Towards Digital Music Performance for Mobile Devices Based on Magnetic Interaction

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Abstract— **Digital music performance require high degree of interaction using natural, intuitive input controllers that provide fast feedback on user's action. One of the primary considerations of professional artists is a powerful and creative tool that minimizes the number of steps required for the speed-demanding processes. Most of the musical performance applications, which are designed for mobile devices, use touch-screen or accelerometer as interaction modalities. In this work, we present a novel interface for musical performance that is based on the magnetic field sensor embedded in recent mobile devices. The proposed method, at this point, promises a new independent ground for inputting momentary data during music composition and manipulation process. Giving the opportunity to freely, fully and quickly utilize the surrounding 3D space, it possesses the potential to bring a wide-spectrum of unique options for production and performance process of music.**

Keywords-digital music performance; electronic instrument; magnetic field sensor; gesture-based interaction; mobile devices

I. Introduction

Along with the ongoing development of innovative technologies, audio production as a concept is in a constant progress, through which artists are given new opportunities and unique methods to compose music and perform their artwork to the masses. Trendsetting functions and capabilities become available with a perpetual motion, inspired from tendency of constructing audio through new and creative approaches. Specifically, diverse methods focused on new input technologies are being introduced that all aim to provide options untried before to artists' process of music creation and performance.

In this work, we propose to use the magnetometer embedded in new mobile devices, such as Apple's iPhone 3GS and Google's Nexus One, for musical performance on mobile devices. The embedded magnetometer provides a measure of magnetic field strength along X, Y, and Z directions. In this method, the user takes a magnet that can be in shape of a rod, pen or ring; in his hand and draws coarse gestures in 3D space around the device. Several characteristics of a song or an audio such as frequency, equalization, filtering, etc. can be altered based on the magnetic field caused by the magnetic gestures. Position, movement, shape, and orientation of the magnet can be used as an input modality to alter parameters of music being played or being adjusted. In comparison with touch-screen or keypad input, this technique provides higher degree of flexibility for musical performance because the interaction space extends beyond the physical boundary of the device. Consequently, it is especially suitable for small and tangible devices while it does not require any change in their hardware or physical specifications.

Musical performance requires the manipulation of several inter-dependent parameters simultaneously; thus, it's gestural interfaces needs to be suitable with motor capabilities of the user. The use of touch-less gestures performed around mobile device reduces the motor and cognitive load of the performer. The proposed method enables a more creative, unique and innovative way of audio production and performance that can be utilized for different type of target groups including both professional artists and leisure oriented hobbyists. Furthermore, the use of natural and intuitive gestures is consistent with the mobile music technology challenges regarding the action-sound relationships and music-movement correspondences.

In order to experiment the methodology, we have implemented proto-types for each use case on iPhone 3GS. For that reason, we have ported SuperCollider (SC) [21], a real-time sound synthesis environment to iPhone 3GS. Then, we have connected the interfaces of different instruments with SC patches through Open Sound Control (OSC) in order to send the raw XYZ data and recognized gestures. Relatively, multiple interfaces are able to connect into one SC server in order to perform collaborative performance. For instance, one can modulate a sound while someone else generates it.

The implementation of the proposed digital instrument on iPhone is still in progress. The current implementation (Fig. 1) offers music composition options on simple level on mobile devices (using predefined pitch intervals, instrumentations and presets for various parameters) and features popular sound effects to the audio in playback, along with a vinyl-scratching simulation.

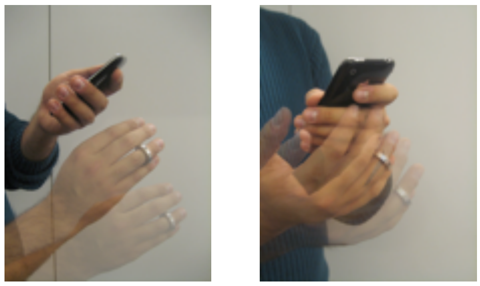

Figure 1. Digital music performance implementation that works on iPhone 3GS

Regarding practical options for utilization of the proposed technology in audio production and performance, three incremental levels of application are considered: sound generation, modulation and effecting.

II. Related Works

Recently, we have proposed MagiTact [15], the use of magnetic field sensor for general-purpose interaction with mobile devices and achieved gesture recognition accuracy over 90%. Similar designs of musical instruments based on electric field sensor (cathode relays) [26] and IR proximity sensor [27] are investigated for musical performance on portable devices. However, series of previous work has been established so far regarding possible new methods to provide control on a mobile audio creation environment.

Lots of researchers already attempted to propose different mappings of action to the audio synthesis. The mappings can be explored in two fields in terms of their excitation type: sustained and impulsive. The sustained mappings are based on continuous energy transfer such as the 3D motion data that is captured using different type of sensors; whereas, the impulsive mappings are discontinuous and generally triggered using gestural interfaces.

Firstly, Campo et al. [5] proposed a design for generalized sonification environment to deal with experimental data analysis and exploration. Then, Klein et al. [24] described a technique for sonification of 3D vector fields to map vectors in a listener's local neighborhood into aerodynamic sound. Afterwards, Pelletier [25] described another motion-based framework for the generation of large musical control fields from imaging data using granular and micro-sonic algorithms, additive synthesis and micro-polyphonic orchestration. Bevilacqua et al. [1] extended 3D optical motion capture sonification through gestural analysis via segmentation and pattern recognition.

The impulsive mapping has been also widely investigated by designing gesture-based instruments. Wanderley et al. [10][11][16][19] deeply investigated the gestural control of the music and defined different aspects that should be taken into consideration for the gesture-based digital instruments. Fenza et al. [20] presented a multi-layer controller with three stages of mapping that explore the analogies between sound and 3D movement spaces using Laban's theory. Kayali et al. described a number of suitable gestures for musical expression with mobile and tangible devices. Malloch [2] provides the design and construction of a family of novel hardware input devices, a collaborative mapping system and a modal synthesizer software for gesture-based performance. Bencina et al. [12] described a technique for developing gesture-sound mappings using three-axis accelerometer of Wii Remote. Dekel [18] et al. used again accelerometer gestures as input to MIDI instruments and sound generator.

Finally in mobile context, Couturier [3] and Jensenius [23] defined the requirements for using mobile devices as digital instruments. Geiger [28] explains the efficiency of using touch-screen as an input controller. Gillian et al. [22] presented a gesture-based DJ-effecting mobile game having vibro-tactile feedback. There have been also works that show the importance of mobile musical performance via real-time collaborative (orchestral) approaches. For instance, Wang [7][9] implemented an orchestral ancient flute-like instrument designed for the iPhone using microphone for breath-control and multi-touch for finger holes. Tanaka [17] presented the collaborative composing with mobile devices using MaxMSP music environment and OSC messages. Essl et al. [8][14] analyzed sensors integrated in mobile devices regarding digital music and they explained the challenges for turning the devices into performance platforms. They have also experimented the sound generation using striking, shaking and sweeping type of natural gestures.

III. Methodology

The proposed method is examined using a multi-layer model with three independent levels (Fig. 2). Using mobile devices as digital instruments, group of users collaboratively generate the sound. Then, characteristics of the generated sound are modulated afterwards by the same group or simultaneously by another group of users. Finally, the users can apply different sound effects onto the performance using gestures.

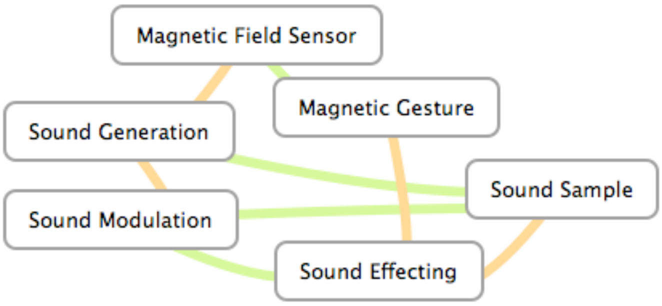

Figure 2. The model for digital music performance that consists of three main levels: sound generation, modulation and effecting

A. *Sound Generation*

With its specific meaning for the purpose, generation of sound defines creation of various audio components for composing a certain piece of music. Fundamental elements of music are various and different categorizations can be considered depending on the type of classification. Several examples to primary elements of music can be given as pitch, melody, rhythm, harmony, tempo, timbre, dynamics and texture. Among the given elements, melody and rhythm are the directly audible elements of a music piece, while all of the other parameters determine the values for different qualities of audio.

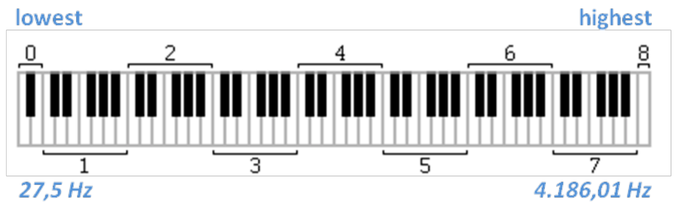

Figure 3. 88-key piano with a virtual range of 8 octaves

In a strict sense, pitch defines the lowness or highness of a sound on a note-based scale. A note with its direct meaning in music is actually a pitched sound itself. Any note played on a piano keyboard includes a certain pitch value and it gets higher as other keys to the right are played and vice versa. Within the audible range from 20 Hz to 20.000 Hz for the human ear, every key played for a note in a modern piano features an absolute frequency in Hertz. An 88-key piano with a virtual range of 8 octaves (Fig. 3) will feature a note range from A0 (lowest) to C8 (highest), around which the frequency ranges from 27,5 Hz to 4.186,01 Hz.

Figure 4. Major and minor chords of the note C

The harmonic element of a music piece is usually obtained through a series of chords that accompany a melody and/or rhythm. In a simple sense, a chord is a set of harmonically related notes that are played simultaneously (Fig. 4). While further varying with their characteristics, chords fundamentally represent a certain single-key note on the keyboard.

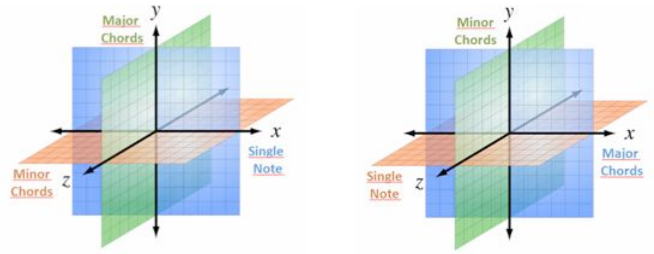

Fig 5. The axes of the magnetic field data are mapped to notes in 88-key piano defined with their pitch, Major and Minor chords.

Using the knowledge described above, we propose to develop a digital piano instrument, which works on the thin air, using the raw data derived from the magnetic field sensor. The X coordinate of the raw data is mapped to a selection of 88 notes defined with their pitch / frequency and the Y and Z coordinates are mapped to Major and Minor chords (Fig. 5). Possibilities for creative composition of musical pieces can significantly increase when the second axis is assigned to Major chords and the third axis is assigned to Minor chords.

B. *Sound Modulation*

After creation of a certain type of sound, it is possible to modify its characteristics through a high number of parameters, including but not limited to Amplitude, Resonance, Pan and Spread, Velocity, Attack / Decay / Sustain / Release, Motion, Legato and Vibrato. Modifications on characteristics of an already created sound enable different expressions to be obtained from the audio, enabling a wide spectrum of options for further improvement.

In addition to pitch-based sound generation functionalities of a magnetic interaction based input, possible combinations regarding allocation of axes to modifiers of sound characteristics will enlarge the scope of sound production and performance for cross-border capabilities (Fig. 6). For instance, it may be used as music synthesizer keyboard modulation wheel of the proposed digital piano instrument.

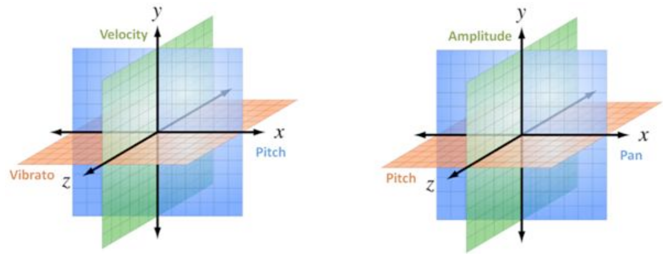

Figure 6. Different combinations of sound characteristics mappings that are considered for the sound modulation

C. *Sound Effecting*

A sound effect can be shortly defined as an enhancement brought to a certain sound with alterations and diversifications applied on the signals. Sound effects can create dramatic changes on any possible parameter of sound and enable a number of opportunities for shifting musical components to various forms. Hence, it supplies advanced sound processing capabilities to any audio performance software.

With the unique freedom given by the proposed method to utilize the three axes for different parameters of sound generation, modification and effecting, various combinations can be considered for desired type of music scoring performance, each with a potential to deliver diverse qualities. While it is possible to reach further results with combinations of parameters, a brief list of possible sound effects follow as Equalizer, Pitch Bend-Pitch-Shift, Reverb, Delay/Multi-tap, Compressor, Chorus, Limiter, Fuzz, Distortion-Overdrive, Flanger, Phaser, De-esser, Noise Gate and Ring Modulation.

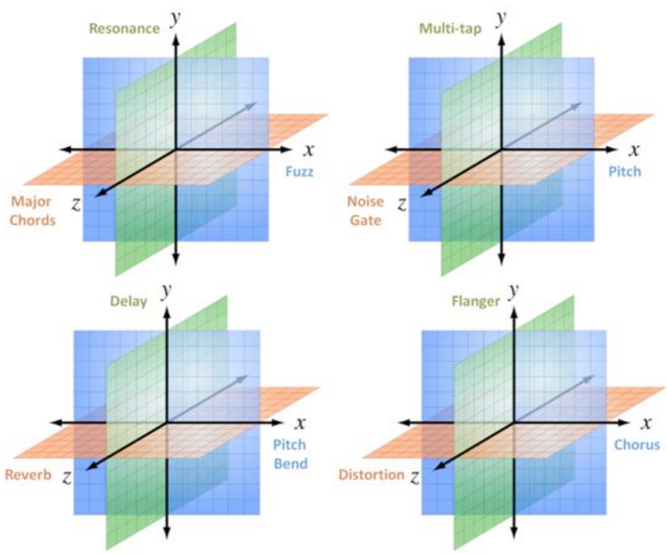

Figure 7. Different mappings of the various combinations of sound effects to the axes of the magnetic field sensor.

For that reason, we have proposed several mappings of sound effect to the axes of the magnetic field sensor (Fig. 7). The sound effects can be applied collaboratively or simultaneously to enhance the digital music performance. The passage between different mappings of sound effects can be performed using magnetic gestures, as an alternative to the touch-screen interface.

IV. Extension of Work

More dimensional mappings for digital music performance stages could be developed though the fusion of multi-sensor data. For that reason, we would like to extend the interaction possibilities by combining data from multiple sensors embedded in mobile devices. Furthermore, stand-alone hardware units can be configured besides mobile devices in order to obtain the minimum latency and maximum accuracy for providing more efficient results during professional-level operation with higher process rate. Several opportunities arise from binding any possible sound generator, modifier or effecter device to the axes of magnetic field based interaction Thus, equipping of a multi-purpose software with sound sampling / generation abilities to various professional audio production software appears very suitable. Finally, we can investigate the separation of sources in order to establish a collaborative magnetic field based digital instrument without having the necessity of multiple devices.

V. Summary and Conclusion

In this work, we have proposed a novel interface for musical performance that is based on the magnetic field sensor integrated in new mobile devices. Moreover, we have proposed different mappings of sound characteristics for the sonification of the 3D vector datum of the magnetic field. Besides the mappings, we have explained how such a digital instrument can be realized using gesture-based interaction. Through trained motions of a professional artist or a leisure-oriented hobbyist, the proposed technology is highly likely to bring a new and effective trend to concept of the digital music performance on the mobile context.

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