Acoustic Design in the Built Environment

By Nigel Frayne

As predicted by Schafer, while the lessons of music may guide us, the art and science of acoustic design will be the process of applying a set of principles such that the by-product of our actions in the built environment may be turned to positive advantage. [1]

INTRODUCTION

The focus of this essay will be on the real world practice of an acoustic designer, myself, working with a science centre, a zoological garden and a centre for the moving image. Each of these public institutions resolved to give due consideration of their acoustic environment within the development of their public programmes, particularly as they were delivered by way of eletroacoustic systems. In as much as these sites are components of our global soundscape it may be of interest to view them as designed elements which stand in relief to the ad hoc sonic by-products found in the wider built environment. The three settings presented are chosen for their apparent diverse requirements. Of particular interest is the inherent balance between technical and creative processes that have to be applied and the decision-making process of the acoustic designer.

Music, Sound and Acoustic Design

Music, acoustic engineering, soundscape design, sound sculpture, sound composition, sound art, sound engineering and sound design. This plethora of terms has emerged from a need to define the finer points and approach of the broad range of people working with sound, what we might call sound practitioners. While these terms do provide some clarification there is also much confusion and cross pollination. For example 'sound design' has been adopted by a broad range of practitioners. There are those who design or craft a single sound, such as a phone ringing tone, warning signal or film sound effect. Sound design is also used to describe the creation of a sound track, perhaps for film or theatre, where the structure and movement of the sound is designed meaningfully into the 'dramascape'. Examples of this would include off screen effects (heard but not seen), artificial reverberation, panning effects across the soundstage as well as startling responses by way of abrupt changes in dynamic range or frequency. Sound design is even a title adopted by some music composers who wish to indicate that they are working with non-traditional instruments, particularly computer, electronic or machine produced sounds.

For many years I too worked under the title of sound designer. For me it described the activity of designing sound into a space where the creation of the content (the sound objects) was intrinsically mapped to the performance of the sound (the sounding space). The production of every sound (content) was deeply informed by the way in which it sounded (performed). For example, the voice of an actor reading the letter of an immigrant to Australia in a museum context would be designed to sound as real and natural as possible. The intent would be to create a sense of the presence of the person in the space, as equally intimate as the inner thoughts expressed in the letter. As such the desire would be for the loudspeaker delivery system and the recording process to be sonically 'invisible' or transparent. This would require a clean and dry (non-reverberant) recording, frequency equalisation to remove artefacts and colouration by the loudspeaker and perhaps DSP convolution to enhance the placement of the sound into the reverberant field of the exhibition space. Alternatively, the replay of a recording of a person such as, say, Winston Churchill would be more effectively exhibited as an historic artefact in its own right. Probably it would be delivered as a scratchy and 'un-natural' voice coming from a radio set dating from the 1940's.

Photography by Nigel Frayne

External view of East Atrium, ACMI, Federation Square, Melbourne

An exhibition will probably include quite a number of individual examples like the ones described above and it is immediately apparent that they will need to be carefully designed into the space. Each sound object with its inherent performance characteristic and informational content will collaborate with its neighbouring sound into a wider general ambience or soundscape. All introduced sound will have to coexist with the given or analogue environment; building reverberation and echo, hum from air conditioner plants and other equipment, visitor activity, voices and so on. The process of achieving a coherent and functional ambience, the structuring of a multitude of existing and introduced sounds, is therefore probably better described as soundscape or acoustic design. Given the multiple uses (and abuses) of the term soundscape these days, my preference now is to use the term acoustic design.

The dryness of the term acoustic design may imply that it is purely a technical quantitative process. As we will see in the following three projects, however, it may not be the case that all acts of acoustic design in the built environment are the result of apparent dehumanisation or mechanisation.

Photography by Nigel Frayne

Naturalistic habitat environment in the modern zoo, Elephants of Asia Exhibit, Singapore Zoological Gardens.

ZOO EXHIBITS

The modern zoo exhibit is a far cry from the historic spectacle of exotic animals behind bars. As a designed precinct the underlying purpose of the public areas is to bring the visitor closer to the animals, both physically and with respect to deeper understanding of their original non-captive life. The way this is achieved is by removing barriers between visitors and the animals and presenting a microcosm of their original habitat. Mock rock, landscaping and indicative vegetation is introduced together with interpretive materials such as related objects, text panels, labels and possibly even art works.

Sound plays a role too. In fact there are a great number of interpretive elements which may rely on the acoustic medium. There may be public address systems for site wide information and announcements and/or large animal shows and small 'keeper talks'. Many newer exhibits will include an audiovisual theatrette and other displays which incorporate sound—'push the button to hear the tiger growl', 'listen to our experts talk about the animals', or perhaps a video programme or computer interactive with sound reinforcement. Each of these elements will require a specific delivery system to be designed into the space which is explicitly tailored for the performance of that content. Voice programmes such as public address announcements or animal show presentations need a high intelligibility index and hence will require directional loudspeakers. A theatrette may call for a surround sound system and a soundtrack which further extends the context of the exhibit. An ambient soundscape will have a diffuse sound field usually delivered by way of vast arrays of loudspeaker networks.

The combination of all of these sounding elements places a lot of pressure on the acoustic environment and therefore a global acoustic design is essential. We will recognise that this example of a zoo precinct can also be translated into our modern urban environment with its proliferation of electroacoustic and acoustic delivery systems generally occurring in an ad hoc fashion. At least within an institution like a zoo we have the potential for an overall level of control and, by good example, can perhaps provide visitors with a subtle message about conservation of the soundscape together with those messages on habitat destruction and animal extinction.

One treatment that has been adopted by a number of the better resourced zoos is the creation of ambient habitat soundscapes. Studies have shown that visitors respond more emotionally to an exhibit, they learn more about animal-environment interactions and have increased awareness of the natural environment when ambient soundscapes are introduced.[2] While each project calls for individual approaches depending on the animal species lists, whether they are mixed environments or include elements of indigenous human culture, there is also a common methodology within the acoustic design, namely the creation of a texture composed of background, midground and foreground layers of authentic natural sounds.[3]

Inevitably there will be elements of the existing acoustic environment which are beyond the control of the acoustic designer whether it be the proximity of the airport in San Diego or the rattle of machine guns from defence exercise areas near the Singapore zoo. The introduction of habitat soundscapes into exhibits can help to alleviate such intrusions to some degree by masking these unwanted sounds (noise) while at the same time performing the desirable interpretive function of synchronising the acoustic space to the designed habitat. The Hamadryas Baboon Exhibit at Singapore requires the recreation of a sense of the acoustic environment of Ethiopia. The Lowland Gorilla Exhibit in San Diego requires the soundscape of the forests of Congo and the Elephants of Asia Exhibit features a rich forest ambience of South East Asia.

The interplay between content and performance is quite apparent within the composition of ambient habitat soundscapes. In general one can predict that there will be a universal hum of insect sounds occurring at a background level. However, this chorus may be interrupted from time to time within the midground zones of the exhibit depending on interaction with other elements such as the (sonic) presence of a predator. There will be birds which congregate in flocks in a single tree or midground area, solitary birds which move through their territory calling regularly to their distant mate, smaller groups of foraging birds chatting in almost inaudible (to humans) high frequencies and the occasional arrival of a raven or fishing eagle. All of these elements must be delivered within an unpredictable and yet totally believable naturalistic sonic environment.

Apart from the suspension of disbelief in visitors for effect there is also the issue of the captive animals themselves hearing and reacting to the sounds. I have heard of anecdotal examples, prompting debate in some circles, of researchers and field recordists using sound replay to attract or cause a reaction in wild birds particularly. In these cases the sounds used were specific calls of those species, not predators or other species, and there are arguments for and against their use. However, I am only aware of one study in which the effects of introduced sound on captive birds were studied for evidence of causing stress with the conclusion being negative for that species, Gouldian Finch.[4] Clearly, to be successful it is essential that the acoustic designer consider all aspects of both the existing as well as the introduced acoustic environment. This would include both the effects on visitors as well as for any other animals who may inhabit the precinct.

These ethical issues seem more acute in consideration of captive animals, however, without going so far as to suggest humans are in a captive situation, is it not reasonable to also apply the same requirements, of care and consideration, to the introduction of any sound into the environment? This basic concern clearly informs all decisions by the acoustic designer particularly when the acoustic space is put to a multitude of uses. For our example above, public address, interpretive sound, ambient habitat soundscapes and video soundtracks are naturally considered as elements within a larger global ecology that is the total zoo acoustic environment.

A VISITOR CENTRE

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) Discovery Centre in Canberra, Australia is an example of a modern exhibition space. The building itself has been designed to present a public image of a vibrant and exciting institution and features a central atrium where visitors can view working laboratories through a two storey glass wall. In addition to presenting the physical environment of the laboratories and education programmes for schools, the lower levels of the building contain a public exhibition featuring a cross section of the work carried out by CSIRO scientists.
(www.discovery.csiro.au)

Exhibit areas

The exhibition areas present research into the weather and energy, biodiversity and ecology, agriculture, medical and gene technology to name a few. As with the zoo examples above the role for the acoustic designer is to work with the exhibition and interpretive designers to synchronise the acoustic space within an overall cohesive functional design. Decisions will be made as to the best methods for presenting information to the visitors including text, graphics, video and sound.

The visitor path through the exhibitions begins with an audiovisual programme on a 10 minute loop. The repeating surround soundtrack has the potential to cause problems for the acoustic environment of adjacent spaces and hence was enclosed in a small theatrette. Rather than have people pushing through doors an open corridor was placed at the entrance and exit. An acoustic engineer was consulted to specify materials that would help to contain the sound from the open doorways and also 'design' the acoustics of the room by dampening wall and ceiling reflections. A large disc faced with absorptive material was floated above the primary viewing area into which an overhead loudspeaker was mounted. One loudspeaker was mounted in each corner and a centre channel loudspeaker was designed into the wall under the video screens. The programme soundtrack was mixed to the six channels using a hybrid of ambisonic[5] (for ambience) and mono (for localisation) signal formats.

The adjacent exhibit area deals with weather and energy and is comprised mostly of text and graphic materials. To help create a context and backdrop for this information a general soundscape was composed. The sonic texture of the sounds of wind and water, almost white noise, serve the additional function of masking the crosstalk from the theatrette and voices from the nearby information desk. From there visitors pass into an enclosed space which houses a display dealing with biodiversity and salinity. The decision to enclose this space was made in conjunction with the exhibit designer to enable the creation of a broad rural ambience without interference from and to the adjacent exhibitions. A four channel ambisonic soundscape was created from background sound materials, mainly insects, from the Australian bush. A mural on one side of the exhibit creates the sense of a distant horizon and in the foreground 8 species of bird and insect are on display. Visitors pick up a shotgun microphone and point it at the 'stuffed' animals hidden within the display to activate a sound recording. Occasionally these foreground sounds will be met by an answering call in the distance. The intention is to give visitors a sense of the practice of sound field recording carried out by the CSIRO scientists. An added feature is to provide visitors with a listening activity where they can identity an animal with a specific sound and also hear similar sounds from within the general rural ambience that has been simulated in the exhibit.

Photography by Nigel Frayne

Not much to see but plenty to listen to - soundscape area on pathway into the Elephants of Asia Exhibit, Singapore Zoological Gardens.

The processing of sound files into an ambisonic format for the background sound level helps to achieve a reasonably large sweet spot within the sound field where distance and perspective can be perceived. The general availability and increasing sophistication in DSP (digital signal processing) functions are providing us with very powerful tools to both generate the sound materials (sound design) and place them within a naturalistic and very believable sound field (acoustic design).

Architecture

In the case of both the zoo and exhibition examples presented so far it can be observed that there can be a direct correlation between the soundscape and the other elements comprising the functional and aesthetic design of a space. Essentially the composed soundscapes in these areas are predetermined and derivative. When we start to consider moving beyond these localised areas and consider transitional spaces and the architecture beyond, a whole new set of issues for the acoustic designer come into play.

Continuing with our virtual tour of the CSIRO Discovery Centre, we can move back away from the lower exhibition spaces and rethink our approach and entry into the building itself. As mentioned this is a striking, imaginative piece of architecture. One is experiencing the facility and an image of the institution, CSIRO, well before one has even entered the building. Is it reasonable that the only sound that would be heard from the car park, across the raised walkway, through the atrium, down the stairs and into the small theatrette would be the incidental flotsam of traffic, air conditioner hum, espresso machine and café sounds combined with conversation not intended for us? Is it reasonable that the building and CSIRO remain essentially mute at this point?

In an attempt to explore this deficiency in the overall precinct design a small extension to the soundscape system was introduced into the external areas and in the central atrium through which one passes to access any of the areas within. The acoustic design is quite elementary where sound is reflected off glass walls and delivered from high up in the atrium, where the reverberated energy of ambience also emanates. The content of this soundscape is a bit more perplexing since there are no functional requirements or features for direct correlation with sound. A somewhat different response is perhaps required whereby sound materials are manufactured which draw the sound and acoustic designer in to new creative territory.

As discussed, the facility is designed to present the public with an image of CSIRO scientists at work and some insight into the topics of their research. The soundscape that was composed for these areas external to the exhibition were comprised of a combination of both manufactured or synthesized sounds as well as a selection of natural sounds from within the exhibition, bird calls specifically, which were processed in various ways. This palate of ingredients was then mixed, matched and manipulated almost as a scientist would do in the laboratory. Single sine tones rise and fall or combine to form more complex tones. Grains of fragmented bird calls combine into clusters of at times completely unrecognisable sounds then reappear in their original and recognisable form. Given the highly reflective nature of the glass walled precinct and the desire not to overpower the general visitor ambience occurring on a human scale, most of the soundscape content is limited to the high frequency range. The tendency of high frequencies to predominate over lower ones works to overcome the mechanical hum of the air conditioning plant and the unnecessary reverberation within the atrium. The unusual nature of these sounds (there being no obvious reason for them to be occurring or sense of association with this place) and yet the inherent logic of their performance combine to create a sense of intention and control much as the structure and aesthetic of the architecture is a subtle and convincing force upon visitor perceptions of CSIRO.

ACMI AMBIENT SOUNDSCAPE

An extension of the concept of what might be referred to as 'architectural sound' in the non-exhibit areas of the CSIRO precinct (above) is presented in this section describing the soundscape for the Australian Centre for the Moving Image (ACMI), Melbourne, Australia. The origins of this project are drawn directly from the client's interest and willingness to explore the creation of a 'voice' for an institution housed in an extraordinary piece of modern architecture. The inventers of Muzak and every store and boutique on the planet will know that the introduction of any sound will perform a simple aesthetic function of animating a space. The acoustic designer will synchronise this 'animation' to a specific building by way of a more considered design process rather than the emotion laden choice by bored staff from a limited range of music CDs.

This building, the home of ACMI, is unique and the sonic imprint of people's experience of the spaces should also be unique. The memory of a visit to ACMI will be an imprint of the architecture and the experiences within. Sounds heard also play a part in this memory and should not be compromised by generic and ubiquitous music. The main architectural feature of the building, based on deconstructionist philosophy, is the constant shifting and motion of angles and perspectives. There are practically no parallel or perpendicular surfaces and a visitor is regularly presented with a view into distant areas through angular windows and shard-like crevasses. A feature of the interior design is a series of video screens and projections carrying what ACMI refers to as public imaging. In a sense one composes one's own movie through multiple choices made along alternative pathways as one moves about the building.

Photography by Nigel Frayne

View from the eastern atrium stairwell, ACMI, Federation Square, Melbourne

The sonic response to this personal habitation is to initially create a sense of cohesion by way of a general background ambience. One is subtly aware of being within the precinct of ACMI rather than any other place because it 'sounds different'. Within this ambience, midground zones of sound generate a sense of orientation. The main entrance is differentiated from the atrium, the toilets, stairwells and so on. Within this structural and spatial logic the visitor can be challenged in a dynamic interplay between subconscious hearing and direct listening achieved by the introduction of a range of foreground sonic materials. The interonset time structure and energy levels of these sonic events are critically matched to the human scale and activity level such that there is neither an imposition on consciousness nor undue distraction for visitors.

Sonic texture

Structurally, a sonic layout plan for ACMI was derived from the placement of five iconic sound sources or themes into specific areas of the building (midground zones). The sounds of trains and trams, reflecting the origins of the site as a public transport hub, were placed in the northern zone where the building fronts the city streetscape. Sounds derived of nature, reflecting the perspective of the nearby hills to the east of the city were sent into the building's eastern atrium. The sounds of water, notionally connecting the wet areas of the building to the nearby river and ultimately the ocean were delivered within the toilets. The sound of footfall or footsteps representing the habitation of an urban space were delivered into stairwells. And, in recognition of the cultural institution housed within the building, the sound of a hand clap, was the basis for sounds generated for the central atrium.[6] Within the ACMI soundscape these iconic sounds are rarely heard in their prime form and are actually departure points (impulses) for the creation of the content both in terms of inspiration as well as the actual production of the sound materials.

Each of the five themes was developed into a large library of sound materials using DSP techniques, particularly filtering, granular synthesis and spatialisation by convolution. Each prime sound is considered an impulse and the product of the treatment is a response. This becomes particularly relevant for the hand clap which mirrors a technique adopted by acoustic engineers when measuring and assessing a building's acoustic properties, the impulse response. A sharp full bandwidth sound (often the pop of a balloon) is generated within a building and the resulting echoes and reverberation are recorded and analysed. As these techniques were applied to the prime sounds of the ACMI soundscape a wide range of variables were tweaked and the resultant sounds recorded. A process of review and selection of appropriate materials was then carried out, a process which threw up a set of very significant issues.

Rhythmic features

The auditioning and reviewing of sound materials in real time is now a common feature of compositional processes involving computers. As sound materials were being generated for this project it became apparent that the sounds chosen featured

Photography by Nigel Frayne

Building façade of extraordinary architecture, ACMI, Federation Square, Melbourne

rhythmic elements far more than they did pitched qualities. It is interesting to speculate that the physical nature of a body inhabiting a space is better synchronised through the macro time scale of rhythm than it is to the micro dimensionality of pitch.

Discarding or selecting sounds could be seen as a purely subjective set of decisions by the acoustic designer. However, it is a process deeply informed by an understanding of the spaces and functions within the final composed soundscape. So the intuitive response in this case was that the rhythmic performance and the passing of time was considered more important to the requirements of this space. It now seems clear that the main intention is not to create a 'piece' that engages visitors in any kind of conscious or coherent listening. Rather, the sounds are, for the most part, to be heard and processed in much the same way as the colour of the walls or texture of the floor might be.

One of the organising principles used in the formation of the rhythmic organisation within the soundscape was the geometry of the basic unit of the building structure, a right angled triangle with two sides having a 2:1 ratio (see photo of building façade). Whenever a decision was required for setting a variable in a DSP function, this ratio was used. This is a fairly tenuous link to the physical building and yet, combined with the enormous sound generating capacity of the contemporary computer, provided ample materials for the selection process. Variables within the replay system, the audio server,[7] were also set according to this 2:1 ratio whenever possible. Multiple layers of sound were built up in each of the midground zones of the building. The main element that references the five basic themes to each other is the specific feature of rhythm or pulse.

As has been mentioned, the experience of listening to this music-like structure and form bears no resemblance to classic music listening experience. Nor is the resulting soundscape derived directly from any interpretive materials or functions such as the habitat sounds described in the zoo exhibits above or specific exhibition themes of CSIRO. The soundscape of ACMI is free to exist purely within the transitional experience of the building in response to architectural features and the cultural role of an institution. In terms of acoustic design the challenge was to move beyond technical or mechanical methodology into a more deeply creative process and yet there was not the kind of freedom to explore and challenge as would be the case for a composer of music or sound art.

CONCLUSION

In each of the examples above we have seen how an acoustic design process was applied to three quite different settings. Each case called for a specific treatment based on the functional requirements of both the site and the institution. The process called on the acoustic designer to make a range of intuitive decisions from a set of both technical and creative skills and apply them to a basic structural format in order that the resultant soundscape exhibits an underlying logic and yet dynamic texture. In all cases the desire was to create a setting where the soundscape was 'tuned in' to the site. People inhabiting these spaces may choose to listen or not, but for those that will, the desire is to reward them with deeper insights and a more complete picture of these fragments of the built environment.

Nigel Frayne is an Acoustic Designer and Soundscape Composer with a background as a rock musician, sound engineer, a theatre sound designer and a graduate in composition and music technology from Latrobe University, Melbourne. Through his company, Resonant Designs, Nigel has travelled the world as a designer of electroacoustic soundscape projects including zoos, museums, aquariums, science and exhibition centres, arts and leisure precincts. His involvement in projects includes a wide range of activities-concept design, acoustic and sound design, sound recording, soundscape composition, audio production, project management and technical installation and commissioning. He spent the early years of his career touring Australia as a bass player in a number of rock groups and later as a sound mixer/engineer for live music and theatre. He maintains a keen interest in electroacoustic music and the applications of computers to music and is actively involved in the broader issue of sound design in the environment as Chair of the Board of the World Forum for Acoustic Ecology (WFAE) and Vice-President of the Australian Forum for Acoustic Ecology (AFAE).

Footnotes

[1] Schafer, R. Murray. "Acoustic Design" in *The Soundscape: Our Sonic Environment and The Tuning of the World.* One Park Street, Rochester, Vermont 05767, U.S.A.: Destiny Books. ISBN: 0-89281-455-1. p.238.

[2] Ogden, Lindburg, Maple. *The Effects of Ecologically-Relevant Sounds on Cognitive and Affective Variables in Zoo Visitors.* Zoological Society of San Diego, P.O. Box 551, San Diego, CA, USA.

[3] For further description of this structure see - Frayne, N. "Electroacoustic soundscapes: aesthetic and functional design." *Sonic Geography Imagined and Remembered*, ed. Ellen Waterman, Penumbra Press 2002, P.O. Box 940, Manotick, Ontario, Canada, K4M 1A8. http://www.penumbrapress.ca ISBN: 1-894131-34-7.

[4] Woodward, C., Ogden, J., Czekala, N. and Lindburg D. *The Effects of Environmental Sounds and Intraspecific Vocalizations on Captive-Housed Gouldian Finches.* Zoological Society of San Diego, P.O. Box 551, San Diego, CA, USA.

5 See www.ambisonic.net for a collection of articles, sources and links detailing the subject of Ambisonic surround-sound and digital audio technology, compiled by engineer/producer Richard Elen.

[6] It has been said that in 1932 an audience erupted into spontaneous applause when they heard the well-known sounds of Australian birds in the soundtrack of one of the first 'talkies' to be shown in Sydney, Cinesound's 'On Our Selection'.

[7] A software package called Krypton Audio Server™ developed specifically for the delivery and fine control over an electroacoustic soundscape by a partnership between my company, Resonant Designs Pty Ltd and software engineer, Stephen Graham of Softeye Pty Ltd.