Sensing GamePad: Electrostatic Potential Sensing for Enhancing Entertainment Oriented Interactions

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ABSTRACT

This paper introduces a novel way to enhance input devices to sense a user's foot motion. By measuring the electrostatic potential of a user, this device can sense the user's footsteps and jumps without requiring any external sensors such as a floor mat or sensors embedded in shoes. We apply this sensing principle to the gamepad to explore a new class of game interactions that combine the player's physical motion with gamepad manipulations. We also discuss other possible input devices that can be enhanced by the proposed sensing architecture such as a portable music player that can sense foot motion through the headphone and musical instruments that can be affected by the players' motion.

Keywords

input devices, game input devices, physical interaction, electrostatic sensing

INTRODUCTION

While the most widely used input device for computer games is the gamepad, several sensor-oriented input devices have been proposed in recent years. VIDEOPLACE is a pioneering work on using full-body motion captured by a camera as an input [2]. Recently, Sony Computer Entertainment also introduced the "EyeToy" [3] camera device for the PlayStation game-console, and provided various gesture-based game titles. Other sensor-based game examples include a foot-mat containing pressure sensors for detecting foot motions and hand-held devices that emit (or reflect) infrared light for position detection.

Experience with these sensor-enhanced games is more direct and involves larger body-motion than that with traditional gamepads, where only small finger movement is enough. This feature makes game interaction more exciting and engaging. It also has the potential to provide entertaining features to rehabilitate people with physical disabilities.

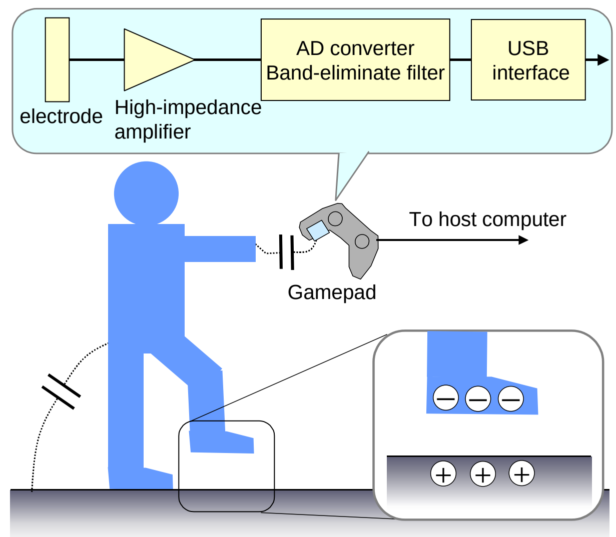

Figure 1: Principle of the proposed sensing architecture. The electrostatic charge caused by human body motion is sensed by the input device held by the user.

On the other hand, these sensor-orientated input devices are more cumbersome to setup than gamepads and are sensitive to external noise, for example from differences in lighting conditions.

This paper introduces a new input device called the "Sensing GamePad" that senses a game player's physical motion by measuring the human body's electrostatic potential. Since all the sensing elements can be embedded within the same form of a usual gamepad and no other external devices are required, this input device retains the simplicity and ease of

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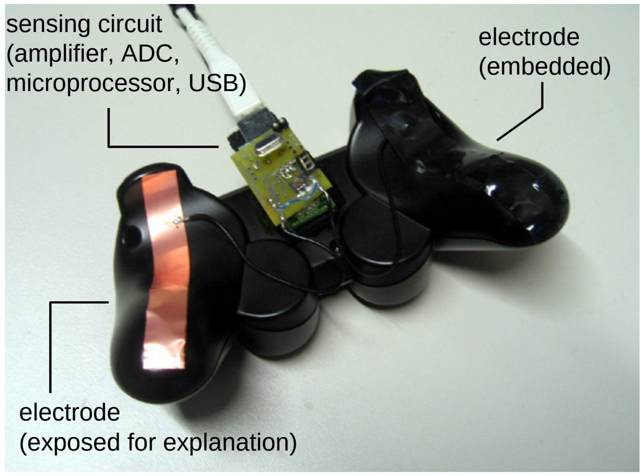

Figure 2: SensingGamepad: two electrodes are attached to a PlayStation gamepad to measure the player's electricity potential caused by foot motion.

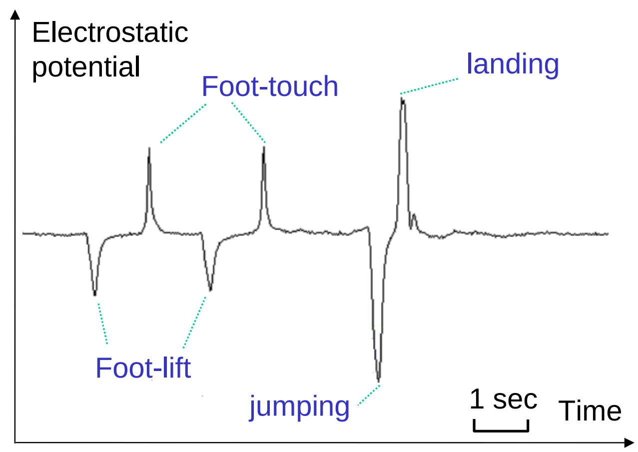

Figure 3: Electrostatic potential of the human body measured by a gamepad with embedded electrodes.

use of the normal gamepad while opening the way to a new class of game interactions involving human body motion in addition to gamepad manipulations.

SENSOR PRINCIPLE AND HARDWARE DESIGN

When a human walks, steps, or jumps, static electricity is produced as a result of these actions, and electric potential is charged within the human body [5]. This static potential change vanishes within several milliseconds because the human body is capacitively coupled to the ground through the air or shoe soles.

A high-impedance voltage amplifier that is capacitively coupled to the human body can sense this change in static electricity potential. For example, a gamepad with an embedded electrode can be used for sensing the player body's static electricity potential (Figure 1).

Note that this static electricity change arises when the foot makes or breaks contact with the ground (floor). These effects are known as contact (separation) electricity charge. The charged potential is significantly bigger than the frictional electricity charge caused by friction between the body and its clothing. It is also possible to distinguish a foot making and breaking contact: a negative charge occurs when the foot contacts the ground, while a positive charge is generated when the foot detaches from the ground.

SENSING GAMEPAD

As a first prototype interaction device, we applied this sensing principle to the videogame gamepad. Two electrodes were embedded in a PlayStation gamepad (Figure 2) and a high-impedance voltage amplifier was connected to these electrodes. The body electricity potential change was measured by a microprocessor with an analog-digital converter (ADC). The results were transmitted to the host computer via a USB serial interface.

Unlike biopotential electrodes used for biomedical sensing, direct contact between the electrode and the human body is not necessary. The electrode is also charged and thus can be measured when there is enough capacitive coupling between the human body and the electrode. Therefore an electrode embedded under the surface of the gamepad shell can be used for this purpose, and no special setting, such as applying conductive paste, is necessary. We chose to embed the electrodes in the left and right grip areas of the gamepad because the player's hands make steady contact there during a game.

The measured potential value contains noise that is mainly caused by nearby power lines or electrical devices. To eliminate this noise, the microprocessor samples voltages every 10 ms (i.e., 100-Hz sampling) and takes the average of two consecutive values. This simple software solution acts as a very accurate band-elimination filter for 50 Hz, which is the frequency of the power lines in Japan.

Figure 3 shows the measurement results. This graph shows that the player's foot motion was clearly obtained.

Foot Motion Detection and Basic Interactions

Since the Sensing GamePad's physical form is nearly compatible with normal ones, a player can use it without changing game interaction style.

In addition, this game pad also senses the player's foot motion. Currently, we use the following steps to detect foot motion events, such as walking, jumping, and stepping. We are also examining further signal processing to recognize more subtle foot motions.

- Determine the neutral electrostatic potential level. The moving average method is used for this calculation while

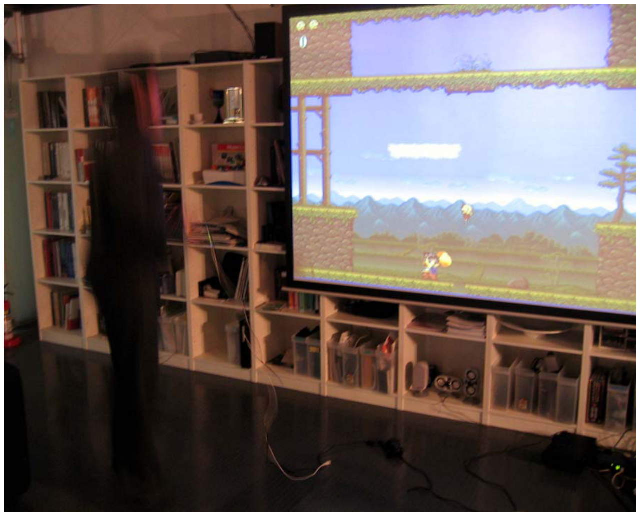

Figure 4: A player is using foot motion to interact with the video game.

a user is standing and holding a gamepad. The obtained value is called the ”neutral level”.

- When the player’s body is positively charged and the difference between the neutral level and the measured electrostatic potential level exceeds the predefined threshold, it is recognized as a ”foot lift” event.
- Conversely, when a negative charge occurs and its level exceeds the threshold, it is recognized as a ”foot touch” event.
- When the player jumps, both feet detach from the floor at the same time, and resulting positive charge is greater than in the case of a single foot. Thus, we can recognize ”jumping” and ”landing” events.
- Walking footsteps are recognized as a repeated sequence of ”foot lift” and ”foot touch” events. Walking speed can be estimated from the interval between these events.

Using these foot motion events, new game interactions can be designed. For example, the following operations can be implemented.

- Virtual-space walkthrough with physical motion: Players can walk about the virtual space using a physical foot stepping motion. They can also avoid obstacles in a virtual space by jumping over them. In addition, when this sensor is installed in portable game devices, players can be walk about the virtual space by actually walking the real world. Walking direction can be controlled by a gamepad, or a combination with the digital compass sensor can be used.
- Modifying (emphasizing) game pad operations: For example, during a fighting game, a button press with simultaneous foot ”kick” would double the impact on the opponent. Similarly, gamepad manipulation while jumping (i.e., between the ”jumping” and ”landing” events) would be treated as a special command.
- Virtual athlete. Players should physical move their feet to run the virtual gymnasium track. The speed of running would be controlled by the interval of footsteps. They might have to jump over hurdles by physical jumping.

Video Game Examples

Figure 4 shows a snapshot of video games we developed for the Sensing GamePad. In this game, adding to manipulating the gamepad, a player should physically walk or jump to move around the game space and to avoid obstacles. Other example we have built include a 3D virtual space application where players should use footsteps to walk around the 3D space and find and shoot the enemy, and an athletics game where players take part in a virtual athletic contest such as a sprint or hurdle race.

Although a formal user study has not been conducted, our initial experience has been very positive. People could easily understand the concept of using their feet for interaction and highly engaged in the game interaction involving body motions.

OTHER INPUT DEVICE POSSIBILITIES

Besides gamepads, electrostatic potential sensing can be applied to virtually any types of input devices that contact the human body.

Portable Music Players

We are planning to enhance the portable music player by sensing electrostatic potential. The headphone is an appropriate position to install electrodes because it is in steady contact with the human body. This sensor configuration would enhance the common combination of jogging and music listening by a portable music player. For example, when the listener with this portable player is jogging, the tempo of the played music would be adapted to the footstep pitch. Joggers might also be able to plan a desired running speed, and while they are jogging, the music player would check it and provide feedback by altering the music being played (e.g., changing music tempo).

Musical Instruments

Another possibility is to enhance musical instruments, such as the electric guitar. Its sound can usually be affected by effectors and a player often uses pedals as controllers.

The electrostatic sensing can be used as a ”virtual pedal”, making a real pedal unnecessary: the player can use his/her feet to affect the sound. In this case, the player’s electrostatic potential is sensed through the body of the guitar.

Using this sensor itself as a new musical instrument is another possibility. For example, a tap dancer might be able to create a musical sound or affect the illumination by foot motion.

Sports Equipment

Another idea is to enhance real sports by installing the sensor in sports equipment. For example, if the sensor is installed in a tennis racket, the player's footstep could generate sound effects. Similarly, a training tool for walking exercises would be able to sense the user's footstep, and give advice.

COMBINATION WITH OTHER SENSORS

Our sensor configuration does not exclude the possibility of additional sensors. For instance, a magnetoelectrometer (i.e., a digital compass) could be added to detect the gamepad's absolute direction. This combination is useful for virtual space walkthrough applications. The user can physically walk in order move forward in a virtual space and can change direction by rotating the gamepad.

Combination with camera input devices is another possibility. In general, camera input is more suitable for recognizing hand motion than footsteps, so the camera and the electropotential sensor could supplement each other.

Other possible sensor combinations include various types of biomedical sensors [7]. For instance, when a user touches a pair of electrodes with both hands, his heartbeat could be recognized by measuring the dipole field of the human body. It might be possible to measure physical footsteps and heartbeats with a single gamepad. Using this combination, game scenarios should be able to identify the player's tiredness. We are also investigating the possibility of integrating a skin resistance sensor (galvanic skin reflex (GSR)) to measure the user's emotional state.

RELATED WORK

Morris and Paradiso designed sensor-embedded shoes to enhance performance [6]. Sensors such as acceleration sensors are embedded in a shoe, and a wireless transmitter and a micro-controller, which are also installed in the shoe, are used to transmit sensor data to a host machine. Our motivation is similar, but the sensor architecture we propose does not require attaching sensors to the shoes, so preparation for interaction is quicker. Instead of putting on special shoes, the player simply picks up the gamepad.

The "Mouthesizer" is a system that uses a head-worn camera to alter the performance of a musical instrument such as an electric guitar [4]. PingPongPlus is a sensor augmented ping-pong table that enhances a physical ping-pong game by projecting images and sounds [1]. The electrostatic potential sensor described in this paper can also be used for similar purposes to these systems, and it has the potential to integrate all sensor elements into a single object (such as an electric guitar or ping-pong bat), instead of using external sensors.

To detect foot motion, embedding an acceleration sensor in the gamepad itself could be an alternative solution. One drawback of this approach is the possibility of cheating; a player might learn how to deceive the sensor by shaking it to generate a motion that is similar to walking, instead of actually jumping or stepping. Our proposed sensor is not affected by the motion of the gamepad itself, and can correctly sense only when the player's feet actually move. Needless to say, the combination of these two is also possible, and this would create new interactions, such as "shaking the gamepad during jumping" or "stepping fast but holding a gamepad without movement".

CONCLUSION

In this paper we introduced a novel input device that senses human's body motion by measuring the electrostatic potential of the human body, and described the Sensing GamePad as an application of it to a game input device. The interesting feature of this device is that although the system is sensing foot motions, the user only needs to hold a normal gamepad. This feature makes it possible to integrate traditional game interaction with a player's physical motion. We also proposed other input device possibilities such as a portable music player, musical instruments, and sporting goods. We believe the use of electrostatic potential sensing opens up a new class of entertainment interactions and will make games and other applications more engaging and enjoyable.

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