

# From Physics to Sound: Comments on Van den Doel, ICAD 2004.

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Wherever we are, what we hear is mostly noise. When we ignore it, it disturbs us. When we listen to it, we find it fascinating. The sound of a truck at 50 m.p.h. Static between the stations. Rain. We want to capture and control these sounds, to use them, not as sound effects, but as musical instruments.

– John Cage on the future of music - from a lecture given in 1937

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## 1. BACKGROUND

The importance of sound in the interaction with virtual objects is well known. Because such sounds are ubiquitous and we are exposed to them from infancy, we usually are not aware of them, unless we specifically direct our attention to them. Yet if they are absent, or if their digital emulation is of low quality, we notice this immediately.

I became first aware of these sounds as a student of music composition when I performed John Cage's 4'33". This is an improvisatory piece of undetermined duration, for any instrumentation, in three pieces, the only constraint being that the performer does not make any sounds. During the 3'50" of the performance (which was the duration I chose) it seemed that my senses were heightened and I could hear a symphony of sounds such as feet shuffling, a distant car, my own breathing, and the angry footfall of a member of the audience who left the performance.

It was only much later that I embarked on a line of research, trying to recreate such everyday sounds digitally on the computer. This is surprisingly difficult. Though these sounds appear simple, the underlying physical processes are extraordinarily complicated.

I prefer to classify these sounds not by their auditory nature, but by the nature of the material objects creating them. Since the matter we normally interact with can exist in three phases, there are three corresponding classes of sounds. **Contact sounds** are made when solid objects touch. The contact forces cause the surfaces to vibrate and emit sound. **Aerodynamic sounds** are the sounds created by air, possibly in combination with solid bodies. They are caused by turbulence in the air. **Liquid sounds** are made by water and other liquids. They are caused predominantly by resonating trapped air bubbles.

## 2. CONTACT SOUNDS

Gaver [1988; 1993] pioneered the use of synthetic contact sounds to accompany direct human interactions with a computer. Takala and Hahn [1992] first constructed a general framework for producing sound effects synchronized with animation. In their framework, sounds are attached to graphical objects, and events can trigger visual as well as sonic events. Hahn et al. [1995] introduced a number of synthesis algorithms for contact sounds. The musically motivated real-time synthesis techniques pioneered by Cook [1995; 1996] can also be used to create sound effects for contact interactions with virtual objects. Specific models to recreate

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timbral variations resulting from touching objects at different locations were described in [Doel and Pai 1996; 1998].

Recently, major progress has been made in the integration of animation, contact sounds, and graphics. O'Brien [2001] describes an off-line system to compute both sound and motion from a single physical model of deformable bodies. The FoleyAutomatic system [Doel et al. 2001] uses modal resonance models to create real-time sound effects to accompany interactions with virtual (simulated) objects. The model data are acquired systematically through measurements as described by Pai et al. [2001]. O'Brien et al. [2002] present methods to compute, offline, and from first principles, the modal data for real-time modal models. Physically based models for the excitations during collision and sliding contacts have also been investigated [Avanzini and Rocchesso 2001; Avanzini et al. 2002]. The quality of the synthetic contact sounds was investigated experimentally in [Doel et al. 2002]. In [Doel et al. 2004] efficient algorithms were developed allowing the synthesis of very complex auditory environments with contact sounds.

### 3. AERODYNAMIC AND LIQUID SOUNDS

Physical models for aerodynamic sounds have appeared very recently [Dobashi et al. 2003; 2004]. A simplified model of turbulence was used to compute sounds made by moving air around fast moving objects such as swords and sticks, or by wind.

The only work on physically based synthetic liquid sounds that I am aware of is the accompanying article. The most interesting discovery for me was that the sounds of resonating submerged bubbles, which have been known to be the key component of water sounds since 1933, can successfully be used as primitives for a versatile and realistic water sound simulation. I am currently working on integrating the water sound simulator with physically-based water animation methods, to create a unified simulation of sound and visuals for water.

### 4. APPLICATIONS TO AUDITORY DISPLAY

Once the material sounds described above have been mastered and can be recreated digitally in real-time, we can consider what to do with these new controllable sounds. Following John Cage we could use them to make music. One attempt in this direction is [Hoskinson et al. 2003], which describes a drawing program that creates sound models for solid objects corresponding to the shapes drawn, which then can be interacted with to produce sounds.

Another application is for auditory display proper. The key distinguishing factor here is that these physically modeled sounds are by nature interactive, and lend themselves particularly well to interactive displays, where the user actively participates in the sensing of the data. We are so used to having these sounds around in the real world, that a proper use and mapping of their meaning in the real world to their intended meaning in the auditory display can potentially be very effective. My SoundView system [Doel 2003; Doel et al. 2004] attempts to use scraping sounds as a metaphor to create an interactive auditory display of color images for the blind.

### REFERENCES

- AVANZINI, F. AND ROCCHESSO, D. 2001. Modeling Collision Sounds: Non-linear Contact Force. In *Proc. COST-G6 Conf. Digital Audio Effects (DAFx-01)*. Limerick, Ireland, 61–66.
- AVANZINI, F., SERAFIN, S., AND ROCCHESSO, D. 2002. Modeling Interactions Between Rubbed Dry Surfaces Using an Elasto-Plastic Friction Model. In *Proc. COST-G6 Conf. Digital Audio Effects (DAFx-02)*. Hamburg, Germany, 111–116.
- COOK, P. R. 1995. Integration of physical modeling for synthesis and animation. In *Proceedings of the International Computer Music Conference*. Banff, 525–528.
- COOK, P. R. 1996. Physically informed sonic modeling (PhISM): Percussive synthesis. In *Proceedings of the International Computer Music Conference*. Hong Kong, 228–231.
- DOBASHI, Y., YAMAMOTO, T., AND NISHITA. 2003. Real-time Rendering of Aerodynamic Sound Using Sound Textures based on Computational Fluid Dynamics. In *Computer Graphics (ACM SIGGRAPH 03 Conference Proceedings)*. Los Angeles, 732–740.
- DOBASHI, Y., YAMAMOTO, T., AND NISHITA. 2004. Synthesizing Sound from Turbulent Field using Sound Textures for Interactive Fluid Simulation. *Eurographics 2004* 23, 3, 539–546.
- DOEL, K. V. D. 2003. SoundView: Sensing Color Images by Kinesthetic Audio. In *Proceedings of the International Conference on Auditory Display (ICAD 2003)*. Boston.
- DOEL, K. V. D., KNOTT, D., AND PAI, D. K. 2004. Interactive Simulation of Complex Audio-Visual Scenes. *Presence* 13, 1.

- DOEL, K. V. D., KRY, P. G., AND PAI, D. K. 2001. FoleyAutomatic: Physically-based Sound Effects for Interactive Simulation and Animation. In *Computer Graphics (ACM SIGGRAPH 01 Conference Proceedings)*. Los Angeles, 537–544.
- DOEL, K. V. D. AND PAI, D. K. 1996. Synthesis of Shape Dependent Sounds with Physical Modeling. In *Proceedings of the International Conference on Auditory Display (ICAD 1996)*. Palo Alto.
- DOEL, K. V. D. AND PAI, D. K. 1998. The Sounds of Physical Shapes. *Presence* 7, 4, 382–395.
- DOEL, K. V. D., PAI, D. K., ADAM, T., KORTCHMAR, L., AND PICHORA-FULLER, K. 2002. Measurements of Perceptual Quality of Contact Sound Models. In *Proceedings of the International Conference on Auditory Display (ICAD 2002)*. Kyoto, Japan.
- DOEL, K. V. D., SMILEK, D., BODNAR, A., CHITA, C., CORBETT, R., NEKRASOVSKI, D., , AND MCGRENERE, J. 2004. Geometric Shape Detection with SoundView. In *Proceedings of the International Conference on Auditory Display (ICAD 2004)*. Sydney, Australia.
- GAVER, W. W. 1988. Everyday listening and auditory icons. Ph.D. thesis, University of California in San Diego.
- GAVER, W. W. 1993. Synthesizing Auditory Icons. In *Proceedings of the ACM INTERCHI 1993*. 228–235.
- HAHN, J. K., FOUAD, H., GRITZ, L., AND LEE, J. W. 1995. Integrating sounds and motions in virtual environments. In *Sound for Animation and Virtual Reality, SIGGRAPH 95 Course 10 Notes*. Los Angeles.
- HOSKINSON, R., DOEL, K. V. D., AND FELS, S. 2003. Real-time Adaptive Control of Modal Synthesis. In *Proceedings of the International Conference on New Interfaces for Musical Expression (NIME03)*. Montreal, 99–103.
- O'BRIEN, J. F., CHEN, C., AND GATCHALIAN, C. M. 2002. Synthesizing Sounds from Rigid-Body Simulations. In *SIGGRAPH 02*.
- O'BRIEN, J. F., COOK, P. R., AND ESSL, G. 2001. Synthesizing Sounds from Physically Based Motion. In *SIGGRAPH 01*. Los Angeles, 529–536.
- PAI, D. K., DOEL, K. V. D., JAMES, D. L., LANG, J., LLOYD, J. E., RICHMOND, J. L., AND YAU, S. H. 2001. Scanning physical interaction behavior of 3D objects. In *Computer Graphics (ACM SIGGRAPH 01 Conference Proceedings)*. Los Angeles, 87–96.
- TAKALA, T. AND HAHN, J. 1992. Sound rendering. *Proc. SIGGRAPH 92, ACM Computer Graphics* 26, 2, 211–220.