focal point from one hemisphere and then diverge into the other hemisphere. At certain times during the propagation of the wavefronts, the quadrature part of the sound field is maximum, and this demonstrates concentric wavefronts with a phase discontinuity between the two hemispheres and a null along the line separating the two.

Introduction

The logo of the Acoustical Society of New Zealand is a set of grey concentric rings, with the rings in one half-space positioned at radii between the radii of the rings in the other half-space. The logo can be seen on the cover of the journal (with an additional emphasis to show which quarter it has appeared in) and on the website of the society (www.acoustics.org.nz). In keeping with aim of the society to "promote the science and practice of acoustics" (www.acoustics.org.nz/files/ASNZ_Rules.pdf), it is incumbent upon us to ask whether the Society's logo represents a physical sound field. This article demonstrates that this is the case, and that our logo has a sound scientific basis. A sound field that looks very similar to the logo is produced by a focused source, in which circular wavefronts converge to a point and then radiate outwards from that point. This article gives a description of how focused sources are produced and provides methods for generating them.

Focusing of sound is a well-known high-frequency phenomenon in which sound rays converge to a point in space and then diverge from that point. Focusing can occur, for example, when a plane wave is reflected from a curved surface [1][2]. At low frequencies where the wavelength of the plane wave is of similar size to, or larger than, the reflecting object sound tends to dif-fract around the reflector and focusing does not occur. At high frequencies where the wavelength is small compared to the reflecting object, geometric acoustics applies and the behaviour is equivalent to the optical case. In this case, a plane wave parallel to the principal axis of a spherically curved surface will reflect sound to the focal point of the surface. The reflected sound converges on the focal point and then diverges out-wards from the focal point with spherical wave fronts.

Focusing can also be produced by a planar surface if the surface is vibrating in a particular manner. This fact is the basis for the generation of focused sources in sound reproduction systems. For example, Wave field Synthesis (WFS) is a method of producing sound fields derived from the Kirchhoff Helmholtz integral, for an arbitrarily shaped volume of space, or in the simpler case of a planar surface, the Rayleigh integrals [3]–[6]. A large 2D planar array of loudspeakers allows a practical implementation of the first Rayleigh integral and can generate a sound field in front of the array produced by an arbitrary distribution of sources behind the array. Since the array is planar, it also generates the same sound field behind the array. If the sound produced by the array elements are reversed in time, the array produces a sound field that propagates back from the array to the original sound sources. This techniques, known as time reversal signal processing, is used in many areas in optics, ultrasonic imaging [7] and acoustics [8][9]. Focused sources may also be generated in WFS to produce the impression of sound originating in front of the array [10]–[12].

In this paper, we will present the theory of sound field reproduction based on the use of integral formulas. We will then consider the special case of time reversal processing and show how it produces focused sources. We will consider a single sound source for simplicity. We will then consider methods for directly generating focused sound sources. For simplicity we will primarily consider the 2D case, but will include a derivation of a focused source in the 3D case. We also make the standard assumption that sound sources have a complex time dependence of the form $exp(i\omega t)$ where f is the frequency of oscillation and $\omega = 2\pi f$ is the radian frequency. Solutions to the wave equation are then complex functions of space which we denote $q(x,y,z)$. The physical sound pressure p(x,y,z,t) is then the real part of the complex time-varying sound pressure, i.e. Eqn(1):

$$
\begin{aligned}
p(x,y,z,t) &= \mathrm{Re}\left\{ q(x,y,z) e^{i\omega t} \right\} \\
&= q_R(x,y,z)\cos(\omega t) \\
&\quad - q_I(x,y,z)\sin(\omega t)
\end{aligned}
\tag{1}
$$

where $q_R(x,y,z)$ is the real or in-phase part of the complex pressure and $q_I(x,y,z)$ is the imaginary or quadrature part. e see that the physical field contains both in-phase and quadrature components.

INTEGRAL FORMULAS FOR CALCULATION OF SOUND PRESSURE

The reproduction of sound fields is based on integral formulas that allow the calculation of the sound pressure at a point in space given knowledge of the pressure or velocity (or both) on a defined surface. The Kirchhoff–Helmholtz (K–H) integral describes the sound pressure inside a region of space, in which there are no sound sources, as an integral over the surface, S, of the pressure, and the normal component of the pressure gradient, produced on the surface by sound sources outside the region [13] (Fig. 1).

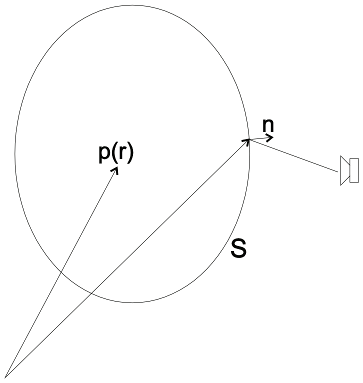

Figure 1: Kirchhoff Helmholtz integral.

Mathematically the integral is expressed, for vectors **r** and **r'**

$$q(\mathbf{r}) = \int\int \left[G(\mathbf{r} \mid \mathbf{r}') \frac{dq(\mathbf{r}')}{dn} - q(\mathbf{r}') \frac{d}{dn} G(\mathbf{r} \mid \mathbf{r}') \right] dS \tag{2}$$

where $q(\mathbf{r})$ is the complex sound pressure inside the region with surface S and,

$$G(\mathbf{r} \mid \mathbf{r}') = \frac{e^{-ik|\mathbf{r}-\mathbf{r}'|}}{4\pi |\mathbf{r}-\mathbf{r}'|} \tag{3}$$

is the free space Greens function (the idealised sound pressure produced by a point source) for a sound source radiating sound at positive radian frequency ω and with wave number $k = \omega c$ where c is the speed of sound.

A remarkable feature of this integral equation is that the sound pressure outside the region is zero. This is possible because the sound pressure inside the region is produced by a combination of monopoles (the Greens function) and normally oriented dipoles (the normal gradient of the Greens function) which allows sound to be directed into the region and sound radiating out of the region to be cancelled [14].

For the case of an acoustic half-space divided by a plane the K–H integral simplifies and the sound field on one side of the plane may be described in terms of the pressure or the pressure velocity produced on the surface by sound sources in the other half-space. In effect, there is no need to cancel sound radiating out of the region because it is of infinite extent.

The two cor-responding integral formulas are known as Rayleigh's first and second integral formulas [13]. We consider the first integral formula here for $z > z_0$.

This equation states that the sound field for $z > z_0$ is the integral over the (x',y') plane positioned at $z = z_0$ of the sound pressure produced by a distribution of monopoles with amplitudes given by the normal component of the complex sound velocity in the (x',y') plane produced by sound sources in the half space $z < z_0$.

$$q(x, y, z) = \frac{-i\rho ck}{2\pi} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} v_z(x', y', z_0) \frac{e^{-ik|\mathbf{r}-\mathbf{r}'|}}{|\mathbf{r}-\mathbf{r}'|} dx'dy' \tag{4}$$

In other words, if we know the sound field on a plane and there are no sound sources in front of it, we can calculate the field at all points in front of the plane, because the sound propagates according to the wave equation.

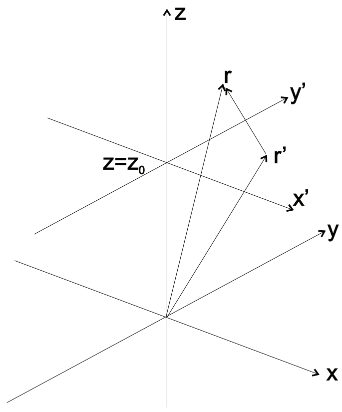

Figure 2: Rayleigh integral.

To simplify our description, we will now consider the 2D case where the sound field is constant in y. This would occur if the sound field was a combination of plane waves which were constant in y, or for a combination of line sources aligned parallel to the y axis. The Rayleigh integral can be simplified because the velocity is no longer a function of y and the integral of the 3D Greens function over y is known. For a point source at (x',y',z') the integral of the Greens function over y' is:

$$\int_{-\infty}^{\infty} \frac{e^{-ik|\mathbf{r}-\mathbf{r}'|}}{4\pi |\mathbf{r}-\mathbf{r}'|} dy' = \frac{i}{4} H_0^{(2)}(kR) \tag{5}$$

where $H_0^{(2)}(kR)$ is the cylindrical Bessel function of the second kind and R = sqrt[$(x\text{-}x')^2+(z\text{-}z')^2$] is the polar radius in the (x,z) plane.

The Rayleigh integral becomes [13]:

$$q(x, z) = \frac{\rho ck}{2} \times$$

$$\int_{-\infty}^{\infty} v_z(x', z_0) H_0^{(2)} \left(k\sqrt{(x-x')^2 + (z-z_0)^2} \right) dx' \tag{6}$$

for $z > z_0$. This equation states that the 2D complex pressure can be reproduced for $z > z_0$ by a continuous distribution of line sources at $z = z_0$, each with complex amplitude .

For example, a line source at produces the complex pressure

$$q_s(x, z) = H_0^{(2)} \left(k\sqrt{x^2 + (z-z_s)^2} \right) \tag{7}$$

The z-component of the velocity at $z = 0$ is

$$v_z(x,z) = \frac{i}{\rho\omega}\frac{dq_s(x,z)}{dz}\Big|_{z=0} = \frac{i}{\rho c} H_0'^{(2)}\left(k\sqrt{x^2+z_s^2}\right)\frac{-z_s}{\sqrt{x^2+z_s^2}} \quad (8)$$

A Matlab simulation was written to demonstrate reproduction of a line source field, using a finite array of 250 sources over -20 to 20 metres (sources are 160 mm apart). The amplitudes of the 25 sources at each end of the array were tapered to zero using a raised cosine window to reduce end-effects [3], [6], [15].

The sound pressure produced by the line source is shown in Fig. 3 and the real and imaginary parts of the sound pressure reproduced by the line source array, calculated over −2 to 2 m, in x and z, are shown in Figs. 4 and 5. The line sources are shown as circles at $z = 0$. The WFS array reproduces the sound field correctly for $z > 0$, and produces the same sound field for $z < 0$, since the line sources radiate equally in both directions.

The reproduction error, defined as

$$e(x,z) = \frac{|q(x,z) - q_S(x,z)|}{|q_S(0,0)|} \quad (9)$$

is shown in Fig. 6. The error is below −40 dB in the reproduction half-space, except for positions close to the line sources. For $z < 0$ the error is large since the WFS array generates a symmetric field, and is not able to generate a sound field that propagates towards it from the line source.

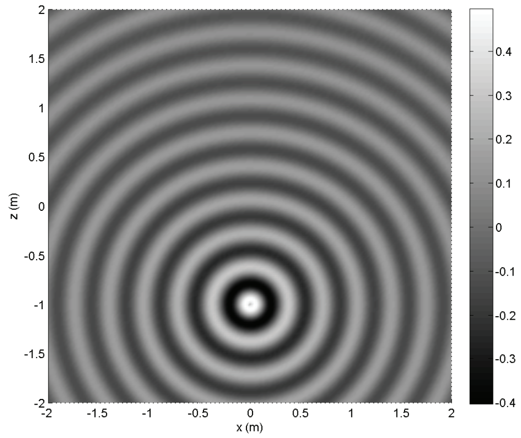

Figure 3: Line source sound field.

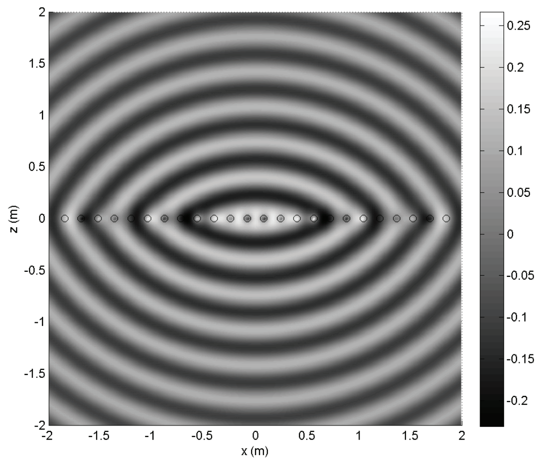

Figure 4: Real part of complex WFS field.

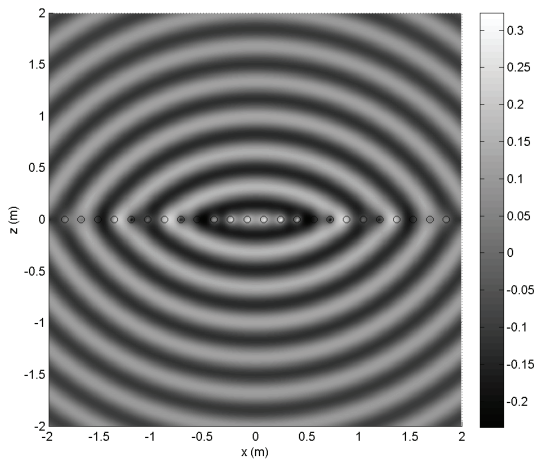

Figure 5: Imaginary part of complex WFS field.

TIME REVERSAL – FOCUSED SOURCES

Time reversal is a technique that allows imaging of sound sources in homogenous media [7][8]. The sound pressure produced by one or more sources in the medium is detected at a number of points on a surface by an array of sensors. If the recorded signals are played back into the sensors (which can operate in reverse), the sound field will consist of wave fronts converging from the sensor array to the original sound source locations [8].

Time reversal can be implemented using the Rayleigh integral approach discussed in the previous section. The time-dependent complex pressure has the form, for $z > z_0$ (Eq (6))

$$q(x,z,t) = \frac{\rho ck}{2}\times \int_{-\infty}^{\infty} v_z(x',z_0)e^{i\omega t}H_0^{(2)}\left(k\sqrt{(x-x')^2+(z-z_0)^2}\right)dx' \quad (10)$$

If the time index is reversed, $t \rightarrow -t$ then $\exp(i\omega(-t)) = \exp(-i\omega t)$ and the integral becomes

$$q_{TR}(x,z,t) = \frac{\rho ck}{2}\times \int_{-\infty}^{\infty} v_z(x',z_0)e^{-i\omega t}H_0^{(1)}\left(k\sqrt{(x-x')^2+(z-z_0)^2}\right)dx' \quad (11)$$

where the Hankel function of the first kind (the conjugate of $H_0^{(2)}(kR)$) is required to produce wave propagation outward from each line source. The sound field produced by approximating this integral using the same discrete array as in Fig. 3 to Fig. 6 is shown in Fig. 7 and Fig. 8. The line array now produces circular wave fronts that converge on the source position as indicated by the arrows in Fig. 7. The same real sound pressure can be produced by conjugating the velocity, which is a well-known result in WFS theory.

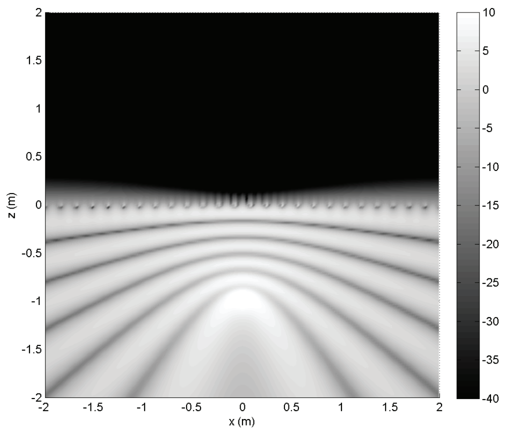

Figure 6: Error in dB.

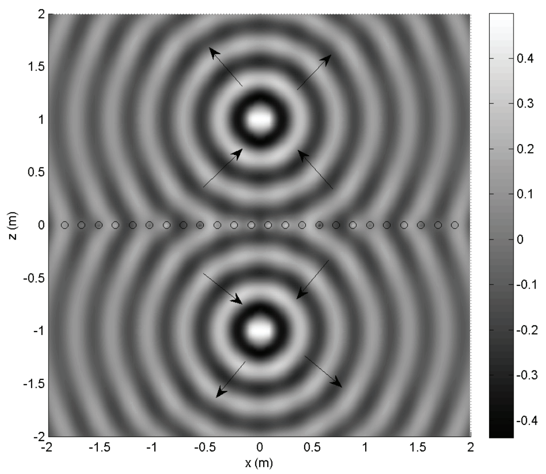

Figure 7: Real part of time-reversed sound field.

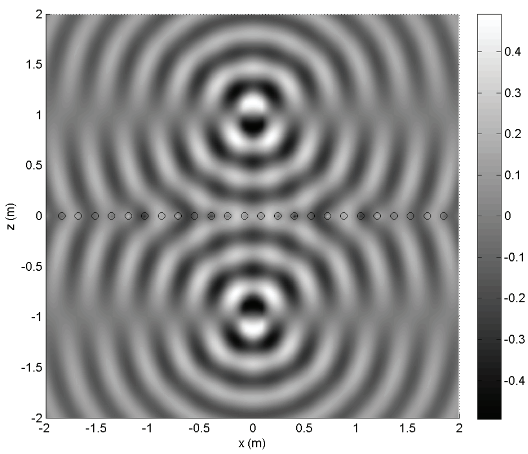

Figure 8: Imaginary part of time-reversed field.

The quadrature (imaginary) part of the field demonstrates circular wavefronts around each focus point with maxima on one side which align with the minima of the wavefronts on the other side, creating a discontinuity along a line between the two where the amplitude is zero. Since the observed sound field is given by Eq. (1), the quadrature field will be maximum at times $t_n = (n+1/2)/2f$ for integers n.

THEORETICAL DESCRIPTION OF A FOCUSED SOURCE

The sound reproduction example in the previous section generates two sets of focused sources, on each side of the array. One could ask the question, is it possible to generate a single focused source at the origin and is there a physical description of such a sound field?

Methods for generating such a field have been given in [10]–[12], [16]. A focused source may be described in two dimensions as a sum of plane waves arriving from angles from 0 to 180 degrees. Mathematically the focused source has the form

$$q_f(x,y) = \frac{1}{\pi}\int_0^{\pi} e^{i[kx\cos\phi_i + ky\sin\phi_i]} d\phi_i \tag{12}$$

where Φ is the azimuthal angle measured from the x-axis. This integral can be evaluated by expressing the plane wave in its cylindrical form using a Bessel expansion [13]

$$e^{ik(x\cos\phi_i + y\sin\phi_i)} = e^{ikR\cos(\phi-\phi_i)} = \sum_{m=-\infty}^{\infty} i^m J_m(kR)\, e^{im(\phi-\phi_i)} \tag{13}$$

For calculating the field over a finite radius R at wave number k, this expansion may be truncated to $m \in [-M,M]$ for M=[kR] [17]. The integral can be carried out and the resulting expansion put in the form

$$q_f(R,\phi) = \sum_{m=-M}^{M} J_m(kR)\, e^{im\phi} \frac{\sin(m\pi/2)}{m\pi/2} \tag{14}$$

where the "sinc" function has the value of 1 for $m = 0$. The sound pressure at $R = 0$ is one since only the $m = 0$ term is nonzero for $R = 0$ and $J_0(0) = 1$. This sound field can be rotated by any angle Φ by using $(\Phi - \Phi_0)$ in the expansion.

The imaginary part of the sound field generated by this expansion is shown in Fig. 9, for a frequency of 1 kHz and Φ =-90 degrees. The sound field is similar to the focused source generated in each half space in Fig. 8. However, one can see interference effects which are caused by the plane waves arriving from 0 and 180 degrees, which create a standing wave component.

This effect can be reduced by limiting the range of integration from α to $\pi - \alpha$ for a small angle α. The sound field expansion becomes

$$q_{f,\alpha}(R,\phi) = \sum_{m=-M}^{M} J_m(kR)\, e^{im\phi} \frac{\sin(m(\pi/2-\alpha))}{m(\pi/2-\alpha)} \tag{15}$$

The wave field produced by this expansion for an angle α = 5 degrees is shown in Fig. 10. The standing wave interference is reduced from that appearing in Fig. 9 but is still noticeable.

A more general approach to generating a focused source is to allow the amplitudes of the plane waves to be weighted arbitrarily, instead of the equal weighting that occurs in Eq.s 14 and 15.

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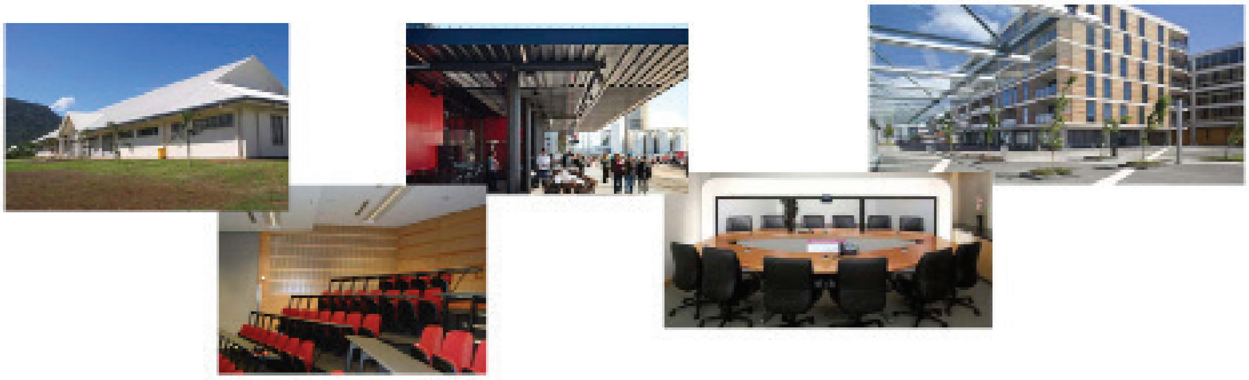

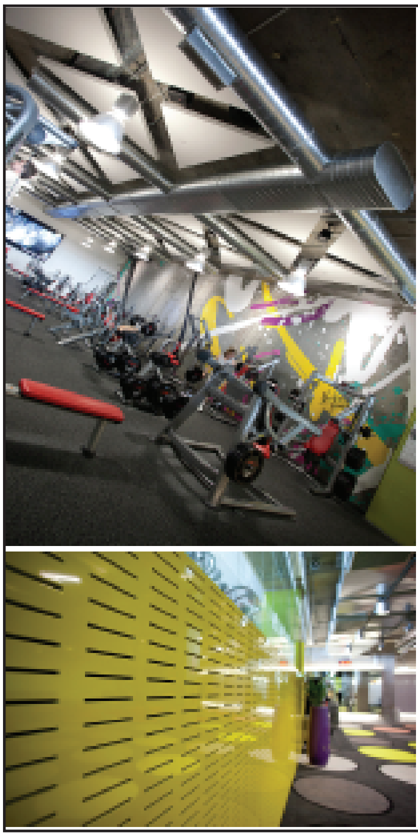

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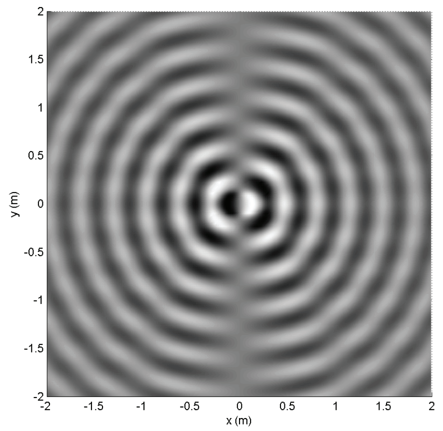

Figure 9: Quadrature focused source field using plane waves from 0 to 180 degrees.

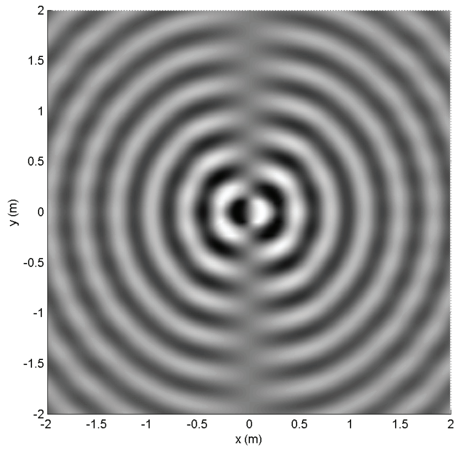

Figure 10: Quadrature focused source field using plane waves from 5 to 175 degrees.

We consider a focused source field given by,

$$q_{f,w}\left(x,y\right)=\frac{1}{2\pi}\int_{0}^{2\pi}e^{ikR\cos\left(\phi-\phi_i\right)}w\left(\phi_i\right)d\phi_i \tag{16}$$

where $w(\Phi_i)$ is a general window which will restrict the angles of arrival to between 0 and 180, of the form

$$w\left(\phi_i\right)=\sum_{m=-M}^{M}\beta_m e^{im\phi_i} \tag{17}$$

where the order of the window is limited to M, since this is the maximum order of the sound field expansion. Note that the order of the window may be less than M if desired by allowing some elements to be zero. Substituting this expansion and Eq. (13) into (16) yields

$$q_{f,w}\left(R,\phi\right)=\sum_{m=-M}^{M}i^m\beta_m J_m\left(kR\right)e^{im\phi} \tag{18}$$

A simple way to determine the coefficients β_m is to assume a rectangular window as above, determine the corresponding coefficients, and then apply a further windowing function to the coefficients to smooth the window. For a rectangular window of range α to $\pi - \alpha$ the coefficients are

$$\beta_m=\begin{cases}\left(-i\right)^m\dfrac{\sin\left[m\left(\pi/2-\alpha\right)\right]}{m\left(\pi/2-\alpha\right)}, & m\neq 0\\ 1, & m=0\end{cases} \tag{19}$$

The effect of truncating the window order is to produce ringing in the window amplitude. A second window may be applied to the coefficients to reduce the effect. For example, the window produced for α = 10 degrees and M = 53 is shown in Fig. 11a, and the window produced by applying a Kaiser window to the coefficients is shown in 11b. The smoothed window rolls of the amplitude of the plane wave near 0 and 180 degrees and reduces ringing.

The sound field produced using 11b is shown in Fig. 12. The sound field shows less interference effects than those in Figs 9 and 10.

THE 3D CASE

The examples given above have all been for the 2D case where the sound pressure is a function of 2 coordinates only. The sources used in the WFS examples are line sources and the focused sources produced are line focused sources. Since we live in a 3D world, we will include a brief derivation of a focused source for the 3D case.

Following the previous section, we will generate a focused source from a distribution of plane waves arriving from angles (Θ_i, Φ_i) in spherical coordinates (Fig 13), (r, Θ, Φ)

$$q_{f,\alpha,3D}\left(x,y,z\right)=\frac{1}{2\pi}\int_{0}^{\pi/2-\alpha}\int_{0}^{2\pi}e^{ikr\left[\sin\theta\sin\theta_i\cos\left(\phi-\phi_i\right)+\cos\theta\cos\phi_i\right]}\sin\theta_i d\theta_i d\phi_i \tag{20}$$

where the plane waves are restricted to the upper hemisphere Θ_i ε [0, $\pi/2$ - α]and where, as before, α > 0 avoids plane waves arriving from Θ_i = $\pi/2$ as these will produce standing waves. In the 3D case the standing wave is caused by plane waves arrive

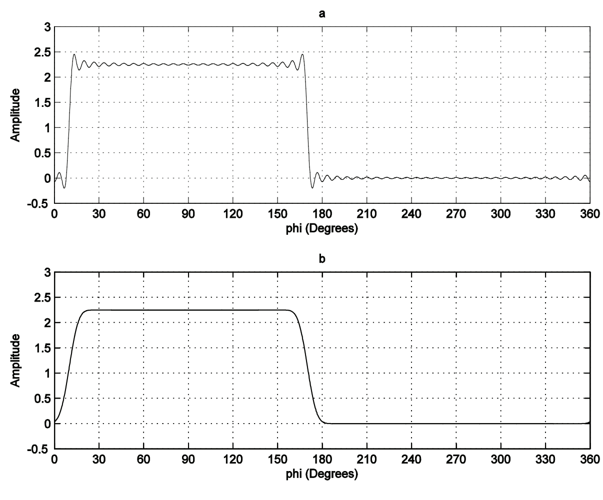

Figure 11: (a): Window for α = 10 degrees and (b) modified by a Kaiser window with Kaiser parameter 20.

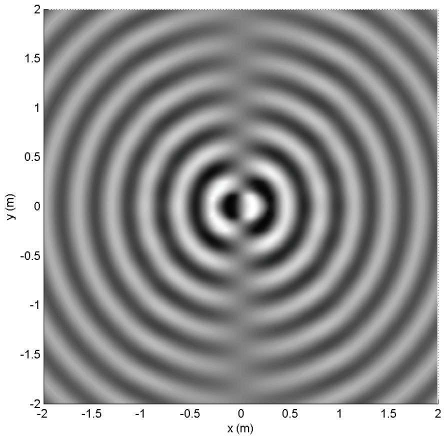

Figure 12: Quadrature focused source field using plane waves from 10 to 170 degrees with window smoothed by Kaiser window with Kaiser parameter 20

from all angles Φ_i ε [0, 2π].

Using the expansion in Eq. (13), it has the form

$$\int_0^{2\pi} e^{ikR\cos(\phi-\phi_i)} d\phi_i = J_0(kR) \tag{21}$$

which is a radial standing wave field.

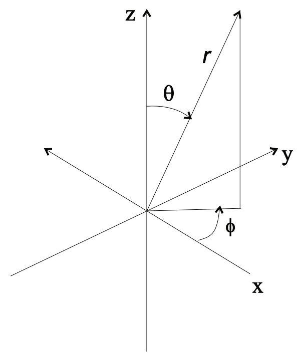

Figure 13: Spherical coordinates.

The integral in Eq. (20) can be carried out using the spherical harmonic expansion of the plane wave [13]

$$e^{ikr[\sin\theta\sin\theta_i\cos(\phi-\phi_i)+\cos\theta\cos\phi_i]} = 4\pi\sum_{n=0}^{\infty}\sum_{m=-n}^{n} i^n j_n(kr) Y_n^m(\theta,\phi) Y_n^m(\theta_i,\phi_i)^* \tag{22}$$

where $j_n(.)$ is the spherical Bessel function and

$$Y_n^m(\theta,\phi) = \sqrt{\frac{2n+1}{4\pi}\frac{(n-|m|)!}{(n+|m|)!}} P_n^{|m|}(\cos\theta) e^{im\phi} \tag{23}$$

is the $(n,m)th$ spherical harmonic, where $P_n^m(.)$ is the associated Legendre function.

Substituting Eq. (22) into (20) yields

$$q_{f,\alpha,3D}(r,\theta,\phi) = 2\sum_{n=0}^{\infty}\sum_{m=-n}^{n} i^n j_n(kr) Y_n^m(\theta,\phi) \times \int_0^{\pi/2-\alpha}\int_0^{2\pi} Y_n^m(\theta_i,\phi_i)^* \sin\theta_i d\theta_i d\phi_i \tag{24}$$

The integral over Φ_i eliminates all terms except the m = 0 term and produces a field which is rotationally symmetric

$$q_{f,\alpha,3D}(r,\theta) = \sum_{n=0}^{\infty} i^n j_n(kr)(2n+1) P_n(\cos\theta) \times \int_0^{\pi/2-\alpha} P_n(\cos\theta_i)\sin\theta_i d\theta_i \tag{25}$$

For the n = 0 case $P_0(\cos\Theta_i)$ = 1 and the integral may be carried out directly yielding

$$\int_0^{\pi/2-\alpha} \sin\theta_i d\theta_i = 1-\cos(\pi/2-\alpha) \tag{26}$$

For n > 0 the integral may be carried out by substituting u = cos Θ_i and using the recurrence formula [13]

$$(2n+1) P_n(u) = \frac{dP_{n+1}(u)}{du} - \frac{dP_{n-1}(u)}{du} \tag{27}$$

yielding

$$\int_{\cos\gamma}^{1} P_n(u) du = \frac{1}{2n+1}\left[P_{n-1}(\cos\gamma) - P_{n+1}(\cos\gamma)\right] \tag{28}$$

the final result is Eqn (29):

$$q_{f,\alpha,3D}(r,\theta) = j_0(kr)\left[1-\cos\left(\frac{\pi}{2}-\alpha\right)\right] + \sum_{n=1}^{\infty} i^n j_n(kr)(2n+1) P_n(\cos\theta) \times \left[P_{n-1}\left[\cos\left(\frac{\pi}{2}-\alpha\right)\right] - P_{n+1}\left[\cos\left(\frac{\pi}{2}-\alpha\right)\right]\right] \tag{29}$$

The field generated by this equation for a frequency of 1 kHz and α = 5 degrees is shown in Fig. 14. The field looks similar to that of the 2D case in Fig. (12). However, in the 3D case the sound pressure will reduce with $1/r$ as opposed to 1/sqrt(R) in the 2D case.

As in the 2D case, the sound field shows some artefacts due to the interference of waves arriving over all azimuthal angles, in a similar manner to the 2D case. These artefacts could be reduced by applying a window $w(\Theta_i)$ to the plane wave integral in Eq. (20).

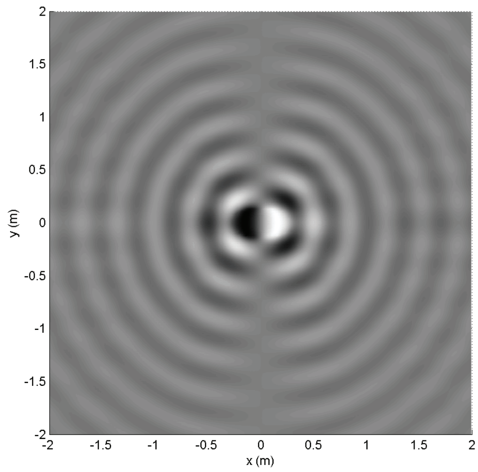

Figure 14: Quadrature focused source field in 3D using plane waves arriving from 0 to 85 degrees in elevation and 0 to 360 in azimuth.

Since the Legendre functions are orthogonal,

$$\int_0^{\pi} P_n(\cos\theta_i) P_m(\cos\theta_i) \sin\theta_i d\theta_i = \begin{cases} \dfrac{2}{2n+1}, n = m \\ 0, \quad n \neq m \end{cases} \quad (30)$$

this window can be written

$$w(\aleph_i) = \sum_{n=0}^{M} {}_n P_n(\ddot{u} \quad _i) \quad (31)$$

and the coefficients β_n may be obtained as

$$\beta_n = \frac{2n+1}{2} \int_0^{\pi} w(\theta_i) P_n(\cos\theta_i) \sin\theta_i d\theta_i \quad (32)$$

For a rectangular window

$$w(\theta_i) = \begin{cases} 1, \theta_i < \pi/2 - \alpha \\ 0, \theta_i > \pi/2 - \alpha \end{cases} \quad (33)$$

the coefficients can be calculated using the results above.

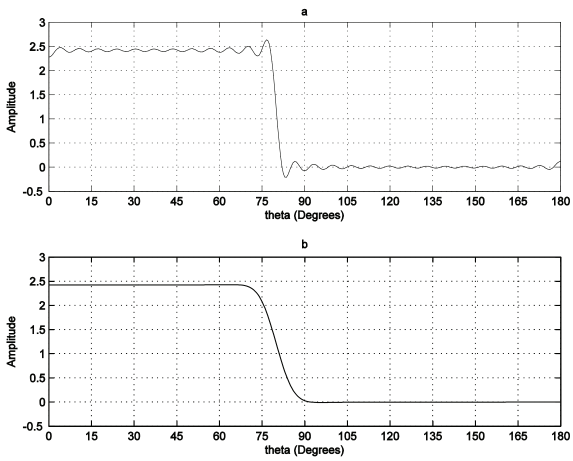

Figure 15a: Rectangular window for α = 10 degrees and M = 53. 15b: Window with additional Gaussian smoothing with γ = 10.

For a normalized sound pressure of one at the origin, the coefficients become

$$\beta_n = \frac{\left[P_{n-1}\left(\cos\left(\frac{\pi}{2} - \alpha\right)\right) - P_{n+1}\left(\cos\left(\frac{\pi}{2} - \alpha\right)\right)\right]}{1 - \cos\left(\frac{\pi}{2} - \alpha\right)} \quad (34)$$

for $n > 0$ and and $\beta_0 = 1$.

These coefficients can be weighted by a further window to reduce the effects of truncation and produce a tapering off of the plane wave amplitudes near $\Theta_i = \pi / 2 - \alpha$. Since the expansion in Eq. (31) is for positive integers n, the window must be one-sided to leave the low order terms unaltered. We will use a Gaussian window of the form

$$G(n) = e^{-\gamma(n/M)^2}, n \in [0, M] \quad (35)$$

with a window parameter γ that controls the rolloff. The window generated for α = 10 degrees and M = 53 is shown in Fig. 15a and the window produced by the Gaussian smoothing for γ = 10 is shown in Fig. 15b.

The resulting sound field is shown in Fig. 16. The wavefronts show less artefacts than Fig. 14.

CONCLUSION

This article has discussed the occurrence of focused sources which can arise naturally in reflections from curved surfaces at high frequencies and in sound re-production with time reversal. It has also been shown that focused source fields can be directly generated using a simple model based on plane waves arriving over a half space. Bessel expansions have been derived for both the 2D and 3D case and a windowing method presented for reducing artifacts in the repro-duced field. The imaginary part of the complex sound field shows wavefronts in the two half-spaces with a discontinuity along a line separating the half-spaces. The sound field is similar to the logo of the Acoustical Society of New Zealand, demonstrating that the logo has a physical basis.

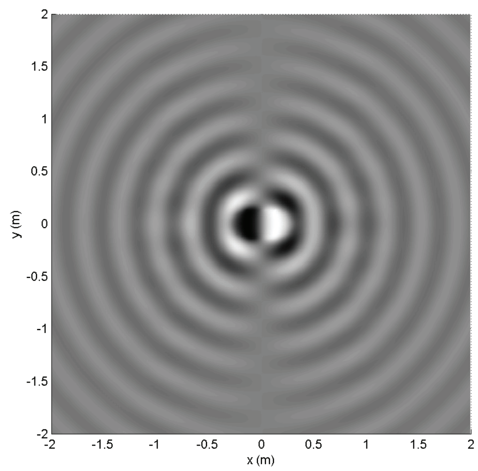

Figure 16: Quadrature focused source field in 3D using plane waves arriving from 0 to 80 degrees with Gaussian smoothing, γ = 10.

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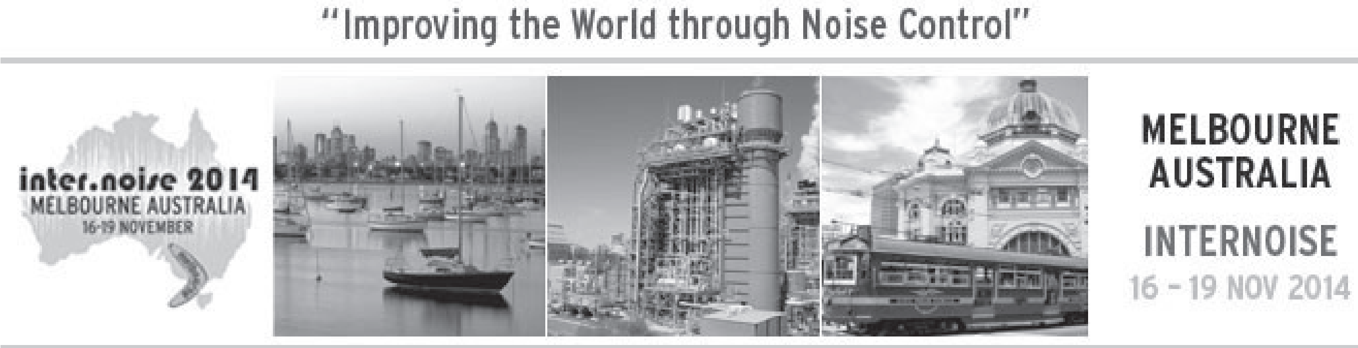

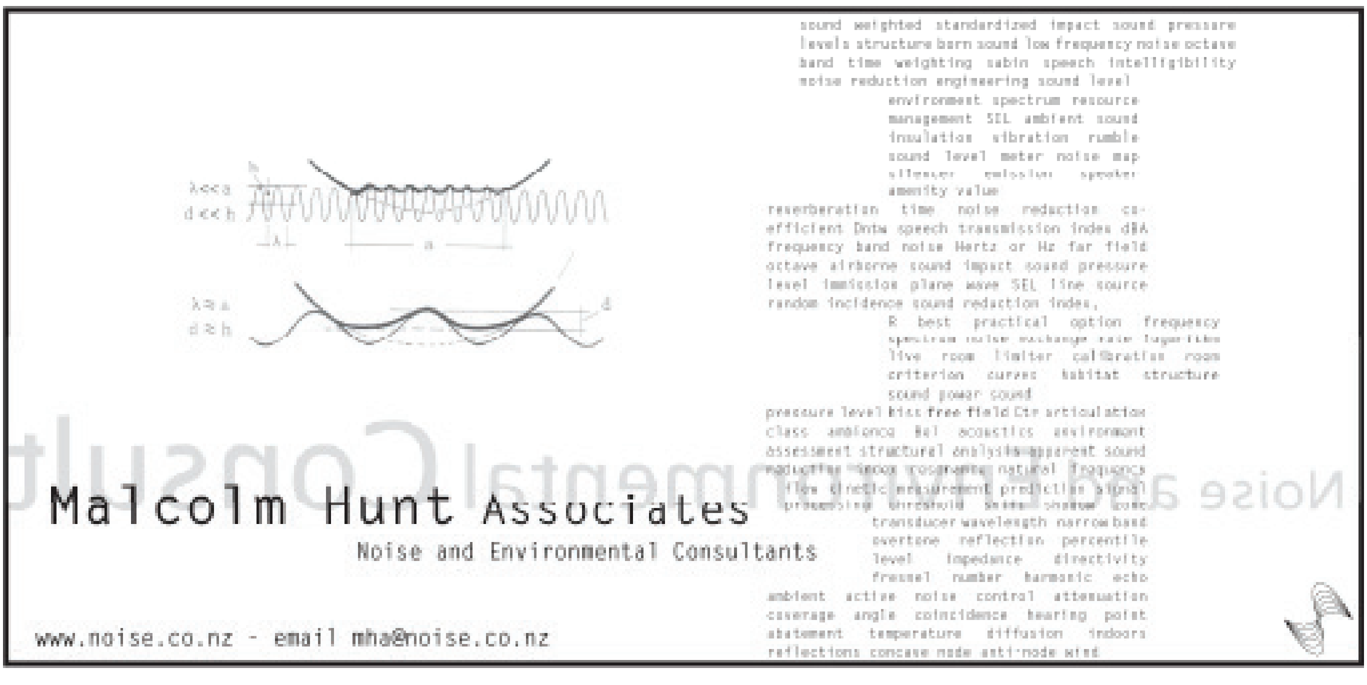

Increasing Obstacle Detection for Travellers with Visual Impairment: The AUDEO device

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An original refereed contribution to New Zealand Acoustics

Abstract

There are approximately 285 million visually impaired and blind persons worldwide who require some form of assistance during travel. Primary mobility devices including white canes and guide dogs can be used for mobility and detection of obstacles that are below waist height, but do not provide feedback for obstacles that are above the waist. Studies have shown that over 50% of individuals with visual impairment have head collisions on an annual basis. The Audification of Ultrasound for the Detection of Environmental Obstacles (AUDEO) device is a secondary mobility device developed to enable individuals with visual impairment to detect obstacles that are above waist height. This paper provides an introduction to the AUDEO device and the concepts of sound localisation and echolocation. It discusses two iterations of the device in an attempt to increase usability and provides some feedback from a blind user.

INTRODUCTION

Mobility is a part of everyday life but for those with visual impairments this task becomes far more difficult. For the visually impaired there are two predominant mobility aids available to them; either a guide dog or a white cane. These mobility aids take the place of the standard visual information by giving haptic feedback to the user.

Mobility devices, such as the cane or guide dog, have aided the visually impaired successfully for many years. The blind have navigated with the assistance of sticks and canes for centuries [1] [Note: the symbolic white cane was introduced in the 1920's [2]]. The environmental information given by these aids is fairly limited. Canes only provide information from a small arc in front the user at ground level. There are other significant risks to the visually impaired from objects such as wall mounted shelves that cannot be detected from ground level and from quiet running moving objects such as bicycles [3].

In New Zealand 8% of the adult population have sensory disabilities, in the form of sight or hearing impairments [4]. The World Health Organisation estimate that there are 285 million people who are blind or partially sighted [5]. There is a requirement for a secondary mobility device for those with visual impairment to further enhance their environmental understanding.

Several secondary mobility devices have been developed to enable perception of the environment above waist height. For the most part, auditory "pictures" are presented to the determined, diligent user who has forty or fifty hours to dedicate to training. Mapping of distance or pixel height to pitch and location to sound intensity seemed logical to the sighted inventor [6-8]. A study of individuals with functional blindness trained in the use of secondary mobility devices [9] found that although 86% reported having a device in their home, only 46% had used it in the 30 days prior to the interview. Although no dominant reason for lack of use was given, 21% suggested that design modifications would improve their usefulness. These devices have often been designed to provide as much information as possible, but require considerable concentration rather than allowing response to stimuli. Providing information that allows the individual to perceive their environments naturally may increase the usefulness of such devices.

From a New Zealand perspective, the Trisensor, later termed the Sonic Guide and more recently the KASPA, was developed by Kay in 1962 as a "wide-angle binaural" ultrasonic aid [6]. Information from the backscatter of ultrasonic reflections is transmitted to the ears binaurally using sonification. Sonification is a method of displaying information to a user by mapping a signal to a specific frequency or pitch. Cognitively, sonifications are abstract and analytical and require significant training [10]. In the case of the Trisensor, interaural intensity differences represent direction and pitch indicates the distance to an obstacle.

This TriSensor is a continuous scanning device that means the user is always provided with signals regardless of look direction. The signal masks most other sounds. An individual using this device cannot readily communicate with those around, limiting the device solely to independent travel situations.

The AUDEO (Audification of Ultrasound for the Detection of Environmental Obstacles) project aims to increase independence of persons with visual impairment by providing them with audible information to allow them to respond instinctively to head high obstacles with no prior training. A device that transmits and receives ultrasound is used to detect reflections off environmental obstacles and those signals are provided to the user in the audible range. Rather than mapping the signal, audification allows for skill based response (with little cognitive effort). Audification represents direct translation of physical energy into audible sound. For example, seismic data have been presented very effectively using audification as the frequency of ground vibrations can be increased to be within the auditory range [11].

In the case of the AUDEO, the audible feedback relies on Doppler. Since Doppler is more pronounced at ultrasound, the audible difference resulting from movement is displayed to the user. The device can then be used to broaden the detection and understanding of obstacles within a user's environment. This paper provides an introduction to the sound localisation and echolocation before discussing the theory behind the AUDEO device.

SOUND LOCALISATION

Sound localisation is an observer's ability to localise the origin of a sound stimulus. In natural environments, it is valuable as a survival aid to indicate the approach of a predator or conversely for enabling detection of the location of prey. Localisation is also important for audible navigation as it allows the observer to interpret the position of obstacles within their environment.

Sound Localisation can be broken down into three operations; localisation in the horizontal plane, the vertical plane, and the plane that defines forward and backward relative to the position of the ears.

Horizontal Localisation

Horizontal localisation is defined as an observer's ability to detect whether a sound source is located to the left or right of the head. This is accomplished by processing the interaural time and intensity differences [12]. For example when there is a sound source to the left of an observer, the left ear detects the sound, while at the right, the signals from the source will arrive later and will be softer. As the sound arrives at the left ear earlier than the right, an interaural time difference is realised. Additionally, the sound at the right ear is subjected to an acoustical shadow as the head obstructs the path of the sound. This causes the sound to arrive at a softer level as compared to the left ear, causing an interaural intensity difference. This is called the head shadowing effect. The head shadow effect occurs for frequencies that can be obstructed by the head, e.g. sounds with a short wavelength relative to the head size. The short wavelength, high frequency sounds are blocked by the head while larger wave low frequencies are able to bend around the head due to diffraction. The combination of interaural time and intensity differences form the basis for directional hearing in the horizontal plane [13]

Vertical Localisation

Vertical localisation is the ability to distinguish sound sources from above or below the observer's ears. Unlike horizontal localisation the sound signal is not obstructed by the head and will arrive at each ear at the same time and with the same amplitude. This means that the interaural time and intensity differences cannot be used to distinguish the direction of the source. Instead the ability to localise sound in this plane results from the shape of the outer ear (pinna) [14].

The pinna is the visible, outer portion of the ear that is common among mammals [15]. The pinna plays a key role in vertical sound localisation. When sound reaches the pinna it is reflected in such a way to alter the high frequency spectrum which is channelled into the ear canal, and therefore what signal reaches the eardrum. The range of the spectrum typically affected is above 4,000Hz. The reflections, and therefore spectral cues, are dependent on where the sound strikes the pinna; hence the spectrum relates to the elevation of the sound source [16]. Simply, the elevation from which sound originates will relate to the sound spectrum at the ear drum [17].

Front-back Localisation

Localisation in the forward-backwards direction is the ability to distinguish if a sound has originated from in front or behind the listener. Again the auditory system relies on spectral filtering from the head, torso, and especially the pinna to resolve front-back confusions [18].

To summarise, binaural hearing (the use of two ears) enables localisation through two key components; detection of the interaural time and intensity differences to allow for horizontal localisation, and pinna reflections that engage natural filtering and alteration to the high frequency spectrum to enable vertical and also front back localisation. These concepts were further demonstrated by Moss & Chui in 2006, when they investigated the effect of manipulating the outer ear (tragus) of the Eptesicus fuscus bat on its ability to localise its prey. As with humans, the outer ear and its shape plays an important role in localisation. With the tragus deflected there was significantly more localisation error than under normal conditions. The majority of the localisation error occurred in the vertical plane [19].

It was also observed that with the tragus deflected, the bat's flight adapted during the attack phase on the prey as a result of the change in hearing ability. The bats approached the prey by dropping more directly down than usual. This would suggest that the bat would travel in the vertical plane until the target was reached, then align itself horizontally with its prey to eliminate the need for vertical localisation.

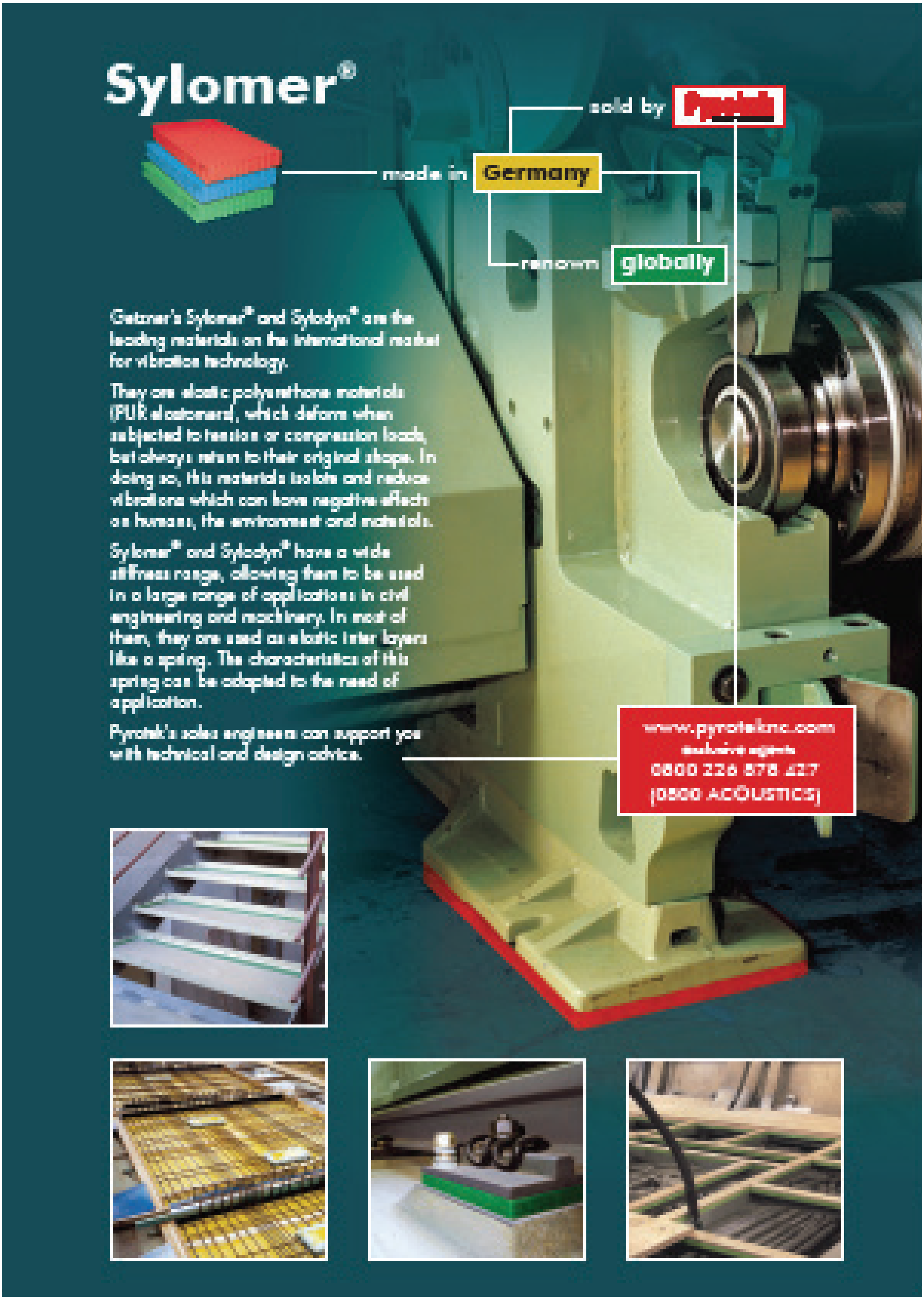
Localisation of objects in the surroundings can be achieved by understanding environmental echoes.

ECHOLOCATION

Passive echolocation capitalises on the localisation principles when interpreting sounds from environmental sound sources. However, as not all obstacles produce sounds themselves, active echolocation relies on the sounds being produced by the observer. These occur in the form of a tongue click, a clap or even a cane tap. Reflections of these sounds are used to detect the presence and location of any objects within the environment. The sound waves propagate until they come into contact with a solid object and bounce back in the form of echoes. The difference in time between the creation of the sound and the echo being received indicates the distance between the transmitter and object. This is because sound travels at a constant speed though a medium, e.g. air or water.

The time (t) for a sound to be reflected back to an observer is equal to the speed of sound in air (c = 340.29ms^{-1} @ sea level) divided by two times the distance between the source and the target (d). The multiplier of "two" represents the round trip that the sound must travel between the source and the object. Based on this formula, the distance from the object can be defined as:

$$d = c * t/2$$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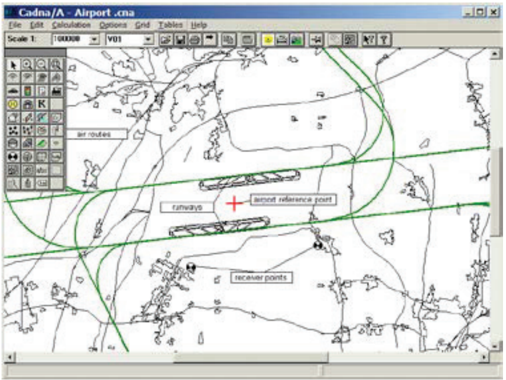
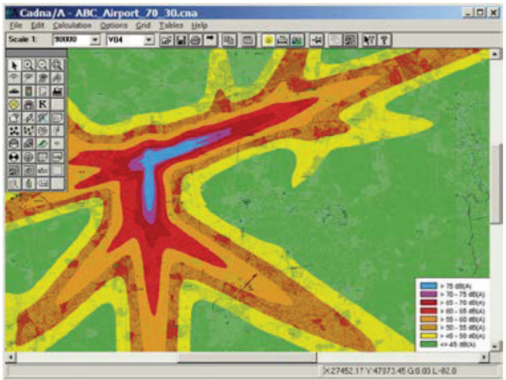


The geometric objects for description of an airport



Noise contours around a heavily used airport

The calculation of aircraft noise with Option FLG is equivalent to the calculation for other types of noise like industry, roads, and railways. This means that in examining the total noise e.g. for the calculation of noise maps the aircraft noise emissions can be seamlessly integrated in the overall assessment.

Features

- Calculation of aircraft noise at predefined receiver points and on a grid
- All relevant international methods implemented (INM 7.0, AzB 2008, ECAC Doc. 29 (2nd/3rd Edition), DIN 45684-1)
- Calculation of noise contours for the noise indicators L_{den} and L_{night}
- Library with predefined aircraft groups (aircraft and helicopters)
- Import of flight traffic data via ODBC-connection
- Completely implemented into the CadnaA user interface
- Can be combined with all other noise types (industry, road, railway)

Echolocation in Nature

Echolocation is a localisation and mobility technique that is common in nature. Animals such as bats, whales, dolphins and even some birds use echolocation as their primary means of navigation [20]. Echolocation is usually used in environments where light is limited e.g. underwater, or in caves. The visual information in these environments is unreliable and animals have adapted to use a more reliable means to understand their environments in the form of sound.

Human Echolocation

Echolocation is also used by a small number of people with visual impairment as their primary means of mobility. Two of the most widely known users of echolocation are Ben Underwood and Daniel Kish. Ben Underwood lost his vision to retinal cancer at the age of two, discovering echolocation at the age of five he was eventually capable of complex tasks such as rollerblading, playing basketball and running relying solely on echolocation [21].

Daniel Kish, who is himself blind, teaches others how to use echolocation [22]. Nicknamed 'FlashSonar', Kish uses tongue clicks and hand claps to get instances of his environment from the echoes (hence "flash").

Each click gives an instance of the environment around the person, but as environments tend to change constantly, the clicks have to be produced at a rate that will keep the person informed. When sense and logic was applied to simple information gained by echolocation (e.g. distance, height, width and density), Kish found he could form a detailed understanding of his surroundings. He writes:

> *For example an object that is tall and narrow may be recognized quickly as a pole. An object that is tall and narrow near the bottom while broad near the top would be a tree. Something that is tall and very broad registers as a wall or building [23].*

As a child, his self-taught version of echolocation allowed him to roam independently without the need from a cane or guide dog as a primary aid.

CURRENTLY AVAILABLE SONAR DEVICES

Sonar systems for the visually impaired [6, 8], virtual environments [24] and robots [25] have largely been designed to simulate the echolocation responses of bats. Is this the most reasonable approach to take for designing sonar systems for humans? Bats have large pinnae or outer ears that they can move independently to determine direction [26]. They can send out clicks that are frequency dependent and orient their ears upon approach to most effectively gather the information from the signal.

Humans don't have the ability to change the direction of their pinnae, nor is interpretation of frequency sweeps intuitive. Systems that attempt to simulate bat echolocation require methods to compensate for this lack of pinnae movement. Dolphins also perform echolocation but they do not have pinnae that change direction. Perhaps a more intuitive display is required, similar to that of the dolphins, rather than one that requires processing of the signal.

THE AUDEO DEVICE

The AUDEO device transmits an ultrasound signal and provides audible sounds to the user based on the size and distance of any obstacles. In this sense, it is similar to a dolphin that transmits and receives ultrasound signals. However, unlike the use of ultrasound in nature, the AUDEO transmits a continuous signal from a point source ultrasound transmitter, then receives signals from environmental reflectors.

Continuous Transmit Frequency Echolocation

The AUDEO is described as an echolocation device as it uses sound reflections for guidance and navigation. It differs from standard echolocation methods, like those exhibited by bats, dolphins or modern sonar systems, in that it employs a continuous rather than discrete method of sound transmission.

As mentioned earlier, the discrete echolocation technique works by transmitting a brief 'chirp' or 'click' of noise then pausing, while the sound wave propagates until it is reflected off an object and the echo returns to the source. The difference in time from the transmitted 'chirp' and the reflected echo determines the distance to an object.

The AUDEO, however, transmits a continuous 40 kHz ultrasound signal. After reflecting off environmental obstacles, two receivers collect the echoed sound. The amplitude (intensity) is a result of the sound absorbance index of the reflecting surface and the distance from it.

The Doppler shift caused by the relative movement of the sound source and reflecting surface produces a relative sound frequency change as described below that can be heard within the auditory range.

Doppler Effect

The Doppler Effect describes the relationship between the wavelength of a sound, and the relative motion of the observer and source [27]. When a sound source is moving towards an observer the sound wave is compressed in the direction of movement, while the wave expands in the reverse direction (Figure 1). Therefore the wavelength is altered. As the wavelength and sound frequency are inversely proportional it can be seen that:

$$f = ((c+v_o)/(c+v_s))\, f_o$$

This equation shows that the observed frequency (f) is proportional to the relative speed of the source (v_s) and observer (v_o), the speed of the sound though the medium (c) and the frequency at the source (f_o).

Doppler Shift

The AUDEO uses 40 kHz transmission signals that are intentionally beyond the natural human hearing range. This means that the device can be used discretely without drawing unwanted or unnecessary attention to the user. This frequency is also above the range that a guide dog can hear. It is coincidentally the case that when echolocating using noise in an audible range the Doppler Effect is less pronounced. As the Doppler formula shows

$$f_{delta} = f_o(1 - (c + v_o)/(c + v_s))$$

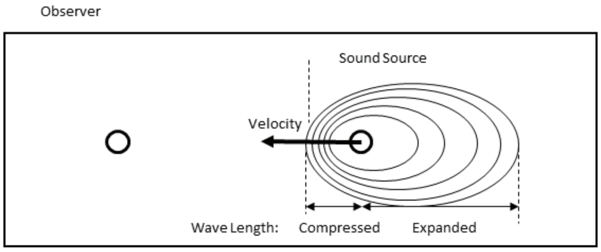


Figure 1 An observer perceives a shift in frequency as a result of movement toward a sound source.

The change in frequency (f_{delta}) is proportional to the transmitted frequency (f_o). Therefore a higher transmission frequency creates a larger, more detectable shift in pitch (frequency), given the same relative velocity between the observer and obstacle (v_o/v_s).

Down Sampling

The AUDEO device uses intentional aliasing to transform the received high frequency, Doppler shifted reflections to an audible range via the process of direct down-conversion or "down sampling" [28]. Using a 40 kHz sampling rate, equal to the transmitted signal, the sound is intentionally aliased.

The final output is the difference between the transmitted signal and the received signal which, at normal walking speeds, results in a signal within the audible range. If movement does not occur, no sound is received by the observer in the audible range, but when moving, the frequency of sound is based on the speed of movement toward or away from the obstacle. This signal is amplified and provided to the user via speakers.

Orientation of Receivers

Unlike typical sonar systems, the receivers on the AUDEO device are outward facing. Although this reduces the signal to noise ratio, it has been found that participants perform as accurately, if not more accurately with the outward orientation [29, 30].

AUDEO TESTING

When avoiding obstacles, the ability to localise the sound source is important as the direction of the hazard determines the reaction strategy. The AUDEO device's ability to localise an ultrasonic point source sound was compared to a person's natural ability to localise audible point source sounds [29]

The tests showed that the participants could detect the general direction of the sound source; however, the participants tended to underestimate the angle of direction the further the speaker was off-centre. Testing also attempted to gauge the participant's ability to localise sound in the vertical plane; however, no significant observations were discovered.

Another experiment was developed to compare an approximation of distance using echolocation via the AUDEO device as compared to audible echoes [31]. There was no discernible difference in the accuracy of approximation between the conditions at shorter distances (<2.5m). There was, however, a difference in accuracy at the further distances (>2.5). Under the auditory conditions, the perceived distance was much closer than the actual distance whereas the AUDEO device allowed a better distance estimate.

Recent Developments

Miniaturising the earpiece, from the large over ear earphones to smaller ear buds, allowed the receivers to be positioned much deeper inside the ear. With the new in the ear (ITE) buds, three additional human participant tests were performed to evaluate static and dynamic localisation [32].

As suggested earlier, horizontal localisation is largely dependent on interaural time, intensity and frequency differences. The horizontal sound source localisation task and the dynamic target localisation task, both of which are based on the participant's horizontal localisation ability, demonstrated that the ITE and OTE (outside the ear) receiver placement performances were equivalent. There was no evidence of diminished performance with the use of the ITE device.

As a result of the redesign, there was noticeable improvement in the vertical localisation ability of the participants using the ITE when compared to the results of the previous OTE style. The evidence suggests an improvement for the broad understanding of what is above or below them. There is also an apparent trend, from the limited test population, to suggest that the ITE design improves the finer details of sound source localisation.

The dynamic target localisation test demonstrated the AUDEO device's ability to differentiate among different materials. There was an observable difference in the participant's ability to locate the target relative to the material used, with more acoustically reflective materials easier to detect. As objects that are more acoustically reflective tend to be structurally more solid, it could be argued that they pose more of a threat to individuals with visual impairments and therefore the AUDEO device's ability to clearly identify them is an advantage. Overall, the change in the audible response provided by the device for different materials is important. This variation could be used by an experienced user to identify and distinguish different objects from one another, greatly improving the user's environmental understanding.

The most significant change to the testing procedure was to move the location of the experiment from an anechoic chamber into a standard room. The change from the anechoic chamber was expected to more truly represent the real-world conditions. The results in an echoic condition were consistent with results from earlier testing.

Testing with Visually Impaired Participants

While much of the device testing has been undertaken by blindfolded visually able participants, the AUDEO device has been evaluated briefly by two members of Royal New Zealand Foundation of the Blind (RNZFB) as well as an orientation and mobility instructor. The feedback has generally been fairly positive. Statements about the device include "A device like this enhances the potential of the blind traveller to be more independent and gives them more information to be able to make good decisions" [33] and "What the device was doing was giving me information through sound" "I could actually hear things around me I otherwise wouldn't have known were there."[34]

Positive responses from members of the Royal New Zealand Foundation of the Blind suggest that this device will be of benefit, but it is also important to remember that additional usability testing and iterative design must also be undertaken.

SUMMARY/CONCLUSION

The development and testing of the AUDEO device has been iterative and methodical, testing blindfolded users in an anechoic environment, moving to a more natural environment, and finally testing with blind users. The AUDEO has been shown to be effective as a "pick up and use" device with no training required by individuals with visual impairment. The next stage of this research is to perform focus groups and usability testing with blind users, with progressively smaller iterations of the device. For more information, and various videos of the testing, please see references [33, 34], and the website:
https://sites.google.com/site/tclairedavies/research-fun

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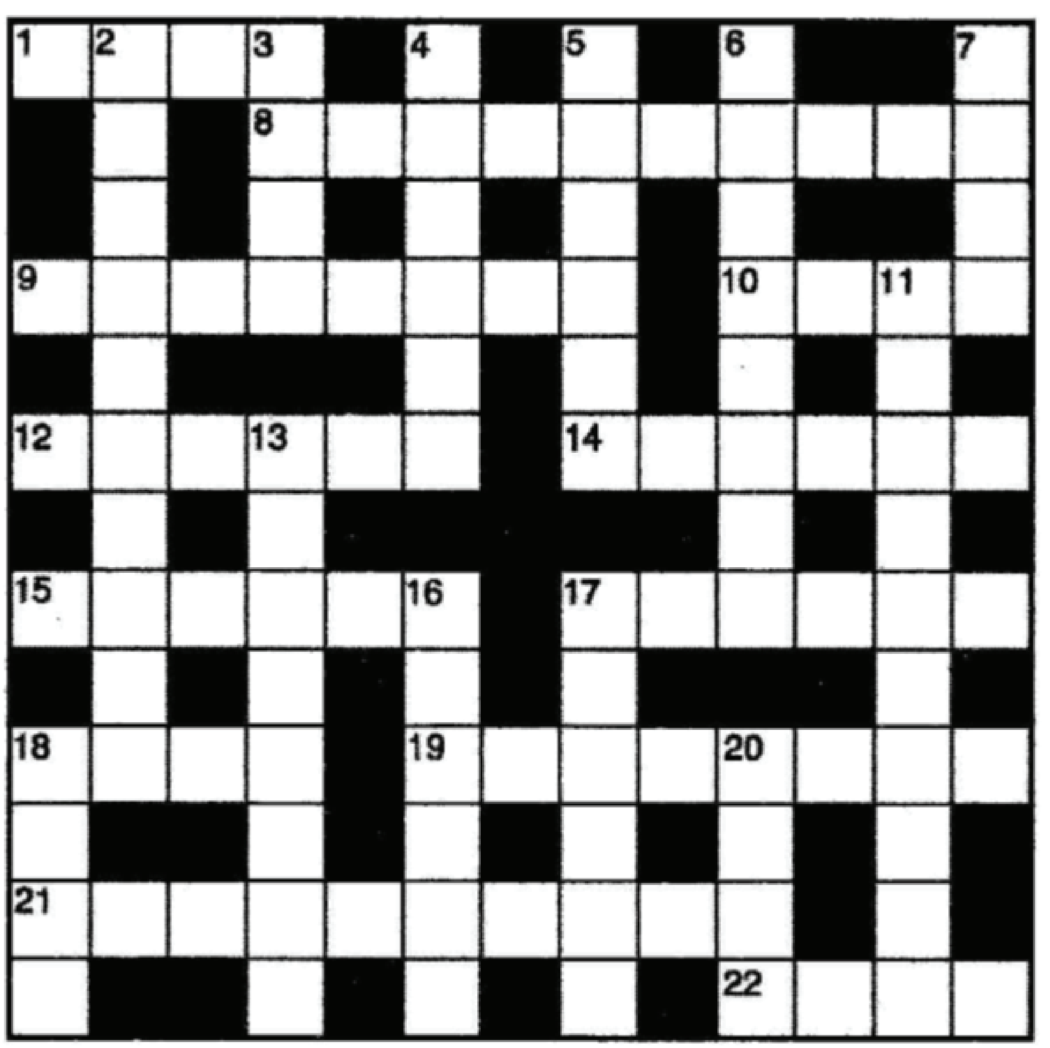
Acoustics Crossword #10



Crossword #10 Clues

Across:

1. Loose and undamped (4)

8. We hear it and are not inclined to give its measure in dB's (5,5)

9. Thinks and redirects a sound (8)

10. It has a mixed tone (4)

12. He's at home on the vibraphone (6)

14. Sounds of destruction indicate someone is up to …. (2,4)

15. Were tape heads not impartial? (6)

17. One song in a groove? (1,5)

18. Neighbours from here can be devilishly noisy (4)

19. Does it keep our hearing watered? (3,5)

20. Christmas entertainments comprising noisy breathing round a ring and soundless dramas (10)

(22) The ASNZ organized this in 2010 (4)

Down:

2. Descriptive of a sound coming again and again (10)

3. English for Speakers of Other Languages (4)

4. Sweet, melodious and harmonious (6)

5. Thanks to him lights got screwed and we got gramophones! (6)

6. Between 10 and 20 he can be very noisy (8)

7. This is one for this! (5)

11. A factor of four in frequency (3,7)

13. To do this may solve the noise problem (8)

16…and then these may be sweet for those retired (6)

17. A New Zealand term for non-noise subjective sounds (5)

18. Two of these are needed to begin a united cheer (4)

20. The keeper of standards in the US (4)

By: Dogged Doer


FORMAN
BUILDING SYSTEMS
FOR YOUR TOTAL ACOUSTIC INSULATION NEEDS

The sound of music… is irrelevant

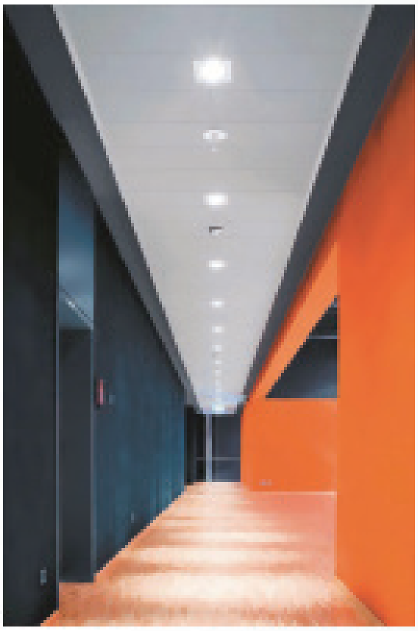
What makes a truly great live musical performance? People consistently report that sound is the most important source of information in evaluating performance in music. However, findings from recent work demonstrate that people actually depend primarily on visual information when making judgments about music performance.

This is the conclusion of work done at University College London that studied people's evaluations of classical musicians performing during competitions (CJ. Tsay (2013) "Sight over sound in the judgment of music performance" Proc Natl Acad Sci U S A. doi: 10.1073/pnas.1221454110).

Both experts and novices alike were given clips from performances at a musical competition and rewarded to accurately guess the winner based on the clips. Across all the experiments, those given the chance to view muted, video-only clips from the competition consistently performed the best when asked to identify the winner.

This is somewhat surprising, given how much most of us consider music to be an auditory experience. The study's author, Chia-Jung Tsay obtained complete audio and video recordings of 10 different classical music competitions, each of which featured three different finalists. At the end of each competition, a panel

Continued on Page 35...



...Continued from Page 33

of expert judges had chosen a winner based on these performances. Tsay then divided these up into shorter clips, some of which featured audio, some video, and others both. She then recruited a large panel of volunteers (some of them professional musicians).

When given the full performance, the novices performed about as well as the experts—and that turned out to be not well at all. With only three clips, they'd be expected to choose the winner a third of the time due to random chance alone. With the full performance, they only managed to guess correctly 35 percent of the time. Those who were given audio-only clips did even worse, getting it right 29 percent of the time.

But the surprise came from those given only visual clips. They got it right 46 percent of the time.

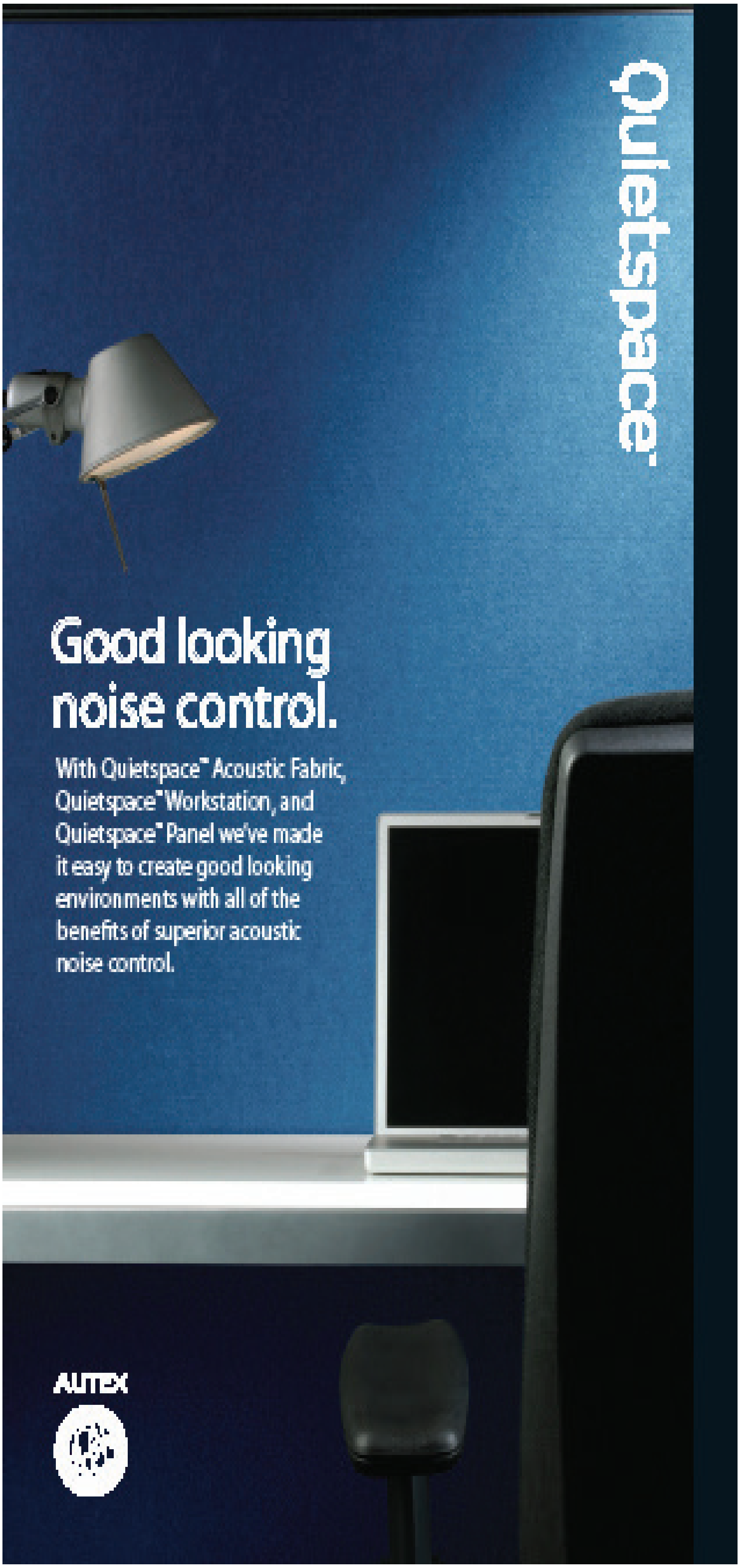
Pros generated similar numbers. Although the number of participants was small and the precise numbers varied from experiment to experiment, having the full audio and visual performance left everyone near random chance when it came to guessing the winner; those with audio-only clips did worse, while those with video of the performance did better. When novices were given either audio-only or visual-only clips, the ones given the visuals doubled the accuracy of the people who were stuck with only sound.

What is this telling us? Participants were shown silent clips and asked to rate the performance on a variety of factors, such as passion and creativity. High ratings for a number of factors—passion, involvement, motivation, creativity, and uniqueness—were all associated with an improved chance of picking the contest winners. (It is notable that all of these factors are very subjective).

The focus on visuals is something that happens in a variety of contexts, so it shouldn't be a surprise that novice musicians do it. What is somewhat surprising, according to the article, is that it happens with the pros, too: "It is unsettling to find—and for musicians not to know—that they themselves relegate the sound of music to the role of noise."

©Adapted from work by John Timmer

Ars Technica 2013



2014

10 -13 March, 8th International TRI Tinnitus Conference, Auckland, NZ
http://www.conference.co.nz/tri14

5 - 9 May, 167th Meeting of the Acoustical Society of America, Providence, USA
http://www.acousticalsociety.org

6 - 10 July, 21st International Congress on Sound and Vibration (ICSV21), Beijing, China
http://www.icsv21.org/

07 -12 September, Krakow, Poland Forum Acusticum 2014
http://www.fa2014.pl/

08 -10 September, Fort Lauderdale, USA
Noise-Con 2014
http://www.inceusa.org/nc14/

29 September - 1 October, Berlin, Germany
16th International Conference on Low Frequency Noise and Vibration and its Control
http://www.lowfrequency2014.org

06 - 10 October, Prague, Czech Republic 11th European Conference on Non Destructive Testing
http://www.ecndt2014.com/

27 - 31 October, 168th Meeting of the Acoustical Society of America, Indianapolis, USA
http://www.acousticalsociety.org

16 - 19 November, Melbourne, Australia
Internoise 2014
http://www.internoise2014.org

2015

18 - 22 May, Pittsburgh, USA
169th Meeting of the Acoustical Society of America
http://www.acousticalsociety.org

12 - 16 July, Brescia, Italy
22nd International Congress on Sound and Vibration (ICSV 22)
http://www.iiav.org

31 May - 3 June, Maastricht, Netherlands
Euronoise 2015
https://www.euracoustics.org/events/events-2015

CRAI Ratings

Auckland

215, Dominion Rd	(1)	★★★★½
Andrea (form. Positano), Mission Bay	(1)	★★★
Aubergine's, Albany	(1)	★★★★½
Backyard, Northcote	(1)	★★
Bask, Browns Bay	(1)	★★★
Bay (The), Waiake, North Shore	(1)	★★★★★
Bolero, Albany	(1)	★★★★
Bosco Verde, Epsom	(1)	★★★★½
Bouchon, Kingsland	(1)	★★
Bowman, Mt Eden	(1)	★★★★½
Bracs, Albany	(1)	★★★★
Brazil, Karangahape Rd	(1)	★★★
Buoy, Mission Bay	(2)	★★★★½
Byzantium, Ponsonby	(1)	★★★
Café Jazz, Remuera	(1)	★★★★½
Carriages Café, Kumeu	(1)	★★★★
Charlees, Howick	(1)	★★★★★
Cibo	(1)	★★★★★
Circus Circus, Mt Eden	(1)	★★
Cube, Devenport	(1)	★★
Del Fontaine, Mission Bay	(1)	★★★★★
Deli (The), Remuera	(1)	★★★★
Delicious, Grey Lynn	(1)	★★★★★
De Post, Mt Eden	(1)	★★
Dizengoff, Ponsonby Rd	(1)	★★
Drake, Freemans Bay (Function Room)	(1)	★★
Eiffel on Eden, Mt Eden	(1)	★★
Eve's Cafe, Westfield Albany	(1)	★★★½
Formosa Country Club Restaurant	(1)	★★★★★
Garrison Public House, Sylvia Park	(1)	★★★★½
Gee Gee's	(1)	★★★
Gero's, Mt Eden	(9)	★★★
Gina's Pizza & Pasta Bar	(1)	★★★½
Gouemon, Half Moon Bay	(1)	★★
Hardware Café, Titirangi	(1)	★★★★★
Hollywood Café, Westfield St Lukes	(1)	★★½
IL Piccolo	(1)	★★★★
Ima, Fort Street	(1)	★★★★
Jervois Steak House	(1)	★★★
Kashmir	(1)	★★★★
Khun Pun, Albany	(2)	★★★★★
Kings Garden Ctre Café, Western Springs	(1)	★★
La Tropezienne, Browns Bay	(1)	★★
Malaysia Satay Restaurant, Nth Shore	(1)	★★★★★
Mecca, Newmarket	(1)	★★★★★
Mexicali Fresh, Quay St	(1)	★★
Mezze Bar, Little High Street	(16)	★★★★
Monsoon Poon	(1)	★★★★★
Mozaike Café, Albany	(1)	★★
Narrow Table (The), Mairangi Bay	(1)	★★★★½
One Red Dog, Ponsonby	(1)	★★★
One Tree Grill	(1)	★★★
Orbit, Skytower	(2)	★★★★
Patriot, Devonport	(1)	★★★½
Pavia, Pakuranga	(1)	★★★★★
Prego, Ponsonby Rd	(2)	★★
Remuera Rm, Ellerslie Racecourse	(1)	★★★★★
Rhythm, Mairangi Bay	(1)	★★
Rice Queen, Newmarket	(12)	★★★★
Sails, Westhaven Marina	(2)	★★★★★
Scirocco, Browns Bay	(1)	★★★
Seagers, Oxford	(1)	★★★★
Shahi, Remuera	(1)	★★★½
Shamrock Cottage, Howick	(1)	★★
Sidart, Ponsonby	(1)	★★★★½
Sitting Duck, Westhaven	(1)	★★★½
Sorrento	(1)	★★½
Stephan's, Manukau	(1)	★★★★★
Tempters Café, Papakura	(1)	★★★★★
Thai Chef, Albany	(1)	★★★★★
Thai Chilli	(1)	★★★★★
Thai Corner, Rothesay Bay	(1)	★★★★★
Tony's, High St	(1)	★★★
Traffic Bar & Kitchen	(1)	★★
Umbria Café, Newmarket	(1)	★★★★½
Valentines, Wairau Rd	(1)	★★★★★
Vivace, High Street	(2)	★★½
Wagamama, Newmarket	(1)	★★★★½
Watermark, Devonport	(1)	★★
Woolshed, Clevedon	(1)	★★½
Zarbos, Newmarket	(1)	★★
Zavito, Mairangi Bay	(1)	★★ ★

Arthur's Pass

Arthur's Pass Cafe & Store	(1)	★★★½
Ned's Cafe, Springfield	(1)	★★★★

Ashburton

Ashburton Club & MSA	(1)	★★★★½
Robbies	(1)	★★★
RSA	(1)	★★★★

Readers are encouraged to rate eating establishments which they visit by completing a simple form available on-line from www.acoustics.ac.nz, or contact the Editor.
Repeat ratings on listed venues are encouraged.

★ Lip-reading would be an advantage. ★★ Take earplugs at the very least. ★★★ Not too bad, particularly mid-week. ★★★★A nice quiet evening. ★★★★★The place to be and be heard. (n) indicates the number of ratings.

Tuscany Café & Bar	(1)	★★★

Bay of Plenty

Alimento, Tauranga	(1)	★½
Imbibe, Mt Maunganui	(1)	★½
Versailles Café, Tauranga	(2)	★★

Blenheim

Raupo Cafe	(1)	★★

Bulls

Mothered Goose Cafe, Deli, Vino	(1)	★★

Cambridge

GPO	(1)	★★★★★

Christchurch

3 Cows, Kaiapoi	(1)	★★★★
Abes Bagel Shop, Mandeville St	(1)	★★★★
Alchemy Café, Art Gallery	(1)	★★★★★
Anna's Café, Tower Junction	(1)	★★★★
Arashi	(1)	★★
Azure	(2)	★★★
Becks Southern Ale House	(11)	★★★★½
Bridge (The), Prebbleton	(1)	★★★★★
Buddha Stix, Riccarton	(1)	★★★★
Bully Haye's, Akaroa	(1)	★★
Café Valentino (St Asaph St)	(1)	★★★
Cashmere Club	(1)	★★★★★
Chinwag Eathai, High St	(8)	★★
Christchurch Casino	(1)	★★
Christchurch Museum Café	(1)	★★★★
Cobb & Co, Bush Inn	(1)	★★★
Coffee Shop, Montreal Street	(1)	★★
Cookai	(3)	★★½
Cortado, Colombo Street	(4)	★★★★
Costas Taverna, Victoria Street	(1)	★½
Coyote's	(6)	★★★
Curator's House	(25)	★★★½
Decadence Café, Victoria St	(1)	★★★★★
Drexels Breakfast Restaurant, Riccarton	(1)	★★★★
Elevate, Cashmere	(6)	★★★
Fava, St Martins	(1)	★★
Foo San, Upper Riccarton	(1)	★★★½
Fox & Ferrett, Riccarton	(1)	★★★★★
Freemans, Lyttleton	(9)	★★★½
Gloria Jean's, Rotheram St	(1)	★★★★
Golden Chimes	(1)	★★★★★
Governors Bay Hotel	(1)	★★★★
Green Turtle	(1)	★★★★
Harpers Café, Bealey Ave	(1)	★★★★★
Hari Krishna Café	(1)	★★★
Holy Smoke, Ferry Rd	(1)	★★
Indian Fendalton	(2)	★★
Joyful Chinese Rest., Colombo St	(1)	★★★★★
Kanniga's Thai	(1)	★★★
La Porchetta, Riccarton	(4)	★★½
Lone Star, Riccarton Road	(6)	★★★
Lyttleton Coffee Co, Lyttleton	(1)	★★★★
Manee Thai	(6)	★★½
Merrin Street (Monteiths)	(2)	★★½
Mexican Café	(6)	★★★
Myhanh, Church Corner	(4)	★★★½
Number 4, Merivale	(2)	★★★★
Oasis	(1)	★★★★½
Old Vicarage	(2)	★★★½
Phu Thai, Manchester Street	(1)	★★★
Portofino	(3)	★★★★★
Pukeko Junction, Leithfield	(1)	★★★★
Red, Beckenham Service Centre	(1)	★★★★
Red Elephant	(1)	★★★★
Retour	(1)	★★★
Riccarton Buffet	(2)	★★★★½
Robbies, Church Corner	(2)	★★★★½
Route 32, Cust	(1)	★★★★
Salt on the Pier, New Brighton	(6)	★★★½
Sand Bar (The), Ferrymead	(2)	★★★½
Speights Ale House, Ferrymead	(3)	★★★★★
Speights Ale House, Tower Junction	(1)	★★★★
Tokyo Samurai	(1)	★★★★★
Tutto Bene, Merivale	(2)	★★
Twisted Hop (The), Woolston	(3)	★★★★½
Untouched World Cafe	(1)	★★★★★
Venuti	(3)	★★★★★
Visions Restaurant, CPIT	(1)	★★
Waitikiri Golf Club	(1)	★★
Waratah Café, Tai Tapu	(1)	★★★

Clyde

Old Post Office Cafe	(1)	★★★★★

Dunedin

A Cow Called Berta	(1)	★★★½
Albatross Centre Cafe	(1)	★★★★★
Bennu	(1)	★★★★
Bx Bistro	(1)	★★★★
Chrome	(1)	★★★★½
Conservatory, Corstophine House	(1)	★★★★★
Fitzroy Pub on the Park	(1)	★★★★★
High Tide	(2)	★★

CRAI Ratings (cont.)

Nova	(1)	★★★★★
St Clair Saltwater Pool Cafe	(1)	★★★★½
Swell	(1)	★★
University of Otago Staff Club	(1)	★★

Feilding

Essence Cafe & Bar0	(1)	★★★★

Gore

Old Post	(1)	★★★
The Moth, Mandeville	(1)	★★★★★

Greymouth

Cafe 124	(1)	★★★

Hamilton

Embargo	(1)	★★★★★
Gengys	(1)	★★
Victoria Chinese Restaurant	(1)	★★★★★

Hanmer Springs

Coriander's	(2)	★★★★½
Laurels (The)	(2)	★★★★★
Saints	(1)	★★★★½

Hastings

Café Zigliotto	(1)	★★★

Havelock North

Rose & Shamrock	(1)	★★★½

Levin

Traffic Bar & Bistro	(1)	★★

Masterton

Java	(1)	★★

Matamata

Horse & Jockey	(1)	★★★★★

Methven

Ski Time	(2)	★★★

Napier

Boardwalk Beach Bar	(2)	★★★★★
Brecker's	(1)	★★★★★
Café Affair	(1)	★★
Cobb & Co	(1)	★½
Duke of Gloucester	(1)	★★★★½
East Pier	(1)	★★
Estuary Restaurant	(1)	★★★★★
Founder's Cafe	(1)	★★★★★
Napier RSA	(1)	★★★★★
Sappho & Heath	(1)	★★

Nelson/Marlborough

Allan Scott Winery	(1)	★★★★★
Amansi @ Le Brun	(1)	★★★★★
Baby G's, Nelson	(1)	★★★★★
Boatshed Cafe (The)	(1)	★★★★
Boutereys, Richmond	(1)	★★★★
Café Affair, Nelson	(1)	★★
Café on Oxford, Richmond	(1)	★★★
Café Le Cup, Blenheim	(1)	★★★
Crusoe's, Stoke	(1)	★★★
Cruizies, Blenheim	(2)	★★★★½
Grape Escape, Richmond	(1)	★★★★★
Jester House, Tasman	(1)	★★★★★
L'Affaire Cafe, Nelson	(1)	★★
Liquid NZ, Nelson	(1)	★½
Lonestar, Nelson	(1)	★★★★
Marlborough Club, Blenheim	(1)	★★
Morrison St Café, Nelson	(1)	★★½
Oasis, Nelson	(1)	★★★★★
Rutherford Café & Bar, Nelson	(1)	★★★★★
Suter Cafe, Nelson	(1)	★★
Verdict, Nelson	(1)	★★
Waterfront Cafe & Bar, Nelson	(1)	★★★
Wholemeal Trading Co, Takaka	(1)	★★★★★

New Plymouth

Breakers Café & Bar	(1)	★★★
Centre City Food Court	(1)	★★★★
Elixer	(1)	★★★★
Empire Tea Rooms	(1)	★★★★½
Govett Brewster Cafe	(1)	★★
Marbles, Devon Hotel	(1)	★★★
Pankawalla	(1)	★★★★★
Simplicity	(1)	★★★
Stumble Inn, Merrilands	(1)	★★★
Yellow Café, Centre City	(1)	★★★
Zanziba Café & Bar	(1)	★★★

Oamaru

Riverstone Kitchen	(1)	★★★★★
Star & Garter	(1)	★★★
Woolstore Café	(1)	★★★★

Palmerston North

Café Brie	(1)	★★★
Café Esplanade	(2)	★★★★
Chinatown	(1)	★★★★
Coffee on the Terrace	(2)	★★★
Elm	(1)	★★★★½
Fishermans Table	(1)	★★★★★

Gallery	(3)	★★★★
Rendezvous	(1)	★★½
Roma Italian Restaurant	(1)	★★★
Rose & Crown	(1)	★★
Tastee	(1)	★★★
Thai House Express	(1)	★★★★★
Victoria Café	(1)	★★★★

Queenstown

Bunker	(1)	★★★★
The Cow	(1)	★★★
Sombreros	(1)	★
Tatler	(1)	★★★★
Winnies	(1)	★★★★★

Rotorua

Cableway Rest. at Skyline Skyrides	(1)	★★★★★
Lewishams	(1)	★★★
Woolly Bugger, Ngongotaha	(1)	★★★
Valentines	(1)	★★★★★
You and Me	(1)	★★★★★
Zanelli's	(1)	★★

Southland

Lumberjack Café, Owaka	(1)	★★★★★
Pavilion, Colac Bay	(1)	★★
Village Green, Invercargill	(1)	★★★★★

Taihape

Brown Sugar Café	(1)	★★★★½

Taupo

Burbury's Café	(1)	★★★
Thames		
Thames Bakery	(1)	★★★
Waiheke Island		
Cortado Espresso Bar	(1)	★★★★
Cats Tango, Onetangi Beach	(1)	★★★★

Timaru

Fusion	(1)	★★★★★

Wanganui

3 Amigos	(1)	★★★½
Bollywood Star	(1)	★★★½
Cosmopolitan Club	(1)	★★★★
Liffiton Castle	(1)	★★½
RSA	(1)	★★★½
Stellar	(1)	★★★★½
Wanganui East Club	(1)	★★★★

Wellington

162 Café, Karori	(1)	★★★★★
180o, Paraparaumu Beach	(1)	★★
88, Tory Street	(35)	★★
Anise, Cuba Street	(1)	★★
Aranya's House	(1)	★★★★★
Arbitrageur	(2)	★★★
Arizona	(1)	★★
Astoria	(2)	★★★
Backbencher, Molesworth Street	(1)	★★★
Bordeaux Bakery, Thorndon Quay	(1)	★★
Brewbar (function room)	(49)	★★★
Brown Sugar, Otaki Railway Station	(1)	★★★
Buzz, Lower Hutt	(1)	★★½
Brewery Bar & Restaurant	(5)	★★★★
Carvery, Upper Hutt	(1)	★★★★★
Chow	(1)	★½
Cookies, Paraparumu Beach	(1)	★★★½
Cosa Nostra Italian Trattoria, Thorndon	(1)	★★★★
Gotham	(6)	★★★½
Great India, Manners Street	(2)	★★★★★
Habebie	(1)	★★
Harrisons Garden Centre, Peka Peka	(1)	★★★★
Hazel	(1)	★★
Katipo	(1)	★★★★★
Kilim, Petone	(4)	★★★★½
Kiss & Bake Up, Waikanae	(1)	★★★
La Casa Pasta	(1)	★★★★½
Lattitude 41	(3)	★★★★
Legato	(1)	★★
Le Metropolitain	(1)	★★★★★
Loaded Hog	(5)	★★★★½
Manhatten, Oriental Bay	(1)	★★★★
Maria Pia's	(1)	★★★
Matterhorn	(1)	★★★
Mungavin Blues, Porirua	(1)	★★★★★
Olive Cafe	(1)	★★★★★
Olive Grove, Waikanae	(1)	★★★½
Original Thai, Island Bay	(1)	★★★★
Palace Café, Petone	(1)	★★½
Parade Café	(1)	★★
Pasha Café	(1)	★★★★
Penthouse Cinema Café	(2)	★★★½
Pod	(1)	★★½
Rose & Crown	(1)	★★★★★
Shed 5	(1)	★★
Siem Reap	(1)	★★
Speak Easy, Petone	(1)	★★
Speights Ale House	(1)	★★
Sports Bar Café	(1)	★★★★
Stanley Road	(1)	★★★
Stephan's Country Rest., Te Horo	(1)	★★★★★
Wakefields (West Plaza Hotel)	(1)	★★★
Windmill Café & Bar, Brooklyn	(1)	★★
Yangtze Chinese	(1)	★★★★½
Zealandia Café, Karori Sanctuary	(1)	★★★½