SONIFICATION OF A VIRTUAL MODEL OF THE OLD RARE MUSICAL INSTRUMENT

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ABSTRACT

The paper describes a project whose goal was to enable users realistically interact with a 3D virtual model of a historical musical instrument – the clavichord attributed to the famous 18th century maker. A challenge of enabling the user to play the virtual copy of the instrument was resolved by using the dynamic MIDI keyboard. The prerecorded clavichord sound samples are controlled by the software using the MIDI commands. Playing the real keyboard is synchronized with the movement of virtual keys and other parts of sound generating mechanism. The sound effects, characteristic for the clavichord *Tragen der Tonne* and *Bebung* may be imitated, which gives the user the impression of playing the real instrument.

1. INTRODUCTION

Old and rare musical instruments constitute a substantial part of museum art collections. However they are different from other artifacts, as they are also sources of sound generated by various, often very complicated mechanisms. Musical instruments were constructed to be played, but with "do not touch" labels in the museum experiencing it is almost impossible or because their playing mechanisms too fragile and often partly or entirely damaged.

With the use of digital media in cultural heritage, the visitors already have the opportunity to listen to the recorded sound in many museums. The state-of-the-art Europeana project undertaken by eleven Europe's musical instruments museums enables an access to digital representation of their collections via the Internet. The photos of musical instruments collections accompanied by audio and video files are processed in the databases so that all this content, along with supporting information is made publicly available on the web [7].

There are attempts to emulate the sound of rare musical instruments with all their characteristics, as e.g. in [2] and [10], where the sound of a clavichord and a clavinet were synthesized. However a real challenge is to attach the sound of a musical instrument – sampled or synthesized - to the virtual model of the instrument, and make the museum visitor play. There are single examples of such an application, e.g. real-time synthesis of contact sounds for multisensory interaction with Japanise drums that has been presented in [6].

The paper presents the 3D digital replica of the rare old 18th century keyboard instrument – Johann Adolph Hass clavichord that may be played as the real instrument.

Different forms of the interaction with the digital model were considered during the life cycle of the project: from a space navigator, through virtual gloves to a multi-touch monitor. These solutions are described in [3,4]. Finally it was decided to use - intuitively probably the most obvious, but in practice not so easy to incorporate to the model – a dynamic MIDI keyboard. This solution is the subject of the present paper.

The paper is structured in the following way. Section 2 discusses characteristics of the playing mechanism and the sound of the clavichord. Section 3 describes the clavichord of J.A. Hass. Section 4 presents the sonification of the virtual model of the clavichord. Section 5 introduces the hardware and the software used for building and testing the application. Section 6 concludes the paper.

2. CLAVICHORD PLAYING MECHANISM CHARACTERISTICS

The action for producing sound in a clavichord is simple: the keys are levers with a small metal blades called tangents at the far end. The sound is elicited when the player hits the key. Then the brass or iron strings are stroked by the metal tangent. Vibrations are transmitted through the bridge to the soundboard that amplifies the sound.

The way in which the tangent moves the string causes its oscillations of low energy. They are much smaller than in the case of a harpsichord or a piano. Therefore, the clavichord is an instrument of rather quiet sound, but its advantage is its relatively large dynamic range and the ability to control the sound while pressing a key.

To increase the volume of the clavichord sound two strings per key. Since the strings are never perfectly tuned to the same frequency, after a certain time strings vibrate in the opposite phases. Sometimes, when the difference in tuning is sufficiently large, the periodic change of the phase of string vibrations causes periodic changes of the sound volume producing a *beat*. A *beat* is an interference between two sounds of slightly different frequencies, perceived as periodic variations in volume whose rate is the difference between the two frequencies.

Two techniques are used for playing the clavichord, called from German *Bebung* and *Tragen der Tonne.* The ornament of the *Bebung,* is a special form of a tremolo. Roland Jackson in [5], quotes C.P.E. Bach, who characterizes the *Bebung* in the following way: "A long *affettuoso* tone is performed with *Bebung*. The finger that depresses and holds the key is gently shaken… the best effect is achieved when the finger withholds its shake after half the value of the note has passed".

Jackson characterizes *Tragen der Tonne* (sometimes called *portato*) as "a series of staccato notes with a slur mark over them" [5]. The effect is that "According to Rigler (1779)…each of the slurred staccato notes is *rather slowly rocked,* but without repeating the finger stroke as in *Bebung".*

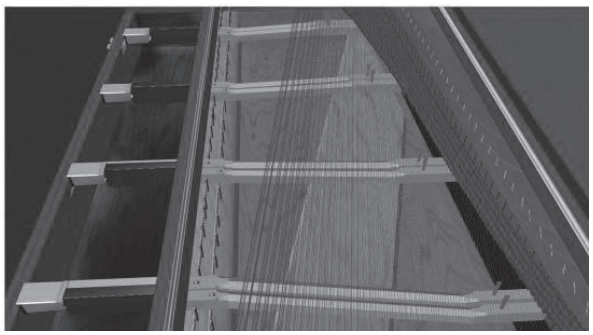

Figure 1: Demonstration of the key mechanism used in the virtual 3D model of Hass clavichord. Most of the keys are removed to increase the visibility of the key supporting pins. Remaining keys are in sequence from the top: C2, C#2, C3, C#3, C4, C#4, C5, C#5

3. J.A. HASS CLAVICHORD CHARACTERISTICS

The most famous among clavichord builders in the eighteenth century were Hieronymus Albrecht Hass (1689-1752) and his son Johann Adolph Hass (1713-1771). The best clavichords had a range of 5 octaves and an extra set of strings for the bass register, tuned an octave higher, to lighten the timbre and improve the bass definition. Hass clavichords were appreciated not only for their tone but also for their workmanship, selection of excellent materials and decoration. Their instruments were often decorated with beautiful veneers, nacre, tortoiseshell, ebony and ivory. The resonance boards were covered with paintings, and the casing was often decorated with *chinoiserie*.

A playing Hass instrument in a good condition is a part of the Edinburgh University Collection of Historic Musical Instruments. It is very similar to the instrument described in this paper. Both instruments have two strings per key, except the bass keys, which are the three strings per key. Both have similar dimensions and the same 5–octave (F2 - F6) scale [1,8]:

The materials and diameters of the strings used in the original instrument are listed in [1] together with the basic tone frequencies. They are tuned a semitone lower than a standard, i.e. the reference tone A4 is 415,3 Hz instead of regular 440 Hz It is a Baroque tuning ([9]).

4. SONIFICATION OF A CLAVICHORD VIRTUAL MODEL

To make the interaction with the clavichord virtual model the most realistic, after several trials with other interfaces, it was decided to use a MIDI dynamic keyboard as an input device. The MIDI standard provides parameters of the sound, but it does not provide the information about its timbre. The actual sounds in MIDI instruments are either played from the pre-recorded sounds or they are synthesized. Since in most instruments the timbre slightly changes with the dynamics of the sound, several samples is usually stored for a given pitch of the sound.

The synthesis of the clavichord sounds was a research subject of [10], however to make the virtual copy of the instrument as realistic, as possible, the sampled sound of the original Hass clavichord would be ideal. Since they were unavailable during the project stage, therefore, for experiments, the clavichord sound samples prepared by Jiri Zurek [11] were used. The samples are attributed to the 4-octaves clavichord (C2-C6, 49 keys), so the remaining sounds were obtained by processing the existing sounds.

The model provides three dynamic levels of sound: *p, mf, f.* Additionally the sound is composed of two parts: *key pressed* and *key released*. The longer the key is pressed, the shorter and quieter is the sound after the key is released. Four time-spans of the sound are provided:

1. $< 0{,}32$sec.
2. $\geq 0{,}32$sec., $< 0{,}95$sec.
3. $\geq 0{,}95$sec., $< 1{,}78$sec.
4. $\geq 1{,}78$sec.

For each time-span and each dynamic level there is a single release sound sample, so there are 12 samples for one key.

The MIDI parameters used for the model are following:

- Note On,
- Note Off,
- Velocity,
- Pitch Wheel Change (for portato),
- Channel Pressure (After-touch),
- Polyphonic Key Pressure (Aftertouch)..

To achieve the realism of playing the differentiation of sound velocity and volume is possible depending on the speed the keys are pressed in the dynamic MIDI keyboard. In addition, the application simulates the *Bebung* and *Tragen der Tonne* effects..

The special Virtuoso mode enables playing back (and moving the virtual mechanism of the clavichord) the MIDI files of music pieces composed for the clavichord. No disturbing latencies have been observed

The virtual 3D copy of Hass clavichord operating the MIDI dynamic keyboard has been tested by the group of Poznan University of Technology students and the Museum of Musical Instruments staff. In both cases the sonificated model found the approval.

5. THE HARDWARE AND SOFTWARE

The clavichord was modeled in the Microsoft Visual C# 2010 Express environment, using C#, HLSL and additional libraries XNA and C# Midi Toolkit (64 bit MS Windows 7).

The application was developed and tested on Dell Latitude E6500 laptop. The laptop is equipped with the Intel Core 2 Duo P8400 (2.27 GHz) processor, 4GB of RAM and NVIDIA Quadro NVS 160M graphics adapter.

The MIDI keyboard used may be a simple one, but the best effects are achieved if Polyphonic Key Pressure (Aftertouch), Channel Pressure (After-touch), and Pitch Bend are available. The application was tested on Roland EXR-3 keyboard.

The software responsible for playing the sound has a class *ClaviKey*. Each object of this class enables playing one sample of the key pressed and several samples of key released, which is necessary when e.g. the same key is pressed very quickly several times (no restrictions from XNA platform).

The samples are played using the class objects from MS XNA environment: SoundEffect and SoundEffectInstance.

Figure 2: The runtime environment of a virtual model of the clavichord interacting with the MIDI keyboard: MIDI Keyboard Roland EXR-3, a Dell laptop, 23 'Dell multitouch monitor.

6. CONCLUSIONS

In the paper the method of the sonification of the 3D virtual model of an old, rare Baroque clavichord of J.A. Hass was presented. Using the MIDI keyboard and MIDI commands to operate the software controlling the virtual model of sound generating mechanism and a set of sound samples it was possible to achieve the realistic audio, visual and partly haptic experience of playing a real instrument including varying sound dynamics as well as distinctive clavichord playing qualities i.e. *Bebung* and *Tragen der Tonne.* The user-clavichord model interaction via an ordinary dynamic keyboard with the reconstructed sound generation mechanism shown in action gives an immersive impression. This solution outperforms the precedent forms of the interaction with the clavichord model proposed in precedent papers, i.e. using or virtual gloves, or a multi-touch screen. The presented solution paves the way to the new forms of presenting musical instruments in museums and enabling active audio-visual experience of visitors.

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