MagiMusic: Using Embedded Compass (Magnetic) Sensor for Touch-less Gesture Based Interaction with Digital Music Instruments in Mobile Devices

ABSTRACT

Playing musical instruments such as chordophones, percussions and keyboard types accompany with harmonic interaction of player's hand with the instruments. In this work, we present a novel approach that enables the user to imitate the music playing gestures around mobile devices. In our approach, touch-less gestures, which change magnetic field around the device, are employed for interaction. The activity of playing an instrument can be transparently pursued by moving a tiny magnet in hand around new generation of mobile phones equipped with embedded digital compass (magnetic sensor). The phonation intentions of the user can be simulated on the mobile device by capturing the gestural pattern using magnetic sensor. The proposed method allows digital imitation of a broad number of instruments while still being able to sense musical hits and relative plectrum gestures. It provides a framework for extending interaction space with music applications beyond physical boundaries of small mobile devices, and to 3D space around the device. This can allow for a more natural, comfortable and flexible interaction. We present several mobile music applications developed based on the proposed method for Apple iPhone 3GS.

Author Keywords

Digital Music Instruments, Mobile Devices, Magnetic Field Sensor, 3D Magnetic Gestures, Around Device Interaction.

INTRODUCTION

The technological advances in the digital devices have dramatically changed the concept of musical performance as well. Today's bands are effectively using instruments (e.g. keyboard) enhanced with embedded digital computers having a variety of software including effectors and equalizers. Nowadays, mobile devices also became popular digital instruments for musical performance [3, 7]. The touch-screen and accelerometer are mainly used for interaction in order to simulate traditional instruments [5, 6, 2].

In this work, we propose to use the magnetic field sensor (magnetometer) embedded in new mobile devices (such as Apple iPhone 3GS and Google Nexus), for interacting with music related applications on mobile devices. The embedded magnetometer provides a measure of magnetic field along X, Y, and Z directions. Moving a peripheral magnet in the device surroundings changes the magnetic pattern of the space around the device and causes continues deviations in the values of mentioned axes. Collecting values of magnetometer in temporal order forms a 3D vector set that can be used to represent various activities. In the same context, MagiTact [8], the use of magnetic field sensor for general-purpose interaction with mobile devices, has been recently proposed. 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. These gestures can be interpreted as interaction commands. As presented in this paper, a similar methodology can be applied for interaction with music performance applications on mobile devices (Fig. 1). This allows effective use of 3D space around the device for more flexible and natural gesture based interaction with music performance applications.

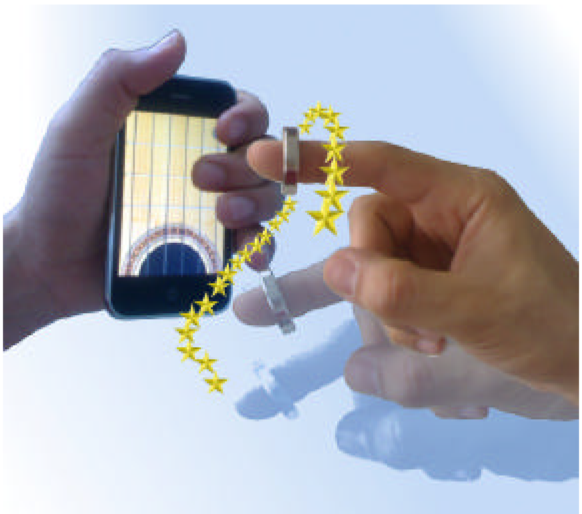

Figure 1: Gestural interaction with music applications using 3D space around a mobile device based on magnetic field.

Using traditional instruments involves the harmonic motion of hands, which alters according to instrument type and shape. In our methodology, we establish a mapping between those motions of hand (or fingers), and movement of a magnet (taken in fingers) in the space around the device. Several audio characteristics such as frequency, equalization, filtering, etc. can be altered based on changes in 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 the music being played or being adjusted. Similar designs of musical instruments based on electric field sensor (cathode relays) and IR proximity sensor [4, 10] was investigated for musical performance. Our interaction method is based on magnetic field which can capture the 3D motion in a more effective and detailed way. Since magnetic field can pass through different materials, the device does not need to be in line of sight for the interaction. As the magnetic sensor is a cheap, simple and small sensor, integrating it in mobile devices does not impose major change in hardware or physical specifications of devices. The magnetic sensor is already integrated in many modern mobile devices such as Apple iPhone 3GS, iPad, Google Nexus, etc.

Recently, the requirements for using mobile devices as digital instruments are defined by [3, 7]. In this context, there have been several attempts using touch-screen and/or accelerometer [5, 6] including a gesture-based DJ-effecting mobile game and collaborative composing approaches (e.g. ancient flute using microphone and multi-touch). There have been also analysis of embedded sensors regarding musical performance [2, 3] where the sound generation using striking, shaking and sweeping type of natural gestures are experimented using accelerometer. However, playing musical instruments on the surface of a mobile device is not natural enough, and usually requires both user's hands on a single small screen of the mobile phone. In comparison with touch-screen or keypad input, our technique provides higher degree of flexibility for musical performance, because the interaction space is extended beyond the physical boundary of the device. When using accelerometer based interaction, the user has to repeatedly turn the device to launch certain actions. This makes the user to loose direct sight to the screen [1]. Whereas in our proposed method, device orientation can be maintained and be adapted to user's natural behavior.

In the next section, we discuss in more details how the output of magnetic sensor influenced by movement of an external magnet can be used for interacting with music applications. We then present different prototype music applications that we have developed based on our interaction method.

METHODOLOGY

In this section, we propose different mappings of sound characteristics for sonification of the 3D vector data provided by the magnetometer. Besides the mappings, we explain how such digital instruments can be realized using gesture-based interaction. As shown in Fig. 2, the magnetic sensor provides a measure of magnetic filed along X, Y, and Z directions. The mapping of sound characteristics to the 3D vector set provided by the magnetometer can be explored in two ways considering 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 interactions. In other words, there are two distinct methods that one can employ magnetic field to play a musical instrument. The first way is using direct sensor values where the projection of sensor value to X, Y and Z axes provides 3 different modalities

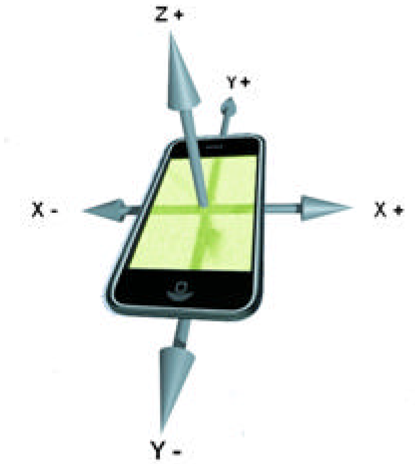

Figure 2. The magnetic sensor provides a measure of magnetic field along X, Y, and Z axis.

which can be mapped to different sound parameters. In the second approach, a sequence of sensor values shapes a 3D gesture pattern. This pattern can be matched against a model to realize their corresponding gesture class as suggested in [8]. We present samples of both approaches in the next sections.

Depending on the application, sometimes a transformation of magnetic sensor output can be more useful than raw signals. The transformation can be time derivative or calculating norm of magnetic signals. Time derivative operation can be especially important when there is a need to remove effect of earth magnetic field on the sensor. In this case, time derivative operation acts as a high-pass filter and removes the effect of earth magnetic field. For instance, in a guitar application, a triggering like gesture in the air (by magnet) can be easily highlighted in time derivatives of magnetic sensor output.

In the following sections, we present the mobile music applications we have implemented based on the magnetic field interaction. The applications are developed for Apple iPhone 3GS. In order to facilitate actual implementation of music applications in the first trial, magnetic signals captured by the mobile device (iPhone) are sent to a PC based SuperCollider (SC) [9] server. SuperCollider is a real-time audio synthesis and algorithmic composition environment. Sending data to the SC server is only to simplify sound synthesis part, and the magnetic interaction is fully implemented through the mobile device. Therefore, there are two components for each application: a client on iPhone 3GS, and a SuperCollider server on PC. The client sends the data related to magnetic field surrounding the mobile device to the server over wireless network. The SC server takes the data from one or multiple clients and synthesizes the parameterized sound.

IMPULSIVE INSTRUMENTS

As mentioned earlier, for simulation of impulsive instruments, we check for a certain gesture pattern in the data provided by the magnetic sensor. This data corresponds to a certain gesture which the user has performed using the magnet in hand.

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Air Guitar

Guitar is a musical instrument belonging to chordophone family which has 6 attached strings. Playing a guitar is performed by 2 distinct actions: strumming and holding (locking). In a normal guitar, strumming comes along with periodically scratching of the instrument strings with right hand fingers. The left hand presses different pitches on different strings alongside the neck of the guitar to generate different tones. In touch-screen based guitar applications offered recently on mobile phones, one can pluck the simulated guitar by scratching the touch screen. The action of holding a note is also done on the same screen (3 different areas for each string). Such arrangement for playing guitar can be to some extent unnatural and inconvenient since it requires using both hands on small screen of the mobile device.

In our guitar application (*Air Guitar)*, we have replaced the touch screen based strumming action with a 3D gesture based action in the space around the device. We let the holding(locking) action to be remained on the touchpad. However, the strumming is implemented with magnetic interaction to imitate the natural action. For string triggering (strumming), values obtained by X-axis component of the magnetometer determine the string which should be triggered. The range of values is divided into 6 intervals each representing a particular string. The key factor to detect the triggering gesture (action) is a rapid change in the magnetic filed sensed by the magnetic sensor, which corresponds to rapid movement of fingers with magnet in a gesture similar to strumming. This can be detected by comparing the variance of magnetic field (estimated over an interval/window) with respect to a pre-defined threshold. The rapid movement of fingers in the air (with magnet) creates a rapid temporal change in the magnetic field around the device, and makes the variance of sensed magnetic field exceed the threshold. To avoid stepping changes from one string interval to another, we have considered a gap between these intervals (X component values) in which no tone will be played.

The combinations of pitches (selected by touch screen), and strings (6 string triggered in the air) results in 24 different states that are sent to the server for playing corresponding sound.

Drum-Kit

Drum is a cylindrical shape instrument from percussion family of musical instruments. Normally in percussion instruments, the head of cylinder is covered by some sort of elastic skin that one can hit by hands or by some special sticks. In playing a drum, two main factors are taken into account: the strength of the hit and the radios of hitting point to the center of surface. In our interaction framework, to simulate the hand gesture on the instrument, the Z component of the magnetic sensor output is mapped to the vertical movement of the hand towards the surface. The second time derivative of the Z component signal is interpreted as strength or energy of hitting. The higher the strength (energy) is, the loader the sound will be generated. The X component of magnetic sensor output represents the radial distance to the center of the instrument, indicating the tone to be played. Having a magnet in hand, one can magically play a drum by hitting back and forth in the air towards the surface of device, and right and left with respect to the center, to obtain different tones. The tone is played only if the strength (second derivative of Z component) exceeds a threshold. If the tone is played, the strength (loudness) of the tone would be proportional to the second derivative of the Z component. Using touch-less magnetic interaction in our Drum-kit for detecting the hit action can be superior to the use of touch screen, as strength of the hit can not be easily calculated based on touch screen. In addition, in our Drum-Kit, we are using a hitting gesture similar to the real Drum, which can be more natural than hitting on a rigid screen surface.

Harmonics

Sound harmonics are integer multiplicands of a base sound frequency. In some instruments such as metallophones or xylophones, on any consecutive pitch of the instrument, an individual harmonic can be produced. In metallophone, different metal bars with different sizes are mounted to an oscillating frame. With a mallet, one can strike on different bars to generate different harmonics. To play one particular metallophone, 2 factors determine the type and quality of the output: The metal bar that is stricken and the strength of the strike. In our framework, the X value of the magnetic field (sensed by magnetic sensor) is dedicated to represent the bars on the instrument. We have split up the X-axis value range of magnetic sensor into 24 different intervals. Depending on the value of X component, the index of its corresponding interval (1:24) represents the bar which should be stricken on the simulated metallophone. The strength of the strike can be also obtained in the same way as Drum-Kit.

SUSTAINED INSTRUMENTS

For simulating sustained instruments, we use the output of magnetic sensor in raw, time derivative or normalized format directly for tuning certain parameters of the sound being generated. The output of magnetic sensor (when the magnet is not engaged in performing a gesture) can be a function of intensity, position, polarity and orientation of the magnet. This means that the sound parameters can be tuned based on position, polarity, orientation, etc. of the magnet in the hand of the performer.

Theremin

Theremin is a touch-less electronic instrument that is controlled by two different shape antennas. The task of antennas is to detect the distance of player's hands to the antennas, and to track the oscillations of the player's hands. The distance of players' hand to one antenna is used to change the frequency (pitch) of the sound and the distance of the other hand to the second antenna is used to adjust the amplitude (volume) of the sound. In order to simulate Theremin based on our framework, we have assigned the X-axis of the magnetic sensor to control the frequency of the sound. The Y-axis value is also used to control the volume of the sound. Forwarding these settings to the SC server, we can play the appropriate sound resembling the original Theremin.

Sound Modulation and Effecting

After creation of a certain type of sound, it is possible to modify its characteristics through a high number of parameters, including amplitude, resonance, pan and spread, velocity, attack/decay/sustain/release, legato and vibrato. Modifications on characteristics of an already created sound enable different expressions to be obtained. Sound effecting is enhancement brought to a certain sound with alterations and diversifications applied on 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. Value of the magnetic signals registered by the magnetic sensor can be used as a basis for altering different sound parameters. As a sample for sound effecting, we briefly mention to a Disk Jokey (DJ) application developed based on the concept of magnetic interaction.

Disc Jockey

DJ (disc jockey) is title of a person who plays and synthesis different types of recorded music for audience. To simulate a DJ medium, we developed an application on a mobile device that enables the DJ to tune and combine music by means of magnetic field interaction. For a demonstration we have implemented two standard effects that a DJ can control: Crossfading and Scratching. Crossfading is the way to interlace two playing sounds. In a simpler sense, crossfading means to increase the power of one sound and decrease the power of the other. On a DJ desk, there is a fader slider that overlaps music with another. How smooth or fast two songs can be fade is depend on the DJ profession. If *M* is the first sound and *N* is the second sound and *C1, C2* are their corresponding coefficients, the output sound can be defined as following:

$$\text{Sound} = (M * C1) + (M * C2) \qquad \text{Where} \quad C1 + C2 = 1.$$

Scratching is a technique to play a part of previously recorded music back and forth. The effect of doing such action is hearing a cutting sound. Naturally, scratching is the act of moving, stopping and reversing a disk on a music turntable. It is known as scratching since DJ finger acts like he/she is drawing some scratches. In our work, we have assigned the X-axis values of the magnetic sensor to the crossfading action, and the Y-axis to the scratching action. *C1* and *C2* coefficients are calculated based on X component of magnetic sensor output, hence relative position of hand with magnet on the X axis. In this way, the DJ can obtain different mixtures of two sounds by moving his hand left and right with respect to the device. Scratching effect is produced when a sharp movement of the magnet in Y direction is detected. The tuning data obtained by mobile phone DJ interface will be sent through wireless network to a SC server to synthesis the output sound based on the user settings. The advantage of such setting is that the DJ can keep his natural gesture to tune the sound output while he can freely move through the audience. DJ pooling can also be imagined when several mobile DJ terminals join to a central server.

CONCLUSION AND FUTURE WORK

In this paper, we have presented a new approach that mimics the music playing gestures on mobile device. We have proposed interaction with music and audio applications based on changing magnetic field around the mobile device using an external magnet. The change in magnetic field is sensed by internally embedded compass (magnetic) sensor on mobile device. We have presented several music applications that we developed based on the proposed method for mobile devices (Apple iPhone 3GS in our case). Our method provides the possibility of extending interaction space with mobile music applications beyond physical boundaries of the device and to 3D space around the device. This allows the user to interact naturally using gestures as he acts in normal life.
Developing more sophisticated gesture recognition techniques can enhance interaction with music applications and reduce the chance of wrong actions. We are also interested to further investigate using multiple magnets (and possibly multiple magnetic sensors) for the interaction. As touch-less interaction with music applications is relatively a new concept in music production, one can also think of inventing totally new instruments using the presented method.

REFERENCES

1. R. Bencina, D. Wilde, and S. Langley. Gesture sound experiments: Process and mappings. In Proceedings of 8th International Conference on New interfaces for Musical Expression (NIME 08), pages 197–202.
2. G. Essl and M. Rohs. Interactivity for mobile music- making. Organised Sound, 14(02):197207, 2009.
3. G. Essl, G. Wang, and M. Rohs. Developments and challenges turning mobile phones into generic music performance platforms. In Proceedings of the Mobile Music Workshop, 2008.
4. I. Franco. The AirStick: a free-gesture controller using infrared sensing. Proc. New Interfaces For Musical Expression (NIME), pages 248–249, 2004.
5. G. Geiger. Using the touch screen as a controller for portable computer music instruments. In Proceedings of the 2006 conference on New interfaces for musical expression, page 64, 2006.
6. N. Gillian, S. O'Modhrain, and G. Essl. Scratch-Off: a gesture based mobile music game with tactile feedback.
7. A. R. Jensenius. Some challenges related to music and movement in mobile music technology. In 5th International Mobile Music Workshop , Vienna, Austria, 2008.
8. H. Ketabdar, K. A. Yüksel, and M. Roshandel. MagiTact: interaction with mobile devices based on compass (magnetic) sensor. In Proceeding of the 14th international conference on intelligent user interfaces, pages 413–414, Hong Kong, China, 2010, ACM.
9. J. McCartney. Rethinking the computer music language: SuperCollider. Computer Music Journal, 26(4):61–68, 2002.
10. L. S. Theremin and O. Petrishev. The design of a musical instrument based on cathode relays. Leonardo Music Journal, 6:49–50, 1996.