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NEW DIGITAL MUSICAL INSTRUMENTS:

CONTROL AND INTERACTION BEYOND THE KEYBOARD

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With a Foreword by Ross Kirk

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Musical Gestures: Acquisition and Mapping

The main focus of this book is on musical instruments that use digital sound synthesis methods to generate sounds. An instrument that uses computer-generated sound can be called a digital musical instrument (DMI) and consists of a control surface or gestural controller, which drives the musical parameters of a sound synthesizer in real time.

Both hardware and software (computer-based) sound synthesizers are widely available. In fact, sound synthesis is a broad research field in which there have been a number of important developments since the 1950s (Dodge and Jerse 1997; Miranda 2002). Several synthesis techniques have been proposed that are able to reproduce acoustic sounds with high fidelity or to create new sounds impossible to produce with existing acoustic instruments.

Gestural controllers can take any form, from that of an acoustic instrument (instrument-like or instrument-inspired controllers) to alternate controllers that do not resemble known acoustic musical instruments. Conversely, the addition of sensors to existing acoustic instruments can increase their control possibilities. Such modified instruments are known as extended or augmented instruments and represent a compromise between the use of a known, but somewhat limited, control surface of an acoustic instrument and development of completely new performance abilities using an alternate controller.

The number of possibilities for designing DMIs is vast. Moreover, apart from the obvious reproduction and extrapolation of the functionalities of acoustic musical instruments, DMIs may be designed for various other contexts: for nonexperts or for experts in other forms of art (such as dance, where a dancer can control the music being generated), for use by multiple performers, as distributed entities in local or distant facilities, and so on. Therefore, the design of a DMI is not a trivial issue; many questions must be answered before we can decide which approach may best suit our musical aims: Why copy or be inspired by acoustic instruments, with their inherent limitations, if any movement can be used as a control variable? What can augmented instruments offer to performers? Why design musical instruments only for experts? Why be limited to a one-person-one-device configuration when networking capabilities are available for virtually all computers nowadays? What new possibilities are offered by digital musical instruments with respect to other artistic contexts?

In this book, we review various examples of DMIs, focusing on the various examples of gestural controllers proposed in the literature. We suggest ways to make sense of the wide variety of existing controllers, explore the most common sensor techniques used in their design, and analyze DMIs that make use of biological signals. Finally, we comment on extended techniques to extrapolate the DMI concept to systems that include artificial intelligence and other advanced techniques.

1.1 INTRODUCTION

Until the end of the 19th century, the design of musical instruments relied upon mechanical systems and the acoustic properties of tubes, strings, and membranes. With the advent of electricity, instrument designers started to experiment with the new possibilities offered by electrical and later by electronic means.

Examples of early electrical and electronic instruments are various (Chadabe 1997; Paradiso 1999), such as, for instance, the theremin (built in 1920 by Lev Termen), the ondes martenot, (built in 1928 by Maurice Martenot), and the trautonium (built in 1930 by Friedrich Trautwein). These instruments were just the first in a whole new range of possibilities offered to instrument designers, including new ways to generate sound and new ways to design control surfaces of any arbitrary shape. Today, the two most common ways to generate sound are through the use of a synthesizer and by means of a general-purpose computer. With the easy digital interconnection possibilities afforded by data communication protocols, anyone can connect different types of control surfaces to synthesizers and computers.

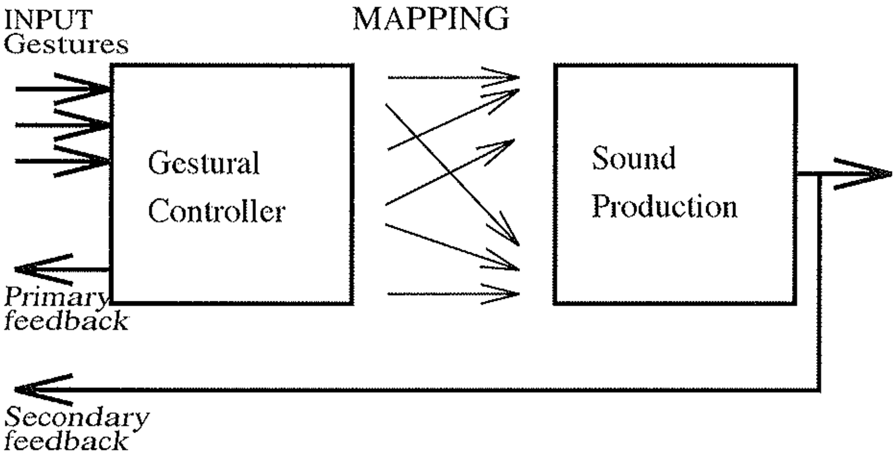
Here we review and discuss examples of DMIs, focusing specifically on their control surfaces. We will start by presenting a simple model of a DMI directly derived from traditional acoustic musical instruments.

▨ 1.2 A DIGITAL MUSICAL INSTRUMENT MODEL

For the purposes of this book we adopted the term digital musical instrument (DMI) to denote an instrument that contains a control surface (also referred to as a gestural or performance controller, an input device, or a hardware interface) and a sound generation unit. Both units are independent modules related to each other by mapping strategies (Figure 1.1).

The gestural controller (or control surface) is the device that provides the inputs to the DMI. It is where physical interactions between the performer and the instrument take place. The sound generation unit involves the synthesis algorithm and its controls. The mapping layer refers to the liaison strategies between the outputs of the gestural controller and the input controls of the sound generation unit.

Figure 1.1 A possible approach to the representation of a digital musical instrument.



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Biosignal Interfaces

In this book we use the term biosignal to refer to electrical signals produced in the body, such as nerve, muscle, and brain signals.

The electrical nature of the human body has been recognized for more than a century. In the 1840s, the physiologist Emil Heinrich du Bois-Reymond reported the detection of electrical discharges created by the contraction of the muscles of his arms (Lusted and Knapp 1996). Du Bois-Reymond made these observations using a galvanometer, a device for measuring voltage. He attached the wires of the galvanometer to his body using pieces of blotting paper soaked in saline. Du Bois-Reymond's method for detecting muscle contraction still forms the basis of current practice in electrophysiology, albeit using more sophisticated electrodes and amplifiers.

The measurement and analysis of biosignals requires sophisticated sensor technology. These signals are normally sensed using electrodes attached to the body, and they normally need to be amplified by a factor as high as 10,000 in order to be useful. Moreover, these signals must be harnessed by means of numerical methods in order to infer their meaning. Only then can the behavior of the biosignals be used to operate a musical system.

4.1 BRIEF INTRODUCTION TO ELECTRODES AND ELECTRICAL SAFETY ISSUES

Biosignals are normally produced by action potentials in nerve fiber bundles or by extracellular potentials generated by the movement of ions in and out of cells during depolarization and repolarization. Because most biosignal sensing is extracellular and takes place at some distance from its origin, what is sensed is the combined voltage of the simultaneous activation of many components (nerves, muscle fibers, or neurons). The signals are conducted through the tissue of the body and detected by sensors, normally electrodes.

It is a common mistake to assume that the electrodes "pick up" electrical activity, which is then sent to a computer for processing. In fact, current flow is measured through a loop composed of the subject, electrodes, wires, and the recording equipment. The voltage fluctuations produced in the subject can be calculated because the resistance to current flow is taken as a reference.

Charge movement in the brain, muscles, or nerves generates the electrical activity. The charge moves into one electrode, goes through the circuitry of the amplifiers, and enters back into the subject through another electrode. Therefore, the subject and the amplifier form a complete circuit loop.

Standard surface electrodes are normally applied to the skin with a conductive gel, and the skin should normally be prepared with abrasion beforehand in order to remove oils and layers of dead skin that may interfere with the electrical conductivity. The conductive gel is essentially a malleable extension of the electrode: it maximizes skin contact and is required for low-resistance recording through the skin. However, electrode technology is rapidly evolving; more ergonomic sensors with built-in signal processing capability and wireless data transmission will soon be available on the market at an affordable price.

4.1.1 Electrical Safety

When working with biosignals, electrical safety should be carefully observed in order to prevent accidents. It is always preferable to use equipment that runs on disposable batteries (e.g., alkaline or lithium batteries) rather than mains AC. Should a mains connection be absolutely necessary, then it must be supplied by three wires: hot, neutral, and earth wire. Hot means that there is alternating voltage (e.g., ±110 V); neutral is the reference for the hot line from the power company, and it is not necessarily at 0 V; the earth is the earth connection.

One of the main problems with biosignals is current leakage. This is mostly caused by faulty earth connection or inappropriately long power supply wires. This is manifested in the signal by the appearance of accentuated noise. A common cause of leakage is when the subject is attached to two pieces of electrical equipment but only one is properly earthed. If the subject is earthed to both devices,