Design Issues for New Performance Systems

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Abstract

The field of new musical performance interfaces is currently undergoing a process of formalisation. This paper considers these developments in the light of both formal product development procedures and the history of musical instrument development. These factors are also considered in relation to the principle of constraint. Constraints focus the process of product development. Constraints also provide stimulus to creativity, both in product development and in musical culture in general. An experimental example illustrates the unpredictability that lies at the heart of musical experience.

Introduction

This paper presents the issue of constraints as a perspective on design processes for new musical interfaces. In the light of perceived tensions in the research activities in this area the paper provides an overview of typical product design processes and compares them to the sometimes unconventional evolution of musical devices. The paper looks at constraints from two different perspectives: firstly, as an imposition on new designs when following objective design procedures; and secondly as a stimulus for new and unique solutions to instrument design problems.

> "At the heart of creativity lie constraints: the very opposite of unpredictability. Constraints and unpredictability, familiarity and surprise, are somehow combined in original thinking." (Boden 1995)

The quest for musical freedom and originality may find its antithesis in the strictures of product development. Sometimes however, the constraints imposed result in surprising and unforeseen developments. This is nowhere more evident in the adoption of the laptop computer as an unlikely but highly successful musical interface. This fact has been the stimulus of a re-evaluation and comparison of two aspects of constraint and creativity. One aspect is in the area of product development and the other is in the area of musical practice. It is hoped that this work will provide a review of these areas for those working in the field of new interfaces for musical expression and provide stimulus for further discussion.

An overview is provided of common product development processes. This is supported with a discussion of generally applicable design criteria and notions of "good design".

Examples and discussion of some historical developments are introduced to show the diversity in the genesis of musical instruments. It is evident that the adoption, adaptation and evaluation of musical instruments have not followed any particular set of rules and that a great variety of factors influence their success.

The area of creativity in musical performance and the influence of constraints are presented in contrast to the constraints that lie behind the development of the musical interfaces used in performance.

Finally, an example of a new interface is presented to demonstrate another approach to developing design criteria and the surprising results that may follow from breaking the rules.

Background

Research in the area of new musical performance interfaces has undergone a process of formalization over the past five years. These developments are evident in such publications as the CDROM "Trends in gestural control of music" (IRCAM 2000), Interactive Systems and Instrument Design in Music Working Group (http://www.igmusic.org/); and most significantly the New Interfaces for Musical Expression Conferences held annually since the year 2000. Prior to this professionalisation of the field, new instrument design research was documented in one of two ways. Firstly, through commercial patent claims and through such non-specific organs as the Journal of the Audio Engineering Society, Computer Music Journal and the Association for Computing Machinery Special Interest Group on Computer-Human Interaction (ACM-SIGCHI) and associated annual Computer Human Interaction conferences; and secondly in such publications as Experimental Musical Instruments and the other works of authors such as Bart Hopkins (Hopkins 1998, 1996) and Michael Atherton (Atherton 1990), and in ongoing research in musical instrument organology.

In the former distribution channels new developments were reported in a non-systematic way focusing on objective research results in diverse areas often supported by general research into human factors engineering. In the second category of documentation, new developments were celebrated for their individuality and idiosyncratic peculiarities. In these documents new instrument development is seen as an art form in itself, not an exercise in product development and industrial engineering.

The process of formalization described above has not escaped the tensions between these two responses and this may be detected in the proceedings and ongoing debates in the area.

Product development and design

Previous work by the author on the eMic (enhanced mic stand interface controller) (Hewitt & Stevenson 2003) had taken an approach that identified specific existing performance gestures and cultural practices and imagined a new interface designed specifically to capture those gestures and solve perceived problems with existing practices. Other aspects of the form of this interface were defined by pre-existing technologies and performance norms. This approach resulted from a creative response to overcoming constraints imposed on the performer/designer in her practice. Rather than providing an idiosyncratic response to these constraints, the designer attempted to create a flexible, broadly applicable interface. The design resulted from research that identified a number of key requirements from the perspective of a wide range of performers working in a variety of musical genres. As a result, the implementation loosely followed a traditional product design process as outlined below.

This approach is clearly not the norm in the field of experimental instrument design (Hopkins 1996, 1998). Indeed, prior to the professionalisation and adoption of contemporary industrial practices in the area of instrument design, the genesis of new musical instruments had been characterized by extreme diversity as discussed later. Alternatives to the standards-based approach outlined below are as numerous as creative processes themselves. The designs of most successful instruments from the Western canon have been constrained by factors such as the acoustical and structural properties of their materials of construction. The reasons behind their success are complex and difficult to define, and are the subject of considerable debate.

Commercial product design

The commercial product design process involves a number of key steps. The approach outlined below provides a linear process where each phase may be evaluated in terms of the criteria defined in the preceding phase. This is the basis of a so-called quality systems approach (Beaumont 2002).

Requirements definition
A demand, unserved need or commercial potential is identified in the marketplace. Experts and users help to identify prioritized requirements in the areas of: capabilities, usability, performance, reliability, compatibility, time frame and cost. This definition includes desirable features/functions and other constraints.

Feasibility
The requirements identified above are assessed in terms of the necessary development effort needed to achieve the requirements. Each requirement is reviewed and further material, technical and organizational constraints and assumptions are introduced.

Conceptual modeling
A broad overview describes how the product will meet the requirements from a user's perspective. Visual design aspects are modeled. Project/product planning and resource requirements are introduced including quality planning. A feature list is developed.

Functional specification
This document describes the product in complete detail from the user's point of view. This forms the basis for all subsequent design and implementation tasks. Details of all aspects of user interaction and product function are covered.

Design and planning
This phase includes the research which determines how exactly the product will fulfill the design requirements and specifications. Included here are design and analysis tasks, design review and testing plans. Basic prototyping may be included here.

Implementation and testing
The implementation phase is where all the designs are worked through resulting in one or more test-bed prototypes. Functional testing is designed and implemented. Usability evaluation is performed and documentation is implemented.

Production engineering and marketing
In a commercial project the final phases involve finalizing the mass production process including production documentation and packaging. The final and most critical step is to reintegrate and implement the marketing strategy that will have

been initiated at the initial requirements definition phase.

General design considerations

The requirements and feasibility phases outlined above introduce constraints into the design process. The requirements specification provides a first pass at prioritizing these criteria. Typical commercial design criteria include: design for cost; time-to-market; function; usability; aesthetics; reliability; zero-defect manufacturing (type of design where product can only be assembled one way); maintainability; environment (reuse, reduce, recycle); assembly and disassembly; safety; packaging and distribution.

The principles of "good industrial design" are of mixed applicability in traditional musical instruments. Such considerations as serving the user's needs and requirements are turned upside down in traditional instruments, where the user must adapt to the needs and requirements of the instrument and the music that is written for it. Similarly, the selection and use of appropriate materials become a moot point when the identity of the instrument is so closely tied to its materials of construction. Again, when considering production requirements as a principle of good design, traditional instruments have been associated with elaborate and painstaking manual labour.

Other principles often considered of value do find applicability. Principles such as visual expression of the time and place of design; expression of materials and design intentions; functionality; performance; and aesthetics are expressed in many familiar traditional instruments.

Of interest to those developing new musical interfaces is the design principle of ergonomics. Many traditional instruments require the user to adopt postures and physical gestures that result in injury from sustained use. Once again, the user/performer is made to bend to the requirements of the instrument.

Many of these contradictions may be considered to be bound up in musical culture. When new instrument designs are evaluated both from the usability point of view and from the point of view of expressivity and musical outcomes, these historical factors may exert an influence as shown in the connection made by some commentators between difficulty of learning and use on the one hand, and potential for expressivity and virtuosity on the other (Ryan 1991) (Arfib & Kessous 2001).

Just as industrial production and mass marketing of musical instruments brought design criteria into focus in the eighteenth and nineteenth centuries, developments in technology in the twentieth century brought new factors into play. The development of electronic musical instruments facilitated the decoupling of the user interface from the sound producing mechanism. The parallel development of digital computing systems has resulted in a sharing of new approaches to the man machine interface (Mulder 1989). Such considerations as ease of use, repeatability (Baeker 1995), and generality of application of the interface (Truax 1984), when coupled with the commercial considerations above may be considered to have adversely influenced creative development in the field of new musical interfaces.

General purpose computing systems stand in contrast to musical interfaces in a number of key areas. One factor is the principle of generality versus strength. This principle holds that the generality of application of a control system increases with the number of dimensions of control. A second principle states that the ease of use of a given control system (and therefore its success) decreases in proportion to an increase in degrees of freedom or dimensions of control (Schneiderman 1987). Here we find a significant contrast between the objectives of composers and performers, on the one hand, whose aim is to take control of an expanded timbral palette, and the wisdom of human computer interaction research that encourages reduced dimensionality, and ease of use. This nexus has been the stimulus of developments in the area of control/parameter mapping (Hunt, Wanderley & Kirk 2000).

Another general design consideration is the nature of unpredictability in the interface. In commercial systems, the elimination of unpredictability is a critical criterion in the design for ease of use and learning. However, unpredictability on the extremes of normal performance practice is an inherent feature of traditional acoustical musical instruments. These behaviours have been reintegrated into digital systems in synthesis techniques based on modeling acoustic systems (Cook 2002).

Historical aspects of instrument development

The histories of musical instrument development may be moulded and re-told to support a great diversity of contrary claims about musical and cultural development. Here I will merely touch on a few concepts and examples to help illustrate some ideas relating to the development of design criteria and the notion of performance constraints.

The success of traditional and folk instruments and the musics that they support is as much a result of economic, military, migration and other social factors as it of inherent musicological or technical factors. These factors have continued to exert an influence in the ages of globalization and mass-communication.

Many traditionally hand-made instruments exhibit complex and subtly nuanced gesture spaces. That is, the range of physical movements required to operate the instrument within its normal operating range and to fully realize its potential for expressivity is complex and requires the coordination of more than one body part. This complexity is exemplified in many string and wind instruments. The development of industrial production methods and mass marketing in the 18th and 19th centuries saw a decrease in the gestural complexity required for developed performance practice for new instruments. This is exemplified by the development of the pianoforte and such mass-market instruments as the accordion, autoharp and harmonica. These developments were also paralleled by constraints in the areas of tuning, resulting in increased conformance to the equally tempered scale. Mass production with its careful design also helped to eliminate unpredictability in the acoustic behaviour of the instrument, largely as a result of the constraints on performance gesture. Whereas a violin allows a range of modes of sound production outside the musical norms, it is much more difficult to achieve these unpredictable results with a modern industrially manufactured instrument such as an accordion.

The piano accordion is an example of a hybrid instrument. Another approach involved augmenting an existing instrument prototype to extend loudness or range. Early examples of this approach include the Stroh Viols and Parson's Auxetophone.

The Stroh viols made by Stroh of London during the 1890s, replaced the body and sounding board with a mechanical linkage from the bridge to a diaphragm in the throat of a conical horn. Similar instruments were used for Maurice Kagel's 1898 developed at Darmstadt in 1973 by Franz-Ernst Peschke (Sadie 1984).

Another similar development was made by the brilliant British inventor and industrialist Sir Charles Parsons. In 1903 he patented his Auxetophone (British patent no. 10468). This device took the form of a mechanical attachment to an existing acoustic instrument. A linkage from the bridge modulated the relative positions of fixed and movable combs, precision milled from alloy. This arrangement acted as a pneumatic valve modulating the flow of air from an air pump to an exponential gramophone horn. The only existing example of this device is in the collection of the Science and Engineering Museum, Newcastle upon Tyne.

This development was contemporary with the invention of the thermionic valve by Sir John Ambrose Fleming ultimately leading to the development of electronic amplification and the most successful example of the augmented instrument, the electric guitar. The spirit of technological augmentation, leveraging existing performance techniques and musical literature, can clearly be seen in hyperinstruments such as those developed at the MIT Media Lab (Machover 1992).

A somewhat less historically determined path in instrument development is that which has occurred in the area of experimental music (Nyman 1999) and experimental instruments (Hopkins 1996, 1998). In this empirical and sometimes whimsical approach, personal interest, available materials and aesthetics are the critical factors influencing the design. Similarly in the areas of sound installation or sound sculpture (Bandt 2001) the designer's creativity is much less constrained by factors external to the work itself. However, the creative process is indeed determined to a large extent by constraints either imposed from outside by exhibitors, curators or collaborators, or accepted by the designer as a convention within the work or as stimulus to some creative outcome.

There are many examples of contemporary musical instrument development that show musical interfaces being adapted to a target performer skill base. An example of one sort is the work of Tod Machover and the MIT Media Lab in productions such as The Brain Opera and Toy Symphony [http://www.media.mit.edu/hyperins/]. Another example is seen in those interfaces supporting the performance skills of the DJ turtablist [www.finalscratch.com][www.denondj.com].

The success of many contemporary mass-market electronic instruments has also been determined by successful marketing and implementation of industry wide standards, most notably MIDI which inherently supports the pitch/rhythm/harmony, note event paradigm.

Creativity in performance

Having considered a variety of constraining factors in the design and development of musical instruments, we will now consider the constraints imposed on the performer by the musical interface, as a stimulus for creative musical outcomes.

Creativity is the ability to bring into existence something new or novel which is widely considered to be of value. Many factors influence the development or realization of creativity. Much has been written on the relation of constraints to musical creativity.

Igor Stravinsky famously defended his continuing to work with tonal harmony claiming that "You cannot create against a yielding medium" (Stravinsky 1974). For Stravinsky, the tonal system presented a problematising framework requiring creative solutions. Another set of musical problems or constraints is presented by the twelve-tone system. This system of constraints was extended and applied to timbre and dynamics in the form of "total serialism" by composers such as Pierre Boulez.

Perhaps the ultimate example of creative constraints is that adopted by the instrumentalist performer of notated music. Although western musical notation provides a limited framework for the specification of musical events, it does provide significant constraints. Even more constrained is the ensemble performer. The creative genius of the virtuoso is measured by the ability to find expressive and interpretive scope within the limits of the composer's notated work.

Constraints preclude some things and promote others. It has been argued that the adoption of constraints leads in many cases to increased variability, a key measure of creativity (Stokes 2001).

Similarly the domain of the improviser is marked by constraints. The improvising performer adopts some conventions or frameworks and is always constrained by the possibilities offered by the instrument interface itself.

Another factor cited as an indicator of creative potential is extensive "domain knowledge" (Piirto 2004). Domain knowledge has been imagined as a complex terrain or mental map (Boden 1995) made up of the rules and features of the domain. This terrain becomes more complex as experience and knowledge are developed. A truly creative thinker can navigate or move from one part of this mental terrain to another with ease, sometimes resulting in the serendipitous outcome of creativity.

An experience instrumentalist and musician maintains a mental map not only of the gesture space of interaction allowed by a given instrument, but also of the rules of the musical domain within which they operate. With an intimate knowledge of the domain boundaries new and interesting musical results may occur.

Given these considerations it may be supposed that there is some relation between the complexity of gesture space offered by an instrument and the potential for virtuosity and creativity (i.e. the violin may be superior to the computer mouse). On the other hand it has been suggested that the user interface of limited complexity (the laptop computer) provides the constraints that facilitate creativity [Knowles, J., personal communication].

Writing on creativity often highlights the oppositional tension of factors such as intellect and intuition, the conventional and the unconventional, and complexity and simplicity. It is evident that these oppositions are relevant factors in the field of new musical interfaces. The adoption of increased constraints in the design of new musical interfaces stands in contrast to developments in the area of unencumbered or immersive controllers (Mulder 1989) (Paine 2002). In works of this nature, interaction and physical human gesture is made unrestricted. The ideal of unconstrained motion controlled by intention and influenced by audible, visual and kinesthetic feedback only is attractive. However, even in environments such as these the performer is constrained by the resolution of the sensing technologies and the implementation of the control mapping, signal processing and synthesis techniques, these being simultaneously part of both the instrument and the composition (if a distinction can be drawn between the two). The idea of unconstrained musical creation resonates with the ideas of early modernist composers such as Edgar Varese who dreamt of a liberating technology that would enable the realization of any imaginable sound structure.

The Didactophone

A simple example of a new musical interface device resulting from strong design constraints and offering significant constraint to the performer is described below. A demonstration interface was required for a university course in new musical interface design. It was intended that this example device should convince students of the potential simplicity of realizing a new interface and encourage them in their own attempts. Therefore, given the temporal and financial constraints in which we operate, the following criteria were identified:

1. The device must cost less than AU$50.00;
2. the device must be able to be constructed within an afternoon;
3. materials must be readily available and easily fabricated.

This requirement resulted in a new interface appropriately called the Didactophone.

Figure 1. First prototype version of the Didactophone using off-the-shelf plumbing fittings

This approach was a radical departure from the author's previous work. No consideration was made of the user's requirements, the gestural language to be employed or the musical paradigm within which the instrument would operate. It was considered that the resulting device would be unplayable and of curiosity value only. We were surprised to discover that, in fact, the Didactophone had many interesting properties and resulted in the development of a new and surprisingly expressive performance technique referred to as *fondling*.

This design fulfils two principles of good design: functional independence; and minimized complexity through symmetry, resulting in minimal information content in the design. The individual parts of the interface are largely independent in operation. Failure or wear in one part will not cause complete failure in the device and repairs require the simple replacement of a single part. The device comprises six identical controls mounted on the six surfaces of a cube. There are essentially only two unique structures, the cube and the controls.

Construction

The initial prototype comprised the following parts:

1 x 50mm square die-cast aluminium box
6 x 10K rotary potentiometers
12 x 50mm PVC plumbing end caps
6 x 100mm sections of 50mm PVC waste pipe
6 x plastic control knobs
30ml epoxy adhesive
2m cat5 twisted pair cable
1 x 6mm cable grommet
1 x 12 pin header connector
100mm x 1mm flux cored solder

Conclusions

The field of research into new interfaces for musical expression must adopt a flexible approach that can exploit developments in objective research but also accept that musical culture is subject to diverse forces of both a personal and a political nature. Designers must not be too ready to adopt apparently rational design rules at the expense of their own musical interests. Design requirements for new products usually result from a comprehensive evaluation of the user's needs. While this may result in useful and successful musical instruments it is not necessarily the only course to take in developing new musical interfaces. Many successful musical interfaces exhibit what may be considered to be undue constraint on the performer. It has been argued that these constraints can be the very source of musical creativity. In musical instrument design as in all fields of human endeavour, a balanced approach may be beneficial.

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