TECHNISCHE UNIVERSITÄT MÜNCHEN

LITERATURE SURVEY

MEDICAL AUGMENTED REALITY AND MEDICAL PERCEPTION

Comparison of 3D UI Input Techniques to Established Methods

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Abstract

With the fast-paced growth and increasing popularity of Augmented Reality, there is a need for input devices which can provide the possibility of interaction in a 3D user interface between human and machine. This paper aims to understand how the state-of-the-art 3D UI input devices work, and compare them to established input devices such as mouse, keyboard, joystick and so on. We have shortlisted a few input devices ranging over various modes of input, and compared them to devices which have a similar or related functionality. We have made use of various parameters such as efficiency, ease of use, cost of productions, error rates and so on, to make our comparisons.

1 Introduction

In Augmented Reality, interaction of humans with other devices, a three-dimensional space, or for that matter any virtual space is an essential component. A user interface makes this interaction possible, by acting as an intermediary between them. For seamless interaction between human and the machine, we need input devices to capture and interpret the actions performed by the user. Among other things, the input device should be able to know the relative position and distance of the user. Different input devices can be distinguished based on the extent of their interaction with the user.

Usually, most alternative input devices which are proposed solve specific tasks which the conventional input devices like mouse, keyboard cannot perform. The success of a new input device depends on various factors, some of which we discuss in this paper.

2 Methods for 3D UI Techniques

2.1 Wii Remote for 3D Input

2.1.1 Introduction to the Wii Remote

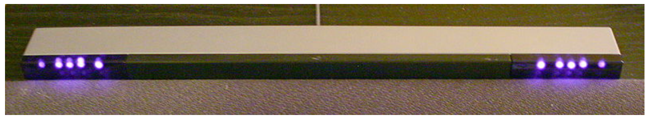
The Wii Remote, also known as the Wiimote, is the primary controller for Nintendo's Wii gaming console. The Wii Remote works by using motion sensing capabilities, which allows the user to interact with and manipulate items on screen via gesture recognition and pointing through the use of accelerometer and optical sensor technology.

The Wii Remote introduced in April 2006 assumes a one-handed remote control-based design instead of the traditional gamepad controllers of previous gaming consoles. This was done to make motion sensitivity more intuitive, as a remote design is more fitting for pointing, and in part to help the console appeal to a broader audience that includes non-gamers. The body of the Wii Remote measures 148 mm (5.8 in) long, 36.2 mm (1.43 in) wide, and 30.8 mm (1.21 in) thick. The Wii Remote comes with a wrist strap attached to the bottom to ensure the safety of the device. This is done in order to avoid the remote slipping from the grip during erratic movements.

2.1.2 Wii Remote - Input Sensing Features

The Wii Remote has the ability to sense acceleration along three axes through the use of an ADXL330 accelerometer. The Wii Remote also features a PixArt optical sensor, allowing it to determine where the Wii Remote is pointing.

Unlike a light gun that senses light from a television screen, the Wii Remote senses light from the console's Sensor Bar, which allows consistent usage regardless of a television's type or size.



The Sensor bar as shown above may be placed above or below the television, and should be centered. If placed above, the sensor should be in line with the front of the television, and if placed below, should be in line with the front of the surface the television is placed on. It is not necessary to point directly at the Sensor Bar, but pointing significantly away from the bar will disrupt position-sensing ability due to the limited viewing angle of the Wii Remote.

Because the Sensor Bar also allows the Wii Remote to calculate the distance between the Wii Remote and the Sensor Bar, the Wii Remote can also control slow forward-backward motion of an object in a 3-dimensional game. Rapid forward-backward motion, such as punching in a boxing game, is controlled by the acceleration sensors. Using these acceleration sensors (acting as tilt sensors), the Wii Remote can also control rotation of a cursor or other objects

2.1.3 Wii Remote - Comparison to Traditional 3D Input Techniques

We compare the Wii Remote to conventional input devices like the mouse and joystick. The choice of mouse and joystick is dictated by the fact that both the devices lye under the umrella of gaming and pointing devices.

The following table shows a list of parameters and our comments on comparing it with the conventional input devices.

Ease of Use The IS-900 precision motion tracking device is a hybrid tracking system, using slower ultrasonic triangulation data to update faster accelerometer data. It is commonly used for 3D tracking, is robust, and is fairly accurate for most 3D tracking issues. Wingrave et al. 2010 mention in their works that IS-900 is much more accurate and useful than the Wiimote because it gives 6-DOF information without any user-required computation. However, it has cables connecting the tracked receivers to the IS-900 box, which can become entangled when the user jumps, spins, and moves his or her arms and legs. The IS-900 has a wireless option, but this still requires a short cable connecting the tracked receiver to the belt-mounted wireless emitter.

Cost The Wii Remote currently costs USD 40 on amazon, which is very cheap when compared with joysticks which are in the same range of cost. However, the conventional keyboard (USD 20) and mouse (USD 15) can still win over the Wii Remote in terms of cost of production and selling. Since these devices use faily simpler technology than the Wii Remote. Wingrave et al. 2010 show that the cost of WiiRemote is only around USD 40 while 3D Connection SpaceExplorer mouse and InterSense 15âĂŞ900 tracking device cost atleast a few thousand dollars.

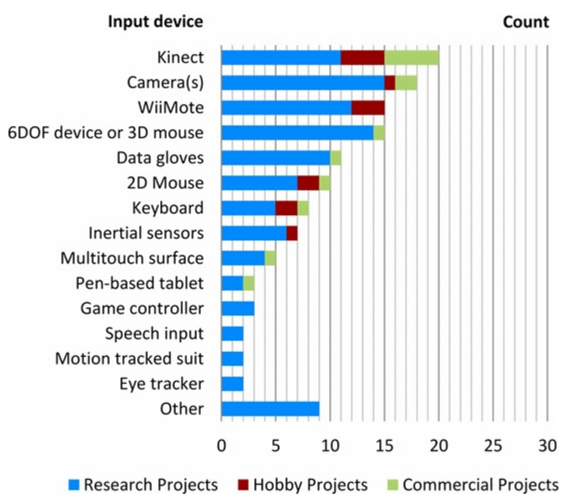
Accuracy and Speed Zaman et al. 2012 present two studies of navigation and object manipulation in a virtual supermarket. The first study compared a mouse and keyboard setup to a game hardware setup using a Wii Remote, Wii Balance Board and a dancemat. The second study used more game-like software interfaces for both conditions and used only the Wii Remote and Nunchuk in the game-hardware setup. The mouse setup was around 36% faster in both studies. In the first study the mouse setup was 98% more accurate; no difference in accuracy was found in the second study.
Among 12 participants, the mouse (mean 159 s) was faster than the Wii condition (216 s) on all trials of selecting and moving objects in a super market simulation. However, the authors speculate that with training, performance showed by the two devices may eventually match, as the users become more expert.

Optimality for 3D UI Interactions Gallo and Ciampi 2009 show that 3D user interface for exploring medical data can be developed using off-the-shelf wireless data glove equipped and LEDs tracked by a Wii Remote, which is able to provide accurate positional information with no need for further six degrees of freedom position trackers. SUch an interface is not possible by using established methods like 3d mouse, keyboard. A joystick can be one alternative but it limits the degrees of freedom.

Robustness The Wii Remote is designed for durability. Wingrave et al. 2010 describes that a similar 3D tracking device InterSense-900 can't withstand the types of impacts a Wiimote can withstand. Stomping the feet, quick punches, and tapping the IS-900 receiver against something else would break the relatively fragile receiver.

Degrees of freedom (DOF) The Wii Remote has a linear 3-axis accelerometer which does not provide it 6 DOF. However with an addon device called Motion Plus, the WiiMote is given a gyroscope which allows for 6 DOF. The 3D Connexion SpaceMouse Pro is a mouse which features 6-Degrees-of-Freedom (6DoF) but with a price tag of USD 400 it is a very expensive option when compared to the WiiRemote.

Preferred by Audience A survey of 3DUI applications and development challenges by Takala et al. 2012 shows the most common input devices among 56 reported 3DUI applications. This figure taken from their research shows Wii remote or WiiMote as one of the most popular input device among developers.



Fatigue Kim et al. 2011 found that fatigue for virtual tasks that use greater motion was higher than that of a mouse for example which uses limited motion.

2.1.4 Limitations of the Wii Remote

Wingrave et al. 2010 have described a few limitations of the Wii Remote. The Wii remote's inability to detect actual position change lets users make only small or limited "waggling" motions, which the Wiimote interprets as full movement. The result is boxing games played by tapping the Wiimote, tennis games played with wrist flicks, and many games winnable by simply moving the device randomly. Although this is still fun for gamers, it limits the Wiimote's utility for 3DUIs and exercise and health gaming, unless you employ better hardware and data-interpretation methods.

By careful manipulation of the 3D UIs, users' tasks and their goals, the shortcomings of the hardware can be avoided. For example, consider the inherent drift in Wiimotes. You can compensate for the drift by requiring the game player to return to a "rally point" from which you can assume the Wiimote's orientation, or require to point the remote to an on-screen button to begin a task.

Nintendo designed the Wiimote for use with a console device. When used in 3DUIs as a camera, Wiimotes are often mounted in the environment, usually up high or at specific orientations, so that they can observe IR-emitting LEDs. Consequently, changing batteries or hitting the Sync button becomes a problem.

2.2 Gaze and Gesture based Input

Gesture-controlled and Gaze-tracking devices can act as more generalised alternatives to a traditional mouse for point-and-click tasks. Although they provide greater and more seamless access to information for more users in more environments, they have their own limitations which need to be looked at. The mouse works with a simple concept of pointing and clicking with which a considerable amount of human-computer interaction can be described. The longevity of the computer mouse has led most user interfaces to be built mouse-driven. Hence, these newer devices need to be built so they are adaptable to existing systems. The mouse has been a preferred device for many years despite being a comparatively non-intuitive device, which provides an edge for newer intuitive devices. In this section we look at Leap Motion Controller, which is a gesture-based device, and The Eye Tribe, which is a gaze-tracking device. Later, we also come describe an approach of combining both these techniques which provides a much better performance.

2.2.1 Leap Motion Controller

Leap motion sensor is relatively quite new in the market as a product however it was first developed in 2008. The first product was publicly announced on May 21s, 2012 as 'The Leap'. Leap Motion sensor is a USB based peripheral input device which is small in size [Size: 0.5" (H) x 1.2" (W) x 3" (D)]. The device is designed to be placed on desktop where as it also has a modular kit that can be attached to a head wearing device such as Oculus rift or HTC Vive etc.

Figure 1: The Leap Motion Sensor ; Image courtesy : leapmotion.com

The device consists at its core two monochromatic IR cameras and three infrared LEDs that track infrared light roughly within a hemispherical area of wavelength of 850 nanometers (not within the visible spectrum), to a distance of 80 cm. The three LEDs generate an IR pattern-less light whereas the cameras generate reflected data of around 200 frames per second as shown by Weichert et al. 2013.

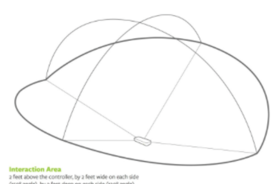


Figure 2: The Leap motion sensor's operational area; Image courtesy : leapmotion.com

This data is sent to via USB cable attached to the computer where this data is analyzed by the Leap Motion software using what is called "complex maths" since the algorithm has not been disclosed by the company. Thus the 3D position data is synthesized in some way by the comparison of 2D frames that are generated by two of its cameras. Since the Leap Motion Controller is a gesture device, it senses all the natural movements of your hands and therefore you can interact within a 3D or 2D environment in a whole new way. Some of the gestures you can do are point, wave, grab, reach. You can pick something up in a scene or move it, you can use your gestures within an Augmented reality environment to use a 3DUI effortlessly. Since the controller tracks all 10 fingers up to the accuracy of 0.70 millimeters as shown by Weichert et al. 2013, it's quite precise and sensitive. This gives you the ability to easily navigate through websites and maps, draw high precision drawings etc.

Figure 3: The Leap motion sensor on a desk ; Image courtesy : https://cnet2.cbsistatic.com

As we are doing a comparison of the Leap Motion Controller with the traditional input devices such as the trackball, mouse and trackpad it should be noted that this controller doesn't replace these devices rather works with them and doesn't need any special adapters. However depending on the use it can replace a lot of functionality and makes it more intuitive. Since we are focusing on 3DUI hence this controller is very useful because of the 3D tracking of fingers and can be used an input within an Augmented or Virtual Reality environment [Daniel 2012]. Now we will look at the traditional devices beginning with the trackpad and the mouse. Both are pointing devices and come with similar technology with some differences. A mouse has a trackball (older technology) or has a laser for tracking whereas the trackball has a large ball held in a socket that contains sensors to detect the rotation of the ball in two axes [MacKenzie and Oniszczak 1998]. The trackball is more like an upside down mouse which gives more advantage compared to a mouse. Since mouse has limited travel depending on the cord length and in other cases the work table's free space, it can travel as far as its limits. However trackball doesn't have any limits on effective travel. Comparing these two devices, the Leap Motion Controller has a limited operational area hence it's not that efficient when it comes to doing tasks such as CAD work, browsing web pages etc. as quick as with the traditional devices. Whereas we can see that trackball and mouse can only be held by one hand and a few fingers are required to push the buttons on the devices. A mouse has more ergonomics than a trackball and it can be tiring for an operator to use a trackball for a longer session and also because of the buttons are hard to access. In the leap controller one doesn't have to hold anything as the fingers are in the mid-air where you can use all of your fingers to operate, hence there is no stress on the wrist and it will not make the operator get tired. Another aspect is that the controller doesn't need much space at all whereas the mouse requires free space to travel and trackball also occupies some space. The touchpad is also a pointing device that is based on tactile sensor technology. It also tracks data in 2D space (two axes) and track fingers to a relative position on the output screen. Touchpads are quite common feature of laptops, notebooks/netbooks etc. The touchpads don't require much space but have a very small operational area. Hence a user need to swipe fingers multiple times to travel distance over the screen, especially if the resolution is high. It also cause wrist sprains for longer session. The traditional input technologies come at a small cost yet they still are able to do most of the everyday tasks within a 2D space/screen. A mouse costs in the range of 4-79 euros depending on the basic and advanced features as well as resolution. Higher resolution mice are quite often used in CAD software or for gaming. The trackpad comes with laptops and some new keyboards however it's not a product that is popular as an external device. The estimated cost of this is around 80 euros. Although the trackball is quite old technology but it is still available today at quite a decent cost of 25 euros. The Leap Motion Controller has the price tag of 70 euros. Hence we can see that Leap Motion is quite an affordable device.

Comparison parameters	**The Leap Motion Controller**	**Trackball**	**Mouse**	**Trackpad**
Ease of Use	Free and natural movement of arms and hands	Trackball is moved with fingers without the motion of hand	Need to move with hand and needs free desk space	Only tracks tactile motion of fingers. The least ease of all

Cost	70 euros	25 euros	4-79 euros	80 euros (not available as a separate product)
Accuracy	1/100th of mm	1000 pixels motion per inch	1000 pixels motion per inch	
Ease of Development	SDK is provided	Plug and Play Device	Plug and Play Device	Plug and Play Device
User Experience	Average	Very good	good	Average
Suitable Task	All type of 3D interaction in AR/VR Environment	2D tasks (Web browsing, CAD work etc.)	2D tasks (Web browsing, CAD work etc.)	2D tasks, (basic navigation and browsing, not suitable for professional software)
Axes	3	2	2	2
Fatigue	No Fatigue but long term use can result in fatigue	Fingers	Wrist	Fingers and Wrist
Performance	Good	Good	Very Good	Average

Table 1: Comparison Table

The Leap Motion Controller has been used for quite many applications already. An interesting article reviews the use of this controller for intraoperative touchless control of diagnostic and surgical images by a surgeon and 3D surgical plan hence it allowed the maintenance of sterile conditions [Rosa and Elizondo 2014].

2.2.2 The Eye Tribe

The Eye Tribe gaze-tracking device is an alternative input device that approximates the location of a user's gaze. It makes use of a high-power LED light source and a high-resolution camera. The location of the user's gaze is calculated by extracting information from the person's face and eyes. The coordinates of the eye gaze are calculated with respect to the screen in a 2-dimensional space. In order to track the user's eye movements and the on-screen gaze coordinates, the tracker is placed below the screen, pointing towards the user as shown in the illustration below.

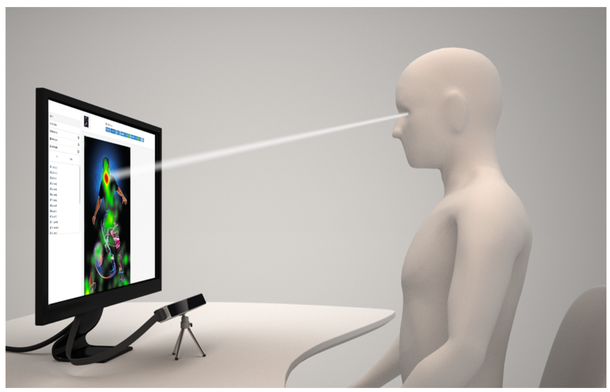


Figure 4: User in front of an eye tracker
Image courtesy: http://dev.theeyetribe.com/general/

Usually a device equipped with an eye tracker can be combined with other input devices such as mouse, keyboard, touch and gestures. There are a wide range of applications from games to navigation to research studies that benefit from eye tracking.

A major disadvantage which comes with the Eye Tribe is that, it requires calibration for individual users. However this calibration is a one-time process and is usually brief, and there are no other requirements from the user. A great plus point is that, this device is sold as a development kit for a price comparable to computer mice.

Eye tracking application can be active or passive. Active applications enable users to use their eye movements combined with other conventional input devices to control an application or device, hence creating a more natural and engaging interaction. Eye tracking can also be used passively to collect eye-gaze data of customers which can be used for analysis to improve a certain application.

Eye movements can be either fixations - which occur when we look at a specific point, or saccades which occurs when there is a quick, simultaneous movement of both eyes. By combining the information of these two actions, a heatmap is created which highlights the regions that attracted most interest from the customers.

Following are some specifications of the device.

Sampling rate	30 Hz and 60 Hz mode
Accuracy	0.5° (average)
Spatial resolution	0.1° (RMS)
Latency	$<$ 20 ms at 60 Hz
Calibration	5, 9, 12 points
Operating range	45 cm - 75 cm
Tracking area	40 cm × 30 cm at 65 cm distance
Screen sizes	Up to 24 inches
Dimensions	20 × 1.9 × 1.9 cm
Weight	70 g
Connection	USB 3.0 Superspeed

Table 2: Specifications of the Eye Tribe

2.2.3 A Comparison with Established Devices

Canare et al. 2015 performed experiments with the EyeTribe as well as the Leap Motion Controller along with the standard mouse, inorder to draw comparisons between these devices. The Fitts's law is used to model the act of pointing, either by physically touching an object with a hand or finger, or virtually, by pointing to an object on a computer monitor using a pointing device. The Fitts-derived index of performance (IP) is a metric which combines a task's index of difficulty (ID) with the movement time (MT, in seconds) in selecting the target. This index is used by various researchers to compare the performance of especially gesture and gaze based input devices. More specifically, the index of performance is calculated as a ratio of the difficulty of a trial to the amount of time required to complete it.

$$\text{performance} = \text{difficulty} \; / \; \text{movement time}$$

The difficulty is defined below, and is a function of the size of the target and distance from the initial point to the final point.

$$\text{difficulty} = \log_2(2 * distance/size)$$

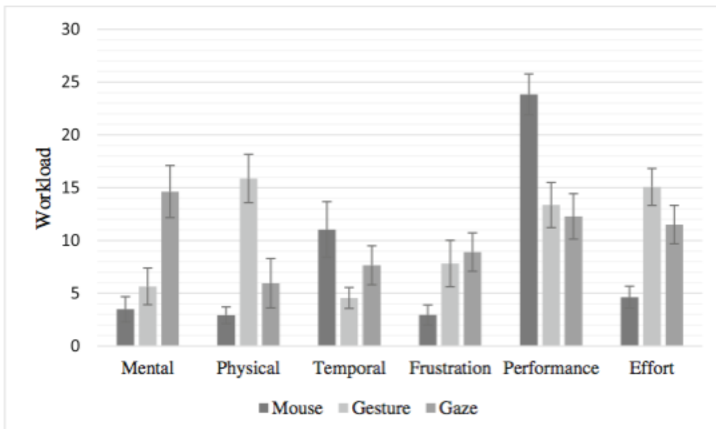


Figure 5: Experimental Results ; Courtesy: Canare et al. 2015

- **Performance**: The results of the tests performed by Canare et al. 2015 show that the performance of gaze-tracking devices was significantly low compared to that of mouse. Also, the number of miss-clicks encountered by the gaze-tracking device was quite high. Although the performance is inferior to that of the mouse, it is noted that the participants undertaking the experiment were able to complete the tasks, and is remarked that since it was the first time the participants were using their devices, it is possible that the performance may improve with practice.

- **Ease of Use**: It makes use of the user's natural movement of eyes. There isn't much workload on the physical front while using the EyeTribe unlike the mouse. However, there seems to be some sort of mental workload that comes with it.

- **Cost**: The developer version of the EyeTribe is being sold at 99$ which is a big deal, considering that most eye tracking devices at the moment cost around 20,000$. This price is actually comparable to the price of high-end keyboards and mice.

- **Accuracy**: Compared to both mouse and gesture-based devices, gaze-tracking devices tend to have a significantly low accuracy with a very large number of miss-clicks, as per the experiments conducted by Canare et al. 2015.

- **Ease of Development**: The device is compatible with the latest operating systems of Windows and OSX, and is in the process of working on support of Android. The developer kit is being sold which uses C++, C# and Java programming platforms.

While the results are not exactly in favor of quick adoption of these devices, it does show that they have great potential. An interesting possibility to consider, is the combination of more than one input devices, which is discussed in the next section. Here we observe that the combination of gesture and gaze-tracking devices produces exceptionally good results for performance.

2.2.4 Gaze+Gesture

Chatterjee et al. 2015 proposed a gaze plus free space gesture approach to enable more intuitive and touch free interactions. Gaze-alone systems are well suited for rapid and absolute pointing, but face issues of imprecision. Whereas gesture-alone systems are slow for pointing but their strength in gesturing can be used to trigger a wide variety of functions. Thereby, fusing these two approaches, it is shown that one can enable much more natural interactions.

Figure 6: (A) User is working. (B) User looks at window they wish to move. (C) User performs a grab gesture, after which the window tracks with the hand until (D) the fist is released ; Image courtesy : Chatterjee et al. 2015

Chatterjee et al. 2015 use two metrics to decide whether to use a gesture input or perform gaze tracking. They break down all inputs into a taxonomy, divided by

- **Size of Target** : Whether it is above the eye tracker's accuracy threshold or below it
- **Type of Action** : Discrete hand pose such as menu item selection or continuous manipulation such as moving a window, or drag-and-drop

For interactions with objects which are smaller than the threshold of the eye tracker, there is a need for a gesture input to aid the understanding of what the user wants to input.

Chatterjee et al. 2015 conducted a user study, and its results show that gaze+gesture can outperform gaze or gesture only systems, and approach the performance of established input devices.

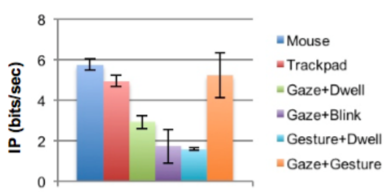


Figure 7: Index of Performance by input method

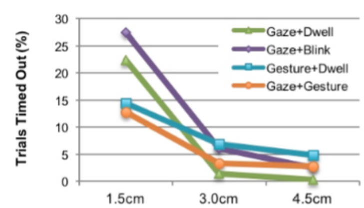


Figure 8: Percentage of timed-out trials by target size

Image courtesy : Chatterjee et al. 2015

The Fitts-derived index of performance (IP) is assessed and Figure 7 shows a significant difference between the performance of gaze+gesture with other new approaches. Figure 8 shows the scalability of these approaches when the target size is reduced. As one would expect, the percentage of trials timed out increases as the target size decreases. As the size increases from 3.0cm, we observe that the error rate is significantly low in all cases. However, as the size decreases, we observe a lesser error rate for gaze+gesture compared to other approaches.

2.3 Haptic Devices

2.3.1 The Virtual Mitten

The Virtual Mitten introduced by Achibet et al. 2014, is an elastic handheld device which uses a visuo-haptic interaction paradigm. The device provides a passive haptic feedback through the fingers which is directly correlated with the grip force applied on the device. The grip force exerted on the device helps in grasping objects and achieving various manipulations. To perceive different levels of effort put in the grip by the user, a pseudo-haptic effect is also introduced.

Figure 9: The Virtual Mitten; Image courtesy: Achibet et al. 2014

This device is used for simulating 3D manipulation of virtual objects. It provides a natural way of interacting with the interface, by giving users an extended freedom of movement, compared to to other rigid devices such as mouse and joystick. What sets this device apart from other established and generic input devices is that it can distinguish different levels of effort of grip. Achibet et al. 2014 have performed a user study, the results of which show that the device allows participants to manipulate virtual objects in various tasks, such as pulling a drawer, screwing a cylinder and so on. Hence, it could be used in a wide variety of applications such as video games, virtual prototyping and virtual training.

2.3.2 DesktopGlove

DesktopGlove, introduced by Achibet and Marchai 2016 is a more sophisticated haptic device, which facilitates multi-finger haptic interaction with virtual objects. This device is a combination of two affordable haptic devices into a bimanual setup proposed instead of expensive exoskeletal data gloves. In this setup, one hand commands the motion of the virtual hand while the other controls its fingers for grasping. The basic idea is to separate the degrees of freedom of one virtual hand between both hands of the user.

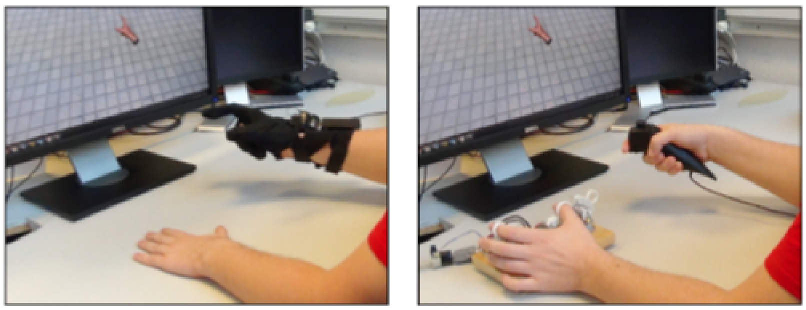


Figure 10: DesktopGlove in comparison to a data glove; Image courtesy : Achibet and Marchai 2016

Based on the user studies conducted by the authors, it is observed that DesktopGlove shows an overall better performance compared to a typical data glove, and is preferred by users. Although the device doesn't seem to be quite intuitive in its handling, it looks like once users have got the hang of it, they consider the separated haptic feedback quite realistic and accurate for manipulating objects in virtual environments.

2.3.3 EEG Headsets

Electroencephalography (EEG) is an electrophysiological monitoring method to record electrical activity of the brain. It is typically noninvasive, with the electrodes placed along the scalp. Electroencephalography is by no means a new technology; first used to record the electrical activity of a human brain by Hans Berger in 1924. EEG measures voltage fluctuations resulting from ionic current within the neurons of the brain. These brain waves can tell the system what you want to do in for example your augmented reality world. In other words, you think "lift," and a virtual rock actually levitates on the screen.

Using EEG a Brain-Computer Interface (BCI) can be developed. Today several companies offer headsets that can read the EEG signals and connect it to a computer which can take actions based on them. One such application can be a 3D UI where a user can navigate through the system using his thoughts. A modern EEG device made by Emotiv is shown below:

Figure 11: Two models of the Emotiv company's EEG headsets; Image courtesy: Emotiv.com

The EPOC utilizes 3 Suites for detection of different signal inputs: Expressiv, which reads facial expressions; Affectiv, which reads the user's emotional state; and Cognitiv, which reads conscious intent for movements.

A recent work by Shankar and Rai 2014 present a human factors study on the use of an Emotiv EEG BCI headset for 3D CAD modeling which is quite similar to controlling a 3D UI. The study focuses on substituting the conventional computer mouse- and keyboard-based inputs with inputs from the Emotiv EEG headset. Five human users were trained to use the EEG headset to create the CAD models. The results of the study showed a learning curve that displayed a peak at the most difficult task. However 80% of the participants demonstrated significant improvement which was indicated by a reduction in time to construct the test model. The author's observations indicate that despite the lower learning curve and users' adaptability to the interface, EEG-based signals were sometimes hard to classify. This could be eliminated by creating more robust classifiers. The reliability of the system degenerates when more than two cognitive actions are involved. The participants also experienced fatigue that could be ascribed to the headset configuration and design. This could be rectified by using BCI headsets that are more ergonomic like the Neurosky mindwave or InteraXon Muse. The human factors study results presented in the paper were based on a small group of users. In future, the authors suggest, a more extensive user study should be performed to get a better understanding of the interface usability. Another future research direction will be to improve the usability of the presented interface by integrating BCI with other modalities such as speech and gestures.

At a developer price of $299, the Emotiv EPOC is the first EEG designed for public usage. This price brings EEG headsets in competition with traditional 3D UI Input devices such as 3D Connection SpaceExplorer mouse which costs around $436. Although the Emotiv EPOC has difficulties of setting it up and using it compared to existing 3D UI input techniques, it is a rapidly advancing device which will soon catch up in terms of portability, robustness and user customization giving us hope for future 3D UI Input techniques using EEG to evolve.

3 Conclusion

We have discussed several input techniques and compared them to established methods. Each of the input techniques has its pros and cons. Some maybe cost efficient while others more suitable for specific kind of tasks. While today we have a wide variety of devices available for 3D UI Input, there is still room for a lot of improvement before we can see a definitive long term solution like the conventional mouse that has stood ground for decades as a standard technique for 2D interfaces.

The presence or the lack of DOF, accuracy, cost, ease of use, ease of development, fatigue and performance are some aspects we looked at. A closer investigation of people's use of dominant and non-dominant hands during interaction with 3D UI can also be an interesting factor to analyze. Ultimately, however, a further extension to the review can be to examine how to best create a 3D UI that allows one to fluidly switch between different interaction scenarios and interaction environments - and then picking the best technique based on a particular task or situation.

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