The Limitations of Mapping as a Structural Descriptive in Electronic Instruments

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Abstract

Mapping, which describes the way a performer's controls are connected to sound variables, is a useful concept when applied to the structure of electronic instruments modelled after traditional acoustic instruments. But mapping is a less useful concept when applied to the structure of complex and interactive instruments in which algorithms generate control information.

This paper relates the functioning and benefits of different types of electronic instruments to the structural principles on which they are based. Structural models of various instruments will be discussed and musical examples played.

Keywords

mapping fly-by-wire algorithmic network interactivity instrument deterministic indeterministic

INTRODUCTION

A traditional acoustic musical instrument typically consists of three components: a controller (to call it by an electronic instrumental term), a sound generator, and a link that connects the controller to the sound generator. In a violin, for example, the controller is the strings and bow, the sound generator is the sound box, and the link is the bridge. In general, in an acoustic instrument the controller excites resonances in the sound generator via the link; and that close and tight relationship between controller and sound generator, through which a performing musician can maintain control over the sound generated by the instrument, has defined the mainstream concept of musical instrument for performing musicians even into the electronic age.

In an electronic instrument, controllers, sound generators, and links are independent structural units that can be combined with great structural and functional flexibility. Electronic controllers can be based on a wide variety of technologies -- capacitance-sensitive devices, mercury switches, stress sensors, video cameras, resistive-ink pads, ultra-sound, radar, and infrared beams, to name a few -- according to whatever physical gesture is found to be appropriate in controlling a particular sound. Electronic sound generators can produce a wide variety of synthesized, recorded, or recorded-and-transformed sounds. And most important, the link between controller and sound generator can be active, which is to say that the link can be a computer that can generate information, run algorithms, or act in any way as an intermediary between a performer's controls and the variables of a sound generator. In short, any physical gesture can be interpreted in any way to control any sound.

Given, then, the flexibility with which gestural controllers can be interpreted by software to control sound generators, the questions are: How do we decide what kind of instrument to design? And how do we build that instrument? The goal of this paper is to describe the different ways an electronic instrument can function, to identify the benefits that different functioning affords a performer, and to relate an electronic instrument's functioning to its structure

FUNCTIONING AND BENEFITS

It is recognized wisdom to state that the goal of technology is to benefit humans. It follows that the design intent of any particular instrument should be based on the potential benefits of that instrument's functioning to a particular group of people with common creative goals.

The functioning of any particular electronic musical instrument can be placed on a taxonomic line marked by deterministic functioning at, let's say, the left, and indeterministic functioning at the right. At the leftmost extreme of the line, a deterministic instrument is defined by the complete predictability of its output relative to a performer's controls. Because such an instrument leaves a performer in precise control of every detail of the output sound and provides no information beyond that supplied by the performer, such an instrument is likely to require skill, talent, and a knowledge of music, and, consequently, benefit a professional (or aspiring professional) musician more than an unskilled amateur.

As we move along the taxonomic line towards the right, instruments contain increasing amounts of unpredictable information. In the functioning of a slightly indeterministic instrument, a relatively small amount of unpredictable information can simulate a performer's talented assistants, automatically supplying creative details while the macro-music remains completely under the performer's control. Depending upon the amount of unpredictable detail and the way it is triggered, such an instrument may become a powerful performance enhancement for a professional.

At the rightmost extreme, an indeterministic instrument outputs a substantial amount of unpredictable information relative to a performer's controls. In working with such an instrument, a performer shares control of the music with algorithms as virtual co-performers such that the instrument generates unpredictable information to which the performer reacts, the performer generates control information to which the instrument reacts, and the performer and instrument seem to engage in a conversation. Interaction means 'mutually influential'. Since the instrument is influenced by the performer's controls, and the performer is influenced by the instrument's output, I have called such instruments 'interactive instruments'.

The definition of interactive instrument is especially important because interactive instruments, which incidentally can not exist in non-electronic technologies, provide a particular set of benefits to a new musical constituency. The primary benefits of an interactive instrument are, first, that the performer is called upon to think and act like a creative person with intelligence, imagination, and musical expressivity, as against like an executor of someone else's composition; and, second, that the level of musical skill required to 'play' the instrument is flexible. Interactive instruments embody all of the nuance, power, and potential of deterministic instruments, but the way they function allows for anyone, from the most skilled and musically talented performers to the most unskilled members of the large public, to participate in a musical process. Since the instrument provides cues for musical actions, thereby obviating the need for a musical score, and since the performance device need not require previously-learned musical skills, interactive instruments may be especially beneficial to interested amateurs. The concept of an interactive instrument may, in the near future, define a new way for the public to experience music.

There is, of course, infinite nuance in instrument design that may cause a particular instrument to be more useful for professionals than for amateurs. But as a general rule, the most important requirement of an instrument for a professional performer is that the instrument demonstrates for the audience that the performer is necessary and is in fact controlling the music; and this requirement assumes a strong degree of determinism at least in certain aspects of the instrument's behavior.

But such requirements of obviousness do not exist when the instrument's behavior need be understood only by its performer, as in the case of an amateur performer-at-home. For the performer-at-home, the creativity in the instrument's output can be in itself rewarding. Indeed, creative instruments may be of great interest even to professionals who wish to explore new musical horizons. As Iannis Xenakis wrote, "With the aid of electronic computers the composer becomes a sort of pilot: he presses the buttons, introduces coordinates, and supervises the controls of a cosmic vessel sailing in the space of sound, across sonic constellations ... now he can explore them all ... " [Xenakis, 1992, 1963]

TYPES OF STRUCTURE

A variable is something that can be changed. If an instrument contains two variables, its output can be changed in only two ways. If it has 100 variables, its output can be changed in 100 ways. The fewer the number of variables in a system, the more powerful is each variable: changing one of two variables, for example, is changing half of the system. The greater the number of variables in a system, the weaker is each variable -- changing one of 100 variables, for example, is changing only 1/100th of the system -- but the more sensitive is the system because it can change in many different ways.

Clearly it is better to have a sensitive instrument with many variables than a crude instrument with a few variables. Yet it is also clear that within the limits of a normal human body, no performer can track and manually control a large number of independent variables at the same time. The connections between a performer's gestures and a large number of sound-generating variables is, at a certain abstract level, what we mean by 'mapping'. But mapping, as the term seems to be generally understood, is a concept that applies to certain instrumental designs more appropriately than to others. Further, the nature of mapping cannot be understood without also understanding the nature of power.

A hierarchy can be imagined as a stack of boxes in which each box contains several smaller boxes. One big box contains several smaller boxes, each of which contains several smaller boxes, each of which contains several smaller boxes, etc. The idea of a hierarchy is that larger things contain smaller things. In a hierarchy of controls, power can be measured by the number of controls a control contains. If a performer's control gesture is translated into 100 controls that cause change in 100 variables, for example, it is more powerful than if it istranslated into two controls that cause change in two variables.

In theory, hierarchies are simple and deterministic. In the ideal hierarchy, controls pass downwards from level to level, each descending level articulating the highest control with greater resolution but without distortion, until the controls reach their target variables. In a deterministic instrument, mapping means the routing of controls through descending levels to the variables. The goal, in the context of a deterministic musical instrument, is to make the performer powerful and keep the performer in complete control.

In a network structure, on the other hand, control is decentralized because, theoretically, all of the nodes in a network can generate and receive controls independently. Each connection between any single nodes or subgroups of nodes can be seen as a single deterministic structure, and since the controls are generated and transmitted through a complexity of different relationships, their total effect is likely to be less predictable than the controls produced by a hierarchy.

In theory, networks are complex and indeterministic. The ideal network is creative rather than obedient and generates unpredictable information. Yet each connection need not be equally important in the performance of the whole. In the design of an interactive instrument, a performer's control is likely to be placed in a more important and visible position than other controls. In such a situation, mapping may partially explain the performer's controls because one can map the causes-and-effects of each connection within a network. But mapping any one line of cause-to-effect does not describe the operation of the instrument as a whole.

THE LIMITATIONS OF MAPPING

Mapping describes the way a control is connected to a variable. But as instruments become more complex to include large amounts of data, context sensitivity, and music as well as sound-generating capabilities, the concept of mapping becomes more abstract and does not describe the more complex realities of electronic instruments. Deterministic instruments include simple and derivative instruments such as electronic pianos, for example, but the category also includes complex and original instruments, where a performer, for example, might use a multitude of touchpads or other devices to control the variables of a probabilistic expression that automatically produce micro-events in the resulting music.

As deterministic electronic instruments become more sensitive and contain greater numbers of independent variables, simple control hierarchies are likely to become less useful as control structures, and fly-by-wire systems that include algorithmic controls are likely to become more normal. In aviation, 'fly-by-wire' describes a system in which a pilot tells a computer what the airplane should do and the computer flies the plane. The advantages of such systems include the computer's ability to expand simple but powerful instructions into coordinated controls for multitudes of variables, to redefine controls in different contexts, and to maintain goal-orientation while introducing enough unpredictability to keep the instrument interesting. A fly-by-wire system might be viewed as a series of if-then algorithms, each algorithm triggered by a performer's action in a particular context and able to react dynamically in changing arbitrary relationships between controls.

As interactive instruments become more common, they will be realized in a variety of different ways. Yet one of the important questions will remain: How does the indeterministic functioning of an interactive instrument derive from its structure? Different composers have answered that question in different ways. In *Voyager*, for example, George Lewis created a 'virtual improvising orchestra' that analyzed a musician's performance in real time and generated a complex response that contained unpredictable information to which the musician continued to react. [Lewis, 2000] Robert Rowe invented a virtual listener that sensed, analyzed, and responded to a player's inputs. [Rowe, 1993] Where both Lewis and Rowe emulated the processes of an independent improvisor that analyzed and responded to the sound produced by a physical performer, my own approach has been to share control of the music with a virtual composer. In *Solo*, for example, I used modified theremins to 'conduct' tempo and timbre while the notes of the melody were generated algorithmically. [Chadabe, 1980] In *Many Times* ..., a more recent composition, a performer's input at any moment shares control of sound-processing algorithms and spatialization with many independent random number generators. In every case of the interactive instrument, whether based on analysis or independent algorithm, controls for the music and sound variables originate simultaneously and asynchronously in different contexts and from different sources; and because the relative importance of each control may vary according to function and in time, the cause-effect relationships within such an instrument, too complex to be usefully described in terms of mapping, are most usefully described as a network.

CONCLUSION

The mapping model, based on the deterministic functioning of traditional acoustic instruments, is limited in describing the most innovative and potentially beneficial approaches in electronic instrument design. The primary benefit of an electronic instrument for a professional performer, which is that it extends the performer's capabilities in interesting, creative, and complex ways, requires an intermediary mechanism between gestural control and sound variable. The primary benefit for the amateur performer-at-home, which is that the instrument provides information to which the performer can react, requires a network structure. To the extent that an automatic mechanism generates information, even while remaining obedient to a performer's commands, it becomes more difficult to conceptualize a performer's control gestures as mapped onto an output. Mapping, in short, is not the best way to conceptualize the structures of the most important and beneficial types of instruments.

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