INVITED REVIEW

Demonstrations for education in acoustics in Japan

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Abstract: Many demonstrations for education in acoustics have been developed in Japan as well as outside the country. Since 1997, the Technical Committee on Education in Acoustics of the Acoustical Society of Japan has been investigating and discussing education in acoustics in Japan. In this review, some of the educational tools and demonstrations in acoustics are introduced. They are all designed to help us visualize and hear different phenomena and to understand abstract theories in a more intuitive way. The work that has been carried out includes some exciting demonstrations in acoustics by the high-school physics teachers' "Stray Cats Group," some visual and aural demonstrations for architectural acoustics, a technical course called "Technical Listening Training," a WWW-based training system, and physical models of the human vocal tract.

Keywords: Education in acoustics, Demonstration, Visualization, Auralization

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This article contains the supplementary media files. Underlined file names in the article correspond to the supplementary files. For more information, see http://www.asj.gr.jp/2006/data/ast2706.html.

Supplementary files

2_velocity.mpg, 2_interference.mpg, 2_rubbing.mpg, 2_dropping.mpg, 2_bottle.mpg, 2_ocarina.mpg, 2_gears1.mpg, 2_gears2.mpg, 2_spring_phone.mpg, 2_optical_phone.mpg, 3_kundt_res.mpg, 3_rect.mpg, 3_fan.mpg, 3_ellip.mpg, 3_rect_d.mpg, 3_fan_d.mpg, 3_ellip_d.mpg, 4_discr.mpg, 4_ident.mpg, 5_cylinder_ieaou.wav, 5_whistle.mpg, 5_cylinder_i_lung.mpg, 5_cylinder_e_lung.mpg, 5_cylinder_a_lung.mpg, 5_cylinder_o_lung.mpg, 5_cylinder_u_lung.mpg, 5_head_a_lung.mpg

1. INTRODUCTION

Nowadays, academic conferences often include a session on education, and education in acoustics is no exception. This is an area that has been attracting more attention recently. For example, at the International Congress on Acoustics 2004, held in Kyoto, there was a demonstration session in addition to two oral sessions on education in acoustics. In the demonstration session, we had 20 demonstration booths in a large exhibition hall. It was very successful and many participants enjoyed the session.

Since 1997, when the Technical Committee on Education in Acoustics seriously started their activities at the Acoustical Society of Japan, we have been investigating and discussing education in acoustics in this country. We have conducted surveys of educational tools, programs and exhibitions, and have generally been directing the education of acoustics in Japan.

In this review, we introduce some of the educational tools and demonstrations in acoustics that have been developed in Japan.

2. EXCITING DEMONSTRATIONS ON ACOUSTICS BY STRAY CATS GROUP

In Japan, to get students interested in a subject, high-

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school physics teachers often form groups to share their ideas and inventions. In Japan, the Stray Cats Group [1] is one such group. The Stray Cats Group demonstrations are exciting and are geared toward 1) understanding how students grasp physics and 2) making simple tools that are exciting, essential and pleasant. The following are some examples of their demonstrations.

2.1. Measuring the Velocity of Sound in Gases

Using a pipe and two microphones, one can make a simple measurement of the velocity of sound in various gases (2_velocity.mpg). The two microphones detect a pulse emitted from a loudspeaker attached to one end of the pipe. The velocity of sound can be calculated by measuring the time difference between the arrivals of the pulse at the two microphones. The gas inside the pipe can be, for example, air, CO_2 or helium gas.

2.2. Interference of Sounds

One can collect a tone emitted from a single source at two different positions and add them together acoustically. A cone-shaped horn works well for collecting sounds. Once two separate tones originally emitted from a single source are collected with two separate cones, the sounds travel inside pipes of equal length attached to the two cones and may be added by merging the two pipes into one at the output. The sounds will seem louder or quieter depending on the position of the cones (2_interference.mpg).

A "sound grating" can be demonstrated with a thick pipe having five holes at intervals of 20 cm along its length. A loudspeaker attached to one end of the pipe emits a tone with a wavelength of 10 cm. If an observer changes positions, he/she can hear a change in loudness.

2.3. Vibration of Aluminum Rod

Two types of vibrations can be made by striking an aluminum rod. Longitudinal waves are created by striking one end of the rod parallel to its length. Striking the rod from the side makes a transverse wave. The pitch of the sound depends on the length of the rod. By cutting several rods with systematically different lengths, the rods can become musical instruments (Fig. 1). Students enjoy the beautiful sounds made by rubbing the rods (2_rubbing.mpg) or dropping them (2_dropping.mpg) on a hard surface.

2.4. Handmade Musical Instruments

Hitting a plastic bottle as shown in Fig. 2 (left)

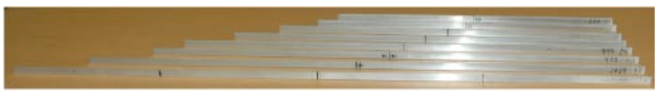


Fig. 1 Aluminum rods.

Fig. 2 Plastic bottles filled with air of different pressures (left) and a handmade ocarina (right).

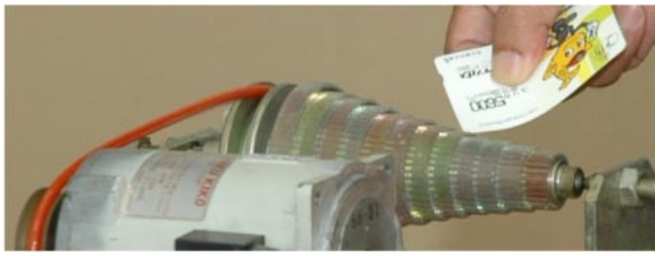


Fig. 3 Rotating gears.

produces a musical sound (2_bottle.mpg). The pitch can be changed easily by attaching a tire valve to the bottle cap to adjust the air pressure inside the bottle. Handmade ocarinas as shown in Fig. 2 (right) can be made from many different shapes of containers by simply making a hole in the body and attaching a mouthpiece of a whistle or a recorder into the hole (2_ocarina.mpg). We can demonstrate that natural frequency changes corresponding to the total area of the holes and is not affected by the positions of the holes.

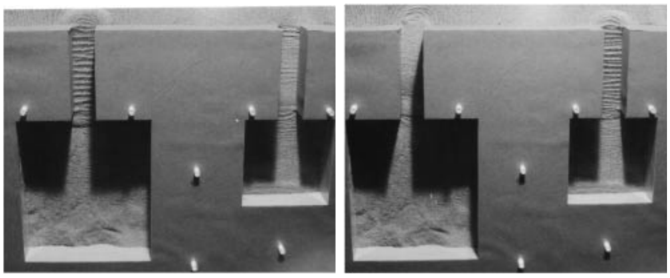
2.5. Rotating Gears

As shown in Fig. 3, a musical scale can be made by lining up several gears with different diameters systematically and rotating them together at a certain speed (2_gears1.mpg). Sounds can be made by touching a piece of paper to the tips of the gears, or illuminating them and detecting the reflection with a photodetector (2_gears2.mpg). Instead of rotating gears, one can rotate a paper cylinder upon which a set of periodic black squares with different pitches are printed.

2.6. String, Spring and Optical Phones

One appropriate tool for an introduction to sound is a "string phone," made with two paper cups and a piece of string. By replacing the string with a spring as shown in Fig. 4, one can make a "spring phone," which acts like a string phone but has echoes (2_spring_phone.mpg). In both cases, we can make a microphone by placing a magnet and a coil at the bottom of the cup of the listener's side and connecting wires from the coil to an amplifier.

Fig. 4 Spring phone.



(a) Resonance for large resonator (170 Hz).

(b) Resonance for small resonator (240 Hz).

Fig. 5 Visualization of Helmholtz resonance phenomena.

Without a string or a spring, we can transmit speech over long distances with an "optical phone" (2_optical_phone.mpg). In this case, the bottom of a plastic cup lined with aluminum tape reflects light from a source, which is modulated by the speech sound. A solar battery panel plugged into an amplifier detects the optical signal and demodulates the speech sound.

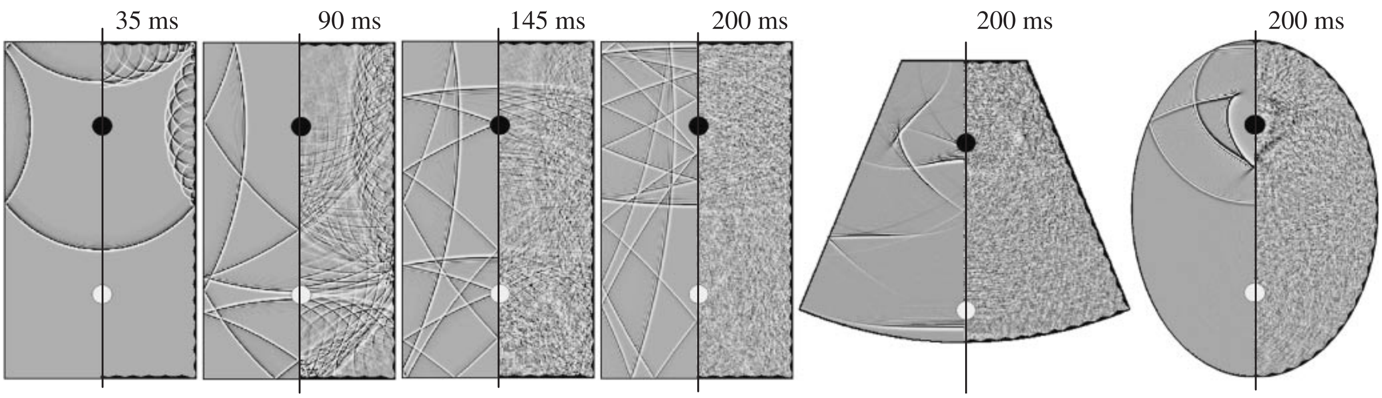
3. VISUAL AND AURAL DEMONSTRATIONS FOR ARCHITECTURAL ACOUSTICS

In lectures on architectural acoustics in universities, visual and aural demonstrations are very effective for making students feel familiar with acoustics and recognize its importance. Among the general contents of a lecture course on architectural acoustics, various visual and/or aural demonstrations have been contrived by Sakamoto Lab. at IIS, University of Tokyo and Tachibana Lab. at Chiba Institute of Technology, especially on such topics as the fundamentals of sound, the fundamentals of auditory sensation, sound absorption, sound insulation, sound propagation, and room acoustics [2–4].

For example, the application of Kundt's dust figure method to visualize resonance phenomena in a 2-dimensional room is very effective for helping students' intuitive comprehension. As shown in Fig. 5, even-sized cork dust scattered on the floor of a box made from acrylic plates shows Helmholtz resonance (see 3_kundt_res.mpg), as well as the normal mode of the room and active noise suppression, by radiating a pure tone sound from loudspeakers mounted at the corners.

Another good example of the demonstration is an animation made by numerical analysis. Owing to the development of computer technology, numerical analysis methods have become powerful tools for visualizing acoustic phenomena. Figure 6 shows some images from the animation of sound propagation in rooms calculated by finite-difference time-domain (FDTD) methods. Viewing the pattern of sound waves in time, the influence of room shape (see 3_rect.mpg, 3_fan.mpg, 3_ellip.mpg) and the effect of diffusing treatments (see 3_rect_d.mpg, 3_fan_d.mpg, 3_ellip_d.mpg) can be clearly observed. With these images, the auralization of the impulse response provides an intuitive understanding of fluttering echo and the treatment required to suppress it.

In addition, visual and/or aural demonstrations on sound diffraction over barriers, the effect of reverberation on music and speech, and the sound insulation characteristics of building walls are good materials for raising a fundamental sense of acoustic phenomena. These demon-



(a) Rectangular room

(b) Fan shaped

(c) Elliptic

Fig. 6 Sound propagation visualized by FDTD methods in (a) rectangular, (b) fan-shaped and (c) elliptic rooms without (left-hand side) and with diffusing treatment (right-hand side).

strations are effective not only for acoustic education but also for acoustic design work with architects. Several video/sound files and detailed information on materials are on the web [5].

4. PSYCHOLOGICAL ACOUSTICS

4.1. "Chono-Keisei" (Technical Listening Training)

The systematic education program "Chono-Keisei" developed by researchers at Kyushu University was designed to help listeners develop a sensitive ear for the general sense of sound including sound discrimination, which is a desirable skill for acoustic engineers and sound designers [6,7]. Sound professionals should have an ability to discriminate and differentiate sounds as well as an ability to quantify their physical properties. They should also have an ability to convert an imagined sound to a specification or design plan, or vice versa. Furthermore, listeners need to have the ability to predict how a sound will change if a particular physical property changes. Thus, this program was designed to train such abilities and provide related knowledge.

There are two courses in the curriculum. The introductory course begins with the discrimination of the pitch, loudness and timber of sounds. Students grasp the relationship between sounds and their corresponding physical properties, as well as each just noticeable difference, or JND. The course then proceeds to identification training, where students are asked to identify, among other things, 1) the frequency of a pure tone or the center frequency of a narrow-band noise in Hertz, 2) the difference between two sound pressures in dB and 3) which octave band is enhanced. In addition, there is also some training on harmonics and spectral envelopes.

The second, more advanced course trains students to make an association between spectral shape and auditory impression. Students are also taught, for example, to identify frequency characteristics, to predict the sound level change of an enhanced musical part, to identify the time difference between two musical parts, and to discriminate "just intonation" and "equal temperament."

For this training program, a specialized system with a host computer and personal digital assistants (PDAs) are used. Figure 7 shows a class during the training program and a palm PDA terminal.

(a) (b)

Fig. 7 "Chono-Keisei," Technical Listening Training: (a) classroom and (b) palm PDA terminal.

4.2. WWW-Based Training System

A system for technical listening training usually requires exclusive hardware and software. The above-mentioned system employed in Kyushu University is an example of an exclusive system. However, a WWW-based training system, which only requires general hardware and software, has been proposed recently [8]. It is distributed under the terms of a GNU GPL (General Public License) [9]. Discrimination training using the system is shown in 4_discr.mpg. Identification training is also shown in 4_ident.mpg. These screen grabs depict easy handling and user-friendly interfaces.

The WWW-based training system is superior to the previous auditory training systems in terms of the following points: 1) software and hardware can be easily organized, 2) the modification and creation of the contents of training courses are easy, 3) individual training parameters for users can be set, 4) many users can use the system individually or simultaneously, 5) the results of training for users are saved and summed individually, and 6) the level of difficulty in discrimination training is automatically set up individually.

5. VOCAL-TRACT MODELS

Acoustic demonstrations are highly effective for education in speech science. One educational tool is a set of physical models of the human vocal tract and related models [10,11]. It contains cylinder-type and plate-type models [12], lung models, an artificial larynx, and head-shaped models [13]. Each model has its own advantages and if combined effectively can produce a systematic, intuitive and comprehensive education in acoustics from the lungs to the head.

Arai proposed two types of model: the cylinder-type model (Fig. 8(a)) with a precise reproduction of the original vocal-tract shapes of Chiba and Kajiyama [14],

(a) (b)

Fig. 8 Arai's models of human vocal tract: (a) cylinder-type models (from left, /i/, /e/, /a/, /o/ and /u/); and (b) plate-type model.

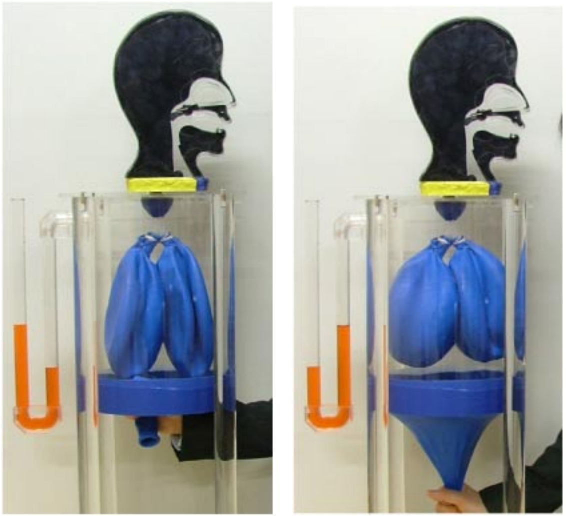


Fig. 9 Head-shaped model for /a/ and lung model: exhalation (left) and inhalation (right).

and the plate-type model (Fig. 8(b)), a step-wise approximation of these original shapes. In both models, a vowel-like sound is produced at the lip end when a sound source excites the glottis end. A listener will hear vowels produced by cylinder-type models with an electrolarynx in 5_cylinder_ieaou.wav.

An artificial larynx, such an electrolarynx and a whistle-type artificial larynx, is one of the best candidates as a sound source. A whistle-type artificial larynx (5_whistle.mpg) requires airflow to produce sounds. For airflow, we can apply a functional model of the lungs and diaphragm (Fig. 9) [13]. With this model, students can slowly pull on a knob attached to the "diaphragm" (a rubber membrane covering the bottom of the cavity) to inflate the "lungs" (two balloons). The balloons are connected to a Y-shaped tube simulating the trachea. You will see an artificial larynx with small lung models attached to each of the cylinder-type models in 5_cylinder_i_lung.mpg, 5_cylinder_e_lung.mpg, 5_cylinder_a_lung.mpg, 5_cylinder_o_lung.mpg, and 5_cylinder_u_lung.mpg.

Head-shaped models [13] are another type of model. Figure 9 shows the head-shaped model for the vowel /a/. In this type of model, the midsaggital cross section with a nasal cavity is visible from the outside, and the models produce actual vowel sounds and their nasalized versions (5_head_a_lung.mpg). For more information, visit [15].

6. CONCLUSIONS

In this review, we were able to introduce only a small number of the many demonstrations available in Japan. For example, a demonstration we did not cover teaches acoustic science by means of a multimedia presentation [16]. A number of demonstrations will be shown at a special demonstration session on education in acoustics at the ASA-ASJ Joint Meeting in Honolulu in 2006. Many of the demonstrations have been developed in Japan, but we hope they will spread throughout the world, wherever education in acoustics is taking place. (Please visit the website of the Technical Committee on Education in Acoustics at the Acoustical Society of Japan: http://wwwsoc.nii.ac.jp/asj/edu/.)

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