A HISTORY OF MUSICAL ACOUSTICS RESEARCH IN AUSTRALIA

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Musical instrument making has a long history in Australia and continues to flourish and produce innovations. Research in musical acoustics has a much shorter history, but here too Australian researchers continue to make an impact. Most of these people began their research in other areas of physics, and continue to pursue these interests along with acoustics.

It is a little difficult to define precisely the scope of the field of musical acoustics. It could be taken to include everything from the design of concert halls, through the physics of musical instruments, to the psychophysics of musical perception and to musicology. For the purposes of this historical review, I will limit myself to recording my perceptions and memories of the development of research into the acoustics of musical instruments, and closely related topics. Even this field is large, and ranges from a study of the traditional instruments of the Australian Aboriginal people, through conventional Western musical instruments, to modern electronic means of music generation. It is unlikely that my survey will be complete, and for this I apologise in advance.

With one exception, there has been little but informal interaction between the researchers involved in this field. The notable exception was the International Symposium on Musical Acoustics, held in Wollongong in 1980 as an adjunct to the Sydney International Congress on Acoustics. This was a most successful occasion.

RESEARCH GROUPS

Musical acoustics is not a large-scale study and does not require particularly expensive equipment. For this reason research has mostly been carried on in university physics departments by individual staff members working with just a few students, rather than by larger groups. A brief survey traces the history of those groups of which I am aware. Many music departments have had related musicological interests, but for the most part these have not ventured very far into the realm of acoustics.

Perhaps the first group was my own, established in 1972 in the Physics Department of the University of New England as an adjunct to my then main interest in solid-state physics. The emphasis of the group was on nonlinear phenomena in musical acoustics, with applications firstly to wind instruments and then to strings, gongs, and cymbals. Four students completed PhD degrees during the 10-year life of the group, and members continued to do at least some work in the field in later years, producing three books [1-3] and some fifty journal papers between them.

Another group with a longer lifespan was developed by Gordon Troup in the Physics Department of Monash University, again initially as an adjunct to his principal research in solid-state physics. The emphasis of this group has been on the role of the vocal tract in wind instrument performance [4], and more recently on some aspects of vocal performance, and several PhD degrees have been completed in these fields. Throughout its history, this group has been closely related to the Melba Conservatorium of Music.

Musical acoustics in the University of New South Wales began with the work of Howard Pollard on the acoustic analysis of pipe organ sounds [5,6]. Since Howard's retirement, Joe Wolfe and John Smith have established a very active musical acoustics group with a focus on the real-time measurement of acoustic impedance, both for wind instruments such as the flute and also for the vocal tract [7]. A novel measurement system has been developed for this purpose [8]. Some work is also in progress on guitars, and also on musical perception by people fitted with cochlear implant hearing devices. The group has continuing a involvement with French researchers through visits by students. Once again, the researchers also have had other interests, in this case in cryobiology.

At Sydney University there are several groups with interests bordering on the area of this review. Fergus Fricke in the Department of Architectural Science has supervised projects on organ-pipe acoustics, as well as having a major interest in concert-hall acoustics, and Ian Johnston in the Department of Physics has an involvement in musical acoustics from a rather general viewpoint [9]. A comparatively new development is the National Voice Centre under the leadership of Pam Davis, who is a physiologist rather than a physicist. As its name suggests, the main focus of the Centre is on vocal technique, but research has also been carried out on the vocal tract in relation to flute performance.

LaTrobe University also had a small musical acoustics group led by Tony Lee and with primary interests in the acoustics of the piano [10], while the Department of Interior Design at RMIT currently has work in progress on several experimental musical instruments, and Hans Gottlieb leads a small group at Griffith University.

Finally, mention should be made of various musical instrument builders who have also contributed to acoustic understanding and innovation, some in quite major ways. I shall return to these people in later sections of this paper.

ABORIGINAL INSTRUMENTS

Most important among the musical instruments of the Australian Aboriginal people is the didjeridu (more often spelt didgeridoo and actually called a yiraki by the Aboriginal people). This is simply a tube, typically about 1.5 m long and with internal diameter flaring from about 30 mm at the blowing end to 40(80 mm at the open end in a more-or-less conical fashion. The didjeridu tube is almost a "found" object, since it is formed by the activities of termites eating the cores of young Eucalypt trees, most of the hand-work being devoted to smoothing and painting the exterior. It is played by lip excitation in the same way as the tuba, combined with "circular breathing" to produce a continuous sound. Although the didjeridu has only two notes, one a drone at about 70 Hz and the other the second mode of the pipe, typically at a little below 200 Hz depending upon the flare, skilled players can produce a multitude of startling effects by combined sounding of the drone and various vocal noises. Even the timbre of the drone can be substantially modified by changing the configuration of the vocal tract . The acoustics of the instrument have been well studied, but there remain many questions about performance technique [11]. Lloyd Hollenberg from the School of Physics at Melbourne University has a continuing interest in this subject.

Another family of instruments of current interest is that of "torsional aerophones." The kurnatja, generally called a "bull-roarer" by Europeans, is the most audibly spectacular. It is a simple, nearly flat, elongated elliptical wooden plate fixed by one end to a long string and whirled circularly by the player. The strip rotates continuously about its long axis in one direction for several seconds, producing a low-pitched roar with a decreasing frequency, then stops and reverses direction to repeat the process. The other instrument is the "gum-leaf" which is a simple leaf strip placed between two thumbs and blown to produce a rather piercing sound with a pitch that can be controlled by the longitudinal tension. In both cases, the operation depends upon non-steady aerodynamic flow and the associated lift and torque forces. This is being studied by Alex Tarnopolsky and the present author in the School of Aerospace and Mechanical Engineering at ADFA.

The Aborigines also have a few percussion instruments, in particular pairs of short wooden cylinders with pointed ends, or even pairs of boomerangs, that are clapped together to produce a rhythmic accompaniment to didjeridu sound. The acoustics in this case is straightforward, but there is considerable interest in the properties of the wood used.

EUROPEAN MUSICAL INSTRUMENTS

Pipe Organs

Australia has a wealth of historic pipe organs, mostly imported from England at the end of last century. Graeme Rushworth has published a survey of those located in New South Wales [12] which also identifies Australian builders, and there are many equally distinguished organs in other states. One of the most notable instruments is the Sydney Town Hall organ, built by William Hill of London in 1890, at which time it was the largest pipe organ in the world. It has been maintained unaltered, except for replacement of the hydraulic bellows by an electrically operated wind supply, and was recently renovated to original condition. One of its notable features is a full-length 64-foot pedal reed stop (contra-trombone) with a fundamental of 8 Hz for the lowest note. The pipes of this rank are of wood, quasi-conical but with square section, and the few longest ones are necessarily mitred to fit within the height of the hall.

Much more recent is the Sydney Opera House organ, designed and built by Ron Sharp of Sydney [13]. It is a five-manual instrument with complete mechanical (tracker) action, supplemented by electric couplers and computer-controlled stop selection. At the time of its construction it was the largest tracker-action organ in the world, and it contains many technical innovations. There are several other Australian organ builders who have produced, and continue to produce, instruments of excellent quality and fine design. Research on pipe organ sounds has been carried out by Howard Pollard at UNSW [5] and on more physically based acoustics by Suszanne Thwaites and myself at New England [14].

Pianos, Harpsichords, etc.

At one time, Australia had several piano manufacturers building instruments for the domestic market, some notable names being Paling and Beale. These operations have long since ceased because of competition from imports, but a remarkable renaissance of piano building has been initiated by Wayne Stuart, now at the Newcastle Conservatorium. His piano is a concert grand that competes with the great international names such as Steinway and Yamaha, and is recently receiving considerable attention from its use by Gerard Willems to record the complete Beethoven piano sonatas. The Stuart piano has several innovations in design: the keyboard is a full 8 octaves and extends down to F1 instead of the usual A1, there is an extra pedal to allow a different style of dolce playing, and the strings are clamped to the bridge in a novel manner using an agraffe so that they do not make the slightly zig-zag path typical of other instruments. Bob Anderssen of CSIRO is collaborating with the manufacturer to better understand the acoustics of the instrument.

Harpsichords and clavichords are also built by several Australians in various parts of the country. In such instruments, tradition is important, and design innovations unlikely to be welcome, though Bill Bright decorates the lids of his instruments with Australian rather than the typical European scenes! A few papers on the acoustics of harpsichords and clavichords were published by the New England group about 20 years ago [15]. There are also Australian builders of less common instruments such as dulcimers, among whom Gillian Alcock of Canberra is notable and also has a concern for the basic acoustics of the instrument.

Guitars

The story of guitar building in Australia is a very interesting one, with solid acoustical underpinnings. In the classical-music scene, most guitars are about the same size and differ primarily in the bracing pattern underneath the soundboard. There is a bass instrument among electric guitars, but we do not consider this further here.

There have been innovations within this tradition through the use of Australian wood for some instruments and, more significantly, through the introduction by Greg Smallman of light-weight graphite-epoxy bracing, which has proved popular with performers. The greatest innovation, however, has been the development by Graham Caldersmith of a four-member family of guitars of different sizes [16], following the pattern established in the United States by Carleen Hutchins in her development of the eight-member "New Violin Family."

The essence of designing such a family was to take a standard guitar as model and then, by appropriate scaling and re-design of body size, soundboard design, etc, to produce larger or smaller instruments with body resonances and cavity resonances appropriately matched to their different pitch. The result was a family of four instruments, scaled up or down in musical intervals of a fourth or a fifth, with one instrument (treble) smaller than the conventional guitar (which is the tenor in the quartet), and two larger instruments (baritone and bass). The result is very successful and has been used extensively in recordings made by the ABC of the Canberra School of Music group Guitar Trek [17].

Bowed-String Instruments

Australian luthiers have been active in violin making for at least a century, one of the founding fathers of the tradition being A.E. Smith of Sydney. Now there are many makers all around the country, some building by the traditions handed down from their teachers, some having studied in European violin-making schools, and some, like Graham Caldersmith, following the new scientific tradition established by Carleen Hutchins, in which vibration modes of the violin body are measured and then modified by careful shaving of the wood to approximate (or, if desired, differ from) corresponding modes measured on violins by Stradivarius, Amati, and other great makers. The same approaches can be followed for violas and cellos.

There has also been innovation in using Australian woods for crafting the instruments and in careful study of the physics involved [18]. It is necessary to use a light-weight straight-grained highly anisotropic timber for the top plate, and "King Billy" pine has been found to be suitable. The choices are larger for the ribs and back plate. Some fine instruments have been made by Graham Caldersmith and others but, as is to be expected, the tonal balance is rather different from that found for traditional timbers, if only because the high-frequency damping is different. Preference is a very individual matter among performers.

As far as I am aware, there has been little or no research carried on in Australia on the dynamics of bowed strings, on radiation transfer functions, or on computer simulation of bowed-string response, all of which are active research areas overseas.

Recorders and Flutes

The recorder is now a popular instrument among both amateur and professional musicians. Australia has a good record in research on the basic acoustics of the instrument and on performance technique [2,19], as well as in the collection of measurements of instruments by famous makers of the past [20]. Even greater is the reputation created by Fred Morgan of Victoria, whose instruments were prized by top players from around the world. Tragically, Fred was killed in a motor accident not long ago.

Study of flute acoustics was also undertaken by the New England group and is now being carried on by Joe Wolfe's group at the University of NSW. While the passive acoustics of the flute tube is simple in principle, there are many subtle effects of bore and tonehole configuration that affect tuning and tone quality. The mechanism of tone production by the air jet from the player's lips, however, still presents many unanswered questions, though the basic operation is quite well understood.

In relation to manufacture, we must distinguish between two types of flute: the tapered wooden flute with few, if any, keys that was used in classical times and survives in both early-music and folk groups, and the Boehm design of silver flute, with a cylindrical bore and sophisticated key system, which dates from the middle of the nineteenth century. Both have excellent makers around the country, such as Terry McGee of Canberra, who specialises in wooden flutes for Irish folk music but also makes flutes to classical design, and Mark O'Connor of Sydney who carries on the work begun by John Lehner, both having spent time with the Powell company of Boston. Both Terry and Mark collaborate with Joe Wolfe's group at UNSW. In addition, there are individuals specialising in the crafting of head-joints, which are the most critical and individual parts of the flute. The fact that many distinguished Australian flute players use head-joints made in Australia on flutes built overseas attests to the quality of the local product.

Reed Woodwinds

Oboes, clarinets, bassoons and saxophones are very little made in Australia for various reasons. The demand is small, except in the case of clarinets, and crafting the instruments is difficult. On the other hand, there is the opportunity to use Australian timbers, which, though scarcely affecting tone quality, can give a fine appearance and durability to the instrument. An example is the use of mulga wood and gold-plated keywork on the oboes made by Tom Sparkes of Sydney.

Mention has already been made of the work of Gordon Troup's group on the importance of vocal-tract configuration in instrument performance, and R.B. Johnston of that group has also examined the acoustics of the harmonica [21]. Some fundamental work on vibrating-reed valves was also done by the New England group and has now been extended by Alex Tarnopolsky and myself at ADFA. Nothing of direct relevance to reed woodwind performance is expected from this work, however.

Brass Instruments

As far as I am aware, brass instruments are not manufactured in Australia, and there has been little research on their acoustics, though this has been an active area overseas. The one exception is that of brass-instrument performance technique, in which the physiological stresses can be very high, leading to difficulties for the player, particularly in the high register of a trumpet. One significant study on this subject has been published recently [22].

Percussion Instruments

The variety of percussion instruments is very large, since the category includes bells, gongs, cymbals and drums, as well as numerous specialist items such as castanets, tambourines, etc. Many of these can be made with little specialist equipment, so that amateur makers are plentiful. In addition, there are many experimental designs that can be tried out, and many nice possible theoretical investigations.

One of the most interesting investigations of drum design was that of Hans Gottlieb and Hubert Aebischer of Griffith University. In a series of theoretical studies of the vibrational properties of an annular membrane, they gradually devised an annular kettledrum with a largely harmonic spectrum, and thus a greatly improved tonality [23]. Such an annular drum bears some relation to the Indian drums investigated by C.V. Raman, but advances the design and the technology. So far there has been no musical exploitation of this development that I am aware of.

Bells for churches and carillons have mostly been imported into Australia, but for a considerable time Hervey Bagot of Adelaide has been designing and casting his own bells for special purposes [24]. While the basic design of a bell determines the general location of its mode frequencies, the extent to which these can be tuned to a pleasant and harmonic sound when two or more bells are sounded simultaneously depends upon fine details. An excellent survey of bells in Australia has been published by John Keating [25].

A new type of tuned percussion instrument has come from the work of Sydney composer Moya Henderson and her scientific collaborators. Her initial idea was to make an instrument consisting of tuned steel triangles (of the orchestral type) connected to tubular resonators to enhance the low partials of the sound. The result was an impressive instrument with a range of about two octaves that she called the alemba [26]. Critical listening, however, led to dissatisfaction with the frequency alignment of some of the partials, and it was not possible to correct this because of the small number of geometrical parameters available in a symmetrical triangle. Modifying the triangle to a pentangle introduced more geometrical parameters and allowed as many as five partials to be tuned to harmonic relationship, including a minor third to give an appropriately bell-like sound [27].

The behaviour of gongs and cymbals was investigated [28] by Katherine Legge of the New England group, now at LaTrobe University, Bendigo, from a rather fundamental viewpoint, the interest being in nonlinear behaviour and the transition to chaotic oscillation. Insight was obtained into the phenomena of pitch glide in Chinese opera gongs, the "crash" of cymbals, and the impressive sound of the Chinese tam-tam. Other work on the design and analysis of gongs of the gamelan type has been done by Neil McLachlan of RMIT [29].

Electronic Instruments

The development of electronic instruments in Australia goes back to the time of Percy Grainger in the 1930s. He built a synthesiser using cut-out cardboard shapes on a travelling belt to control the frequency of an oscillator, and this instrument can still be seen in the Grainger Museum at Melbourne University.

More recent and much more successful has been the development of the Fairlight synthesiser by Peter Vogel and Kim Ryrie in Sydney during the 1970s. This instrument was remarkable for its versatility, allowing the use of both sampled natural sounds and also synthetic sounds, with the possibility of detailed editing of spectra, attack and decay transients, etc. The Fairlight was the instrument of choice for many performers around the world, and was used to provide background music for such prestigious films as "The last Emperor". The company now produces a wide range of professional audio and video equipment.

Another notable Australian achievment relevant to musical acoustics is the development by LakeDSP in Sydney of sophisticated signal-processing software to produce surround-sound and to simulate a variety of acoustic environments. These developments are likely to play an increasing role in music reproduction.

Electronic music now features in the activities of most university music departments, and it would be invidious to list just a few. One approach that is gaining popularity both here and overseas is the mathematical simulation of actual physical systems, such as struck metal plates for example, which can then be extended to immense size or otherwise modified and their sound output computed and recorded. The possibilities are unlimited, but convincing results depend upon physical understanding of the systems being simulated.

CONCLUSION

It has proved impossible in the brief compass of this article to give more than passing attention to the many interesting research studies and practical developments that have occurred in musical acoustics in Australia in the past quarter-century. I hope, however, that I have adequately reflected a wide and thriving enterprise, and that those whose work has been omitted will forgive my ignorance.

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