HapTONE:
Haptic Instrument for Enriched Musical Play (II)
–System Detail-

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Abstract. We developed a novel musical entertainment system 'HapTONE' that draws on auditory, tactile, and visual senses. HapTONE presents players with high-fidelity vibrotactile sensations, not only after a key on pressing the keyboard but also during the actual process of pressing the key itself. HapTONE is composed of eight key units that is composed of a vibrator and a distance sensor. This instrument reproduces the touch sensation of a keyboard and stringed, wind, percussion or non-musical instruments. We also developed some applications using HapTONE, which were exhibited at the computer graphics and interactive techniques conference 'SIGGRAPH 2016'. In this paper, we describe the system details of HapTONE that enable accurate, low-latency feedback and easy expansion.

Keywords: vibrotactile, musical instrument, haptics

1 Introduction

For centuries, playing musical instruments has been one medium humans have used to entertain themselves. In recent years, electronic instruments have enabled people to play a variety of instruments using just one interface such as a synthesizer to produce various type of audio output. However, haptics are not typically used. One can hear a sound of xylophone or violin when the keys on the keyboard of an electronic piano is pressed, but the touch sensation remains that of a plastic keyboard.

Although several studies on haptic feedback have been linked to music, many of them aimed to enhance the listening experience [1][2]. However, Hachisu et al. aimed to enhance the playing experience on tablet PCs by using vibrotactile sensations [3], thereby augmenting haptic sensation. For keyboard-type instruments, Lewiston [4] added tactile sensations to a piano to create a learning system, and Oboe and De Poli

adfa, p. 1, 2011.

[5] created a virtual keyboard that reproduced the touch sensation of keyboard instruments such as the piano or organ.

Here we report on a system we developed called ‘HapTONE’ that modulates the haptic sensations of a keyboard by presenting the player with different vibrotactile sensations, not only after pressing keys on the keyboard but also during the actual process of pressing the key itself [6]. We also developed applications using HapTONE (percussion, pseudo-string and interactive projection mapping of living creatures using haptics), and exhibited it at the annual computer graphics and interactive techniques conference ‘SIGGRAPH 2016’. In this paper, we describe the system details of HapTONE that enable accurate, low-latency feedback, and easy expansion.

2 System detail of HapTONE

Main components of HapTONE.

Fig. 1 (left) shows the appearance of HapTONE system. It is comprises eight key units, five microcontrollers (mbed NXP LPC1768), four Digital-to-Analog(DA) converters with two outputs (MCP4922, Microchip Technology Inc.), one Analog-to-Digital(AD) converter with eight inputs (MCP3208, Microchip Technology Inc.), and a PC for audio-visual feedback. A key unit is composed of a vibrator (Vp408, Acouve Laboratory) and an optical distance sensor (Fig. 1 (right)). All units were 3D-printed. The vibrator is driven by an audio amplifier (SA-60, S.M.S.L). The distance sensor is composed of a photo-reflector (TPR-105F, GENIXTEK).

Fig. 1 HapTONE system (left) and the key unit (right)

Calibration of optical distance sensor

The voltage output from the optical distance sensor was non-linearly rated with distance. We calibrated sensors by using cubic natural spline interpolation. First, for five distances (measured by height gauge), we obtained voltage data repeated 10 times and calculated the mean. From these five sampled pairs of distances and voltages, a spline curve was estimated. Then, by using this spline curve, we interpreted sensor values into a linearized 256-step distance value.

Multi-channel, high-speed feedback

HapTONE measures the stroke distance of each key at a 1-kHz sampling rate. This provides vibrotactile and auditory sensation not only after pressing the key but also during the actual stroke operation. This gives the sensation of continuous vibration associated with the player's motion such as the vibration of a violin (i.e., stringed instruments). Stroke distance and speed are calculated using these data and are also converted into MIDI data. Then, these data are sent to the PC for audio-visual feedback. The PC presents the auditory feedback, but the vibration waveform model for haptic feedback is programmed in the microcontrollers beforehand, and played by changing some parameters depending on the stroke distance and speed. This structure greatly reduces latency between the user's action and haptic feedback, enabling users to feel not only simple vibration, but also the physical properties of a contact object.

To achieve such a low-latency system, HapTONE adopted a multiprocessors structure (Fig. 2). The five microcontrollers are divided into two groups according to their function: mother and children. Four children microcontrollers control vibrotactile feedback of two keys, and one mother microcontroller sends MIDI and distance data to the PC. The sensor outputs are fed in parallel to mother and children, and stroke distance and speed are calculated at each microcontrollers independently. Mother and children communicate with each other via a serial interface to change instruments. This independence simplifies development and enables high-speed feedback in the case of such a multi-channel situation.

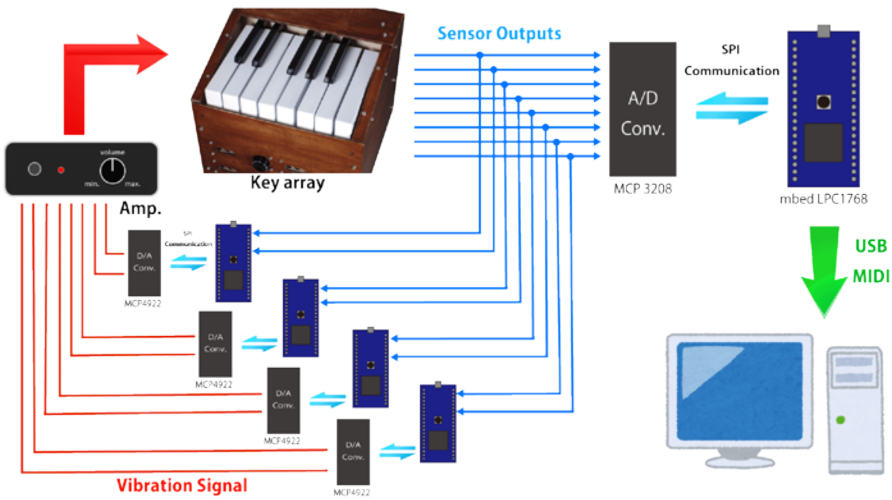

Fig. 2 The overall system of HapTONE.

3 Exhibit at SIGGRAPH 2016

We developed three applications: percussion, string and living creatures, using interactive projection mapping of animations and haptics (Fig. 3). These applications are briefly described in [6], and were exhibited at SIGGRAPH 2016. Fig. 4 is a photograph of our exhibition. Over 1500 people experienced HapTONE, and a majority expressed surprise and appeared impressed by the differences in touch sensations for each application. Children were observed to be especially absorbed in playing with HapTONE, with some playing with the system for >5 minutes. HapTONE and its combined interactive sound, visual, and tactile sensations appeared to be enjoyed by many people.

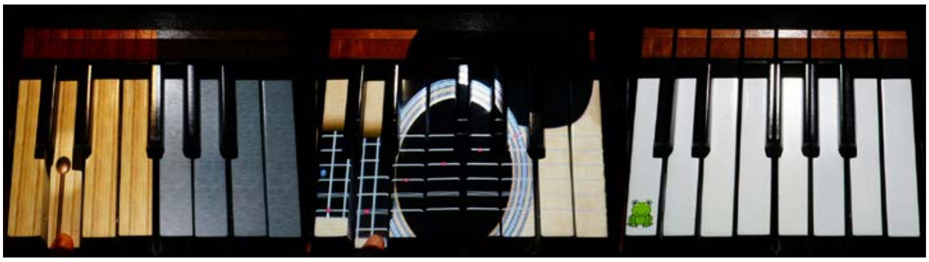

Fig. 3 Applications using HapTONE

Fig. 4 Exhibit in SIGGRAPH ‘16

4 Conclusion and future work

In this paper, we described the system details of a haptic musical instrument device ‘HapTONE’. The calibrated optical distance sensor and the multiprocessors system enabled accurate, low-latency feedback and easy expansion of the system. We also developed three applications using HapTONE, which were exhibited at SIGGRAPH 2016. Our future work will include developing suitable vibration parameters for each musical instrument, and expanding the system to include non-musical instruments such as gaming devices.

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