Chapter 15
Behaviour, Structure and Causality in Procedural Audio[1]

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ABSTRACT

This chapter expands some key concepts and problems in the emerging field of procedural audio. In addition to historical, philosophical, commercial, and technological themes, it examines why procedural audio differs from earlier "computer music" and "computer sound". In particular, the extension of sound synthesis to the general case of ordinary, everyday objects in a virtual world, and the requirements for interactivity and real-time computation are examined.

INTRODUCTION

Procedural audio is sound as a process. Instead of thinking about nouns, we think of verbs, or the actions that cause sounds. Procedural sound is also a structural and reasoned, rather than purely sensible, approach to sound, in which behaviour supplants identity and we ask not what sound *is*, but what it *does*.

This chapter follows the publication of Designing *Sound* (Farnell, 2008) in which I lay foundations for procedural audio, particularly its use in real-time virtual worlds. Here I would like to talk about the ideas of behaviour, causality and structure which are implied by the identification of sound as a branch of dynamics requiring energetic change.

The task at hand is producing sound for film, computer games, or other interactive entertainment applications. This task requires creativity, knowledge and understanding. Creativity in traditional sound design is directed at capturing, curating and matching audio data to depicted circumstance, whereas creation of procedural sound is from first principles: so it is truly *design* as opposed to selection. Insights into process are therefore at the root of the work.

The end product is sound as code, or *sound objects* (Polotti, Papetti, Rocchesso, & Delle, 2001). One must create new digital signal process-

DOI: 10.4018/978-1-61692-828-5.ch015

ing (DSP) algorithms, or a set of parameters for existing sound objects, rather than actual sound files. The product is "potential sound", rather than particular audio data as it would appear at the digital analog convertor (DAC). The complete package of a sound object is DSP, control, and encapsulation code compatible with a set of parameters to be supplied in the future. Objects may be instantiated and animated at some later time, in any contrived circumstance. We say this media has *deferred form*, exhibiting desired behaviour according to supplied runtime parameters.

Procedural Audio as a Design Philosophy

It's worth adding that the above goal is not the exclusive end. Merely adopting a procedural way of thinking about sound can inform and enhance traditional design approaches. For this reason I teach a sound design syllabus based upon this premise. Students begin the first semester by considering the physical processes inherent in all sound sources They then progress to devising models and appropriate synthetic methods in an implementation language. This deeper understanding enables choices and creativity through structural metaphor and simile rather than only empirical (surface) features.

For example, we study the design of bells with reference to design traditions on shape and material properties. Combining metallurgy and geometry (which leads to modal interpretation) with the study of basilar physiology and sensory psychoacoustics of Barkhausen/Zwicker (1961) and Plomp and Mimpen (1968), we arrive at a firm understanding of *why* some bells are sonorous, dissonant, hollow, or foreboding. In another exercise we decompose the sound of fire to arrive at the components corresponding to physical processes of combustion. This results in models of fire with surface parameters like crackles, hiss, and roar, which can be abstracted further into scalable fire models for burning trees or liquid fires. Hybridisation of models at an abstract level is possible, perhaps to combine fluid models like bubbling mud with fire to create lava flows.

If procedural audio implies the sound is based on process, then *behavioural* audio implies that the internal model and supplied parameters reflect the behaviour of the target object in some way. What is behaviour? Behaviour relates environmental stimulus to what is observed in time. It is a strange concept because it must both change and, to some degree, remain fixed in time. A purely signal interpretation might define behaviour as repeatable changes in one or more output features in light of one or more supplied, dependent variables with little restraint on the whole cavalcade of qualifiers, discrete, continuous, linear, non-linear, causal, or non-causal that might apply. A useful behaviour might be supposed to be time invariant on a medium to long scale (in the order of seconds). In other words, behaviour that changes too rapidly ceases to be observed as behaviour.

When talking about behaviour we might incorporate *statefulness* into sound objects, for example; whether a container is full or empty will cause it to respond differently to a collision. Within a larger context behaviour implies a narrative. A drink can or tumbleweed in the street is destined to roll around as it is blown in the wind. Of course it can do many things, but rolling around is its "script", its purpose in life. One way of understanding the narrative is a context that places particular emphasis on certain features. In real life the function of glass windows is to keep out the wind while allowing light in. In a first person shooter their primary concern (understood tragic destiny) is to be shot at and broken. As we will examine later, this change of narrative focus (and thus reality) is both a dynamic force in interactive sound, and the source of an error in some programming approaches that assume the need for a literal, uncoloured interpretation of reality.

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