DAMPER: A Platform for Effortful Interface Development.

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ABSTRACT

This paper proposes that the physicality of an instrument be considered an important aspect in the design of new interfaces for musical expression. The use of Laban's theory of effort in the design of new effortful interfaces, in particular looking at effort-space modulation, is investigated, and a platform for effortful interface development (named the DAMPER) is described. Finally, future work is described and further areas of research are highlighted.

Keywords

Effortful Interaction. Haptics. Laban Analysis. Physicality. HCI.

1. INTRODUCTION

The exploration and design of digital musical instruments and musical performance interfaces raises numerous issues, including those surrounding concepts of synthesis, mapping, gesture analysis, and movement capture. One aspect of musical performance however that is often overlooked in the design of electronic musical instruments is the role of the body as a site for performance, and bodily effort as the impetus of musical expression. Simply expressed, "Physical effort is a characteristic of the playing of all musical instruments. Though traditional instruments have been greatly refined over the centuries the main motivation has been to increase the range, accuracy and subtlety of sound and not to minimize the players physical input. Effort is so closely related to expression in the playing of traditional instruments. It is the element of energy and desire, of attraction and repulsion in the movement of music." [1].

Most digital musical instruments are characterized by a decoupling of the synthesis of the instruments' sound from the physics of its sound producing mechanism. This decoupling of interface from sound production has removed the need for driving energy in the context of a computer based musical instrument. Indeed, with many synthesis techniques, excluding physical modelling, the notion of driving energy or excitation has no direct equivalent. The performer is no longer tied to a requirement to input energy in a particular place within the sound production system. Instead of being the source of the energy in the sound, the gesture is used to trigger, command or control various parameters of the sound-producing algorithm. Elsewhere we have discussed the problematic notion of control in relation to music performance and have suggested alternative paradigms [2].

In addition to shaping the performer's interaction the notion of physicality and effort in musical performance also impacts upon an audience's perception. The act of listening/observing in a musical context has been described by Cone [3] as "vicarious performance". In this sense listening is ultimately a physical involvement - a virtual performance experience for the audience. An artist playing an acoustic instrument usually exploits a mental model that the audience has of the instrument's action-to-response characteristics, allowing virtuosity to be readily appreciated. But what can we say about the case where the instrument obfuscates this action to response relationship? A criticism of many electronic controllers, especially those with overly complex high-level mappings or relatively hidden interfaces (e.g., a laptop keyboard or bioelectric sensors) is that they can confuse an audience, who often can't follow and relate to what the performer is doing [4-7]. As Bahn, Hahn and Truman point out "the more familiarity the listener has with the musical context, the more vivid the empathetic experience can become. This describes a connection of the body to sound production, a kinaesthetic empathy with the act of creating sound and the visceral/gestural interaction of the performers in the musical context" [8].

With an acceptance of effort and physicality as key components in musical expression, we then ask the question, how can we integrate the notion of physicality into the design of new interfaces?

This paper presents a new interface test platform that addresses the notions of physicality and effort. It draws on prior work in the description of effort as part of a general description of movement to suggest ways in which effort could guide instrument design. However rather than taking a mimetic approach based on the physicality of traditional instruments we present an interface that allows for the dynamic variation of a braking force.

1.1 Physicality and Effort

To begin to consider the role of effort and physicality in musical performance it is first helpful to define these terms more closely. Several definitions of physicality exist. Here we consider physicality to be "The fact, state, or condition of being physical (as opposed to mental, spiritual, etc.)." [9].

Effort is often defined in terms of a "strenuous putting forth of power, physical or mental;" or a "laborious attempt; a struggle." [9]. This view of effort however is overly simplified, emphasizing

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a notion of some difficulty to be overcome. A more detailed insight into effort that we believe is relevant to designing an effortful interface is that of Rudolf Laban, who carried out an in-depth analysis of movement in the context of manual labour [10].

1.2 Laban's Theory of Effort

Laban's theory of effort gives a formalized approach to studying effort as part of a wider analysis of movement known as Laban movement analysis. Effort, or what Laban sometimes described as dynamics, is a system for understanding the more subtle characteristics about the way a movement is executed with respect to inner intention. For example, in terms of body organisation there is little difference between punching someone and reaching for an apple on a tree – both involve the extension of the arm. However, the attention to the strength, control and timing of the movement is very different. In his description of effort, Laban indicates four components that generate what is termed effort space. These are commonly referred to as Weight, Flow, Time and Space.

Weight: Strong / Light
Flow: Fluent / Bound
Time: Quick / Sustained
Space: Direct / Indirect

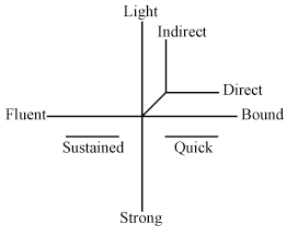

Figure 1. Laban Effort Notation [11]

Often represented in notation form (fig.1) this system allows the depiction and description of a given effort in terms of these four factors. A detailed overview of Laban's theory of effort is beyond the scope of this paper, however it is useful to explain briefly what each of the four components refers to.

Weight refers to the level of exertion involved in effort while flow refers to control. So for example the swinging of an axe would require a strong fluent effort, whereas the placing of a delicate object at an exact place would require a light bound effort. Any skilled movement is led along a definite path in space. An effort applied through a meandering path would be termed indirect whereas an effort with a straight or tightly defined path through space would be termed as direct. Finally consideration is given to the time characteristic of the effort: Sustained exertion is represented by a line parallel to fluent flow and quick exertion by a line parallel to bound flow.

Table 1. Laban's Effort Actions

Laban Effort	Time	Space	Weight
Gliding	Sustained	Direct	Light
Pressing	Sustained	Direct	Strong
Floating	Sustained	Indirect	Light
Wringing	Sustained	Indirect	Strong
Dabbing	Quick	Direct	Light
Punching	Quick	Direct	Strong
Flicking	Quick	Indirect	Light
Slashing	Quick	Indirect	Strong

The combination of the three dimensions, Space, Weight and Time produces eight distinct types of action, commonly known as Effort Actions or Action Drive. These are shown in the table above (Table 1). With an understanding of these primitives we can then look closer at a movement that transitions from one effort type to another in terms of a modulation of one two or three of our basic effort components, i.e. a transition from a Gliding effort to a Pressing effort would involve a change in the Weight component from light to strong. This is illustrated below in the effort-action cube (Fig.2).

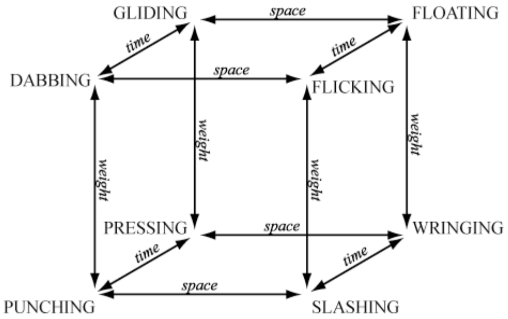

Figure 2 Effort-Action Cube [11]

2. BACKGROUND

Laban Movement Analysis has been primarily used as a means of notating choreography. More recently, the extraction of Laban parameters from motion-capture data has been investigated as a means of classifying the expressive nature of motion with a view to its application in procedurally driven computer animation [12]. Other research has looked at its possible use in the description of ancillary gestures of clarinetists [13].

Our emphasis in this paper is to look at the influence of an instrument's construction upon the movement range of the performer. The construction of the instrument, its weight, degrees of freedom, sensing technologies, mapping strategies etc, define the range of movement the performer will find rewarding when playing the instrument,. Here Laban's theory of effort is used as a basis for considering movement in terms of the effort-space affordances of the instrument (using Norman's definition of affordance [14]).

2.1 Related Work

The G-Sping [15] is an instrument that utilises the bending of a large spring, and was designed with the idea of incorporating physical-effort in its performance. In the discussion, the authors note that the spring stiffness requires that force be constantly applied to it in order to maintain a bent position making the instrument uncomfortable. They comment, "an instrument requiring a constant physical effort by the performer may not necessarily be desirable". It must be noted however that all movement no matter how fine requires physical effort. It is the quality of this effort not its presence or absence that varies. Examples of an interface that requires the maintenance of a constant force over a prolonged period of time are not evident in traditional acoustic instruments. Rather we see interfaces that support rhythms of force and relax. The Damper interface provides a configurable test-bed to explore the multidimensional qualitative properties of physical effort.

2.2 Dynamic Resistance modulation

In considering the effort-space of an interface, we draw a distinction between the aspects of an interface that can be modulated and those that are static. Although the static aspects are important, they are the ones that have been thoroughly investigated in traditional instrument design. The aspect that interests us is the relatively unexplored area of actively modifying the physical characteristics of the interface.

To achieve effort-space modulation it has been decided to restrict the research to the particular area of dynamic resistance. This in effect allows the interface to change its resistance to the users movement and thus influence the effort-space that the interface occupies. In terms of Laban's theory, resistance modulation can be viewed as influencing the required Weight component of the effort (from strong to light) for a given movement. Indirectly however it will also influence the range of Time and Flow.

When thinking of mapping in this context it is worth considering aspects of traditional instrument performance practice that can be related to notions of dynamic resistance. Although traditional instruments do not display the types of dynamic change described above, it is worth observing how physical changes are related to changes in musical space. As guitar frets get closer together as one moves through the fret-board, the level of resistance and its relation with musical articulation varies. A clear feedback mechanism is in place here as we learn to relate high fret positions to changes in timbre. Most acoustic instruments display characteristic changes in resistance that are closely coupled with articulation and timbre.

3. The DAMPER

The DAMPER interface has been created to act as a test-bed for dynamic resistance interface mappings. It is a simple one-degree-of-freedom interface consisting of two handles connected to a magneto-rheological fluid brake. The main action available to the user is the relative movement of the two handles towards and away from each other. By applying an electric current to the MRF brake the resistance to this motion can be varied. The relative position of the two handles to each other is measured using a continuous turn potentiometer. This setup is shown below (fig.3).

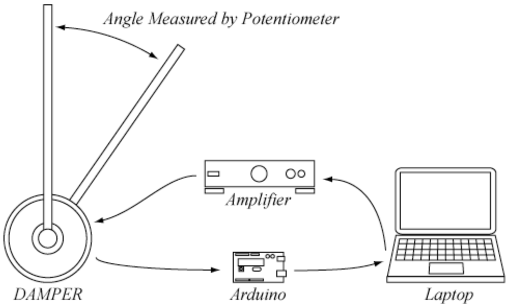

Figure 3. System Diagram.

3.1 MRF Brake

The Magneto-Rheological Fluid brake is the key component as it allows a highly controllable damping force to be applied between the arms of the interface. The brake works by applying a current to a coil contained inside the device, hence creating a magnetic field that stiffens the magneto-rheological fluid and increases the braking force. Due to the nature of the fluid there is some residual viscosity when no control current is applied, however the leverage of the arms makes this force negligible. The maximum stated continuous braking force that can be achieved is 4Nm when 1A is applied; however it is possible to safely apply up to 1.5A as long as the signal is not continuous. The robust nature of the brake allows it to double-up as the axle holding the two arms together. The response time of the brake is relatively fast at a stated 10ms. In practice however it has been found that frequencies higher than 100Hz can be applied to the brake with the amplitude of the experienced braking force dropping off with increasing frequency.

Figure 4. The DAMPER in the "edge-trimmer" configuration.

3.2 Edge-trimmer Configuration

In the first configuration, a force-sensing resistor (FSR) has been added to the top of one of the handles, which can be depressed using the thumb. The FSR and potentiometer are interfaced to a PC via an Arduino microcontroller board. A MaxMSP patch running on the PC uses the potentiometer signal to set the frequency and the FSR signal to set the amplitude of a rectangular wave. This wave is fed from the audio out port of the PC to the MRF brake's input via an amplifier.

The novel aspect of this configuration is that the rotation of the axel of the MRF brake, which is being switched on and off at audio frequencies, causes sufficient vibrations that with the use of a soundboard (such as a desk), the instrument can be played 'acoustically' without the need for speakers. This results in a very tight correlation between the haptic and auditory feedback, as they are produced from the same mechanical vibrations. The resulting tone of the instrument is somewhat like that of a bowed cello. It is possible in this configuration for the user to achieve a continuous pitch with a slight vibrato, by moving the handle rapidly back and forth around a fixed point. When the FSR is untouched the amplitude of the wave is set to zero and only increases as pressure is applied to the FSR. This allows the users to both turn off the volume, so that silence can be produced between notes, and increase the volume of a note as needed.

In terms of musical performance and expressivity, it is best to view the edge-trimmer as an infra instrument [17] as it fulfills the criteria of having a constrained interactive repertoire, making use of few sensors and few gestural movements, it engenders relatively simple music and finally is restricted in the possibility of virtuosity/expressivity.

3.3 Stretched-String Configuration

In the second configuration the resistance to movement is directly proportional to the angle between the handles. As the handles are moved further apart the resistance increases. A MaxMSP patch running a physical model of a string receives the position information from the potentiometer, and updates the models tension parameter. The excitation of the string model is mapped to the approximate acceleration of the handles. In this configuration, the output from the model is played over speakers, thus keeping the haptic and audio feedback disconnected.

4. RESULTS AND DISCUSSION

Considering the effort space occupied by the Damper by virtue of its physical construction we see that due to its limited degree of freedom the Space component of effort is confined to being

Direct. This leaves the performer with the ability to vary the Weight, Flow and Time components of any effort applied. If we consider a static case, where the resistance is fixed at a given value independent of the position of the handles, we see that large resistance to movement will support a strong Weight component in the effort. Conversely low resistance to movement will support light effort. However the resistance the device offers to any movement will also influence the range of Flow and Time components of effort that the performer finds natural or rewarding on the instrument. For example increased stiffness can support the execution of more bound and also quick efforts. Conversely a lower stiffness can assist in the execution of fluent efforts.

Introducing the ability to dynamically vary the resistance during movement however affords the instrument a greatly expanded gesture set and encourages the transition between different effort types. In the first configuration, where separation of the handles is inversely proportional to the frequency of the driving oscillator, the stiffness increases with increased separation due to the MRFs frequency response. This mapping therefore supports a continuum of effort types depending on the angle between the handles with bound, strong, quick efforts being well supported at large diversion of the handles due to the increased resistance and light sustained and fluent efforts being better supported when the handles are closer to each other.

5. FUTURE WORK

The role of effort in music performance is still to be understood in a way that can be useful for the design of new instruments. Much work is needed to both expand and hone the theories of effortful interaction, effort space modulation and dynamic resistance modulation. It is hoped that through a series of iterations in the design of the DAMPER it is possible to refine both design techniques and the accompanying theories.

5.1 Potential Mappings

Even with such a simple interface there is a large range of possibilities for mappings other than those described above. So as to give a better idea of where the development of the device is heading, some potential mappings are outlined below.

5.1.1 Pump

Using the handles in a pump like fashion it would be possible to generate a similar experience to pumping bellows. This may work suitably well with a physical model of a foot-pump organ. This is a particularly suitable use of the brake, as bellows only impart a resistive force on the user. Using this method it would be possible to generate some non-traditional interaction such as actively changing the size of the virtual aperture from which the virtual air is being pumped through, and hence changing the resistance of the action.

5.1.2 Waveform Scrubbing

In this mapping, a sample could be played by using the handles to scrub back and forth through a sample. If the sound generated by the scrubbing is fed directly into the brake, it is possible to produce interesting haptic feedback straight away. For instance, it would become harder to move through a louder part of the sample than a quieter part, thus allowing the user to accurately feel their position within the sample. This could be further refined with filtering and frequency analysis so that only the relevant parts of the sample (for instance the rhythm) are presented to the user through the haptic feedback.

6. CONCLUSION

A new interface was presented that features the ability to dynamically vary the effort space it occupies. Observations were made on how Laban's theory of effort may prove useful when considering physical effort in musical interface design. Particularly it has been shown that dynamic resistance modulation can potentially modify the effective effort-space of an instrument.

7. ACKNOWLEDGEMENTS

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