DEVELOPING A NON-VISUAL OUTPUT DEVICE FOR MUSICAL PERFORMERS

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ABSTRACT

Musical performers conduct music information processing while playing, and there are many information flows that they receive visually. The major concern in introducing new systems into live musical performances seems to have been the development of input devices that reflect musical gesture. However, there have been many fewer attempts to develop 'output devices' that convey musical information to the performer. As such an output device, we developed a thermoscore-display that dynamically alters the temperature of the instrument/player interface. We consider that it is well-suited for use as feedback system that denotes the frequency of the occurrence of notes in an improvisation. Also it contributes as special score display, that also conveys a feeling of the existence of the composer.

1. INTRODUCTION

Generally, the major concern in the introduction of new systems into live musical performances seems to have been the development of sensing devices (namely, input devices) that reflect the performer's musical gestures. On the other hand, there have been many fewer attempts to develop 'output devices' that convey musical information to the performer via non-visual (and non-auditory) senses. For example, a bio-feedback system developed by Nagashima [7] uses electric pulses as the feedback signal. Using this system, Akamatsu et. al. created a live performance, "Flesh Protocol," in which those signals are sent to a dancer. Vibrotactile suits developed by Gunther et al. can transfer musical information by vibrations on the surface of the body [2], though they were made to enable audiences to listen to music using the sense of touch. These devices contribute to the creation of new expressions rather than improving the existing environment. For example, we can observe unpredictable movements in "Flesh Protocol," that can not be found in any dance styles.

However, it seems unreasonable to transmit advanced musical information with electric pulse or vibration; perhaps the best these systems can do is to carry click signals for synchronization. In this paper, we chose temperature as a sensation to convey musical information, for temperature sensations can be easily associated with expressions of musical emotion. For example, we use musical directives like *con fuoco* (with fire) to represent vehement energy in music. In addition, it is possible to alter temperature quantitatively and to convey it sustainably, while electric pulse and vibration are mere on/off signals. Both the biofeedback and vibrotactile systems were designed as wearable devices. Therefore they could hinder a performer's movement to some degree. When designing a new 'output device' for a musical performer, we must create an environment in which the performer can concentrate on playing. With a few exceptions like the Theremin, the performer touches the instrument during a musical performance. Music arises from the interface between performer and instrument. As a result, the more s/he concentrates on playing, the more the senses in the fingertips become acute. We focused attention on that contact point, and considered developing some sort of 'display' there. In the next chapter, we introduce the thermoscore-display system as an output device to the performer.

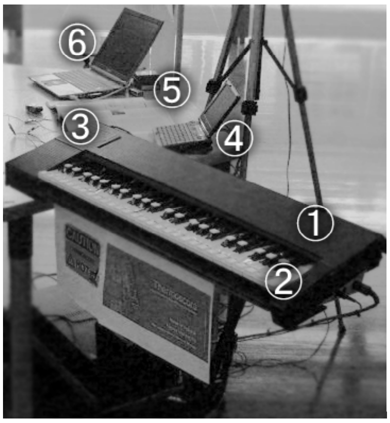
2. SYSTEM

2.1 Thermoscore-display

To control the temperature of the interface between performer and instrument, we adopted Peltier devices for the thermoscore-display. A Peltier device is a thermoelectric cooler that works as a heat pump. It is a sandwich formed by two ceramic plates; when an electrical current is applied, it transfers heat from one side of the device to the other (Peltier effect). By reversing the current, we can interchange functions, cooling and heating. As we started designing the first version of the system, we chose the piano keyboard because the piano is one of the most common and versatile instruments. Also, the size and shape of Peltier devices fit in well on piano keys.

2.2 MIDI control

As shown in Figure 1, the system is controlled by Musical Instrument Digital Interface (MIDI) signals. The MIDI-to-Temperature Converter receives a MIDI note-on messages, and sends electricity to the Peltier devices of the corresponding keys on the thermoscore-display.



① MIDI Keyboard
② Peltier Devices
③ D/A Converter Module
④ PC（MIDI-to-Temperature Converter）
⑤ MIDI Interface（MIDI Input）
⑥ PC（MIDI Sequencer for Demo）

Figure 1. The MIDI control system of thermoscore-display demonstrated at NIME04 [3]

With MIDI, it is easy to apply existing MIDI files in a piece or to synchronize the system with another MIDI system, and moreover, it is possible to build a progressive system using MIDI input from the instrument used for the thermoscore-display. Note that in principle, this system is not a feedback system from an instrument. Signals flow only in one direction, and the instrument serves simply as an output device. In other words, the instrument sends messages to the performer by means of temperature, receives his/her action as 'feedback', and then transforms the action into sound.

2.3 Performance

Nobody can touch a very hot object for a long time. In an extreme case, when objects are much hotter than body temperature, a person will pull his/her hand away immediately by reflex action. In this manner, if we control the thermoscore-display to make some keys so hot that the performer cannot hold them as tenuto, the sound tends to be short, or, a passing note toward some note that is not as hot. Of course, we don't need to make the keys so hot that they burn the performer's fingers. What is important is to send the message.

To test the performance of the thermoscore-display, we measured the time change of temperature at the surface of the Peltier device, and the reaction latency of the performer. Figure 2 shows the performance and latency of the thermoscore-display. The horizontal axis represents the time from applying the electric current to Peltier device, and the vertical axis represents its temperature, measured by a noncontact thermometer. It takes about 2 seconds for the performer to perceive changes in temperature, and when the key gets hotter than 50 degrees centigrade, s/he can not hold it down.

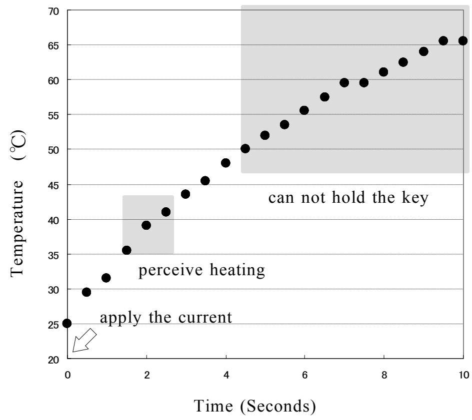


Figure 2. Performance and latency of thermoscore-display

3. DISCUSSION

3.1 Information flows in musical performance

While playing music, a musical performer conducts music information processing. According to Bongers [1], the relationship between performer, instrument and audience can be represented as Figure 3. In this way, the musical performer receives information from (a) an instrument and from (b) audience as feedback.

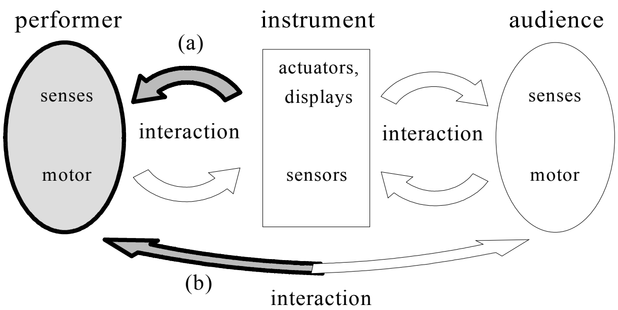


Figure 3. The relationship between performer, instrument and audience [1]

Figure 4 expands the relationships around the musical performer. The performer receives musical information from (c) the conductor, from (d) other performers, and from (e) a musical score. (Note that the relationship between score and performer flows in one direction.) Thus there are five information flows that the performer receives, and excluding haptic feedback from an instrument, they tend to be perceived visually and auditorily in large part. Let us discuss application possibilities in each information flow.

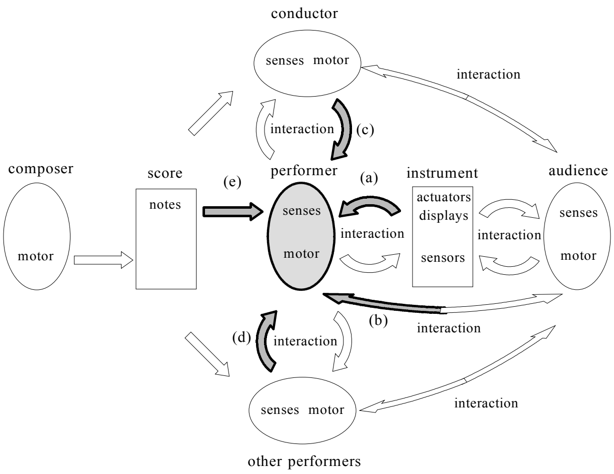
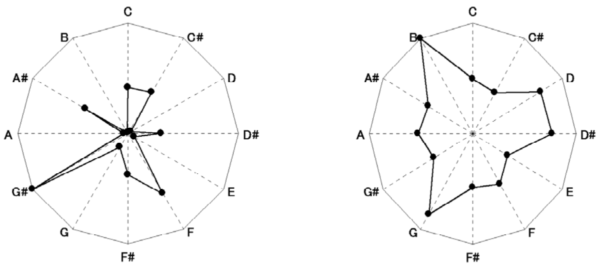


Figure 4. Expanded relationships around the musical performer

3.2 Feedback from an instrument

In the thermoscore-display system, information is transmitted at the contact point between performer and instrument. Thus, introducing the system to convey feedback information from the instrument will be effective. Especially, our system is great for presenting sustainable musical information. By way of example, we propose to indicate the frequency with which a pitch notation is played in the performance.

To visualize the music's tonality (or modality) space, the characteristics of the composer, and the era in which the piece was composed, we developed chroma-profile [2]. This is a radar chart representation of the frequency of pitch notations in the piece, computed from MIDI data. For example, Fig 5(1) is a chroma-profile from Chopin's "Minute Waltz," Op.64-1. It was written in C# major, so we see higher frequencies in the dominant (G#) than in the other keys. On the other hand, Figure 5(2) is a chroma-profile from Schoenberg's "Six little pieces for piano," Op. 19, which was composed with a backdrop of atonalism. All the notes tend to be used at more equable frequencies here. The standard deviation of frequency is 2.7 here, while the standard deviation in "Minute Waltz" is 7.6.

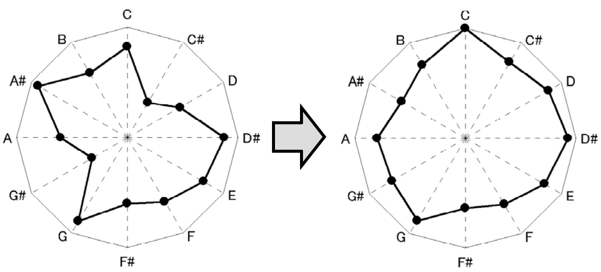


(1) Standard Deviation = 7.6 (2) Standard Deviation = 2.7

(1) Chroma Profile of "Minute Waltz" Op.64-1 (F. Chopin)
(2) Chroma Profile of "Six little pieces for piano" Op.19 (A. Schoenberg)

Figure 5. Examples of Chroma-Profiles (Normalized to the maximum recurrance)

With this in mind, the performer who attempts an atonal improvisation will tend to use every note a more equal number of times, but of course it is impossible to actually count and compute the frequency of the notes while playing. If the system monitors the frequency and makes often-played keys hotter than others, it must be helpful for the performer; avoiding hot keys will create more atonal music. Figure 6(1) is a chroma-profile of 1 minute piano improvisation by the first author of this paper (20-year-experience for piano), intended to be atonal without use of chromatic melodies. The standard deviation is 2.3, lower than Schoenberg's piece above. However we see higher frequencies in C and G (tonic and dominant in C), D# and A# (tonic and dominant in D#), that means the improvisation is not atonal yet. Figure 6(2) is also a chroma-profile of 1 minute improvisation, but this time under support of thermoscore system that heat often-played keys. All the notes tend to be used at more equable frequencies, and the standard deviation decreased to 1.1. That is, improvisation was supported to be more atonal in terms of the frequency of pitch notations.



(1) Standard Deviation = 2.3 (2) Standard Deviation = 1.1

(1) Atonal improvisation under no support
(2) Atonal improvisation under support of thermoscore system

Figure 6. Effectiveness of atonal improvisation support (Normalized to the maximum recurrance)

We need not apply the system only to atonal music, it is possible to bring an improvisation close to a certain piece. Let us suppose that a performer is not inclined to hit hot keys. Under this supposition, we have only to make keys with the same letter names (same chromas) hot in reverse proportion to the value of the chroma-profile. For example, to achieve the performance of an improvisation around the "Minute Waltz," temperatures of the dominant (G#) key will be cooler.

3.3 Feedback from the audience

Using the thermoscore-display to convey information from the audience is also possible. Sometimes the performer wants to know the audience reaction, which can be difficult to sense from the stage. Thermo-display can be used to reflect the audience excitement by employing devices that sense the audience reaction and send it to the thermoscore-display. We think that it may be more intuitive to cool off the keys when the audience excitement goes down. In this case, this heat does not mean that the performer should not play these keys. The performance of Yolande Harris et al.[1] used a moving graphic score created from signals from the audience, and to realize this, they used special chairs equipped with sensors. To convey information from the audience, we must combine the system with similar devices.

3.4 Other feedbacks

We do not think that thermoscore-display functions well for musical information from conductor and other performers. Most of this information should correlate with musical synchronization, but the 2-second latency is too long to realize sending and receiving with precise timing.

3.5 Application as 'score'

Finally, we discuss the application possibility in using thermoscore-display to convey the musical information as a score. Here there are no ill effects from the latency, because the relationship between score and performer flows in one direction. However the amount of information which the thermoscore-display can denote is not satisfactory for conveying all score information. Still, we consider that it can contribute as a special score display.

In a very real sense, the written score does not present the full picture of a musical piece. What is written in the score is only the minimum information needed to re-create the music. In the process of playing, a musical performer interprets the score and compensates for the lacking information. In this sense, we can define the score as a set of minimum instructions from a composer to a performer.

If we refer to graphic scores and text scores, several pieces are open to a great variety of interpretations. For example, the graphic score of "Concert for Piano and Orchestra" by John Cage allows many more interpretations than traditional musical scores, especially in the sequence of the notes. The text score of "RIGHT DURATIONS" by Karlheinz Stockhausen never specifies the pitches of any notes, but provides more descriptions of duration instead. In such cases, we can say that the scores set fewer constraints on the performer's improvisation. We suggest displaying those key and harmony constraints on thermoscore-display. By changing the temperature at the interface with the instrument, we may be able to communicate which note the composer wants (or does not want) to be played. All we have to do is to make every key hot, except the notes indicated by the composer. First, the composer describes the chord progressions and available notes on the piano-roll window in a MIDI sequencer. To apply them to the thermoscore-display, the piano-roll image is 'reversed,' like a negative film (Figure 7). The performer does not need to hesitate to hit the keys. S/he can play freely, and the hot keys will be reflected in the duration of the notes.

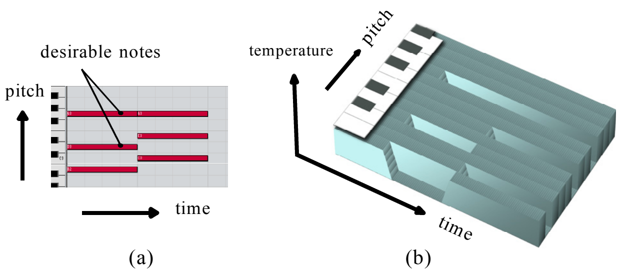


Figure 7. Example of (a) an image in composer's mind and (b) the corresponding sequence of temperature

Of course it is possible to instruct the performer to 'Strike the key while it is hot,' and in that case we don't need to 'reverse' the piano-roll image. On September 29th, 2004, we are going to hold a concert using Thermoscore system[5]. In that concert, we are scheduled to use both instructions.

Needless to say, results will vary depending on the performer. Note that, however, that the original purpose in using the system in this way was to get improvisations, not to get precisely played music. If a composer wants to control the music exactly, s/he should control the instrument directly via MIDI. As mentioned previously, a musical performer interprets, adds, and sometimes ignores information from the composer, but that process makes music even more vital, and therein lies the talent of the performer. This is why many composers use the traditional medium called a 'score' even today.

A score is not an order from a composer to a performer, but a sort of communication medium that enables them to create music together. We believe that the best advantage of using thermoscore-display as a score is that it conveys the feelings, emotion, and 'body warmth' of the composer to the performer. All music is the product of collaboration between composers and performers. Usually they do not (or cannot) meet each other, but performers should get a sense of communion with the composers, whatever kind of score is used.

4. CONCLUDING REMARKS

Robotics is one of the fields for discussion about what the desirable relationship between human and artificial systems should be. Historically, the idealized vision has varied across the ages, from systems that do as humans say, to systems that communicate and interact with humans. Today, wearable robots that sense the behavior of the wearer and suggest actions to him/her are being heavily developed (Parasitic Humanoid[6].) In a similar way, we think that musical instruments should not only react as the performer intends, but also inspire him/her to new expressions. Output devices for musical performers are the most inspiring devices, and that is why we consider these approaches important.

5. FUTURE WORKS

Now we are developing an improvisation support system as an application of thermoscore-display that heats keys outside available note scale. And we are planning an experiment to examine the effectiveness of the system, comparing it with the typical improvisation support system and the instrument with no support.

6. ACKNOWLEDGEMENTS

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