ACADEMICAL AND RESEARCH WIIMOTE APPLICATIONS

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ABSTRACT

This paper proposes the employment of the Wii Remote controller, better known as Wiimote, as an useful tool for educators and researchers. The quick development on fields such as Wireless Sensors and Actuators Networks or Hybrid Systems, and their applications, requires engineers with a solid knowledge in these areas. To achieve this goal the Wiimote becomes a great alternative to other options due to its great variety of analog and digital components, for a very low price, and the good documentation about it existing in Internet. As will be seen in this paper, the possible academical and research uses of the Wiimote are almost endless and cover many interesting problems in control engineering.

KEYWORDS

Wireless Sensor and Actuators Networks, Hybrid Systems, Wiimote.

1. INTRODUCTION

1.1 Problem Motivation

Nowadays, it is complicated to venture what wireless technology will prevail in the future. There are many candidates and some of them are complementary. However, what seems sure is that this new technological philosophy, which is based on tiny wireless transceivers, will play a very important. Probably, we will assist to the proliferation of mass market devices that some years ago would have been unthinkable. This is the case of the Wiimote, the remote controller of the successful Nintendo's videogame system Wii, that could be considered as a scouting party of the new applications that all these technologies will bring.

The Wiimote is a wireless device that uses Bluetooth as communication protocol. Due to this, it is possible to send and receive data to the remote controller from any PC provided with just a simple Bluetooth adapter. The Wiimote will identify itself under the HID profile (Human Interface Device) which is commonly employed by many USB or Bluetooth peripherals (*Wiili, 2007*).

But what makes Wiimote a special device is the peculiar way of Human-Machine Interaction it offers. Actually, the controller has a great variety of input sensors that allow all these new control possibilities: three accelerometers to measure forces in x, y and z axes, a small camera that detects infrared sources and the typical analog and digital buttons of a gamepad. The controller also provides some elements to give some feedback to the user: a little loudspeaker, an engine for rumbling and 4 LEDs. Finally, we cannot forget its 16KB of internal EEPROM memory and its expansion port, that enables to add new functionalities by means of different add-on's. Maybe the most spectacular one is the known as Nunchuk, a device for the left hand with an extra 3 accelerometer set, an analog stick and two extra buttons, so that games can register player actions with both hands. This technological arsenal can be acquired for a very low price, less than forty dollars, due to its mass market production (*Nintendo, 2007*).

Another interesting point is the growing popularity of Nintendo Wii. It has been estimated that more than ten million of Wiis have been sold worldwide during its first year of life (*Nintendo Revolution, 2007*). Nintendo's marketing strategy has expanded the market so that many of the new players are people who have never been interested in videogames before, people almost "afraid" of technology in some cases. Another side effect is the great support that the Wiimote is receiving from Internet communities. Information, drivers, applications and other resources can be easily found in Internet (*Kenner, 2007*)(*Peek, 2007*).

1.2 Main Contribution

The key contribution of this paper is the introduction an alternative for educators and researchers when studying disciplines such as Wireless Sensor and Actuator Networks, Hybrid Systems,etc. The applications of the Wiimote to these and other fields show its versatility and lighten the path for future developments in these areas. In this paper we will first analyze the Wiimote and then examples and developments of all the possible applications are surveyed in this paper.

2. WIIMOTE ANALYSIS

2.1 Wiimote's Communications

As we explained on the Introduction, Wiimote's Communications are based on Bluetooth architecture. If we want to start communications between Wiimote and a host, we must push SYNC button, place at the rear of Wiimote. Then, the blue lights, on the frontal side, start blinking and the Bluetooth SDP (Service Discovery Protocol) begins. At that moment, Wiimote and the host swap a great amount of information that identifies Wiimote from other Bluetooth devices, such as its Vendor and Product ID.

Bluetooh's adaptation layer allows the use of upper level protocols belonging to other technologies. In this case, HID (Human Interface Device) protocol (*Ranta, 2003*) is placed on top of adaptation layer. HID is an original USB protocol designed to keyboards, mouse and game controllers. Wiimote used this one to exchange its information. It defines protocols, methods and characteristics.

Reports are the main issue of HID protocol. Basically, it is a data packet of a given fixed payload and a number ID that identifies a particular service, in our case, some Wiimote's part like A-button. As reports are unidirectional, Output and Input reports are defined.

2.2 Wiimote's Brain

Broadcom BCM2042 System-on-a-chip is the real Wiimote's Brain. It deals with Wiimote's communication, since it integrates the Bluetooth protocol stack with data processing in a low cost system. In order to carry out these two functions it use On-board 8051 processor and RAM/ROM memory.

2.3 Motion Analysis

A three accelerometer set provides the motion recognition. Before the data exchange, the first important thing to do is the calibration procedure. As a simplification, we will assume a linear motion response of the Wiimote. We considered the following three positions to calibrate the Wiimote controller:

- (x_1, y_1, z_1): Wiimote placed horizontally on a flat surface. The B trigger is in touch with the surface and A button, D-pad and the rest of buttons are upwards.
- (x_2, y_2, z_2): Vertically on a flat surface, with the infrared sensor in touch of the surface and the expansion port upwards.
- (x_3, y_3, z_3): Horizontally on a flat surface, with the right side of the Wiimote in touch of it.

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Figure 1. Wiimote Motion Variables

As accelerometers register the force of gravity in every Cartesian axe, the previous values correspond to three orthonormal acceleration vectors in $\mathbf{R}^3$. It is desirable to work with an orthonormal base, g, so we look for a vector base on which on each axe, two of its three components should be zero. In this way, we find the following correspondence between the null data (of the desired base) and the data taken from the Wiimote before:

$$x_0 = \frac{x_1 + x_2}{2} \qquad y_0 = \frac{y_1 + y_3}{2} \qquad z_0 = \frac{z_2 + z_3}{2}$$

So, let $\vec{r} = \{x, y, z\}$ be the raw data vector we receive, and $\vec{r_0} = \{x_0, y_0, z_0\}$ the data vector that would correspond to a null force in two of the three axis. In order to obtain a normalized base, $\vec{\Delta r} = \vec{r} - \vec{r}_0$, the following scale factors are needed:

$$k_x = \frac{1}{x_3 - x_0} \qquad k_y = \frac{1}{y_2 - y_0} \qquad k_z = \frac{1}{z_1 - z_0}$$

Once the scale factor is applied to the corresponding axis, we should obtain $\vec{k}$, $\vec{j}$ and $\vec{i}$ as normalized acceleration vectors in the calibration positions defined before. In this case, an unit value corresponds to a *g* force made on this direction.

2.4 Pointer Analysis

The Wiimote controller has an infrared camera in its top, so that it can be use to point at the screen. The IR sensor is used in junction with two IR beacons, placed on a device called Sensor Bar.

These two IR beacons are tracked by Wiimote's IR camera. The sensor also includes a PixArt System-on-a-Chip to procces the images and it sends minimum information needed for tracking.

Wiimote can detect and transfer up to four dots to the host. By tracking the two points in the sensors field of view, the system transfers various amount of data, including position coordinates of every dot, size and pixel value. This data can be retrieved by using different modes, extended or full for example. The mode refers to the way data is interleaved on the reports.

2.5 Feedback Features

Wiimote incorporates different periferals that feed off effects to the player, so that improve the interaction. These are LEDs, Rumble and a Speaker.

In first term, we can see 4 blue LEDs in the upper side of Wiimote. This feature is mainly used to quickly know which number of player is selected. On the other hand, LEDs deals with another functions, for example, the number of blinking LEDs is releated to the battery level. It's important to remark that LEDs can be fully controlled, it can show different patterns, brigthness can be managed,…

Wiimote also adds rumble features, implemented by a small engine that adds the controller the ability to vibrate. Besides, we can find a small low quality speaker, used for short sound effects during gameplay.

3. WIIMOTE APPLICATIONS

In the previous section, we've dealt with the reverse engineering related to Wiimote. In this one, this information will be employed to pose different Wiimote applications. The key contribution of this paper is showing the employment of this high technological capability, which involves the game controller that can be found in the present literature. This survey is structured by posing several application fields, on which we will introduce some developed,while the others are a present research or new ideas.

3.1 Entertainment for Everyone

The Remote is the main controller of Nintendo's Wii console, so natural application arises in the context of entertainment. Using its capabilities we are able to bring computer games to a more heterogeneous marketplace. In the context of Wiimedia project (*Shirai, 2007*), authors propose a few gaming applications, employing a different control system over Wiimote. These gaming applications are a racing game, a drawing entertainment software called Papier Poupee Painter and even in a sword play.

Wiimote motion-sensing is used by Justin R. Belcher to propose an interactive percussion (*Belcher, 2007*), that can replicate the feel of drumming. It has been mainly aplied in the musical academical field, since it deals with the very first approach to percussive world.

Wiimote can also bring handicapped people the possibility of playing. In this way, several authors have developed different applications. As stated by (*Gonzalez, 2007*), videogames are able to address the development of the skills, for example of children with communication problems. Designing new ways of human-computer interaction is an effective way of dealing with the improvement of social relationships: learning by playing. These researchers are also in the development of some didactic videogames based on associations of letters, words and sentences to concepts. Wiimote is used as an input that also improves user's motion skills.

Another paradigmatic example is AudiOdyssey (*Glinert, 2007*), a prototype video game for sighted and non-sighted players which, thanks to a rhythm based game and fully accessible menus, offers a common gaming experience, despite of different level of vision. The Wiimote is the main input, as a more natural and intuitive user interface.

Galego *et al.* (*Galego, 2007*) are in the development of another virtual reality game based on Wiimote and multiplayer online game Second Life for rehabilitation. One of the games is Memory-matching game. Authors think that Wiimote's employment allows pathients to develop both motor and cognitive skills.

New ideas will come by common used of different sound, video features and Wiimote. For example, authors are in the research of a guitar game for blind people. The idea is that users listen a melody to play, and next, by using motion-detection, movements are translated into notes and chords.

3.2 Home Automation

Home automation brings new technologies home that turn our lives easier by using devices controlling, security, connection between heterogeneous nets, etc. In a very near future this technology will be integrated in our daily lives.Wiimote could be the an ideal interface device between users and home automation system. In this framework, we have taken into practice the idea and for have developed a prototype application on which Wiimote directly controls the blinds and lights of a room, only by simple movements and buttons.

3.3 Robotics Control

The interface system with a robot system should be as intuitive and effective as possible. In this context, B. Peek (*Peek, 2007*) has developed an aplication on which he emploies the Wiimote to control a radio-control car by using an intermediate relays card that acts into the RF controller. In (*Song, 2007*), it can be found authors' research about Human Robot Interaction (HRI). This work shows the development of an HRI device that groups a force sensing hardware and the Wiimote. Therefore, a robot can be controlled using the former as a joystick.

In a similar context, Wiimote has been applied in Virtual or Augmented Reality, as an intuitive human-computer interface which can be directly applied to robotics control. Specifically, HYUI (*Geiger, 2008*) is a visual framework for hybrid user interfaces, developed to be used in an academical context as a testbed for designing user intefaces in virtual reality.

WiiRemote is also the navigation controller in a virtual reality theatre (*Schou, 2007*). In this case, Wiimote's IR sensor is the main feature used. To improve the control and avoid some problems, these authors have developed an application that uses five sensor bars. This is a good example of how IR sensor can be applied in location systems. Virtual pointing methods using the Remote can be found in (*Looser, 2007*), as well as a propossed interaction device for aircraft inspection training environments in (*Sadasivan, 2007*) that can provide enhanced orientation and position information compared with the analyzed devices in this study. Wiimote has been also used in Gesture Recognition in (*Schlomer, 2008*)(*Sreedharan, 2007*), because of its motion-recognition capabilities, and in people tracking (*Ikeda, 2007*) combined with a vision sensor.

In a previous work (*Maestre, 2007*), we have propossed the employment of the Wiimote's motion-detection capability to control the Scorbot ER Vplus, a jointed manipulator with 5 joints and a grip. The proposed control is based on the 3 acelerometers in order to map Wiimote's movements to movements in the 3 dimensional Scorbot's working space. Operator only has to take Wiimote in his hand, move it to the desire position and these movements will be translated into robot's movements.

3.4 Sound Feedback

In this paper, we have remarked that Wiimote offers a lot of interesting feedback features. One of these is the speaker, that adds sound capability to the Wiimote. In our related research, we have found out the problem that Wiimote's speaker is the least known element of Wiimote. In a present time, enthusiasts (*Wiili, 2007*) are dealing with this issue, trying to reverse engineering the wiimote, and they have discovered that sound data is codified in 8bits PCM and also, it 's posible to use a 4bits ADPCM format.

3.5 IR Tracking

Besides the refered work in (*Schou, 2007*), some other interesting possibilities emerge from the use of the Wiimote as an IR camera. Its 1024x768 100Hz embeded IR camera tracks IR sources so that it is possible to find out where the Wiimote is pointing with the aid of two IR beacons. This idea can be used to follow the path that Wiimote is following, and was employed as an alternative Scorbot control in (*Vicaria, 2007*).

It is also possible to use the Wiimote as a fixed camera that tracks the movement of moving IR emitters as the one show by J.C.Lee (Lee 2007). Such an interesting idea could be used in different applications for handicapped people, for example computer control.

4. CONCLUSION

Wiimote's affordable price and great possibilities make it an excellent choice as an HMI device for new projects.We consider that Wiimote has an interesting academical value and many of the ideas are suitable for degree projects (*Vicaria, 2007*) or in ordinary subject practice (*Ortigosa, 2008*). It seems clear that in a very near future, it will be important to develop interface devices that improve human computer interaction, even if we consider the great development in the former. In this paper we've shown a device that is able to light this aspect on, standing on a new concept of interaction.

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