

iiBOARD

Development of a Low-Cost Interactive Whiteboard using the Wiimote Controller

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Abstract: Interactive whiteboards are gaining importance in our society, both at a business level and, especially, at an educational level. However, the products offered by the major manufacturers have a major barrier to their acquisition: very high prices. There is an urgent need to use new technologies in order to provide solutions that present the same performance levels than typical interactive whiteboards, but with a significantly reduced cost. Throughout this paper the steps taken for the development of an innovative low-cost interactive whiteboard are described. The proposed system is based on the Wii Remote command of the Nintendo Wii video-game console. This command, although very inexpensive has an infrared camera, and supports Bluetooth communication. The system control is based on a wireless device, based on infrared emitters, which supports most of the mouse events. A complete whiteboard application was also developed using Borland Delphi for Windows. This application may be used with either one or two Wiimotes and has a very simple and efficient calibration method. The application also includes viewing capabilities of some of the Wiimote characteristics, as well as a flexible Notebook to increase its range of possible uses. The results obtained through a survey conducted to a small set of whiteboard users were very positive indicators about the acceptance of the inexpensive solution proposed.

1 INTRODUCTION

The work described in this paper refers to the design and implementation of an interactive whiteboard. This type of equipment has gained increasing importance in our society in the last few years. From the business world to personal uses, through the education system, the interactive whiteboards are gaining a growing market in recent years. Today, many solutions already exist in what concerns interactive whiteboards. However, they still have very high prices, corresponding to a large investment that not everyone is willing to do. There

is an urgent need to find a solution that at least maintains the same performance levels currently proposed by commercial applications but making them accessible by a more reasonable price.

Recently, some applications have emerged, that can offer a relatively similar effect to that offered by traditional interactive whiteboards, but are based on devices with a much more moderate cost. One of these applications is an interactive whiteboard based on a pen with an infrared emitter used together with the Wii Remote, command of the Nintendo Wii console developed by Johnny Chung Lee (Johnny Lee, 2008). The application has been widely

disseminated on the Internet. However it still has some major limitations, because it only emulates the movement of the mouse together with the corresponding action of the left click. However, behind this application is a very interesting idea, which may result in a well crafted application that allows emulate the events of the mouse almost entirely, and also contain some features offered by the software usually provided in the purchase of a more traditional interactive whiteboard, as a notebook application, virtual keyboard, etc.

The objective of this work is to study the operation of interactive whiteboards in general and the Wii Remote controller and to design and implement an interactive whiteboard based on the use of that device together with infrared emitters.

This section is a brief introduction to the work done, and the remaining sections of this paper are described below. In section 2 a short overview about what is currently offered in the interactive whiteboards market is presented. Emphasis is given to the technologies used and the prices of the final product. Section 3 presents the Wiimote and its characteristics as well as the protocol used for sending and receiving information, especially regarding the infrared camera. Section 4 states the decisions taken in the draft of the control device for the interactive whiteboard developed and illustrates its final appearance. Section 5 deals with the design and implementation of the computer application developed. The calibration method and features of the application are explained. The same section presents the results obtained in a precision test and accuracy of the calibration model. Finally some results are analyzed by a statistical study carried out from a survey having in mind examining the acceptance of the interactive whiteboard developed. The last section contains the general conclusions of this work and some prospects for future developments.

2 INTERACTIVE WHITEBOARDS

An interactive whiteboard is a touch-sensitive board which is connected to a computer and a digital projector which projects images from the computer screen onto the boards.

The interactive whiteboards in the market can make use of different technologies to perform its tasks. The type of projection may use three different types: front, rear or the use of a flat panel. The

interactive whiteboards with front projection are cheaper than those of rear projection, but have some disadvantages, such as shadows caused by the presence of the user in front of the board and the fact that if the user is speaking to an audience be dazzled by the projection. These boards usually do not bring projector included. There have however appeared interactive whiteboards using front projection with projector included. It is placed on top of the board, with an angle of projection about 45°, which almost completely cancels the situations of shadows and dazzle of the user. Obviously these boards have a higher price. Boards of rear projection, usually, have already incorporated the projector and the projection is made on the back of the board, then there are not the problems described above. However their main drawbacks are an increased price and a larger volume and therefore cannot be fixed to a wall, unless the exception of being embedded in it. In the use of a flat panel, there is no projection and the technologies used are more limited, generally those of infrared and/or ultrasound. The most common technologies are resistive, capacitive, electromagnetic, infrared and ultrasonic.

Interactive whiteboards are present in several aspects of our society. Already at the beginning of the 90's they were used in business. More recently there has been a great interest in education to insert the interactive whiteboards on teaching methods. A study dated of 2007 held in the UK (Kitchen, 2007) indicates that the interactive whiteboards are used in almost all schools, specifically in 98% of secondary schools and 100% of primary schools in that European region. In Portugal this implementation is a little delayed, but this process is included in the Technology Plan for Education from the Portuguese Government (Ministério Educação, 2007). Some manufacturers also create models of its interactive whiteboards directly targeted at government and military areas.

Almost all the interactive whiteboards need a manual calibration, which usually is the selection of nine points in the interactive area. Table 1 present five models of some major manufacturers, such as SMART Technologies (2006, 2008), InterWrite (2008), Promethan (2008) and eBeam (2008). In this table the main features as well as the price are presented (Wedgwood, 2008).

In a study from Becta (2005), it is mentioned the fact that students are motivated and learning is enhanced during the early stages of the use of the technology. The same study claims that if the computer is an increasingly part of the everyday armoury and ICT is regarded as a key skill underpinning all subject areas. But use interactive

Table 1: Comparison of features of five interactive whiteboards.

Model	Wireless	Taking notes	Writing Recognition	Projection	Projector included	Price
eBeam Integral 65	No	Yes	No	Front	No	790€
InterWrite 1071	Yes	Yes	Yes	Front	No	1142€
Activboard 95 studio	Yes	Yes	Yes	Front	No	1890€
SMARTBoard ESP680-N	Yes	Yes	Yes	Front	Yes	3390€
SMARTBoard 2000i	Yes	Yes	Yes	Rear	Yes	7090€

whiteboards have positive aspects (Miller and Glover, 2006; Smith et. al, 2006; Becta, 2005; Cuthell, 2005) such as:

- Facilitate collaboration with colleagues and co-workers;
- The visual information is more easily shared, by using drawings that the class may visualize together.
- The most widely claimed advantage is that it motivates students because they enjoy interacting physically with the board, manipulating text and images, thereby providing more opportunities for interaction and discussion.
- Pedagogical advantages are also noticed such as improved planning and preparation, marking and assessment, storing and editing lessons, teaching style, awareness of learning styles, planning for cognitive development, clear visual representation of concepts, activities that encourage an active thinking approach.
- Engagement: Motivation, Credibility and validity and Classroom focus.
- Socio-cultural aspects: Social interaction and working together
- Technology: drag-and-drop, hide-and-reveal, matching and using movement.

Further educational studies emphasise social activities focused around the Interactive Whiteboard as fundamental to subsequent knowledge transfer (Convery et. al, 2006). The problem is not use the interactive whiteboards, but the ways it is used.

The main problem with the interactive boards is still its cost that prevents its general use. The solution presented in the next sections intends to help solving this problem in a very simple way.

3 WIIMOTE CONTROLLER

The Wii Remote is the command of the Nintendo Wii, and is more commonly called a Wiimote. The Wiimote can be connected to any computer via *Bluetooth* as an ordinary cell phone. The decoding of the Wiimote protocol requires much reverse engineering (Wiibrew, 2008) and is still not complete, and it is not yet possible to take complete control of all its components. Among other features, the command incorporates an infrared sensor, and returns the data resulting from its reading as a frame of 16 bytes. The command may take different types of reports. The one we are interested in this project is the 0x33 and is illustrated in Figure 1.

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(a1) 33 BB BB AA AA AA II II II II II II II II II II II
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Figure 1: Data received at the 0x33 mode

The bytes BB contain information of the status of the buttons, the AA bytes contain information about the accelerometer and bytes II contain information on the infrared camera.

The infrared camera, when properly initialized, returns information up to four infrared points hypothetically visible. As it can be seen in the figure illustrated above, 12 bytes of information are received from the camera. So we are 3 bytes per infrared point. In Figure 2 is illustrated the codification of the X and Y coordinates and the size of each point in their 3 bytes.

As it is visible, it is relatively easily obtained in the computer the coordinates of the infrared sensor up to four points visible in space. The angles of vision, horizontal and vertical, of the infrared camera of the Wiimote are 42.8° and 31.2°, respectively. These data was collected by carrying out a test at various distances, which were 1, 2

	Bit							
Byte	7	6	5	4	3	2	1	0
0	X<7:0>							
1	Y<7:0>							
2	Y<9:8>		X<9:8>		S<3:0>			

Figure 2: Codification of data from the infrared camera on extended mode.

and 3 meters. Another feature that was duly noted was the frequency of receipt of reports that was around 100Hz. So it was cleared for 20 seconds the number of reports received every second, and that number was always around 100 reports per second.

4 CONTROL DEVICE

The control device is the element of the system that allows the control of the interactive whiteboard. It allows the emulation of the events of the mouse left button and the right click. It has two infrared leds, which may take different orientations in case of use of two Wiimotes very far away from each other and that the surface of interactive area is not reflective. If the surface is reflective the infrared leds may take the same orientation in order to increase the potency of the signal. The device can operate in two modes, the calibration mode or continuous operation mode. In calibration mode, the infrared leds are turned on when the left button is pressed. In continuous mode the leds are turned on, by default, and linked to the state of left and right buttons, the events are sent when requested. A green led have a similar behaviour then the infrared leds to give some feedback to the use of their state. It was chosen to base the construction of the control device using a four AA batteries case, illustrated in Figure 3.



Figure 3: Support for four AA batteries.

The leds chosen to implement the control system are high-brightness and small beam angle. Table 2

(RS – HIRL5020, 2008) is present the main features of the led HIRL5020.

The generator of control signals chose is the AtTiny85V, an 8-pin microcontroller from *Atmel*. Table 3 (Atmel, 2008) presents the AtTiny85V main features, including its unit price.

Table 2: Main features of HIRL5020.

Half intensity angle	$\pm 17^\circ$
Radian intensity	60mW/sr
Peak emission wavelength	940nm
Spectral bandwidth	50nm
Led diameter	5mm
Forward voltage	1.45V
Forward current	100mA
Power dissipation	170mW
Unit price	0.40€

The maximum current allowed by pin is below the current drawn by the infrared emitters, which will take some additional hardware that allows check their state.

Table 3: Features of AtTiny85V microcontroller.

Number of timers	2
Number of bits of processor	8
Clock frequency	8MHz
Data memory (SRAM)	512 bytes
Program memory (FLASH)	8 Kbytes
Number of inputs / outputs	6
Number of pins	8
Output DC current per pin	40mA
Input DC current per pin	40mA
Operating voltage	1.8V – 5.5V
Unit price	1.95€

The power supply for the device is provided by three AA batteries, and the vacancy left by a possible fourth battery is completed by the printed circuit board.

4.1 Transmission of Mouse Events

In order to send the events generated by the mouse buttons on the control device by a single led, it was created a protocol for sending this data. The infrared leds are, by default, turned on so the beginning of the data is sent by a shutdown of them. Each event is encrypted in 8 bits, with each bit corresponds to the state of the led during spaces of 30ms. The events implemented are described below and their frame of coding are presented in Figure 4.

1. Left Button Pressed: This event is relative to a pressure on the left button during 360ms.
2. Left Button Released: This event is relative to the act of release the left button while he was previously pressed and that his state is no longer changed in 360ms following.
3. Left Click: This event is relative to a left click on the control device, made in a maximum range of 360ms.
4. Double Left Click: This event is relative to a double click of the left button, made in a maximum range of 360ms.
5. Right Click: This event is relative to a right click on the control device.

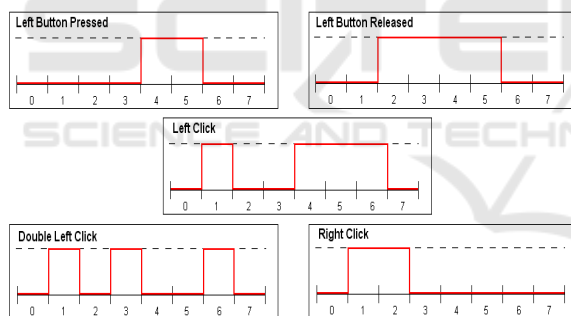


Figure 4: Telegrams of the events implemented.

As shown, the telegrams are all quite different, which prevents the execution of events undesirables because of erroneous readings. Otherwise, sending a significant number of bits in a relatively short period of time prevents that the dazzle of the infrared leds is wrongly interpreted as an event.

4.2 Implementation

The solution to control the infrared leds is to use a Darlington transistor to have a sufficient gain of current to the concrete situation. To view the current level of supply voltage, it was made a sequence of diodes and leds to view three possible states, like in Figure 5, while they were the batteries are full, used

batteries and dead batteries. The circuit is powered when a push-button is pressed, in order to reduce consumption caused by this section of the control device. The leds are red, yellow and green. The green led is turned off to tensions below 4V and the same applies to the yellow led to tensions below 3.3V, for which only the red led lights, then suggesting the exchange of batteries.

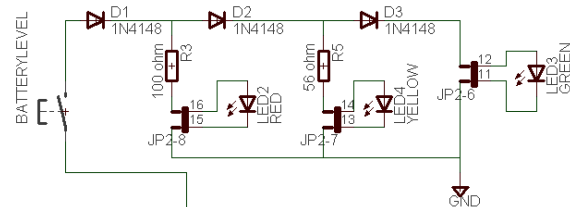


Figure 5: Circuit for viewing of the batteries state.

In Figure 6 it is illustrated the final aspect of the control device and its components.



Figure 6: Final control device and its components.

5 APPLICATIONS DEVELOPED

The application was developed in Delphi 7.0 and can work with one or two Wiimotes at the same time. The application includes a method of calibration simple and efficient, receiving the events sent by the control device and some extra features.

5.1 Calibration

In order to place the mouse cursor in the correct position, it is necessary to transform the coordinates provided by the Wiimote in coordinates of the desktop of the computer. With the formulas (1) and

(2) it is possible to obtain the coordinates of a point in a 2D plan, from the viewpoint from another 2D plan.

$$x_s = \frac{a_1 \times x + b_1 \times y + c_1}{a_3 \times x + b_3 \times y + 1} \quad (1)$$

$$y_s = \frac{a_2 \times x + b_2 \times y + c_2}{a_3 \times x + b_3 \times y + 1} \quad (2)$$

During the calibration process it is requested to the user the selection of four consecutive points from the desktop such as illustrated in Figure 7.

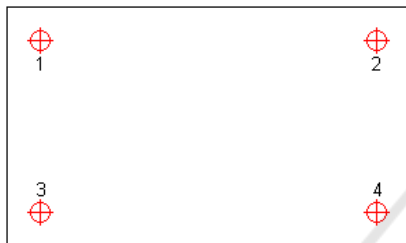


Figure 7: The four calibration points.

With the X and Y coordinates of the four points given by the Wiimote and knowing its location X_s and Y_s on the screen, and then we may get eight equations with eight unknowns. Calculating then the value of the unknown values $a_1, a_2, a_3, b_1, b_2, b_3, c_1$ and c_2 get a model that relates the X and Y coordinates given by the Wiimote infrared sensor with the coordinates X_s and Y_s where we must put the mouse cursor.

It was made a test of the quality of calibration, using one or two Wiimotes with different positions and with two different types of leds, where the maximum average error for the precision was 0.49% and the maximum average error for accuracy was 0.38%, these values perfectly acceptable.

5.2 Reading the Mouse Events

To read the telegrams sent by the control device, it was used the multimedia timer of Windows, because the default timer of Delphi does not work well for intervals of less than 1s. The process is that when the infrared leds are turned off, the timer is launched with an interval of 15ms. In the first interruption, the interval is changed to 30ms and it is reading the state of the leds. In the seven followed interruptions is repeated the reading of the leds state, thus filling a frame of 8 bits, as in Figure 8.

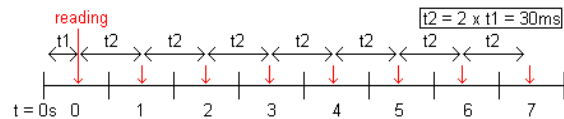


Figure 8: Reading of the 8 bits of a telegram.

Once the telegram filled it is compared to know events, and if there is a match the respective event is processed.

5.3 Features

The aspect of the application is illustrated in Figure 9, with one or two Wiimotes connected.

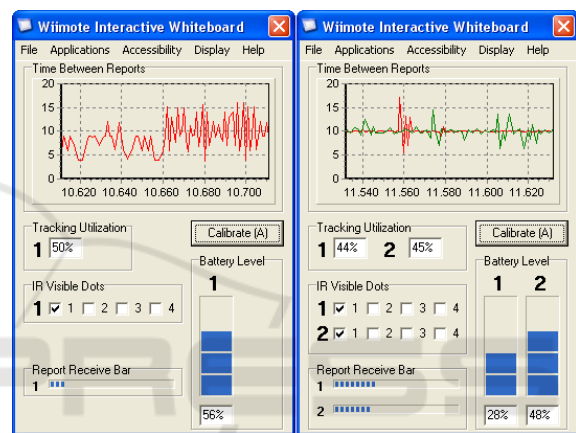


Figure 9: Application using one or two Wiimotes.

Different information is given about the state of the Wiimote(s) as well as the calibration status. The application contains a menu with shortcuts to applications such as virtual keyboard, paint or notepad, among others.

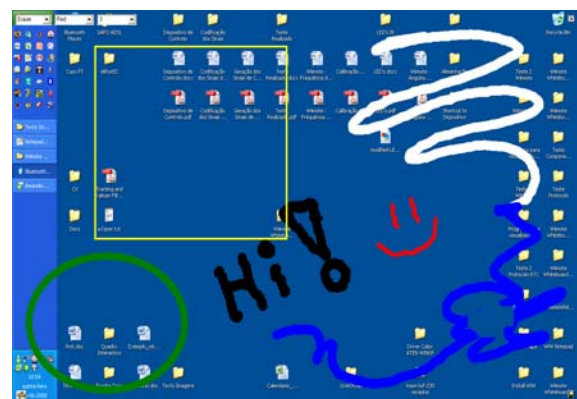


Figure 10: Example of use of the implemented Notebook.

It was developed a notebook application that allows taking notes on the desktop, with some tools like a colour pen, shapes and an eraser. It is possible to save the notes in the form of an image. In Figure 10 it is illustrated an example of use of the implemented Notebook.

5.4 Survey Results

To analyze and evaluate the preference on the low cost interactive whiteboard project using wii controller a survey was conducted. The survey was made to 21 people that after testing the solution with complete freedom, managed to respond a questionnaire. The methodology practiced followed the general steps of research based on survey (Hill & Hill, 2005), starting with the definition of the objectives of the investigation, planning and doing a general design of it.

The population on this study was formed by users with good skills in Informatics and Computer Science and the convenience and probabilistic sample had 21 individuals that work in Portuguese territory.

Some interesting conclusions were found after analyzing the answers. The majority of the user inquired (81%) considered the price of general interactive whiteboards too high. On the other hand 95% stated that the quality/price relation of the new solution (interactive whiteboard project using Wii controller) was "Good" or "Very Good". Finally in the event of needing to acquire a whiteboard, over 90% of the inquired users preferred the presented low-cost solution.

This work was complemented by analyzing two kinds of situations for compare proportions. First, one in two independent samples compares users with and without experience on interactive whiteboard and the second one was intended verifying opinions before and after having experience with the interactive whiteboard with the wii controller. To test if there were statistical evidences to claim that the kind of answers differed with the kind of user it was applied the Fisher's Test. For the knowledge differences on the level of answers among users it was applied the Mann-Whitney Test.

In fact for a level of significance of 0.05 it wasn't possible to affirm that the variables experience with classical interactive whiteboards and preference of the *IIBoard* solution are associated ($p_value \approx 1,000$) and there were statistical evidences to claim that both groups prefer the low cost whiteboard solution.

In conclusion, the results clarify that the low cost interactive whiteboard project using Wii Controller

had good acceptance and could be an alternative solution for the very expensive whiteboards available on the market.

6 CONCLUSIONS AND FUTURE WORK

In this paper the design and implementation of a low-cost interactive whiteboard, based on the Wiimote was presented. The most relevant aspects concerning the practical application developed are:

- Construction of a control device that allows to emulate almost all mouse events;
- Implementation of a calibration method of the interactive whiteboard simple and efficient, whose precision and accuracy have been properly proved;
- Flexible application, which can be executed with one or two Wiimotes, so as to reduce cases of occlusion of the infrared emitters;
- Implementation of a Notebook application in order to increase the usefulness of the main application.

The *IIBoard* system developed is a prototype of a very low cost interactive whiteboard, having however the main features of such frameworks. The preferences shown therefore by the users of *IIBoard* enable us to conclude that it would not be difficult to transform the prototype into a commercial solution.

There are several improvements that this project could still suffer. The main ones are:

- Transmission of the events via *Bluetooth*, to make its execution in almost real time and limit the event losses, which would also implement the events of the mouse entirely, including scroll;
- Implementation of a Kalman Filter to merge the information of two Wiimotes and to estimate the position of the cursor when occlusion of the infrared leds occurs;
- Development of a feature for the conversion of written to digital text, subject to a calibration of different writing for each user. It could also use a dictionary that would give suggestions according to the letters that were already written;
- Implementation of the ability to use two Wiimotes to further extend the board interactive area. The board would have two halves, each of them monitored by a different Wiimote.

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