Economical Solution for an Easy to Use Interactive Whiteboard

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Abstract–**This paper presents a new technology combining infrared tracking and Bluetooth communication to create an effective and low cost interactive whiteboard, the wiimote whiteboard. The author, a high school student, got the idea after he observed inattentive students and a deteriorating classroom environment on several occasions. After extensive research, he decided to solve the problem by building an interactive whiteboards. This paper gives the details, including how to gather the components, assemble the elements, install software, setup and calibrate the whiteboard. Due to the frequent low tracking resolution of the device, four methods of improving the tracking resolution are also provided, based on the author's many tests. Finally, the paper analyzes the basic theory, compares wiimote with the commercial whiteboard, introduces the history of the new technology, and lists a number of useful resources for referencing. With the help of the author's school and the advisor's funding, the device was successfully installed at Watertown High School of Connecticut.**

Keywords–Interactive whiteboard infrared tracking Wii Remote

I. INTRODUCTION

Interactive whiteboards, more commonly known as SMART boards, have existed for quite a long time now, but only very exclusively. Very few private corporations owned them and schools could not even consider using them due to the high cost. As technology evolved, they became much more affordable and they quickly became a hot commodity. Many businesses and schools now use them to capture their audience's attention. The best feature is that documents can be saved and stored for later use. Even though manufacturers have lowered the cost considerably, many businesses and schools have still struggled to obtain one. In 2007, , Dr. Johnny Chung Lee of Carnegie Mellon University created the first wiimote whiteboard which employed the Nintendo Wii remote technology and made the impossible become possible. This system is literally thousands of dollars cheaper than the cheapest whiteboard on the market today. Dr. Lee's creation is a gift, especially for teachers. Thanks to this innovation, teachers are now able to capture student's attention without needing to spend thousands on a commercial interactive whiteboard.

A. Interactive whiteboard History

Interactive whiteboards have rapidly gained popularity since they were first introduced in 1991. They can be seen in many places, such as schools, companies and museums. People are utilizing this fantastic new technology to captivate the minds of their audiences.

First introduced by SMART, the SMART board was the first interactive whiteboard to provide users with the touch control of a computer onto a projected screen. As technology advanced, the SMART board system evolved. There are now many types of Interactive whiteboards, including Resistive technology and Electromagnetic technology. Resistive whiteboards are comprised of two layers of sheets separated by air or microdots. When pressure is applied to the sheet, an accurate location of the pen is given. Electromagnetic whiteboards contain many magnetic sensors that interact with the magnetic pen and give an accurate location of the pen.

Several programs have also been introduced to fully utilize the interactive whiteboard. The software allows the presenters not only to write and draw, but also to bring in images and videos from other sources. The ability to recognize handwriting and convert it to text has also been added. These tools make presentations and lessons feel more personal. In addition, after the presentation is finished, it can then be saved as a document and stored for a later session.

B. Related Research

In 2007, Dr. Johnny Chung Lee discovered an inexpensive way to replace the conventional interactive whiteboard. Dr. Lee is a Ph.D. graduate student from Carnegie Mellon University, and is seeking new ways to improve interactions between humans and the computer. According to an interview by actiontrip.com, Dr. Lee was on a plane in April 2007 when the idea suddenly hit him. He discovered that he could create an interactive whiteboard by using a Wii remote and an infrared LED pen. He called it the wiimote whiteboard. The wiimote whiteboard is extremely economical and intuitive to use.

C. Reason for a Wiimote Whiteboard

One day in class, my mind wandered off. I looked around the classroom, and noticed that the students were not really paying attention to what the

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teacher was saying. I was thinking that perhaps it was because the whole blackboard was filled with notes and the students were not able to follow the teacher's train of thought. This was when I started to get an idea about making the classroom a better place.

I observed a couple more classes and saw that paying attention was not the only problem. Some students were having a difficult time digesting the overwhelming amount of information. Some students were might asking questions about something the teacher had just said.

Teachers also seemed to have a problem keeping track of everything. I had a teacher who kept today's lesson on the board and just talked about them. She did this because her lessons contained a lot of graphics and it was just a pain for her to draw them over and over again. To eliminate the effort of drawing diagrams repeatedly, she used four chalkboards but it was extremely difficult to keep track of everything.

Determined to find a solution, I searched on Google and found out about interactive whiteboards, which our school cannot currently afford. I wanted something that would be cheap and effective. I tried to think and search for new ways to improve the classroom environment; but did not find any practical solutions for a long time.

One day, I stumbled upon a video of Dr. Lee demonstrating his new wiimote whiteboard. It t was exactly what I needed - a cheap and easy to use interactive whiteboard! I talked about my plan with Dr. James Louey, my Chemistry teacher. He agreed to help me with the project. With assistance from my school and teachers, I began to build the first wiimote whiteboard system at my school.

II. RESEARCHING

A. Understanding How the Wiimote Whiteboard Works

After I saw Dr. Lee's video, I was very intrigued and I began to do some research. I visited his website and found a description of how the wiimote whiteboard works and how to build one. I also found a helpful forum, https://sourceforge.net/forum/forum.php?forum_id=764898, to discuss the wiimote whiteboard.

I found that the wiimote whiteboard uses Nintendo wii remote's infrared camera to determine the location of the infrared pen. The remote uses triangulation to determine the position of the pen. Two points inside the wii remote measure the angle from the wii remote to the LED light source. Once two angles are found, the third angle is easily figured out by subtracting the two angles from 180. Using the law of Sine and Cosine, the position of the infrared light source can be calculated (see Figure 1).

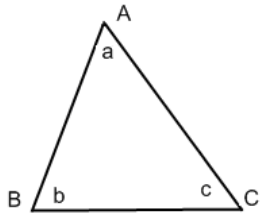

Figure 1: Law of Sine and Cosine

In a triangle like this:

Law of Angular Sum of Triangles:

$$a = 180 - a - b$$

Law of Sine: $\frac{\sin a}{BC} = \frac{\sin b}{AC} = \frac{\sin c}{AB}$

Law of Cosine:

$$BC = \sqrt{AB^2 + AC^2 - 2AB * AC * \cos a}$$

The information from the wii remote is used to map out the relative position of the project screen. The wiimote whiteboard program uses a standard four point calibration to determine the size, shape, distance and the position of the project screen.

B. Main Hardware Components

Table 1 is the main equipment list which contains all the required hardware components, its usage and where it can be obtained.

C. Main Software

Table 2 is a list of main software incorporated in the wiimote whiteboard. There are a total of 5 software components, including the operating system. All of the following software, except the operating system for the computer, should be free.

III. EXPERIMENT AND ASSEMBLY

A. Gathering Supplies

- Nintendo wii remote

Nintendo wii remote (see Figure 2), the most important part of the wiimote whiteboard, can be found in many places; RadioShack, Wal-mart, BestBuy, etc. It usually costs around $40.00 in retail stores. However, there are many great deals on the Internet.

- Bluetooth Dongle

There are two problems when buying the Bluetooth dongle (see Figure 3). One is that some of them are not compatible with the wiimote whiteboard. To check if the Bluetooth dongle is compatible, go to http://www.wiili.org/index.php/Compatible_Bluetooth_Devices. The other problem is that it is very hard to find in retail stores. I went to many RadioShack stores but did not find any. I also checked online at BestBuy and RadioShack. It turned out they are very expensive. The price ranged from $49.99 to $79.99. I

decided to go on a hunt and find a cheaper one. On www.sparkfun.com, I found one for only $16.95. Since all Bluetooth dongles work relatively same, I was glad I saved over 33 dollars.

TABLE 1. MAIN EQUIPMENTS NEEDED TO BUILD WIIMOTE WHITEBOARD

Equipment Name	Usage	Where to Obtain
Nintendo Wii Remote	The most important part required. There is an infrared camera inside to make the wiimote whiteboard work.	Wal Mart, Online
Bluetooth Connection Device	It is used to connect the wii remote to the computer with the Bluetooth signal. It can be a built in Bluetooth receiver or a Bluetooth dongle.	Wal Mart, Online
Projector (Optional)	Used to project the computer screen to the board, optional but strongly suggested	Online
Computer	The computer's screen is projected on to a big display and serves as the interactive whiteboard	Stores, Online
Infrared LED	Emits infrared light to be detected by the wii remote	RadioShack, Online
Momentary Switch	An on and off switch for the Infrared LED pen	RadioShack
AA Battery Casing	To hold the AA battery	RadioShack
Wires	Connect the infrared LED, momentary switch and the AA battery casing together	RadioShack
Soldering Iron	Used to solder together wires	RadioShack
AA Battery	Power source for the LED pen	Stores

TABLE 2. MAIN SOFTWARE NEEDED TO BUILD IIMOTE WHITEBOARD

Equipment Name	Usage	Where to Obtain
Nintendo Wii Remote	The most important part required. There is an infrared camera inside to make the wiimote whiteboard work.	Wal Mart, Online
Bluetooth Connection Device	It is used to connect the wii remote to the computer with the Bluetooth signal. It can be a built in Bluetooth receiver or a Bluetooth dongle.	Wal Mart, Online
Projector (Optional)	Used to project the computer screen to the board, optional but strongly suggested	Online
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Wires	Connect the infrared LED, momentary switch and the AA battery casing together	RadioShack
Soldering Iron	Used to solder together wires	RadioShack
AA Battery	Power source for the LED pen	Stores

Figure 2: Nintendo wii remote

Figure 3: Bluetooth Dongle

- Projector (Optional)

The projector (see Figure 4) is the most expensive part of this project. However, depending on how the wii whiteboard will be used, the projector is optional. This is one of the greatest features of the wii whiteboard. Its versatility can turn any display surface into an interactive whiteboard. Using a projector to project the computer screen on to a smooth surface is one way to use it. The wii whiteboard can also be used on any display device that the computer can be connected to, like monitors and TVs. I searched for an economical projector online and was able to find one for about $349.99. There is, however, another way to get around the price of projectors –building your own projector. A simple projector can be made using only a normal LCD monitor and a projector. However, the construction requires some technical skills which I am not going to go into detail about here. For instructions on how to build a projector, visit http://www.instructables.com/id/DIY-Projector-on-the-Cheap/.

Figure 4: Projector

- Equipment used to build Wiimote Whiteboard

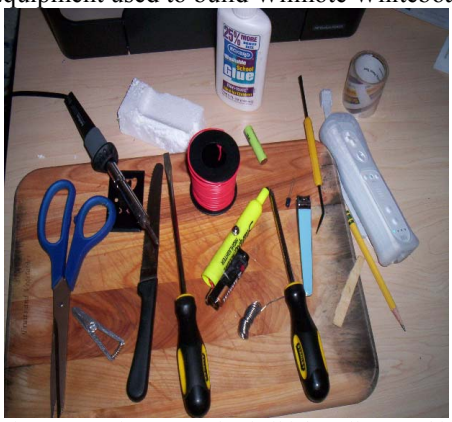

Figure 5: Equipment used to build the Wiimote Whiteboard

A. Software

- Wiimote Whiteboard.exe

This software is programmed by Johnny Chung Lee. This software uses the information from the wii remote to figure out the relative position of the projected screen. When the calibration is complete, the software enables the computer to recognize the wii remote as a HID, human interactive device. The software is able to do this by using the wiimote library programmed by Brian Peek. This program can be downloaded from http://www.cs.cmu.edu/~johnny/projects/wii/. This program does not need to be installed, so just extract the file to a convenient place on the computer.

- Microsoft .NET framework 3.5

.Net framework is the common ware which is used for many programs. If your computer does not have one, you can download from http://www.microsoft.com, and install. Follow the instruction given by the installation wizard, .NET framework should be installed in no time. After installing .NET framework, the computer may require a restart.

- Bluetooth Connection Software

The other major software is the Bluetooth connection software. If the computer already has Bluetooth connection software, then this step is not necessary. There are many options for this software and all of them should work very well. BlueSoleil is recommended by Dr. Lee. However, I find that there are many problems with this software. On many computers, BlueSoleil 6.0 is not compatible with the wiimote whiteboard program and will cause the computer to crash. BlueSoleil 5.0 is outdated and will not recognize some of the Bluetooth devices. In addition, BlueSoleil is not a free program. After 5MB of data have been transferred, it automatically shuts down. I recommend using the software that came with the Bluetooth device. Just follow the instruction given by the installation software to install the Bluetooth connection software.

- Paint.NET:

Paint.NET is a drawing program that is similar to Adobe Photoshop, but it is very easy to use and does not take up too much memory. Paint.NET is a fully developed program that is useful for painting and teaching. Paint.NET offers a layering system which acts as slides. By changing the visibility of the layer, it can create an effect of changing slides. It is also easy to add a new layer. The new layer will automatically cover the current one. It has a history bar which is used to keep track of changes in the document. The best thing is it is keyboard-free and only requires a mouse. The only problem that I found with paint.NET is that when there are multiple layers, it is difficult to switch from one to another.

B. Hardware Assembly: Infrared LED Pen

- Assembly

The Led Pen is a vital part of the wiimote whiteboard. However, it would be impossible to find an infrared LED pen at a store because it has not yet been commercialized. It is no doubt one of the hardest steps in building the wiimote whiteboard.

The infrared pen requires an infrared LED diode, some wires, a battery holder, a momentary switch, hollowed out sharpie highlighter, soldering supplies and batteries. While making the LED pen, I suggest wearing gloves since the solder can cause serious burns. Figure 6 is the simple demo connection for the components. The battery holder is connected to the momentary switch which is in turn connected to the infrared LED. The momentary switch stops the power supply from the battery so the LED can be turned on and off. The power from the battery lights up the infrared LED and is detected by the wii remote.

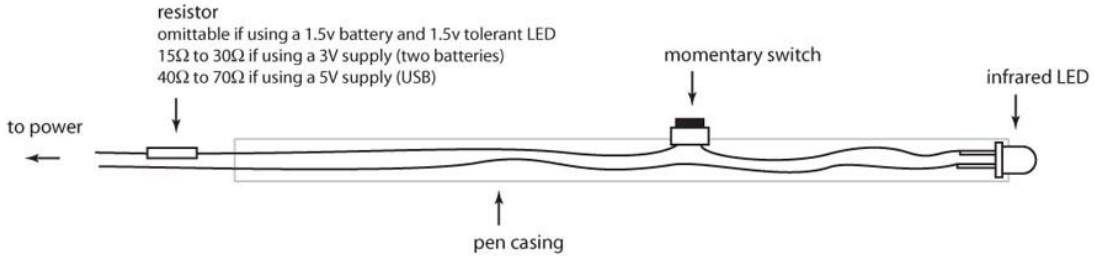

Figure 6: Schematic Diagram for Infrared LED Pen Connection

To make the infrared pen, first drill a hole on the pen casing big enough for the momentary switch to fit through. Then solder a wire from the cathode end of the battery holder to the cathode end of the LED. Carefully place the wiring inside the hollowed out pen casing. Next, solder the anode end of the LED to the momentary switch and put the momentary switch in place. Finally solder another wire from the momentary switch to the anode end of the battery holder. Figure 7 is the model infrared Pen I made.

Figure 7: Infrared Pen

- Testing

Put a battery inside the battery casing and test if it works. Since infrared ray is invisible to the human eye, a cell phone camera is the best way to test it. Turn your cell phone's camera on and point it at the infrared pen, if the LED lights up, it's working.

IV. SETUP THE WHITEBOARD SYSTEM

A. Setup

The first step is to connect the wiimote to your computer via the Bluetooth. Press the 1 and 2 buttons on the wii remote simultaneously, and the blue lights on the bottom should flash. This means that the wii remote is sending out signals. Keep pressing the buttons, and while doing that, use the Bluetooth program to detect the wii remote. If everything works out well, there should be an icon that looks like a game controller and text saying Nintendo RVL.

Next thing is to find a good placement for the wii remote. The wii remote should be placed far enough from the screen so that it can see the whole thing but not too far that it loses tracking resolution. Keep in mind that the wii remote has a camera range of about 45 degrees. I also should mention that the wii remote does not have the best tracking resolution, but it is the best for its price range, and the resolution is more than enough for a decent size interactive whiteboard.

B. Calibration

Upon launching the software, a dialog box should appear. Click "Calibrate" and the whole screen will turn white. A red circle with a cross hair should also appear at the upper left corner of the screen. Now it's time to use the infrared LED pen. Point the LED part of the pen at the center of the cross hair and push the momentary switch. The red circle should move to the upper right corner of the screen. If it does not work, make sure nothing is preventing the infrared ray reaching the wii remote. If there is nothing blocking, then it is because the wii remote cannot see the LED, place the wii remote somewhere else. After all of the points are calibrated, I would calibrate it again just to make sure the wii remote can see everything.

After finding a perfect position for the wii remote, it is time to stabilize the wii remote. Do not put the wii remote on a desk where it can be easily moved. I recommend putting the wii remote on a stable surface or stabilizing it by using a microphone stand.

If the wii remote is placed on a counter, it would be best to secure the wii remote with masking tape. It is also a good idea to trace out the shape of the wii remote using masking tape. This way if the wii remote is ever moved, it can be placed back exactly where it was. It is best to stabilize the wii remote with a microphone stand. The wii remote fits perfectly in the microphone holder. Put some masking tape around the microphone stand incase it is ever moved. It can be put back the way it was. The demo results as figure 8.

Figure 8: Demo result of Wiimote Whiteboard on LCD display

C. Comparison with Commercial interactive whiteboard

The wiimote whiteboard, needless to say, is the most economical solution for bringing the classroom to life. Instead of paying for one expensive commercial interactive whiteboard, the school can use its money to setup the wiimote whiteboards for all the teachers at of my school.

The wiimote whiteboard is also more intuitive to use than the normal commercial interactive whiteboard. On the commercial one, the user needs to take out a pen from the pen tray to draw on the whiteboard. It also requires firm pressure to be applied to make it work. When the user needs to scroll or switch to another application, he needs to replace the pen in the pen tray, otherwise the movement will be interpreted by the computer as brush strokes.

The wiimote whiteboard is more intuitive because it does not distinguish between pen strokes or hand gestures. The wiimote whiteboard requires only an infrared LED light source which is interpreted by the wiimote software as the input device.

Unlike the commercial whiteboard, which is cumbersome to use and the user is limited to the size of the screen, the wiimote whiteboard is versatile. It can be used on any smooth surface, such as an LCD screen, the wall, a table, or even on the floor. The wiimote also does not require a projector, but it is recommended.

The down side to the wiimote whiteboard is the tracking resolution. The wii remote does not offer the high quality tracking resolution as SMART boards. However, there are several ways to overcome this problem.

V. IMPROVING TRACKING RESOLUTION

Open up Microsoft paint and draw five free hand circles on each corner of the screen and in the middle. If the circles come out well, you're all set. But most likely the circle will not be uniform. The circle on the side of the screen furthest away from the wii remote will look jaggedly, almost like a square. This is happen because as the wii remote moves further away from the screen, it loses tracking resolution.

The wiimote whiteboard program uses the data from the wii remote to determine where the cursor should move. When the infrared light is far away, it is hard to measure the angle between the wii remote and the infrared light source. Because of the distance, the wii remote will measure the angles incorrect and cause the wiimote software to move the cursor to an incorrect position.

A. Solution One

The best way to deal with this problem is to move the wii remote closer. For an average sized whiteboard, the wii remote should be able to cover the whole screen from 15 feet away. It is best to move the wii remote as close to the screen as possible to get the best tracking resolution. Also place the wii remote on the side, not directly in front of the screen. This is because when we write, our bodies tend to be right in between our hand and the wii remote. This will block the infrared light for the camera. To avoid this, we stretch out our hand to write, but this is a very uncomfortable position for writing or leaving out. By placing the wii remote on the side, this inconvenience is eliminated.

B. Solution Two

Another way to improve the tracking resolution is to use a strong infrared LED diode. It is easier for the wii remote to detect the infrared signal when the LED is strong. I found a powerful infrared LED diode at http://www.rentron.com/remote_control/IRLED.htm.

C. Solution Three

The solutions discussed above all include hardware adjustments. There is also a software solution. To do this step, the computer must have Paint.NET installed. In Paint.NET, there is a feature called anti-aliasing. This feature can be enabled by clicking on the curved line on the top menu. Anti-aliasing makes the jagged edges disappear and the image smoothed. This solution is used to fix minor tracking resolution problems. Adjusting the position of the wii remote is still the best way.

D. Solution Four

I have also come up with another way to improve tracking resolution. When writing on the wiimote whiteboard, our hands often block the infrared ray. When this happens, the wiimote will receive only little packets of light making circles look like squares. As I mentioned above when I was talking about building the infrared pen, I have come up with a new idea to replace the infrared pen.

My idea is to create an infrared ring. The ring is to be worn around the top of the index finger. The LED is attached to the ring. Instead facing the whiteboard, it is facing the wii remote. The momentary switch is placed, so that the thumb can easily reach it. The battery holder is attached to a strap so it can be worn comfortably around the hand. This is very ergonomic, just like operating a touch screen.

VI. APPLY TO WATERTOWN HIGH SCHOOL

After I finished installing the wiimote

whiteboard system in Watertown High school, Connecticut, I showed it to my teacher. He was satisfied with the results of the whiteboard. The wiimote whiteboard worked just like the commercial one, allowing the teacher to teach and write. The wiimote whiteboard not only provides the school with an economical solution, but also provides students with a hands-on experience of their learning. Students can get a deeper understanding of how trigonometry works in real life or why infrared light is invisible to the human eye.

The wiimote whiteboard revolutionizes teaching, getting rid of the chalk dust and pungent smell of markers and opening up a new way to communicate with students. The wiimote whiteboard is unquestionably a valuable resource for teachers. The once novel interactive whiteboard can now be afforded by every teacher.

VII. CONCLUSION

Wiimote whiteboard is the most economical multimedia tool for teaching and presentation, especially for the schools and companies that have a limited budget. The price of the wiimote whiteboard can pose a potential threat to big interactive whiteboard companies, like SMART. These companies will be forced to think of new ways to lower the price of their interactive whiteboards.

Due to time constraints, I am not able to do further research and testing. However, I want to stress the fact that the wii remote has uncanny abilities and it should not be confined to gaming and interactive whiteboard systems. Wii remote has the potential to revolutionize the way humans communicate with computers. There are already developments using multiple wii remotes to track movements in 3D space.

The wii remote is only the beginning of change. I believe that this technology will not fade out with time, it will prosper. Maybe one day the technology inside of the wii remote will free us from the key board and mouse.

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