Embodied Sound Media Technology for the Enhancement of the Sound Presence

Kenji Suzuki

Dept. of Intelligent Interaction Technologies, University of Tsukuba
305-8573 Tsukuba, Japan
kenji@ieee.org

Abstract. In this paper, the paradigms of Embodied Sound Media (ESM) technology are described with several case studies. The ESM is designed to formalize a musical sound-space based on the conversion of free human movement into sounds. This technology includes the measurement of human motion, processing, acoustic conversion and output. The first idea was to introduce direct and intuitive sound feedbacks within the context of not only embodied interaction between humans and devices but also social interaction among humans. The developed system is a sort of active aid for an embodied performance that allows the users to get feedback for emotional stimuli in terms of sound surrounding the users. The overviews of several devices developed in this scenario and the potential applications to physical fitness, exercise, entertainment, assistive technology and rehabilitation are also addressed.

Keywords: Embodied sound media, wearable device, sound interface, sound conversion, social-musical interaction.

1 Introduction

Sound is a typical and important channel of non-verbal communication that humans often use to express their feelings. In addition to that, sound plays a key role for humans to transmit information to others. It is essentially a mode of expression and a mode of emotion and affection among people. So far the paradigms of the embodied interaction between humans and devices in the framework of *Embodied Sound Media* (ESM) have been exploring [1]. Since humans often accompany music with body motion, a number of studies have reported wearable systems and sensing technologies for a musical performance. Bahn et al. [2] focused on the human body itself in the musical performance, and addressed that musical performance has been inextricably linked to the human body. For increasing the degrees of freedom of musical expression, a number of researchers and musicians have explored new types of musical system that overcomes the physical limitations of musical instruments and the human vocal cords [3], [4], [5]. Various types of sensing techniques have been used to detect human motion, and the measured body movements are mapped to music or sound.

These developed instruments provide the ESM environment where everyone can enjoy it for playing the sounds and also can interact with others through collaborative musical experiences. In the interactive environment, people can communicates with each other by means of sound, music and his/her own body motion.

J.A. Jacko (Ed.): Human-Computer Interaction, Part II, HCII 2009, LNCS 5611, pp. 745–751, 2009.

In this paper, the paradigms of Embodied Sound Media technology are described with several case studies such as (i) an interface for socio-musical interaction, (ii) a wearable device designed to some musical pieces by a simple and intuitive manipulations, and (iii) another wearable device to convert human bioelectrical signals caused by human movement or muscles activity. The ESM is designed to formalize a musical sound-space based on the conversion of free human movement into sounds. Performances in these three applications followed by the discussed concept.

2 MusicGlove

This research aims to develop a wearable musical interface which enables to control audio and video signals by using hand gestures and human body motions. An audio-visual manipulation system has been developed, which realizes tracks control, time-based operations and searching for tracks from massive music library. It aims to build an emotional and affecting musical interaction, and will provide a better method of music listening to people. A sophisticated glove-like device with an acceleration sensor and several strain sensors has been developed. A realtime signal processing and musical control are executed as a result of gesture recognition. A stand-alone device is developed in order to perform as a musical controller and player at the same time. The development of a compact and sophisticated sensor device, and the performance of audio and video signals control are described in this session.

In this case study, a sophisticated interface that enables users to control the sound and music in intuitive and efficient manners is investigated. The glove-like input device is one of the conventional interfaces for human-computer interaction. The developed system, *MusicGlove*, has a role of interactive music player and explorer, which performs tracks control, time-stretching of audio and video signals, and information retrieval from massive music library as a result of hand gestures and body motion recognition [6].

Hardware Configuration. The overview of the developed glove-like sensing device is shown in figure 1. The device consists of one 3-axis acceleration sensor, 4 strain sensors, 1 microprocessor for signal processing and control, Bluetooth wireless module, a portable music player and a battery. The measurement range of the acceleration sensor is from ±10[g]. As the sensor is fixed on external side of the wrist part, X, Y, Z-axis are also fixed at a given position. Four strain sensors are mounted at upside of index finger and mid finger, and also inner and exterior side of wrist. The strain sensors provide analog value of bending of each position. The glove like device has lightweight and is designed to satisfy the minimum requirement for musical control. The arrangement of sensors is determined as a result of preliminary experiments. The microprocessor is used to obtain sensor data, to perform gesture recognition, and then to transmit processed data to the wireless module. The device communicates with the host computer via Bluetooth. The music player can be connected to the microprocessor via dock connector port. In the all-in-one application, the microprocessor generates control signals for the music player.

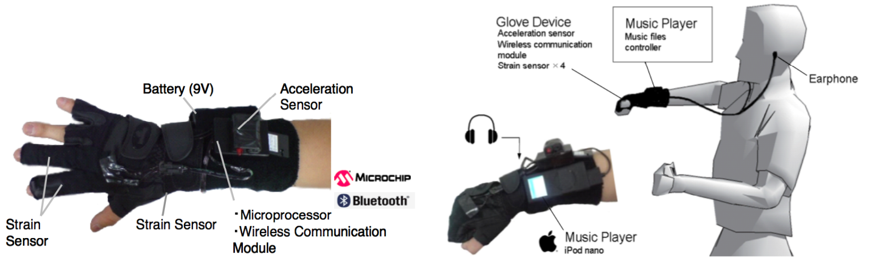


Fig. 1. MusicGlove - a wearable interface for sound/music manipulation. The glove-shape device allows the users to explore music pieces. Human gesture and body motion are measured by the developed wearable device capable to control the tracks, audio and also video signals.

Interaction Style. A portable music player can be attached with the glove device, and the users are able to control music player by his/her gestures. This enables the system to be stand-alone, and users can listen to music via headphone or earphones that are directly connected to the developed device without any other equipments. The embedded microprocessor produces a control signal to the player such as: play or stop tracks, skip to the next or previous music, fast forward and rewind, and volume control by means of acceleration and strain sensors.

The control of tracks is done according to the hand posture, which includes the following functions: play, stop, skip to the next music, back to the previous music, and volume control. This mode is initiated when the user stretches index finger, and the hand is then shaped like pointing to the air. In addition, the user is able to search audio tracks by grasping gesture at the air. In this mode, audio tracks presented to the user in a successive manner. Search for audio tracks is regarded as repetition of trial and error to choose a music (or album) from massive libraries. The system will present the first part of a track in a music library at each step of search successively according to the user's searching motion. The searching motion is regarded as a simple hand motion which is detected based on the accumulated value of the acceleration sensors in all-axes. The user listens to audio data, and acts a grasping motion of playing music when she/he finds a desired track or library. Grasping motion is detected based on the strain sensors. In addition, waving user's hand is regarded as “shuffle search.” The user is able to choose a media library or tracks in a random manner. These manipulations provide users with intuitive search like grasping a music at the air.

3 Beacon: An Interface for Socio-musical Interaction

Beacon is a novel instrument for socio-musical interaction where a number of participants can produce sounds by feet in collaboration with each other. The developed instrument will provide an interactive environment around it. The *beacon* produces laser beams lying on the ground and rotating. Audio sounds are then produced when the beams pass individual performer's foot. As the performers are able to control the pitch and sound length according to the foot location and angles facing the instrument, the performer's body motion and foot behavior can be translated into sound and music in an intuitive manner. A number of line laser modules are installed around the

Fig. 2. Performance with *beacon* - an interface for socio-musical interaction. The battery operated device with cylindrical shape, 75[cm] height and 15 [cm] diameter, performs the sensing the movement of surrounding humans, music processing and audio output.

top of the interface, and the laser beams are produced and rotated around the interface. The beam performs like a moving string because sounds are generated every time the beam lying on the ground passes the performers' feet. A real-time motion capture technique and pattern recognition of users' feet are used in order to create a new style of musical interaction.

Hardware Configuration. The developed instrument consists of a loudspeaker, a small-size computer, 60 line laser modules, 2 laser range finders, dial and buttons interface, and battery. All equipments are installed in a cylinder shaped interface as illustrated in figure 2. This instrument is a kind of small lighthouse sending out line laser beams. The beams are used not only to mark the current location to produce the sound but also to assist musical interaction. In the current implementation, up to 4 laser beams with equiangularly-spaced directions are lying on the ground and rotating during musical performance. The rotation speed of laser beams can be set from 40bpm to 100bpm. At the bottom of the instrument, two laser range-finders are installed and used for the distance measurement to performers, in particular those foot positions and its angles every 100 ms at the height of 1 cm from the ground. The installed range-finder has 4[m] measuring range with 99% range accuracy, and also has a 240 degree angle of view for each. Two range-finders are used in order to obtain omni-directional distance map every time.

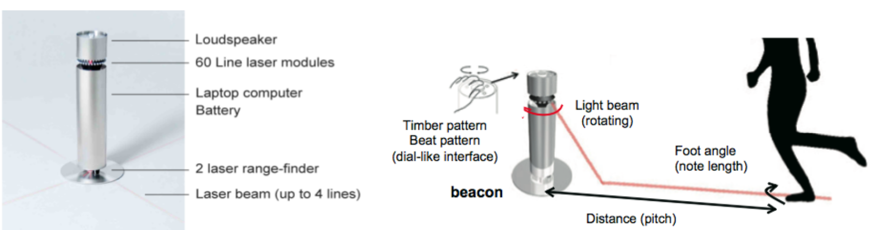


Fig. 3. Performance with *beacon* - an interface for socio-musical interaction. The battery operated device with cylindrical shape, 75[cm] height and 15 [cm] diameter, performs the sensing the movement of surrounding humans, music processing and audio output.

Motion-to-sound Mapping. The performer is regarded as a musical note. *beacon* generates sounds when the beams passed individual performers as if the rotating laser beams could detect them. However, in reality, the performers around by *beacon* are detected at all times by the equipped omini-directional laser range-finder. A number of performers, therefore, can participate in a musical session, and individual performers is able to change the pitch in accordance with the distance from the center of the instrument to the foot. The sound lengths, on the other hand, are determined based on the foot angles. When the performer points his/her toes toward the *beacon*, shorter sounds are produced. The performer put the entire length of the foot facing beacon, longer sounds are played. The attack and decay of each note are predetermined, and the sound volume is fixed in this work. The timbre, tone colors and major/minor keys can be selected, even during the performance, by using buttons and a dial interface that are equipped at the top of instrument.

The relationship between the facing angle to the instrument and measured angular area with different distances is also investigated. The measured data are collected with facing foot angles every 22.5 [deg]. A clear difference can be seen according to the facing angles of foot at the distance of 500-1000 [mm]. However, there are small differences over the distance of 1500 [mm]. Based on this result, the foot angles are used for control of sound length within the area less then 1500 [mm] radius from the instrument.

Here a novel interface *beacon* for socio-musical interaction is introduced. This instrument allows performers not only to communicate with each other via music and motion, but also to improve the quality of sound production by training and devising various types of behavior. This novel instrument thus can be used for the physical exercise or recreation with fun. Moreover, by arranging small objects around the instrument, a variety of sound will be produced like an environmental music box. Sounds are generated when the laser beam passes the objects as well as human performers. This installation provides a new artistic expression for spatial designers. This round-shape interface does not have any directional characteristics and plays a key role of gathering people for affective communication.

4 BioTones

In order to convert directly human movement to sound, a wearable device to generate sounds based on bioelectrical signals, especially surface electromyogram(EMG) is developed. In the proposed method, salient features of EMG signal are mapped into sound features by a wearable device that is capable to obtain the EMG signal and also to create audio signal. This device allows people to get auditory feedback from muscle tension while preserving the property of original signal. The proposed approach is suitable for several applications such as biofeedback treatment, sport training, and entertainment. In particular, an application to biofeedback treatment for migraine headache and tension headache is considered.

The electromyogram monitor is used to monitor human's neuromuscular function as visualization of muscular activities. The monitor is widely used for not only the medical purpose but also the analysis of muscular activities in exercise and sports science. However, there are several critical problems in terms of visual feedback i) people are forced to stay in front of the monitor, and ii) showing multiple EMG

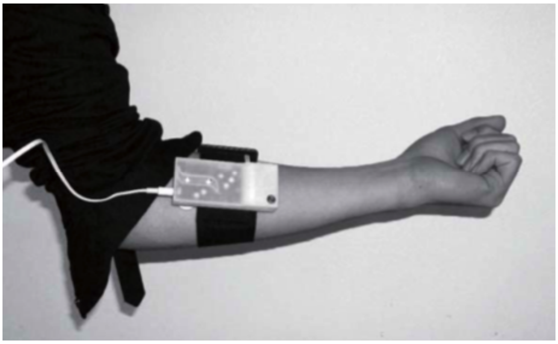


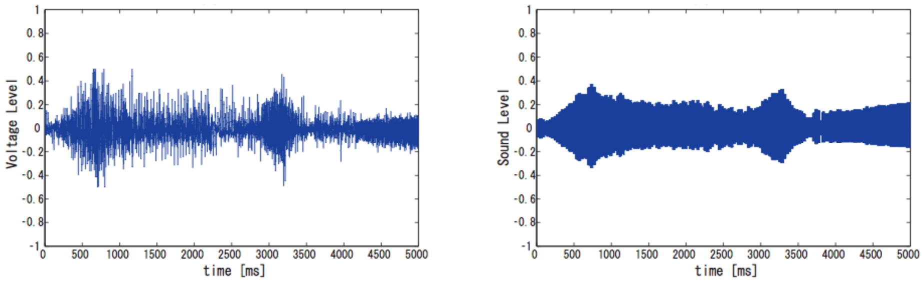
Fig. 4. BioTones: a wearable device to convert his/her bioelectrical signals based on electromyogram signals into audio sounds. The device is capable to extract the signals and also to generate audio sounds. The users simply can listen to sound by using normal headphones.

signals by using the traditional monitors due to the complexity of the signal features although the principle feature is the activity level. On the other hand, the auditory feedback is also effective to show the change and characteristics of bioelectrical signals caused by the muscular activity. Sound has three basic characteristics: loudness, pitch, and timbre. Not only the control of loudness and pitch but also the timbre control is capable to represent a variety of muscular activity.

Hardware Configuration. The *bioTones* consists of a pair of disposable electrodes, bioelectric amplifier, microprocessor, digital signal processor, and audio amplifier. This enables to extract bioelectrical signals and also generate audio signals. The user is able to listen to sounds simply through the normal headphone system. The developed prototype is designed to measure the bioelectrical signals on the surface of the flexor carpi radialis muscle. This is a muscle of the human forearm that is used to flex and abduct the hand. The device is fixed to the forearm with a tightened belt.

Motion-to-sound Mapping. There are several mapping rules in accordance with the target application. There are two features of bioelectrical signals: level and frequency characteristics as well as sound features. Direct mapping is regarded as the direct correspondence between bioelectrical and audio signals in terms of the level and frequency. On the other hand, cross mapping is regarded as alternation of the level and frequency characteristics between bioelectrical and audio signals. This device does not aim to extract salient features of bioelectrical signals but to preserve the original features as much as possible. The purpose of these mapping is to represent a variety of the muscular activity by a variety of sound features.

This is a novel method of sonification that is an alternative to visualization technique. It should be noted that the temporal and pressure resolution is higher than the visual perception due to the characteristics of auditory perception. The wearable device benefits a wide range of users because people can get auditory feedback solely by wearing it and listing to sound at any time and place, even in transit or on the walking.



(a) (b)

Fig. 5. Examples of bioelectrical and audio signals: (a) is an example of bioelectrical signal, and (b) is the converted audio signal. The signal conversion is performed by two types of mappings: direct mapping and cross mapping.

5 Conclusions

In this paper, the paradigms of *Embodied Sound Media* (ESM) technology are described with several case studies. This media technology is designed to formalize a musical sound-space based on the conversion of free human movement into sounds. Three case studies, (i) MusicGlove, (ii) beacon and (iii) bioTones, have different perspectives of ESM, and all devices are designed to provide direct and intuitive sound feedbacks within the context of not only embodied interaction between humans and devices but also social interaction among humans. The developed system is a sort of active aid for an embodied performance that allows the users to get feedback for emotional stimuli in terms of sound surrounding the users. The potential applications include physical fitness, exercise, edutainment (education and entertainment), assistive technology and rehabilitation.

Acknowledgments. This work is supported in part by CREST project "Generation and Control Technology of Human-entrained embodied Media" of the Japan Science and Technology Agency (JST), and the Global COE Program on "Cybernics: fusion of human, machine, and information systems," MEXT, Japan.

References

1. Suzuki, K., Hashimoto, S.: Robotic Interface for Embodied Interaction via Dance And Musical Performance. Proceedings of the IEEE 92(4), 656–671 (2004)
2. Bahn, C., Hahn, T., Trueman, D.: Physicality and feedback: A focus on the body in the performance of electronic music. In: International Computer Music Conference, pp. 44–51 (2001)
3. Wanderley, M., Baffier, M.: Trends in Gestural Control of Music. IRCAM, Paris (2000)
4. Camurri, A., et al.: EyesWeb - toward gesture and affect recognition in dance/music interactive systems. Computer Music J. 24(1), 57–69 (2000)
5. Paradiso, J.: The Brain Opera Technology: New instruments and gestural sensors for musical interaction and performance. J. New Music Research 28(2), 130–149 (1999)
6. Hayafuchi, K., Suzuki, K.: MusicGlove: A Wearable Musical Controller for Massive Media Library. In: 8th International Conference on New Interfaces for Musical Expression, Genoa, Italy (2008)