Citation:
Holzinger, A., Softic, S., Stickel, C., Ebner, M., Debevc, M. & Hu, B. (2010) Nintendo Wii Remote Controller in Higher Education: Development and Evaluation of a Demonstrator Kit for e-Teaching. *Computing & Informatics,* 29, 4, 1001-1015.

Nintendo Wii Remote Controller in for Higher Education: Development and Evaluation of a Demonstrator Kit for e-Teaching

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Abstract. Increasing availability of game based technologies together with advances in Human–Computer Interaction and Usability Engineering provides new challenges to virtual environments for their utilization in e-Teaching. Consequently, a goal is to provide learners with the equivalent of practical learning experiences, whilst, at the same time, supporting creativity for *both* teachers and learners. Current market surveys showed that the Wii remote controller (Wiimote) is more wide spread than standard Tablet PCs and is the most used computer input device worldwide, which, given its collection of sensors, accelerometers and Bluetooth technology, makes it of great interest for HCI experiments in the area of e-Learning and e-Teaching. In this paper we discuss the importance of gestures for teaching and describe the design and development of a low-cost demonstrator kit for the Wiimote in order to demonstrate that gestures can enhance the quality of the lecturing process.

Keywords: Wii, Wiimote, finger tracking, gestures, usability, e-Learning, e-Teaching

1 Introduction and Motivation for Research

1.1 Is Minority Report still too far away?

In Minority Report (Dick, 1956), a movie directed by Steven Spielberg (2002), Tom Cruise as Chief John Anderton danced gracefully through a plethora of evidences in the 3-D virtual reality world presented in front of him. He touched things with his magic fingers, opened and examined them, and threw away less important ones by a single wave of hands. This scenario is, of course, still far beyond the capabilities of the Human–Computer Interaction (HCI) that average computer end users experience in a day-to-day basis and indeed only exists in this science fiction movie. This scenario is, of course, still far beyond the capabilities of the Human–Computer Interaction (HCI) that average computer end users currently experience in a day-to-day basis and indeed only exists in this science fiction movie. Mouse and keyboard are still the only means available to the majority of end users. In the last seven years, technology has brought us closer to this fascinating scenario, though we, as ordinary users, are still a significant distance away from becoming Chief Anderton. The desire to have “magic fingers” is not driven purely by sci-fi stories. Instead, explicit application scenarios have been the main inspiration behind recent developments. Among others, e-learning is a major driving force, especially game based learning approaches (Ebner & Holzinger, 2007), (Robertson & Howells, 2008), (Law, Kickmeier-Rust, Albert & Holzinger, 2008).

1.2. Teaching and the importance of Gestures

Electronic Learning (e-learning, also referred to as technology-enhanced learning) has a long history of virtualization dating back to the early Sixties (Lawson, 1969). It gained substantial attention recently due to the advances of the Internet and virtual reality (Thomas, Carswell, Price & Petre, 1998). Various e-learning researches can be summarized in a few fundamental questions with communication as an important one. As in real classrooms, the outcome of learning activities is influenced by the effective delivery of the learning materials, which can be significantly influenced by our method of communication.

In real-life, we communicate through speech and gestures. Consequently, gestures are an important part of non-verbal communication within demonstration and presentation tasks, which are essential for human cognition. It is evident that co-speech gestures can support the construction of a complete mental representation of the discourse content, subsequently leading to an improved recollection of conceptual information (Cutica & Bucciarelli, 2008). Consequently, gestures can be seen as a pervasive element of human communication across cultures (Pavlovic, Sharma & Huang, 1997), (Roth, 2001), and they carry particular weight when using artefacts such as computers (Klerfelt, 2007). Studies demonstrated that gestures influence the students' comprehension of instructional discourse, thereby influencing students' learning. Thus, teachers' gestures can indeed facilitate student learning (Valenzeno, Alibali & Klatzky, 2003).

However, gestures depend on various factors including personality, cultural background, social and geographical surrounding, and especially the level of previous knowledge (Holzinger, Kickmeier-Rust & Albert, 2008). In user interfaces, gestures can also be used for scoping or marking displayed objects, for target indication to point to the location of interest, for entering operations, such as mathematical operations and for literals (handwritten word) and modifiers (handwritten parameters for operations) (Rhyne, 1987).

In this paper, we discuss the importance of gestures for teaching and report on the development of a low-cost application to demonstrate that gestures can enhance the quality of the lecturing process. Merging these gestures by use of unified interfaces can offer the possibility of implementing a non-verbal communication code for a certain purpose; in our case the transfer of information, Within the scope of the demonstration and the presentation of the teaching subjects, tracking gestures will be used to highlight and underline the essence of the learning material presented. For example, just pointing to a particular location of an object saves time and sometimes can be more efficient than a longwinded verbal description of it.

2 Theoretical Background and Related Work

2.1 E-Teaching and the Wii

The advance of ICT technologies has ushered e-learning into a different territory. E-learning has long been considered just as an extension of conventional classroom-based learning with teachers presenting and delivering learning materials and students accepting and digesting such materials. However, Internet and Multimedia have reshaped the way that information is presented, consequently e-learning is becoming a real alternative to traditional classroom learning (Zhang, Zhao, Zhou & Nunamaker, 2004).

The process is similar to what we experience in a real classroom with variants that are unique to distance learning. For instance, context-awareness (Gellersen, Schmidt & Beigl, 2002) can offer highly personalized learning materials and help to decide the most appropriate way to deliver such materials. Mobile devices allow students to participate in learning whenever and wherever they can (Holzinger, Nischelwitzer & Kickmeier-Rust, 2006).

We do not deny the advantage of such learning paradigm and the improved learning experience that new technology can bring to us. We would like to argue that even though benefiting from new ICT technologies, mimicking the classroom in the virtual world is **not** the future of e-learning. We argue that there is a critical element missing from current e-learning scope: **participation**. In real-life, classroom learning only accounts for a small part of our knowledge acquisition – we acquire the rest through participating in problem solving activities. Formerly, apprentices learnt by observing and acting together with the masters (cognitive apprenticeship, see e.g. (Collins, Brown & Newman, 1989)). In modern societies, we learn and solidify our knowledge by participating in various events. We pass knowledge onto others by demonstrating what we have learnt through activities. Although, nowadays, the master-apprentice learning pattern is not as prevalent as before, participation is still critical for acquiring knowledge, in particular practical knowledge, e.g. dance, sports, medicine, etc. Participatory learning has certainly caught the attention of, and started to infiltrate, classical e-learning. For instance, Second Life (Wheeler, 2009) has become a learning phenomenon involving virtual participation. Not bound by any physical conditions or even physical laws, your avatar can participate and experience in almost any events and activities. Yet one minor thing has ruined all the greatness. Until recently, the dominant input devices were still mouse, joystick, keyboard navigation keys, touch screens, etc. restricting our participating experience to an unreal one. Our hope hovered as Wiimote appeared. Although developed originally as the input device for the Wii game console, Wiimote has a unexpected, far-reaching impact on e-learning. However, we must take into consideration that learning is a cognitive and social process, while teaching is a didactical and social process, accordingly, there is a lack of experience and evaluation of the benefits and risks of e-Teaching techniques (Peter, 1998).

2.2. Background of Wii

The distinctive advantage of Wiimote can be seen from the following aspects.

- Availability

  Wiimote has been distributed together with the game console and can also be purchased separately from almost any electronic shop.
- Extensibility

Wiimote communicates with the game console through a standard Bluetooth interface. It also features an expansion port allowing various attachments (e.g. Wii Wheel, Nunchuk) to further enrich the functionality.

- Open

  Unlike the equipment from other providers, the Bluetooth wireless link allows one to connect Wiimote to virtually any device that is Bluetooth enabled. Data collected from Wiimote can then be processed by such devices with high computational power.

- Popularity

  Since Wiimote, and the Wii game console, was released in 2005, a mature community has been established with programmers, designers, human computer interface experts, hackers, etc. exploring and experimenting with new applications based on Wiimote. Open source library repositories, online tutorials, and well-established discussion forums (e.g. www.wiili.org) have pushed the use of Wiimote to an entirely new frontier.

- Cost effective

  Wiimote is relatively cheap (roughly 35 Dollars or 25 GBP in July 2009) compared to other devices offering similar functionality. This low retail price encourages a further growth of the Wiimote community.

The built-in motion sensors make Wiimote perfectly suitable for realistic training simulation. For example: in Second Life, Wiimote makes it possible to experience an almost real-life environment at a very low cost. Companies, e.g. construction, chemical manufacturers, power plants, etc. have started using a combination of Wiimote and Second Life for early stage, hands-on, job training.
The feeling of reality in such simulators, however, is still diminished by the fact that one has to hold the Wiimote and thus cannot mimic actions requiring finger movement. This shortcoming inspired us to explore “hand-free” scenarios with Wiimote and its applicability in e-learning.

Able to convey information through hand and finger movement enhances the e-learning experience in both the virtual classroom and the “hands-on” training simulators. Imagine that one can “touch/toggle” buttons on a virtual control panel in the same way as in real-life; one can move things by gripping and releasing; and one can flip the pages of a virtual book in the same way as one reads a real book. Wiimote, though not the first device facilitating such functionalities, represents a major step towards lowering the cost barrier.

In this paper, we piloted how Wiimote can be used in presentations involving a significant amount of gesture-based communication. Although not demonstrating the capacity of Wiimote in a full scale, we show how a simple extension to Wiimote can lead to significant improvement in usability.

2.3 Benefits of the Tracking Gestures Method

An additional benefit of using the tracking gestures method is the adaption of computers to users with special needs. This special group needs a much wider support for additional input channels than average users. The amount of information and the possibilities for communication are much more limited (e.g. hearing, vision problems). Consequently, there is a strong need to support end users with special needs by providing them with additional devices and interfaces, which enable them to work on an equal footing with average users (Debevc & Peljhan, 2004).

Gesturing, such as the "Go right" demonstration, involves sensing the direction in which a finger, or other object, is pointing. This achieves an economy in dialogue by substituting a pronoun plus a pointing gesture for a much longer string of words. Such methods are an essential example of Human–Computer Interaction, because they do not simply offer redundancy. Instead, the modalities supplement each other's information. When the speech part is uncertain, the system takes information from the gesture to support the decision about what was said (Edwards & Holland, 1992). A further benefit is that advanced multimodal user interfaces are becoming continually affordable due to the availability of low cost mass market interfaces, such as the Nintendo Wii gaming console (Nintendo, 2009), together with the wireless input device Wii Remote, or short: Wiimote. Together with the Wii sensor bar, these can detect motion and rotation in 3D through the use of accelerometer technology (Hofmann, Heyer & Hommel, 1998), (Wang, Yu, Shi & Li, 2008), (Lee, 2008), (Rehm, Bee & André, 2008). Separating the controller from the gaming console, the accelerometer data can be used as input for gesture recognition and this can be use for various new multimodal user interfaces (Schlömmer, Poppinga, Henze & Boll, 2008).

3 Methods and Materials

Following the research recommendations presented by Stephanidis & Salvendy (1999), (Stephanidis & Salvendy, 1999), we tested whether, and to what extent, the use of gestures during real life university teaching settings enhance the efficiency of lecturing as well as the learning in large traditional lecturing rooms. Apart from purely technological testing on site, we additionally used interviews and short questionnaires, supported by usability inspection methods and supported by additional video analyses (Brun-Cottan & Wall, 1995), (Holzinger, 2005).

3.1 Questions of Research

The following research questions will be answered within this paper: 1) What is the central advantage, for both teachers and students, of using intuitive interface devices such as a Wii remote controller? 2) How can such controllers enhance current e-Teaching methods? 3) What basic design considerations must be taken into consideration?

3.2 Design and Development of the Demonstrator Kit

As the main user interface device for our experiments, we used the Wii Remote Controller (Wiimote), which is equipped with a 128 x 96 monochrome camera (see figure 1) and an infrared (IR) pass filter in front of it. Additionally, Wiimote also includes an in-built processor (see figure 2) capable of tracking up to 4 moving objects at a frequency of 100 Hz. These features classify Wiimote as a very feasible sensor for infrared projection planes. The on-board 8x sub pixel analysis is used to provide valuable resolutions (up to 1024 x 768) for the tracked points. The IR pass filter detects reflecting sources up to a wavelength of 940mn with approximately the double intensity of equivalent 850 nm sources, however, does not resolve them very well at very close distances. The IR sensor alone, without the filter, can track any bright object. Additionally, the Wiimote includes a Bluetooth interface for communication, which enables it to connect to any Bluetooth compatible device.

Using the in-built features and adequate open existing source library, we aimed to implement communication, finger tracking and capturing of infrared reflections. Every infrared reflecting surface can be the used as a projection surface (computer screens, beamer projections etc.). A simple LED-array, made of long-range infrared light diodes, was used to enhance the range and the supported working distance.

This approach offers the possibility of interaction once the tracked movements – such as mouse movements, mouse clicks, selections or keyboard commands – are interpreted into the boundaries of the operating system. The implemented gesture recognition enables interaction, which enhances the learning and teaching process and information transfer between the participants.

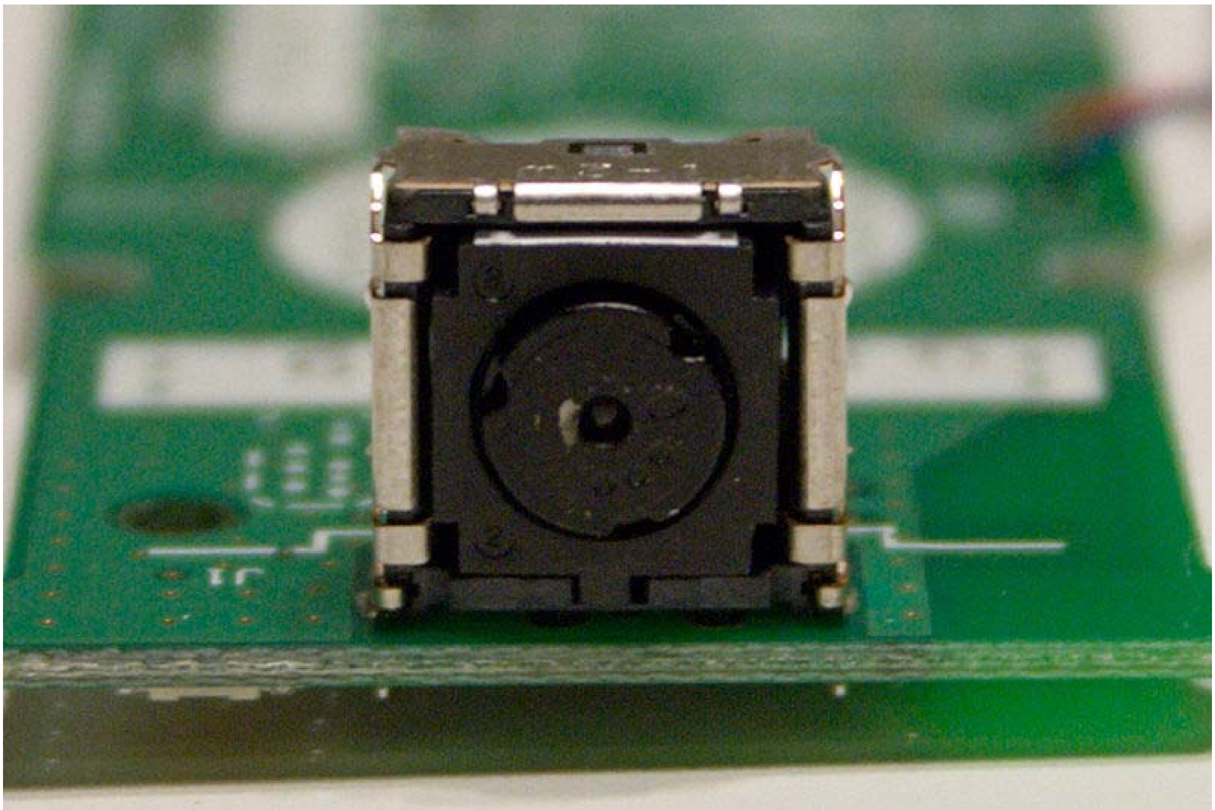

Fig. 1 Wii Remote IR Camera

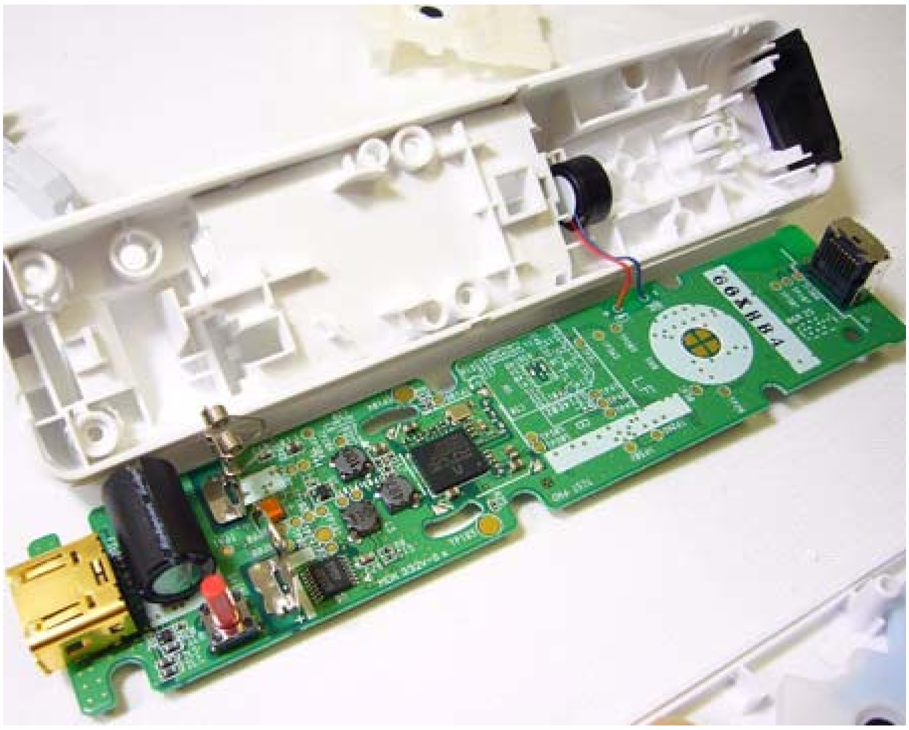

Fig. 2. Inside the Wiimote

In order to prove our assumptions, we developed a practical demonstrator kit, based on the Wii technology, which we used as support equipment for a test bed on multi medial teaching methods. This kit includes the Wii remote controller and an infrared diode array (IR LED array) as sensors and reflecting finger pads as interaction hubs. The reflecting finger pads are used as pointers and as interfaces for gestures, while the Wiimote itself is used in one of two tested setups in order to simulate a hand free mouse and an interaction tool on projected surfaces. For connection, communication and the parameterization of the hub, we developed a special demonstrator kit.

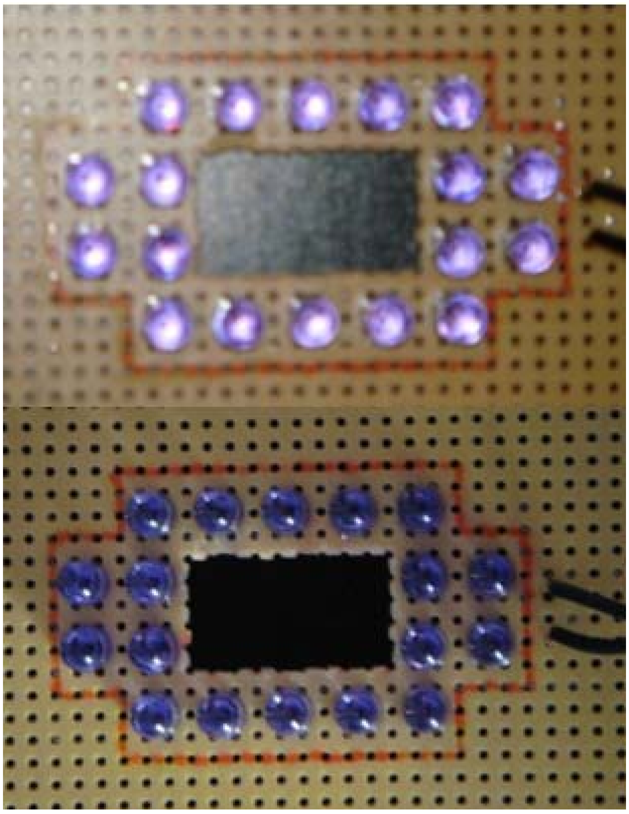

Fig. 3 IR LED array

3.3. Test Procedure Setups

We tested two different setups: in the first setup, the Wiimote served both as the capturing and the input device. The IR LED array, with its radiated IR field, was the static sensor reference. In the second setup, the Wiimote acted as a passive sensor field receiver enhanced by the radiation strength of IR LEDs array. The software component used to support these two setups is called *Wiimote Control Desk*.

The *Wiimote Control Desk* application was developed based on the code of Wiimote *Whiteboard*, originally programmed by *Johnny Chung Lee* as part of his experiments (Lee, Hudson, Summet & Dietz, 2005). Originally, it was intented for controlling and tracking an IR Pen using an IR sensor of Wiimote as a capturing device in order to simulate a white board. For the purposes of finger tracking and mouse remote control it was lightly changed and some features were added in order to achieve the new goals. The Wiimote Control Desk was implemented using the Visual Studio C# Express edition, which is freely available on the Web (Microsoft, 2008). It runs on the Microsoft's .NET Framework 2.0. The communication

inside relies on the Managed Wiimote library for .NET. The library was originally developed by *Brian Peek* (Peek, 2008). The Application Programming Interface (API) uses Bluetooth to communicate with the Wiimote and to retrieve and to handle the various states of the Wiimote components. The Wiimote is treated as an Human Interface Device (HID) compliant device when connected to a regular PC. The API uses the advantage of the P/Invoke mechanism. In general, there are two different ways to retrieve data from the API: using events or using polling. Our implementation uses the event based approach.
Hence, the Wiimote Control Desk can be operated corresponding to setups in two different modes:

- Controller mode
- Presenter mode

3.3.1 Controller Mode

The *Controller Mode* (CM) was implemented in order to use the Wiimote as a pointing and presenter device similar to a free hand mouse. The IR LED array was used as a capturing background device (see above and figure 3). For this controller mode, some of the Wiimote's standard buttons had been re-programmed to support the mouse-like functionality. This mode also uses the Wiimotes's buttons “A”, “B” and the navigator cross button. The button “A” emulates the left click of a mouse and the button “B” (at the bottom side of Wiimote) emulates the right click. Double click can be simulated by pressing the “A” button twice with a medium velocity. The “Navigator cross button” provides the mouse selection and, for example, the navigation of slides in Powerpoint presentations.
The object of the implementation of this controller mode was to use the Wiimote as both a pointing and presenter device, similar to a free hand mouse. An appropriate setup for the *Controller Mode* can be seen in figure 4.

3.3.2 Presenter mode

Finger tracking support requires the usage of a so-called *Presenter Mode (PM).* This mode enables the end user to navigate through presentation slides of a Powerpoint or similar presentation or any other application which supports the forward or back function based on keyboard events. Basically this is done by firing the left or right keyboard keys respectively to the relative position of the mouse cursor on the screen pointed through the finger tracking pad. Switching to this mode can be done manually only if the required prerequisite was satisfactorily fullfilled, otherwise the change will not be accepted. Usually the switching happens automatically when the application notices that the conditions are met. The prerequisite needed in our case is a running Powerpoint or any other presentation software. Mode migration is also signalized by the changing the cursor shape (cross direction cursor appears instead of arrow cursor).

A further section is available in addition to this Presenter Mode. This section is revealed by switching to PM and offers the possibility of configuring for trigger ranges of “left” (next) and “right” (previous) commands, intended for the navigation of the presentation's slides. The numbers in the text boxes represent the time ticks, for example one second lasts approximately between 25 and 50 ticks. Holding the mouse cursor positioned by the tracked reflecting finger pad for the length of time defined by the range of ticks boundary triggers the command to switch to the next slide or the previous slide, depending on where the last cursor position was tracked; on the left or on the right half of the screen. Changes of boundary parameters will be automatically saved and remain recallable in the configuration when the application is started next time. The appropriate setup for the *Presenter mode* can be seen in figure 4 and figure 5.

3.3.3 The IR LED Array

The IR LED array (figure 3) was built by application of the highly reliable SFH 485 IR Emitter Diodes built by Siemens (Siemens, 2008). The average wavelength at peak emission is 880 nm, which is quite adequate for the the Wiimote’s IR sensor. The IR LEDs array requires a constant 3V (1A) power supply. The main areas of application for this diode are remote controls, Hi-Fi and TV sets, video tape recorders and various sorts of dimmers.

4 Study Results Summary

The first tested setup considers finger tracking as a natural gesture interpreting method. The finger tracking setup consists basically of three main components: the IR LEDs array; the Wiimote and the Wiimote Controller Desk, as shown in figure 4 below.

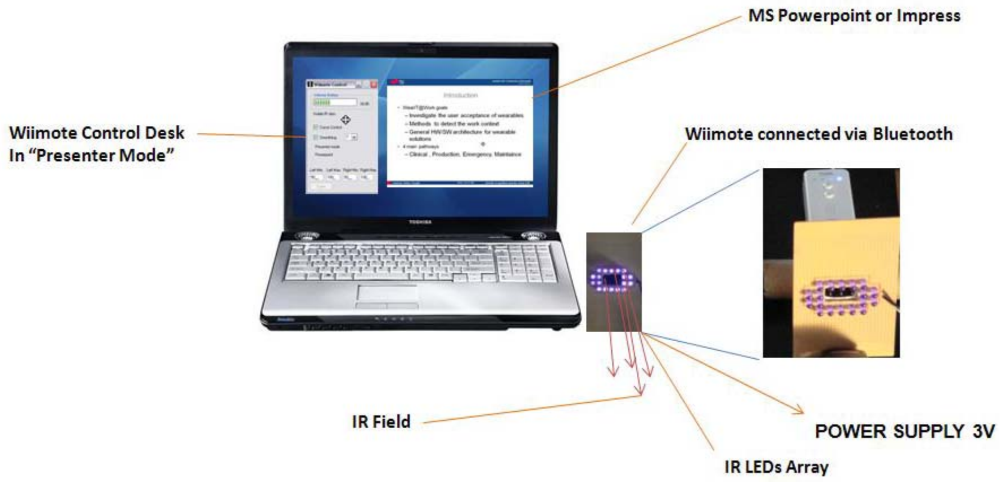

Fig. 4. Sensor setup for finger tracking

The IR LEDs Array radiates an IR Field towards the observer standing in front of the setup. The IR sensor of Wiimote is placed behind the array looking through the hole provided in the middle of board. In this way, the sensing area of Wiimote's sensor is enhanced by the strength of the emitter diodes in the IR LED array. This increases the area covered by the Wiimote, which would otherwise be too narrow.

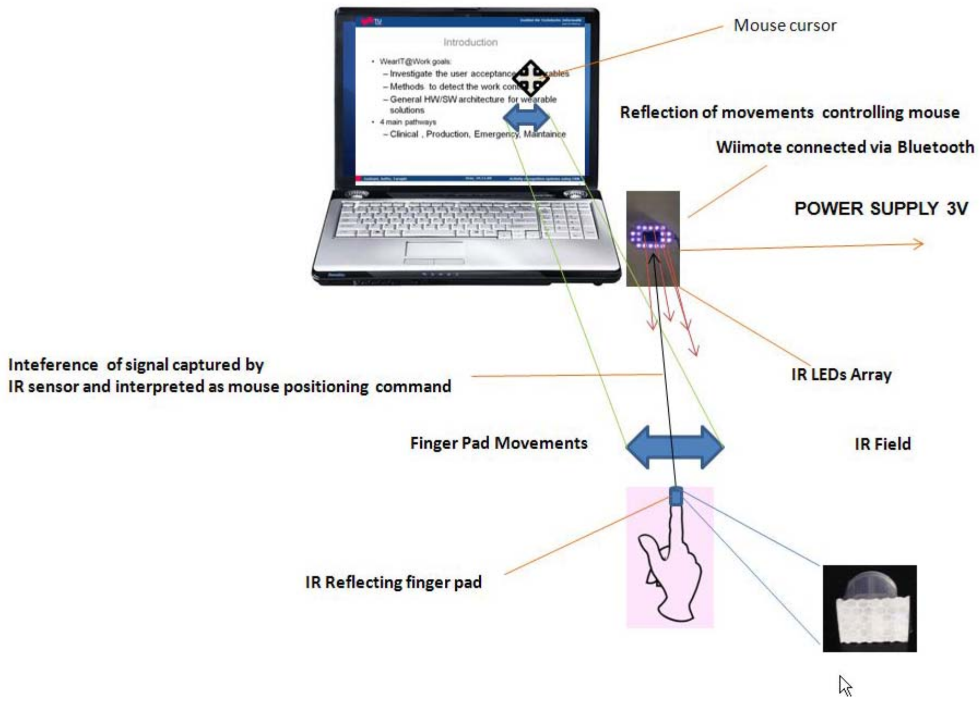

Fig. 5 Finger tracking in action

A reflective tape, commonly used with light barriers, was mounted on a standard bottle plastic cap as the reflecting device,. The finger pad used for sensing can be seen in figure 2. As part of the Wiimote Controller Desk implementation, the smoothing mechanism calculates and rejects the falsely sensed points in order to interpolate the movement of the single tracking path, thus smoothing out any unintentional tremors.
The bottom line of this setup is to set the appropriate position of the mouse on the screen, corresponding to the appropriate position of the reflective finger pad in the area covered by IR field. Depending on position and length of the appearance of the mouse cursor, *Wiimote Controller Desk* interprets the appropriate actions.

This setup is only actually used for navigating through presentations in MS PowerPoint or Open Office's Impress. After starting, the Wiimote Controller Desk software checks continuously at short intervals whether there are any common presenter applications, such as MS PowerPoint or Open Office's Impress running. In the case that an instance of these applications has been started, it switches automatically to "Presenter mode".

Bringing the reflecting pad into the radiation field of IR array activates the Wiimote IR sensor to recognize the reflecting point and its movement. The position of the finger pad is then interpreted and projected on the computer screen.

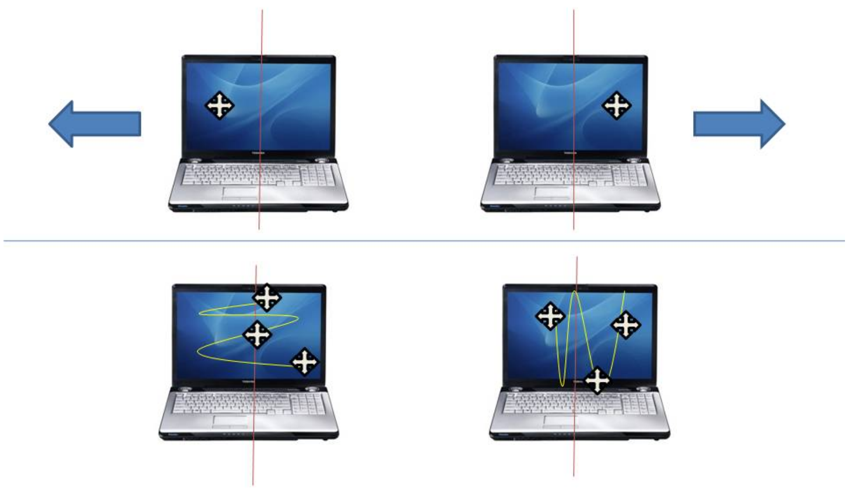

Fig. 6 Moving patterns

To simulate the “forward” and “backward” commands properly in a running presentation, it is necessary to calibrate the *Presenter mode* in the *Wiimote Controller Desk* by setting up the appropriate heuristic values for ticks ranges.

Switching slides can be triggered by holding the projected cursor on the right or left side of the screen for a defined time interval based on previous experience and then removing it from the field, e.g. by hiding or covering the reflecting area of the finger pad. Depending on where the cursor is detected, this is interpreted either as a command to switch to the previous slide (left half of the screen) or to the next slide (right half of the screen).

All other moving or positioning patterns and time intervals will only lead to a mouse pointing action. Both behaviors are depicted in figure 6. Provided the setup for using the Wiimote as a pointing and presentation input device is depicted in figure 7.

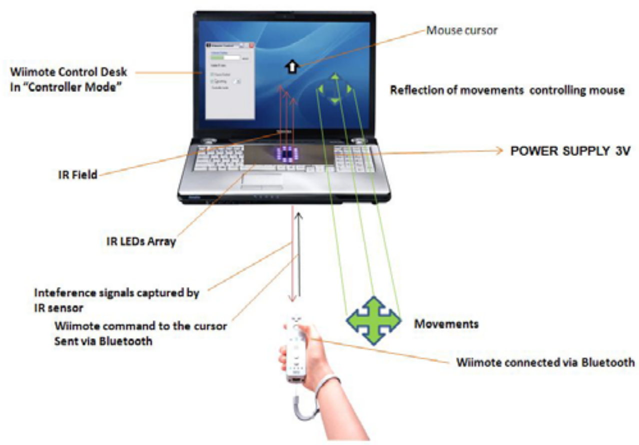

Fig. 7 Setup for using the Wiimote as a pointing and control device

Basically, the second setup consists of a IR LEDs Array positioned in front of the screen of targeting projecting surface. The field rays from the IR LEDs array should be aligned vertically upwards along the screen of the projection area. *The Wiimote Controller Desk* should be also up and running. Operating in this setup, the Wiimote can be used instead of a mouse, supporting all the basic mouse functions, such as cursor pointing, left click, double click and right click. Additionally, the navigation button enables the Wiimote to simulate the operations of the selection and forward or backward action of the keyboard arrow keys (e.g. when running presentations or image galleries).

The principle of the projection of mouse movements is very simple: The field vertical to the projection area radiated by the IR LEDs Array (here notebook display) represents a static reference to the moving IR sensor on the Wiimote. As long the Wiimote is moving, its perception of the constant IR field in front of the display deviates at the point of observation. This deviation will be recognized as an isolated IR signal and reported to the *Wiimote Control Desk*, which treats this information as an instruction to point the mouse on the appropriate place on the projection screen. The Wiimote's button "A" is used for the left click and pressing it quickly twice has the same effect as the regular double click of the mouse. Button "B", located underneath, triggers the right click.

In this way, Wiimote becomes a very handy mouse controller and pointing device with a wider range than the usual wireless mouse.

6 Conclusion and Future Work

Our demonstrator kit was used as a presentation tool during various lessons and practical lab sessions at Graz University of Technology. Moreover, it was used as an interactivity and cooperation tool during learning and discussion tasks using a visual tracking of mouse movements on electronically shared whiteboards. In comparison to the classic approaches, our method allows the *direct intuitive cooperation* between all participants within the learning process. Consequently, such an approach offers more comfort and provides more flexibility in everyday e-Learning and e-Teaching activities. Furthermore, there are no similar low cost product, which contain a higher or equal grade of interactivity and such a wide appliance area that would be as suitable for these purposes. Altogether, it can be emphasized that Wiimote is a fascinating collection of sensors that can be used for many purposes, even for recognizing gestures, and which can be adapted freely using adequate open source libraries available on the internet. Using Wiimote as a pointing and mouse device works well but demands more work in order to capture the mouse positions and moves more accurately. Using the approximation of motions could result in improved smoothing, an area which should be considered for future development considering area of application targeted. Future research will include the use of IR LEDs with a lower wave length to assess the achievement of a wider range and more accurate isolation of tracking points and increasing the number of

LEDs in the array, to see whether this increases their accuracy. The main area of research will be other methods of triggering commands. Using time as a base for command delegation shrinks the potential of possible operability range massively. Improving the personal gesture interpretation capturing the data from Wiimote's accelerometer should be also considered an important research issue.

Tracking general basic gestures relevant for e-Teaching and e-Learning tasks works stably for several meters (3-5 m) distance to Wiimote (depending on the light conditions and the position of Wiimote) with an enhanced radiation field as shown in the finger tracking example. While testing different setups, heuristic experience showed that placing the Wiimote beside the computer at a height between 1 and 1,5 m, and at an angle between 45-60 degrees, offered the best setup.

References

Brun-Cottan, F. & Wall, P. (1995) Using Video to Re-Present the User. *Communications of the ACM*, 38, 5, 61-71.

Collins, A., Brown, J. S. & Newman, S. E. (1989) Cognitive apprenticeship: Teaching the crafts of reading, writing and mathematics. In: Resnick, L. B. (Ed.) *Knowing, learning and instruction: Essays in honour of Robert Glaser*. Hillsdale (NJ), Lawrence Erlbaum, 453-494.

Cutica, I. & Bucciarelli, M. (2008) The deep versus the shallow: Effects of co-speech gestures in learning from discourse. *Cognitive Science*, 32, 5, 921-935.

Debevc, M. & Peljhan, Z. (2004) The role of video technology in on-line lectures for the deaf. *Disability and Rehabilitation*, 26, 17, 1048-1059.

Dick, P. K. (1956) Minority Report. *Fantastic Universe*, 4, 1.

Ebner, M. & Holzinger, A. (2007) Successful Implementation of User-Centered Game Based Learning in Higher Education – an Example from Civil Engineering. *Computers & Education*, 49, 3, 873-890.

Edwards, D. N. & Holland, S. (Eds.) (1992) *Multimedia interface design in education*, New York, Springer.

Gellersen, H. W., Schmidt, A. & Beigl, M. (2002) Multi-sensor context-awareness in mobile devices and smart artifacts. *Mobile Networks & Applications*, 7, 5, 341-351.

Hofmann, F. G., Heyer, P. & Hommel, G. (1998) Velocity Profile Based Recognition of Dynamic Gestures with Discrete Hidden Markov Models. *Workshop on Gesture and Sign Language in Human-Computer Interaction.* Springer-Verlag.

Holzinger, A. (2005) Usability Engineering for Software Developers. *Communications of the ACM*, 48, 1, 71-74.

Holzinger, A., Kickmeier-Rust, M. & Albert, D. (2008) Dynamic Media in Computer Science Education; Content Complexity and Learning Performance: Is Less More? *Educational Technology & Society*, 11, 1, 279-290.

Holzinger, A., Nischelwitzer, A. K. & Kickmeier-Rust, M. D. (2006), Pervasive E-Education supports Life Long Learning: Some Examples of X-Media Learning Objects. Online available: http://www.wccee2006.org/papers/445.pdf, last access: 2009-04-18

Klerfelt, A. (2007) Gestures in conversation - the significance of gestures and utterances when children and preschool teachers create stories using the computer. *Computers & Education*, 48, 3, 335-361.

Law, E. L.-C., Kickmeier-Rust, M. D., Albert, D. & Holzinger, A. (2008) Challenges in the Development and Evaluation of Immersive Digital Educational Games In: Holzinger, A. (Ed.) *HCI and Usability for Education and Work, 4th Symposium of the Workgroup Human-Computer Interaction and Usability Engineering of the Austrian Computer Society*. Berlin, Heidelberg, Springer, 19-30.

Lawson, D. R. (1969) Who Thought of It First? A Review of Historical References to Programmed Instruction. *Educational Technology,* 9, 10, 93-96.

Lee, J. C. (2008) Hacking the Nintendo Wii Remote. *IEEE Pervasive Computing,* 7, 3, 39-45.

Lee, J. C., Hudson, S. E., Summet, J. W. & Dietz, P. H. (2005) Moveable interactive projected displays using projector based tracking. *18th annual ACM symposium on User interface software and technology.* Seattle, WA, USA, ACM.

Microsoft (2008), Visual Studio C# Express edition. Online available: http://www.microsoft.com/express/vcsharp/, last access: 2009-07-09

Nintendo (2009), Wii Gaming Console. Online available: http://www.nintendo.com/wii, last access: 2009-01-25

Pavlovic, V. I., Sharma, R. & Huang, T. S. (1997) Visual interpretation of hand gestures for human-computer interaction: A review. *IEEE Transactions on Pattern Analysis and Machine Intelligence,* 19, 7, 677-695.

Peek, B. (2008), Managed Library for Nintendo's Wiimote. Online available: http://www.codeplex.com/WiimoteLib, last access: 2009-07-09

Peter, G. N. (1998) Risks of e-education. *Communication of the ACM,* 41, 10, 136.

Rehm, M., Bee, N. & André, E. (2008). *Wave Like an Egyptian - Accelerometer Based Gesture Recognition for Culture Specific Interactions*. The 22nd British HCI Group Annual Conference, Liverpool John Moores University, UK, BCS, 13-22.

Rhyne, J. (1987) Dialogue management for gestural interfaces. *SIGGRAPH Computer Graphics,* 21, 2, 137-142.

Robertson, J. & Howells, C. (2008) Computer game design: Opportunities for successful learning. *Computers & Education,* 50, 2, 559-578.

Roth, W. M. (2001) Gestures: Their role in teaching and learning. *Review of Educational Research,* 71, 3, 365-392.

Schlömmer, T., Poppinga, B., Henze, N. & Boll, S. (2008) Gesture recognition with a Wii controller. *Proceedings of the 2nd international conference on Tangible and embedded interaction (TEI 08).* Bonn, Germany, ACM.

Siemens (2008), 880 nm GaAIAs Infrared Emitters. Online available: http://www.alldatasheet.net/datasheet-pdf/pdf/45674/SIEMENS/SFH485.html, last access: January, 15, 2009

Stephanidis, C. & Salvendy, G. (1999) Toward an information society for all: HCI challenges and R&D recommendations. *International Journal of Human-Computer Interaction,* 11, 1, 1-28.

Thomas, P., Carswell, L., Price, B. & Petre, M. (1998) A holistic approach to supporting distance learning using the Internet: transformation, not translation. *British Journal of Educational Technology,* 29, 2, 149-161.

Valenzeno, L., Alibali, M. W. & Klatzky, R. (2003) Teachers' gestures facilitate students' learning: A lesson in symmetry. *Contemporary Educational Psychology,* 28, 2, 187-204.

Wang, Y., Yu, T. L., Shi, L. & Li, Z. (2008). *Using Human Body Gestures as inputs for gaming via Depth Analysis*. IEEE International Conference on Multimedia and Expo (ICME 2008), Hannover, GERMANY, IEEE, 993-996.

Wheeler, M. (2009) Developing the Media Zoo in Second Life. *British Journal of Educational Technology,* 40, 3, 427-443.

Zhang, D. S., Zhao, J. L., Zhou, L. & Nunamaker, J. F. (2004) Can e-learning replace classroom learning? *Communications of the ACM*, 47, 5, 75-79.