Towards Participatory Design and Evaluation of Theremin-based Musical Interfaces

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ABSTRACT

Being one of the earliest electronic instruments the basic principles of the Theremin have often been used to design new musical interfaces. We present the structured design and evaluation of a set of 3D interfaces for a virtual Theremin, the VRemin. The variants differ in the size of the interaction space, the interface complexity, and the applied IO devices. We conducted a formal evaluation based on the well-known AttrakDiff questionnaire for evaluating the hedonic and pragmatic quality of interactive products. The presented work is a first approach towards a participatory design process for musical interfaces that includes user evaluation at early design phases.

Keywords

3D interaction techniques, Theremin-based interfaces, Evaluation.

1. INTRODUCTION

The challenge of designing new interfaces for musical expression is to identify a suitable mapping of interaction elements to sound generation attributes. An arbitrary mapping of sound parameters to interface device properties, e. g. X-orientation mapped to pitch control, may not directly lead to an intuitive musical interface for casual players or even advanced artists. It may also be less attractive for the audience, a property that is important for audio-visual performances. Due to missing interface standards and little design experience in this domain, a “try-and-error approach” is the best design method of choice. Unfortunately, little attention has been given to a structured design approach that allows for design reviews at early design stages including end user participation. These problems are well known in the HCI area of post-WIMP interface design and the focus of attention shifted towards authoring concepts and evaluation techniques recently. In this project we propose to directly apply methods and techniques from advanced HCI fields like tangible and embedded interaction and 3D user interfaces to the design of NIMEs. In the “VRemin” project presented in this paper we built a simple music synthesizer simulation based on the Theremin concept. The Theremin was one of the earliest electronic instruments and unique in that it was the first instrument that was played without being touched. The player stands in front of the instrument and moves her hands to control pitch and volume. With the work presented here we want to propose both, a set of alternate approaches to a virtual Theremin as well as an empirical evaluation providing support to the theoretical basis as well as to new methods to compare musical interfaces.

2. UI DESIGN BACKGROUND

Few WIMP interface concepts make efficient use of both hands. In contrast the use of both hands is an important concept for musical interfaces. At present there are no widely accepted design methodology that could guide musical interfaces designers. We are convinced that development of successful NIMEs needs an intensive testing of many application concepts as well as the active user participation in the design and refinement of promising designs. A simple implement and test approach, however, is not viable because the implementation of working prototypes is expensive, time consuming, and is limiting the number of concepts and designs that can be possibly explored. Therefore, we propose to evaluate the concepts under controlled conditions with potential end users. Recent developments in HCI suggest a paradigm shift for the usability evaluation of interactive products. The most recognized definition of usability is provided by ISO 9241 and defines it as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction”. In recent years the majority of research activities have been based upon this definition but more recently a broader perspective has been suggested that considers the motivation of the user in more detail. The traditional key element of user satisfaction provides only a limited description of the user’s experience with an interactive product. Trying to evaluate the complete spectrum of experience a person has when interacting with a specific design, this lead to a number of new quality measurements approaches. A common distinction is between hedonic / aesthetic and utilitarian qualities of a computer system interface [9]. In the model of Hassenzahl he distinguishes between hedonic quality – identification (HQI), hedonic quality – stimulation (HQS) and pragmatic quality (PQ) [9]. HQI measures how well a user identifies with a product and HQS measures to what extent a product stimulates the user by offering novel and interesting functions, contents, interactions and styles of presentation. PQ measures the traditional concept of usability, i.e., how well the user achieves her goals with the product. This model has been implemented as AttrakDiff2™, a web-based instrument for measuring the attractiveness of interactive product. With the aid of pairs of opposite adjectives, users indicate how they experience the design [5]. Innovative interfaces for intuitive music expression should also have pragmatic and hedonic qualities. Creating musical expressions with new interface concepts should be easier and more joyful for a performer and attractive for the audience. Thus, measurement approaches for hedonic and pragmatic qualities, like the ones developed by the HCI community, can be very helpful to design and evaluate new musical interfaces. In particular, we used the AttrakDiff2™ approach to evaluate our designs.

3. RELATED WORK

As we see the work presented here falling into two categories we will refer to both, Theremin inspired controllers as well as the evaluation of new musical interfaces. Due to its successful use during decades the Theremin has a sustained influence on researchers working in the field of musical expression. Looking at the idea to use two hands, freely moving in the air to play electronic sounds "the hands" [1] are an early example of an highly flexible and expressive musical interface offering a set of sensors and keys to be played by hands and fingers. For his virtual musical instruments Mulder [3] used data gloves and a Polhemus 3-D tracking system to shape and play sounds including a visual representation of sounding objects and virtual hands. A Swedish project used optical tracking to develop virtual instruments that are controlled by gestures [4]. Four virtual instruments including a virtual xylophone and air guitar have been developed using a Cave-like virtual room and have been evaluated concerning their efficiency and learning curve. As we are following the interface paradigm "low threshold, high ceiling" the controllers involved in this research are low cost and commercial available ones. We use the Nintendo Wii controllers and as we do, others have been using those for the control of sound. Paine [6] developed a method for dynamic sound morphology using the Wiimote and the Nunchuck controllers seeking two goals, to increase the performance and the ability for communication with the audience. While having the system successfully used in several concerts he points out the potential of further investigation. While a method for evaluation using tools from HCI has been provided by Wanderley and Orio [7] it has not yet often been used. Isaacs [10] presents a study comparing a 3-D accelerometer with a Korg Kaosspad KP2 looking at participants learning to play with those. In addition, a method to compare digital instruments based on findings of music psychology on musical expression has been provided [8]. Since basic evaluation methods seem not yet to have been established, however, we consider this as an important issue to provide and test frameworks for evaluation of newly designed interfaces.

4. DESIGN OF VRemin VARIANTS

The design of NIMEs is a challenging task and we propose a participatory design approach that evaluate design prototypes through end users and iteratively refine the designs according to test results. Our design approach for NIMEs consists of the folliwing steps: 1) the classification of NIMEs with regards to interface complexity and interaction space, 2) the development of interface prototypes with high-level tools, 3) user testing and analysis, and 4) cycles of refinement and final implementation. In this study we classify NIMEs along two dimensions: *interaction space* and *interface complexity*. The interaction space is defined as the spatial extent occupied by the user during interaction with the NIME. Figure 1 denotes the different values for interaction space along with the second dimension interface complexity. A detailed description of the two dimensions and how to define and measure interface complexity for NIMEs will be presented in [15]. The prototype development is divided into a music generation backend and an interface front end. The presented interface variants were assembled using the MIDI-based sensor kits from I-CubeX [2], optical tracking using IR lighting and/or fiducials [13], and the Wiimote game controller.

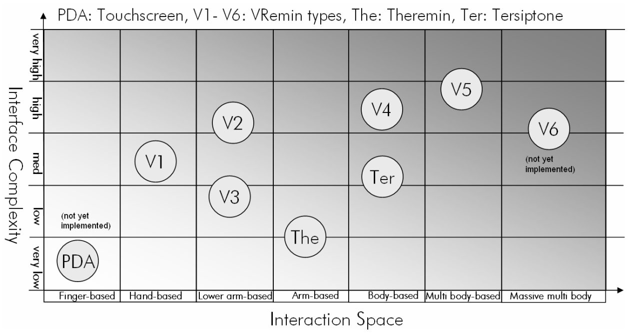

Figure 1. Classification

The prototyping of the back-end was straight forward. We implemented a small synthesizer application using Native Instruments Reaktor 5. We implemented a lean MIDI interface that allows selecting a small set of predefined instruments or effects and controlling effect parameters, pitch and volume by MIDI commands. This allows us to develop different variants of input devices and techniques without altering the music generation back-end. The PDA based version and the massive multi user version will be described in [15].

4.1 VRemin I – Wii Controller

The initial approach for a Theremin-based interaction scenario uses the Wii game controllers for interaction. For the **VRemin I**, the Wiimote is controlled by the dominant hand (DH, usually right) and the Nunchuck is used by the non-dominant hand (NDH, usually left). Pitch and volume are controlled by the Wiimotes acceleration sensor. The buttons are used for switching the current note on and off and permit to interrupt the sound generation. The NDH is used to select the predefined effect with Nunchuck buttons and control the effect parameter with the acceleration sensor (see figure 2). The Wiimote / Nunchuck values are recorded and transformed to midi notes using the DarwiinRemote software and a virtual midi device (IAC device driver). The interaction space is determined by each hand's rotation and thus is the smallest of all variants. The sound generation is designed as an asymmetrical two-handed interaction [10] because both hands perform different tasks and with different gestures / interaction techniques.

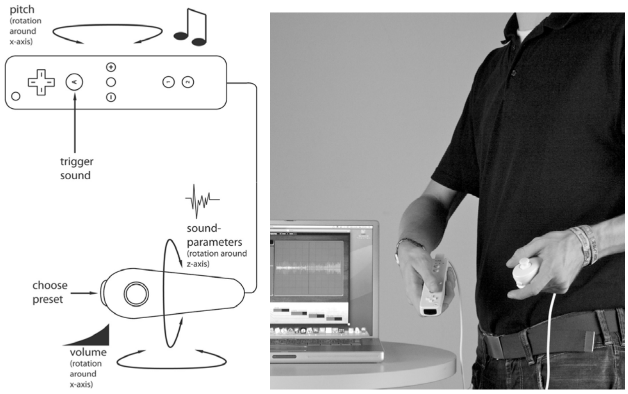

Figure 2. VRemin I – Wii controller

The second variant interacts within an arm-based space. The **VRemin II** tracks the X and Y position of the dominant hand and assigns volume level and pitch level based on the assigned position values. We selected optical tracking for monitoring the hand movement. In the current prototype we attached a small fiducial marker at the DH's wrist and use a web cam to capture the image. The reacTIvision software package [13] is used to analyze the image, calculate the position values and sends a MIDI value which controls pitch of the sound to the back end interface. The selection and adjustment of effects is also controlled with the DH. We built a small custom glove-based input device that uses a bend sensor for each finger. The sensors are connected to an I-CubeX midi converter that generates MIDI signals. The poses of all fingers determine an individual combination of effects and their strength. This approach realizes a unimanual interaction technique.

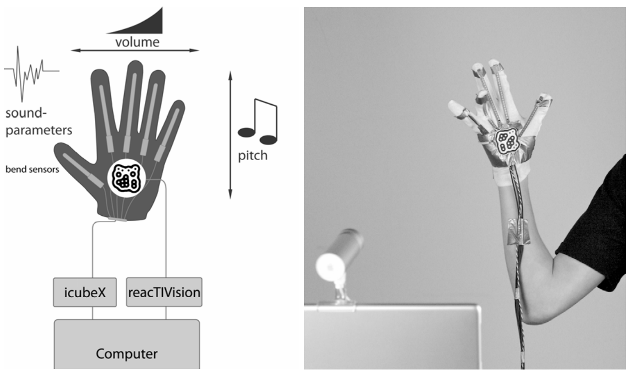

Figure 3. VRemin II – Hand tracking and Glove (prototype)

5. EVALUATION

We are interested in usability and manageability of our interfaces as well as the potential they offer for interaction variations. Since the AtrakDiff test is new in the evaluation of musical interfaces we decided to start with a pre-test. Controlled laboratory tests of the variations »Theremin«, »VRemin I« and »VRemin II« were performed for deployment to the usability evaluator. Three questionnaires surveyed the subjects' evaluations after each test. Video and audio recordings added quantitative data to the collected materials. However, the pre-test focuses on the quantitative data of the questionnaires, since the surveyed subjects showed high computer affinity, but little experience with musical instruments.12 persons (9 male, 3 female) with an average age of 26.75 years (min=20, max=47) participated in the study. Three of them had attended a musical school long ago and played a musical instrument (0.2 – 2 years experience). The questionnaire allowed assigning integer values from one to five to each question. Here a one stood for »very little« or »very few« and five indicated »very much« or »very many« (see figure 4).

Participant Questionnaire	Mean Value [1..5)
Familiarity with computers	4,25
Ear for music	2,83
Familiarity with sequencers	3,00
Familiarity with game controllers	2,17

Figure 4. Participant questionnaire

Subjects were assigned the test variants in permuted order to exclude corruption of the results by learning experience or change of perception by preceding tasks. Each subject received a short introduction to the instrument immediately before each test. After a short familiarization period of five minutes the subject was given two tasks. The first task consisted in playing a musical scale. The second task allowed the subject to improvise to a played back drum beat. Subsequently the subject answered two questionnaires. The first form is based on the attrakDiff2 described in section 2. A second form amended the attrakDiff2 questionnaire. This form queries facts which are also similarly surveyed in attrakDiff2 (complexity, precision, comfort, etc.) and thus increases result validity. In addition the subjects evaluate musical qualities to allow for further indications on the adequacy of the interface as a musical instrument. Due to the limited training of the subjects as musicians this questionnaire was considered only in a reduced fashion. The tests were concluded for each subject with a comparison questionnaire, which allowed to comparatively checking the results of the previous questionnaires once more. The result diagram of the attrakDiff2 questionary (figure 5) shows that the Theremin (number 3) is neutrally valued in pragmatic (PQ) and hedonic (HQ) quality. The Theremin was deemed suitable for playing music, but it only achieved average evaluations. Also the hedonic quality was within the average range. The Theremin was only averagely interesting. The VRemin II (number 1) has similar PQ values as the Theremin. It supports the user in fulfilling his tasks, but obtains only average values. However, compared to the Theremin it is valued more exciting and it generates curiosity (HQ). Both instruments show a large variance in user rating (confidence rectangle). The VRemin I (number 2) convinced the subjects with its pragmatic and hedonic qualities. (PQ and HQ of number 2). The users had the feeling to be able to play music more easily and it motivated and stimulated the user more than the other two variants. The Theremin and the VRemin II show potential for improvement with respect to usability, though the VRemin II with a value of 0.6 was deemed more attractive than the Theremin at 0.05. Figure 8, right shows the averages of some important values of the second questionnaire. The VRemin II is deemed as more complex and having more capabilities than the Theremin and the VRemin I. The VRemin I is superior to the other two variants with respect to handling, usability, precision, comfort, and controllability.

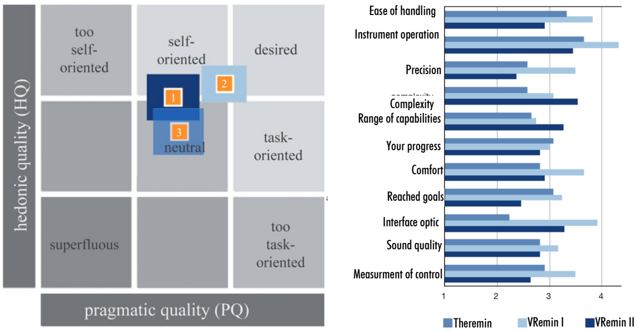

Figure 5. AttracDiff Results and second questionnaire

Progress with all instruments is deemed similar in the neutral range (value 3). With respect to appearance the VRemin I is placed before VRemin II and the Theremin in the positive range. This confirms the findings of the attrakDiff2 questionnaire. Both VRemins appeal more to the subjects. Both generate curiosity and stimulate the participants. Due to the complexity and prototypical character of the VRemin II the subjects were able to attain the task goals (pragmatic values), but they are valued slightly below the values for the Theremin and much more so below the VRemin I. On the other hand, the VRemin II is valued as more complex and having more capabilities. The VRemin I obtains throughout neutral to very good values and hence shows also in the specialized questionnaire its qualities. While the Theremin is viewed as mostly neutral with respect to usability of an interactive device for playing music, the VRemin I is seen as superior in all aspects. The VRemin II appeals as interesting, stimulating, and fascinating with the cost of an increase of complexity and accordingly operational difficulty. Further development of the VRemin II will require a reduction in its capabilities or a longer training phase and the transformation of the prototype into a more stable version. A further planned test in spring with a group of musicians (sound editors) with a longer training period will analyze the identified points of criticism and the harmonic capabilities of the interactive devices.

6. Conclusion

The presented approach methodically analyzed digital input devices as computer supported musical instruments. The presented evaluation steps and the pre-test argue that digital developments based on the Theremin appear to the casual player as tantamount. At the same time the attractiveness and use of the new input modes is viewed as more positive and more appealing. The capabilities seem to the subjects as higher-valued, than the original instrument introduced by Lev Theremin. For our subjects, the VRemin I seems to be superior to the VRemin II for playing. However, the VRemin II is still at a prototype stage, has a higher degree of complexity and this results in a higher degree of usage difficulty. The approach with attrakDiff2, the specialized questionnaire with explicit music-related questions and validity check by comparison questionnaire has proven itself. The claims were congruent even with a small number of subjects. The variance fluctuations are defensible – a larger number of subjects or a firmer selection of subjects should result in a reduced variance. The planned test for the analysis of the potential of musical expression of the evolutionary VRemin series should give more information on the pragmatic quality and further the advancement of the VRemins as musical instrument. We plan to use this research to develop Interface Design Patterns for Musical Instruments (IDP-FMI).

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