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Wii Remote-based Collaborative Interfaces for Music

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ABSTRACT
Wii Remote is the main controller for Nintendo's Wii console. Thanks to the use of accelerometer and optical sensor technology, it presents motion sensing capability, which implies gesture recognition and intuitive pointing. Such a controller is user-friendly, inexpensive and easily available, due to growing Wii console's popularity. These features make Wii Remote a good device to create and manipulate both music and audio in a home entertainment environment. In this paper, the most interesting characteristics of the controller will be reviewed. A case study will be presented, namely the creation of a virtual music instrument to be controlled in a collaborative way through a set of Wii Remotes.

Keywords
Wii Remote, virtual music instruments, human-computer interfaces

Categories and Subject Descriptors
H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems; H.5.5 [**Information Interfaces and Presentation**]: Sound and Music Computing

General Terms
Design, Experimentation.

1. INTRODUCTION
The study of heterogeneous means to control music and audio parameters is currently one of the most interesting fields of research in Computer Music. Many applications can be cited, ranging from intuitive music production to advanced music listening. If we take into consideration the field of computer-based virtual instruments, it is worth remarking some noticeable examples. For instance, in [7] both the function and the interface of a virtual piano are discussed. The movements of the pianist's hands in the air, over an imaginary keyboard, are caught by a webcam and interpreted through a computer system in order to produce sound. This approach inspired our work, first of all as regards its goal - i.e. the simulation of a real keyboard instrument playable even by untrained people - but above all for its low requirements: an ordinary computer equipped with a webcam and running a piece of software. Many other works and experiments can be cited, from reacTable [3]- which represents an example of tangible user interface - to the research products annually presented at New Interfaces for Musical Expression (NIME) conference. In this context, our goal was creating both a virtual multi-timbre music instrument resembling a traditional one and an interface for a new collaborative instrument. They share the following characteristics: i) Intuitiveness and easiness of use, so that both musicians and untrained people can interact with the instrument; and ii) Support of collaborative performances, i.e. the possibility for many players to work together on the same performance, also in an improvisation context. The interaction is based on an advanced device to control music parameters, namely Wii Remote. Wii Remote is basically used to play and interact with the popular Nintendo Wii console. This one-hand remote controller is designed to make motion sensitivity intuitive. Users' movements are caught in a precise way, thus making this tool an accurate pointing device. Besides, an extended set of buttons is provided, so Wii Remote can be considered both a wireless mouse and a sort of gamepad. In our view, the key features of a traditional music instrument have to be supported. As a consequence, melody, rhythm, dynamic effects are mapped on movements perceived by Wii Remote and on its pressed/released buttons, in order to provide the user with a rich set of controls.

2. AUDIO AND MUSIC PARAMETERS
In our proposal, the main parameters that can be affected belong to two families, namely audio and music. In some cases, both the families share a similar meaning for parameters: for instance, audio volume can be somehow assimilated to music dynamics. Other parameters belong to only one specific domain: e.g. a scale is defined only in the music field, whereas the waveform characteristics of a timbre are defined only in the audio domain. In order to design a virtual instrument, first of all we took into consideration the typical parameters which can be controlled on a traditional monophonic music instrument: pitch, rhythm, and dynamics. Moreover, expressiveness is reached with a wider set of variables controlled by the performer, so in this section we will try to introduce a group of them that can be suitably driven by the controller. Some inspiring ideas about interaction between human gesture and music performance

can be found in [2]. As a final remark, please note that not all parameters should be used for each performance nor controller. Let us cite some alternative options: the environment could be created with a limited subset of parameters per controller; each controller could be assigned to a different subset of parameters; different devices could share the control over the same sound affecting different parameters. Some of these ideas have been postulated in John Cage's compositions, such as *Imaginary Landscape No. 4*. We will now present a non-exhaustive list of features which follow the mentioned classification, namely music vs. audio parameters.

2.1 Music

The main parameters which belong to this family should sound reasonably understandable by non-experienced or untrained people. In the following, they are briefly described in a qualitative way.

- Note: It is perhaps the most obvious music parameter. For a given temperament, only a well-defined series of notes (corresponding to a discretization of frequency range) can be produced. In Western music, equal temperament is usually adopted, namely a system of tuning in which every pair of adjacent notes has an identical frequency ratio.
- Octave: In music, an octave is the interval between one musical pitch and another with half or double its frequency. The octave information is directly related to note definition.
- Dynamic: This parameter reflects the volume produced by an instrument (i.e. the softness or loudness of a sound or note) that the player can control through his/her gesture.
- Timbre: This is the quality of a musical note or sound or tone that distinguishes different types of sound production, such as voices or musical instruments.
- Bend: This musical effect is obtained in e.g. string-plucked instruments by bending one of the strings.
- Vibrato: It is a rapid, slight pitch variation in singing or playing some music instruments, such as strings.
- Tremolo: Similar to vibrato, it is a rapid, slight variation in volume. Even if typical of bowed string instruments, this technique can be applied also to mandolin, marimba, classical guitar and many other instruments.

2.2 Audio

In the following we list the most basic audio parameters.

- Pitch: It represents the perceived fundamental frequency of a sound. Instead of applying a temperament to obtain a discrete subdivision of frequency range, we can fix the frequency of the fundamental tone in a linear or logarithmic space.
- Volume: This is the audio counterpart of dynamic.
- Spectral composition: Frequency spectrum is directly related to sound source timbre. In music domain, users usually choose the instrument to reproduce a sound, whereas in audio domain very subtle variations in timbre can be achieved (e.g. setting the number and relative weight of overtones).
- Filtering: A change in the spectral shape could be achieved by adding a filter effect. Some variables of the filter can be controlled, such as the cutoff frequency or the Q factor.[1]
- Modulation: It is the process of varying one or more properties of a periodic waveform, called the carrier signal, with respect to a modulating signal. In music synthesizers, modulation may be used to synthesize waveforms with a desired overtone spectrum. Some common techniques are frequency-modulation and ring-modulation synthesis.
- Panning: If a non-monophonic configuration of speakers is present, sound sources can be located in virtual points. Stereo panning or even more immersive 3D-sound spatialization systems can create interesting and rich audio effects, such as in Acousmonium-based performances [1].

2.3 Rhythm

A few words need to be spent about rhythm. As regards this aspect, the most obvious way to produce a performance is allowing the user to choose when to play a note. In a traditional context, this *note on* event is associated to a gesture of the performer, such as pressing a key or plucking a string. However, in our computer-based approach also another way of interaction is possible. If a set of predetermined rhythms is made available to the user, he/she could switch among them by using an *ad hoc* control. Obviously either the performance needs a global BPM[2] value, or the user should have the capability to choose one.

3. CASE STUDY: A COLLABORATIVE WII REMOTE-BASED MUSIC INSTRUMENT

The main focus of our research activity is creating a collaborative music instrument by connecting a number of Wii Remotes to a computer system via Bluetooth protocol. Since the instruments to design are virtual, we had no constraints about the interface to adopt. Our first attempt was creating a keyboard-like interface, similar to the one of a real instrument. As the action of playing keys on a piano is well-known also to untrained people, this should achieve an intuitive interaction even for this category of users. Our experiments shown that an interface composed by a number of discrete areas (roughly corresponding to the keys of a keyboard) made collaborative performances easier to be achieved. Nevertheless, we did not aim at merely reproducing a real instrument. In this sense, a trivial evolution is represented by the simultaneous presence of multiple keyboards, as illustrated in Figure 1.

[1]The Q factor, namely the quality factor, is a dimensionless parameter that characterizes a resonator's bandwidth relative to its center frequency.

[2]Beats per minute.

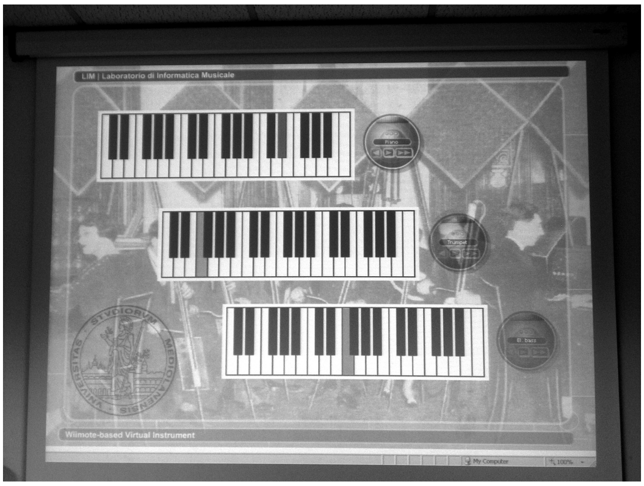

Figure 1: The multi-keyboard interface projected onto a wall. Pressed keys are colored: the main color represents the association with a controller, whereas the brightness is related to key velocity.

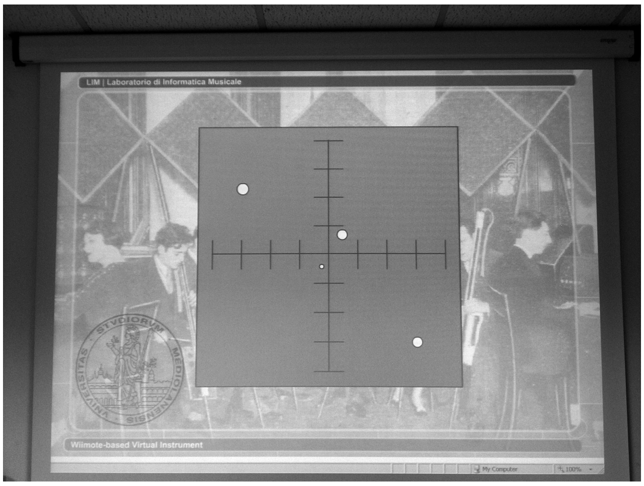

Figure 2: The Theremin-like interface projected onto a wall.

Any 2D interface can be reproduced on a monitor and/or through a fixed wall projection, like we did in the installation discussed later. This device allows us not only to show the interface to be played (e.g. a piano keyboard), but also to graphically represent multiple-Wii Remote pointing. In fact, it is important for the user to understand if and how he/she is interacting with the system, above all in a collaborative environment. Basically, an X-Y grid is projected onto a wall in order to provide a visual feedback for the sound parameters to control. Located at the base of the display area, a set of infrared LEDs permits capturing the Wii Remote position and orientation. Basically, this mechanism is the one implemented in Wii console, where a so-called *sensor bar* is provided. In its original configuration, the sensor bar is about 20 cm long and features ten infrared LEDs, five at each end of the bar itself. This allows the Wii Remote to be used as an accurate pointing device up to 5 m away from the bar.

Music parameters have been mapped over Wii Remote's controls as follows: movements along X axis increase or decrease pitches, motion along Y axis selects the keyboard to be played, and finally the position on Z axis affects key velocity in terms of loudness. Please note that any other choice to map movements over music parameters would be acceptable. Wii Remote presents a 4-button pad and a set of 7 configurable buttons (except Power button). The A button, the most accessible one, is employed to enter rhythm information. Pressing it produces a *note on* event, whereas releasing it produces the corresponding *note off*. The trigger, namely the B button, is configured to produce very short and detached sounds, where the *note on* and *note off* events are almost simultaneous. For some instruments, this kind of articulation implies the use of a different timbre, e.g. staccato for piano and pizzicato for bowed string instruments. In our configuration, pad buttons (which can be pressed by the other hand) implement bending (up/down) and panning (left/right). The remaining buttons could be used to control other music and audio parameters. According to Nintendo specifications, a console can receive up to 4 simultaneous Wii Remote signals via Bluetooth, but a PC-based implementation via Bluetooth lets more users interact and mix their music productions.[3]

Wii Remote supports also basic audio and rumble feedbacks. These features can be employed to create a more immersive experience. For instance, audio could provide all the interacting users with a common metronome information, whereas vibration effects could simulate key stroking. Other advanced features are currently under development, e.g. enriching polyphony by using the controller's built-in loudspeaker; unfortunately, the quite harsh sound coming from the loudspeaker better fits audio effects and indeterminate pitches than well-defined music notes.

The basic scenario consists in a single player handling a Wii Remote inside a multimedia installation, equipped with a computer, a projection system and loudspeakers. When the user moves the controller, its parameters are transmitted to the computer, that maps the pointed position over the X-Y grid and shows a graphical feedback on the wall. For instance, the implementation illustrated in Figure 1 assigns a different color to each controller; when a key is pointed at, the corresponding area becomes colored accordingly. Also the distance of the user from the wall is measured: when the distance increases, the brightness of the colored area decreases. When the system receives the 3D coordinates from a Wii Remote, it computes the corresponding sound to be generated, mixing up timbre, frequency, loudness, and other information. As soon as the user presses the A button, a sound is played. The production of a monophonic melody is performed by moving the remote along the horizontal axis, and different timbres - represented by different keyboards - can be explored by moving the Wii Remote along the vertical axis. The cooperative approach we have implemented allows up to 8 users to generate a mix of independently-generated sounds.

[3]Bluetooth supports 8 devices in Active Mode and 255 devices in Park Mode.

Let us introduce another case study. We have also implemented an interface to let the user control continuous parameters: the previous discrete pitches become generic frequencies, harmonic components in waveforms can be fine-tuned by the user to achieve timbre variations, and so on. An experiment we did was replacing keyboards with unsegmented rectangular regions, so that sound frequency could change in a continuous rather than in a discrete range. This produced an effect similar to various Theremins that are mixed up when the players interact with the system. In this case the position over each active area is accurately acquired, as shown in Figure 2. The mentioned attempt revealed to be promising from an artistic point of view: in this electronic-music experiment also untrained people have been able to interact with music contents. An evolution consists in letting users enter an immersive multimedia installation where no information is provided about the correspondence among their motion and audio parameters. As an extreme consequence, many users could cooperate by influencing different aspects of the same sound.

4. RELATED AND FUTURE WORKS

There are many experiments and scientific works that investigate the application of Wii console to music composition, production and education. For example, [5] lists a number of approaches to the adoption of Wii remote as a virtual music instrument. This aspect of interaction is investigated also in [8], which presents an attempt to make use of Wii Controller to develop an interactive music performance system on PC platform. In this case, analytical techniques are employed to study the motion data captured, and the system recognizes and maps the detected gestures meaningful and interesting to music performance. The relationship between music and gesture recognition, which clearly is one of the most interesting applications of Wii remote, is discussed in [6]. In our opinion, an aspect of novelty of our proposal is the use of Wii remotes to create a collaborative environment where trained as well as untrained users can create a participative performance. In this sense, other works have applied the collaborative paradigm to art production, as illustrated in [4]. Since the release of Nintendo Wii console, new ways to employ Wii Remote have been explored. Many third-party applications are currently in development, thus feeding the shadow world of so-called *Wii homebrew*. Our research belongs to the wide area of gesture-based communication in human-computer interaction. In this field, we are focusing on the design of interfaces to make music production easier and somehow involving also for untrained people. Much work can be done to achieve significant developments of our proposal. First, the scalability of the system should be deeply investigated. In fact, some limitations imposed by Nintendo specifications (e.g. the simultaneous presence of no more than 4 controllers) could be overcome. Wii Remote also features an expansion port at the bottom which allows various functional attachments to be added. The main add-on is *Nunchuk*, an analog joystick provided with two buttons and an accelerometer. The potential usage of such an expansion has not been analyzed yet, but we believe that many interesting features, e.g. independent control for two-hands performances, could be added. Needless to say, many other approaches can be studied and implemented. Wii Remote is a relatively recent tool, and it represents an innovative way to trace user's motion. Born for home-entertainment purposes, it can be employed in a number of educational and professional applications: the future is open.

5. CONCLUSIONS

In this paper we have proposed an approach to interact with virtual instruments through Wii Remote controllers. The key advantages of this approach are the low requirements and the availability of such devices even in home-entertainment environments. In addition to controllers, only an entry-level computer system equipped with a piece of software is required. In our case study, we have employed a C# library that is easily portable to a number of different platforms. Neither music education nor particular skills are required to play the described instruments; nevertheless, musicians or Wii users can experience more accurate performances. The main features of the installation are easiness of use and support for collaborative performances. In fact, Wii Remote guarantees an intuitive way to interact with virtual music instruments. As shown before, collaborative pieces can be performed by using multiple controllers, where players cooperate with their different ability and their peculiar style.

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