# Evaluation of Sensors as Input Devices for Computer Music Interfaces

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**Abstract.** This paper presents ongoing research into the design and creation of interfaces for computer music. This work concentrates on the use of sensor as the primary means of interaction for computer music, and examines the relationships between types of sensors and musical functions. Experiments are described which aim to discover the particular suitability of certain sensors for specific musical tasks. The effects of additional visual feedback on the perceived suitability of these sensors is also examined. Results are given, along with a discussion of their possible implications for computer music interface design and pointers for further work on this topic.

## 1 Introduction

The use of sensor technology is a fundamental part in the creation of interfaces for computer music. However little investigation has taken place into the suitability of particular sensors for specific tasks in these interfaces. While a number of taxonomies and evaluations of sensors have taken place [1] [4], these have not been concentrated on the use of such sensors in musical applications.

The experiments described in this paper have been designed to investigate a number of important aspects in the use of sensor technologies in these interfaces. This includes investigation of the usability of particular sensors for specific musical tasks and investigation of the effects of additional visual feedback on this usability.

The work performed has involved three major phases. These are:

- a survey of existing interfaces for computer music and the use of sensors in them
- classification of the sensors based on the parameters sensed
- experiments to determine the suitability of sensor classes for musical tasks

This document will discuss each of the phases of the research, along with the results achieved and the possibilites for future work evident from these results.

## 2 Survey of Sensor Use in Interfaces for Computer Music

In order to allow the results of our experiments to be as useful as possible, it was determined that the sensors examined should be representative of those most commonly found in computer music interfaces. To facilitate this a survey was made of a large number of computer music interfaces to determine which sensors were the most common.

### 2.1 Scope of the Survey

The first step in the survey involved determining where to find the information related to the instruments in order to be able to detemine which sensors were used in them. It was decided to use the instruments which had been presented at a major conference on the design of digital musical interfaces as the basis for the survey. Therefor we examined the instruments presented at the New Interfaces for Musical Expression (NIME) conferences from 2001 to 2004, which resulted in a total of 123 instruments and interfaces being surveyed.

It should be noted that the survey only examined the sensors used, so that complex devices such as joysticks and cameras were ignored. This reduced the number of interfaces to 105, due to 18 interfaces which were controlled solely by means of a complex device. A further 54 interfaces contained a combination of complex devices and sensors.

The ten most used sensors based on this survey are shown in Table 1 (from most often to least often used). It should be noted that this count is based on the number of distinct instruments using the sensor (i.e. while 19 instruments use accelerometers, each of these instruments may have used more than one accelerometer as well as other sensors). There are also a further 12 sensors which were present in 4 or less instruments and are not shown in the table.

**Table 1.** Most commonly used sensors

| Sensor | Number of Instruments |
|---|---|
| Accelerometer | 19 |
| Force Sensing Resistor | 18 |
| Infrared Sensor | 9 |
| Light Sensor | 8 |
| Touch Pad | 8 |
| Bend Sensor | 6 |
| Capacitive Sensor | 6 |
| Rotary Potentiometer | 6 |
| Gyroscope | 5 |
| Linear Potentiometer | 5 |

## 3 Categorisation of Sensors and Tasks

Previous work has attempted to show a mapping between sensors and classes of musical task [5]. This work classified sensors by the form of input that they sensed (linear position, rotary position, force etc.) and classified musical tasks by the range and form of input they required (static, absolute dynamic and relative dynamic). The experiments described here make use of these categorisations and attempt to evaluate empirically whether any mapping from sensor type to musical task holds.

Table 2 shows how the sensors used in this experiment were classified. The sensors chosen are all among the ten most commonly used sensors as found by our study and have been selected to allow for at least one sensor from each class.

**Table 2.** List of sensor devices used in the experiments and their associated categories

| Sensor | Sensor Category |
| --- | --- |
| Linear potentiometer (fader) | Linear position |
| Rotary potentiometer | Rotary position |
| Linear position sensor (ribbon controller) | Linear position |
| Accelerometer | force |
| Force sensing resistor | force |
| Bend sensor | rotary position |

The task list consists of two simple tasks and one complex task, the complex task being created by combining the two simple tasks. The two simple tasks have been chosen to represent common musical tasks, while also conforming to the classification of musical function as presented in [5]. It has been proposed in [7] that the concept of a musical task is an inherent part of the evaluation of controllers for computer music. The authors also presented a partial list of musical tasks which might be used in the evaluation of controllers for computer music. The tasks chosen for this work are based upon this list and have been categorised based on the scheme presented in [5]. The tasks are also consistent with those used in [6] to allow for a comparison between the results of these experiments and those of that work.

Table 3 shows the chosen tasks and their classification.

## 4 Test Setup

Two experiments have been designed, each of which involves performing the selected tasks with each of the selected sensors. The experiments differ only in the feedback provided to the user during the tasks. The experiments themselves will be described in detail in later sections.

**Table 3.** List of tasks and their associated categories

| Task | Task Category |
|---|---|
| Note selection | Absolute dynamic |
| Note modulation | Relative dynamic |
| Note selection & modulation | Complex combined |

The setup is the same for each experiment. It consists of the user manipulating a synthesis system through the use of a sensor and a button. Pressing the button causes a sound to be emitted from the system, the frequency of which is controlled by the sensor. The sensor is controlled with the user's primary hand, the button with the secondary hand.

Synthesis is performed in Max/MSP and is a simple waveshaping synthesis system based on Chebychev equations. The frequency of the synthesis is variable in semitones.

There was a total of 11 participants in the test group. The participants were all graduate students in Music Technology and their areas of specialisation ranged from acoustics and physical modelling to interaction design to music information retrieval.

Eight of the participants had extensive musical instrument training, while the remainder either did not play, or had only played for a period of less than two years and had since stopped. Five participants had experience of playing electronic instruments whether software or hardware in form.

As already stated, each experiment consisted of three tasks. Each task was performed with each sensor. When a task had been completed with all sensors a short break was taken before beginning the next task. A task was considered to be completed with a given sensor when the user was happy that they had performed it as well as they could, or when the user decided they could not perform the given task with the particular sensor.

Information from the experiments was gathered by a number of means. On completing a given task with a sensor, the user was asked to rate the ease of use of this sensor for the task, by setting the position of a slider object in Max/MSP. This slider gave a percentage rating of the ease of use of the sensor, which was recorded. This allows us to gather data indicating the subjective usability of the sensors for the tasks.

The length of time taken before completion of the task was noted, along with the success or failure of the task. This gives an indication of the learnability of the sensor, as well as its suitability for the task.

A video recording containing the interaction with the system and the audio from the system and user themselves was also made. This allowed for later analysis of factors such as ease of learning, accuracy and quality of sound produced with each sensor.

Finally, the users were debriefed verbally after each task was complete and asked to comment on any particular strengths and weaknesses of the sensors for that task. This gave a subjective opinion of the sensors as well as offering ways of possibly improving the interaction of a given sensor.

## 5 Experiment 1 - No Additional Feedback

### 5.1 Description

The first experiment is the baseline experiment for determining the suitability of the sensors for the tasks. It consists of the user manipulating the frequency of synthesis with the sensors and causing a sound to be emitted with a button. No additional feedback (haptic, tactile or visual) is given from the system except for that intrinsically provided by the sensor itself.

### 5.2 Tasks

The first task is the note selection task. The user is asked to attempt to play a short melody with each sensor. Choice of the melody is left to the user. The sensor can be used to manipulate the pitch of the sound produced in intervals of a semitone, with a range of one octave. The note currently selected by the state of the sensor is emitted when the button is pressed. The users are asked to restrict themselves to emitting short single notes. The task is considered completed when the user feels they have played the melody to the best extent allowed by the sensor.

The second task is a note modulation task. In this task the computer plays a short melody, one note of which is emitted at every button press. Notes can be sustained by holding the button. The user is asked to play the melody through, sustaining every fourth note and adding a trill effect between this note and the note above it using the sensor. Thus the sensor is used to modulate between the current semitone and the next.

The third task is a combination of the first two. The users are again asked to play a short melody, but as well as the short single notes used in the first task, they are now allowed to sustain and modulate notes using the sensor. This provides a more complex task than the previous two and allows us to examine the effects of increased task complexity on the sensors suitability.

### 5.3 Results

For the first task, note selection, the users showed a very strong preference for the linear position sensor. The linear and rotary potentiometers were next in preference and received similar ratings.

For the note modulation task user preference was split between the linear position sensor and the force sensing resistor. Viewing of the recorded video from the experiment indicated that preference was highly dependant on the technique used to manipulate the sensors. All users giving preference to the force sensing resistor attempted the modulation using the linear position sensor by sliding their finger along the sensor. Those prefering the linear position sensor used two fingers in a rocking motion, similar to playing a trill on a keyboard. It should be noted that those who performed the sliding movement were creating a more vibrato-like effect and that the preference of these participants is consistant with the results of [6] who found that users prefer the force sensor for creating vibrato effects.

Finally, for the complex task, user preferences seemed to depend on their preferences for the first two tasks. Sensors which were preferred for part of the task (i.e. for one of the simple tasks) were rated well for the whole task. The linear position sensor and force sensing resistor were the prefered sensors.

Figure 1 shows the average normalised ratings for each sensor for each of the tasks. These ratings were achieved by normalising each users rating relative to the highest rating they gave and then finding the mean of these ratings across users.

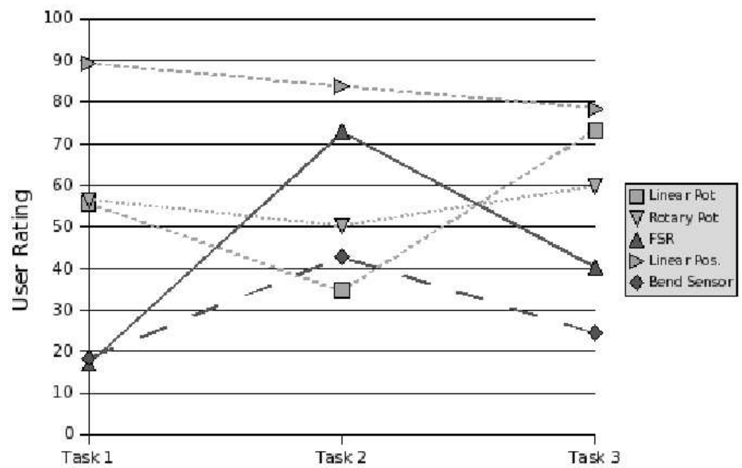


**Fig. 1.** Normalised average user ratings for each sensor for each task

## 6 Experiment 2 - Additional Visual Feedback

### 6.1 Description

Evidence exists that tactile and kinaesthetic feedback prove important to expert musicians playing traditional instruments ([3]). However, it has been stated in [5] that visual feedback is most useful to beginning musicians. Therefor, the second experiment performed consisted of the same setup and tasks as the original experiment, but with the addition of a visual feedback system. This visual feedback system involved the displaying of a line of white boxes on the screen. Each of these boxes represented a semitone over the octave range of the sensor. The semitone which was selected by the current value of the sensor was highlighted by a yellow circle within the box representing that semitone. The boxes were 2.5 x 2.5 cm in size, and were displayed against a grey background.

### 6.2 Tasks

As stated previously, the tasks chosen for this experiment are the same as those in the first experiment. Therefor, the participants perform a note selection task (playing a melody), a note modulation task (adding a trill to an automatic melody) and a composite task (playing a melody with added trills). The difference between these experiments is solely due to the additional visual feedback.

### 6.3 Results

For the note selection task and the combined task, with the exception of the FSR and the linear position sensor, all sensors showed a large increase in the normalised rating given to them by each user. Each of these sensors achieved a rating at least 25% higher than without feedback. The FSR improved by only 0.4% and the linear position sensor showed a decrease in rating of 4%. Comments from users about the linear position sensor indicate that the difference in location of the visual feedback system and the sensor itself causes confusion about which one to pay attention to. It is possible that were the visual feedback system integrated into the sensors, this confusion would not arise. Figure 2 shows the user ratings for each sensor for this task, both with the additional feedback and without.

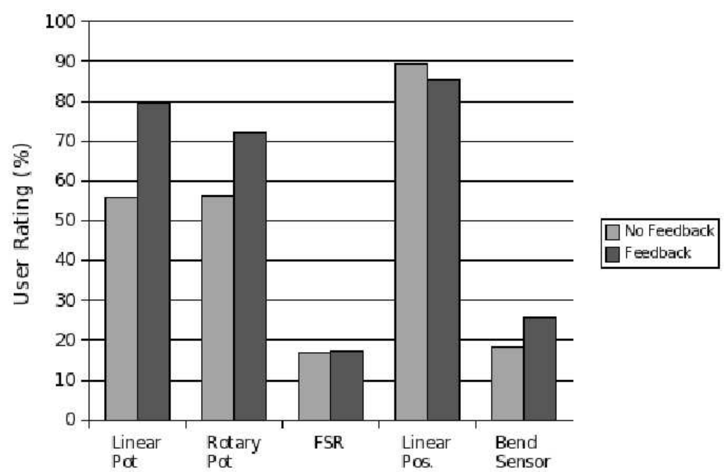


**Fig. 2.** User ratings for each sensor both with and without visual additional feedback

Also for these two tasks, a major improvement was also found in the accuracy of users once the visual feedback system was added to the experiment setup. An improvement in accuracy of at least 8% was found in all sensors not belonging to the linear position class of sensors. This is shown in Figure 3. When these improvements are taken relative to the accuracy achieved without the additional feedback, this shows a minimum relative improvement of 15% for these sensors, as shown in Figure 4.

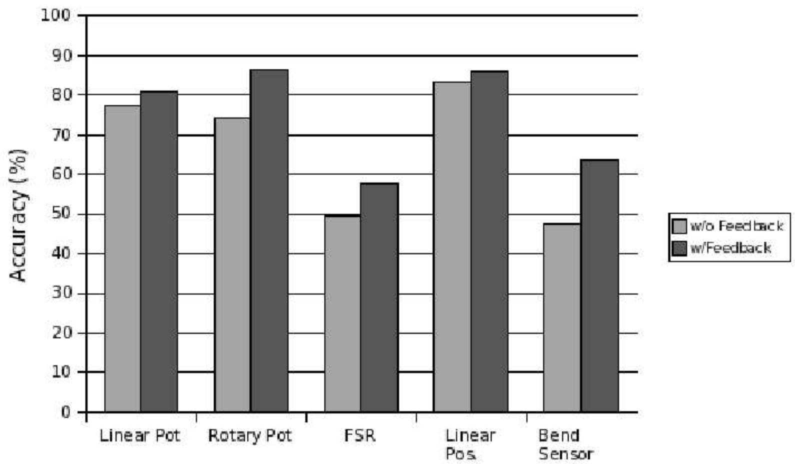


**Fig. 3.** User accuracy for the note selection task, both with and without additional feedback

The results of the modulation task are not examined here as interviews with the participants indicated that the majority of them were not using the visual feedback for this task. They found that it offered no advantage to use it and so did not.

## 7 Overall Results

As can be seen from the results of experiment 1, users show a strong preference for certain sensors for specific tasks in musical insterfaces. These preferences are consistant across many users, with the only obvious variation in preference (some users preferring the FSR to the linear position sensor for the note modulation task) being explainable by the technique used in performing the task.

Also notable is the effect of the additional visual feedback in experiment 2. User accuracy in the note selection task was greatly improved, with the majority of users now capable of playing a melody with all sensors. This indicates that proper visual feedback in an instrument system can greatly increase the playability of the system. It is interesting to note that the positive effect of this visual

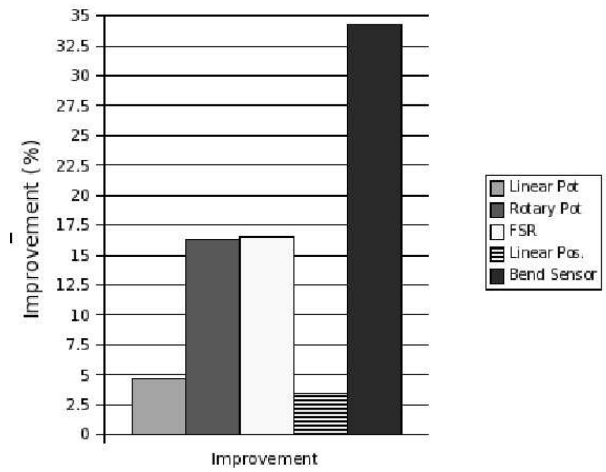


**Fig. 4.** Improvement in user accuracy for each sensor, relative to their initial accuracy

feedback (which was in the form of a linear representation of the notes) was only present for sensors which are not linear position sensors themselves. This may be due to the linear visual feedback which is inherent in the linear position sensors.

## 8 Conclusions

This paper presented the results of a number of experiments to determine the suitability of sensors for specific tasks in digital musical instruments and the effect of the addition of visual feedback on this suitability. The experiments have shown that users do express a preference for certain types of sensor for certain musical tasks and that these preferences are consistant across users. The results for users producing a vibrato-style modulation in the modulation tasks also proved consistant with those of previous work in this area [6].

Also shown was that additional visual feedback had an effect, not only on the perceived suitability of the sensors for the tasks, but also on the accuracy of the users when using the sensors. These results show that it should be possible to derive guidelines for the use of sensors in digital musical instrument interfaces and for the use of visual feedback to improve the interaction in these instruments.

It is hoped that these experiments will aid in the future design of computer musical instruments, by providing an indication of the mappings suitable for a particular sensor or for a particular parameter in an interface. By careful choice of the sensors and mappings used in an instrument interface, instruments more suited to expert performance can be created [2].

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