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An overview and evaluation of modern human interface devices

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1 Introduction

The man-machine interface has always been an important part of technical devices. Especially general purpose computer systems (like personal computers, workstations or notebooks) need reasonably designed human interfaces, providing a barrier-free environment in which the user may perform any intended task. The text below will try to define what "reasonable design", in the given context, is and take a look at some well established devices, but also at the manifold promising developments. As covering every single application of human interface devices would go far beyond this document's scope, we will focus on ordinary everyday computer-aided work like reading and writing mail, drawing, managing stored data or surfing the Internet. Occuring devices, which might seem not to fit that mold, are only mentioned because they represent entire categories, that can't be clearly separated from, or might, in the future, have great effect on our focus.

2 Well established devices

We will roughly walk through the classical input devices, that have been in use for a long time. For a more detailed overview check the reference table [1]. Ignoring punchcards and related antiques, we will start with the keyboard. This input device has developed from the typewriter, what also implies it's main purpose. Writing text. Even in the time of graphical user interfaces (GUIs), a computer can barely be used without. It's high efficiency (every keystroke carries information), flexibility (combinations of certain keys imply specific operations) and accuracy (keys can't be maybe-stricken) make it a

very powerful tool for both commanding computers (like in using a shell) and massively feeding data (e.g. writing text). But being able to unleash this power, the user must pass through the slow and learning proceedings of typing.
Yet, even having mastered this challange, one will do very poorly in particular tasks like drawing or freely arranging objects, displayed at the screen. This is where pointing devices come into play.
The most common interface in that family is the mouse, which's functional priciple I asume as known. As it's cursor is entirely detached from the keyboard's input, it may, instead of replacing it, serve as an expansion. With the advent of graphical user interfaces, programms became easily controlable. The user does not have the read a manual, describing the effects of keyboard commands. Features can be described on top of the buttons, which evoke them.
The mouse's closest relative is the trackball, which has the major advantage of being independent from a planar surface to operate on. Graphics tablets, are just another pointing device, but are, in the first place, even more intuitively to use for anyone, who has ever been holding a pencil and, secondly, allow the user to encode additional information (like a drawn line's width) in the amount of pressure, applied to the pad.
The major disadvantages of all these pointing devices is their lack of mobility (crucial in today's world of mobile computing) and the low informational throughput. Appliying only one single hand's mostly gross motions in 2 dimensions and, in clicking, one of the fingers' most basic operations, the user needs to run through many little, time-consuming actions, to perform one complex task like for example readjusting a diagram's multiple boxes independently.

3 Promising devices

Being aware of the grievance, scientists have consistently come up with new, promising ideas of how man-machine interaction might be improved. In the following, I will, from an overviewing perspective, give an account of what technology they have come up with, and in how far resulting devices are different from the traditional ones, described above.

3.1 voice processing

One of the oldest ideas in man-machine interaction is, that one day, computers might be able to "understand" what we will be telling them. A lot of research, in that field, has been, and still is being, done. Although we still are far away from computers, that can be "aware" of what is said, voice processing is very common, in areas like telephony, but, not in productive day-to-day computing. There is even an open source project called *Sphinx* [2]. Such input software, that could help blind people, still is very fault-prone (for example in discriminating ideophones). Furthermore this way of input implies the use of sound, what may be not suitable in certain situations, like in places, where multiple people work independently with their computers, and so would cause great noisiness.

3.2 oberserving the user

A silent way of feeding data to the computer, is using direct visual input observing the user with a camera. There are two major applications of this. One is eye tracking. The user controls the cursor by simply looking at where it is supposed to point at. Clicking operations may be performed by twinkling. The key problem here is, that one can not not interact with the machine. For example, consider involuntary eye movements, that would result in unwanted reactions of the computer system. Still one has to keep in mind, that, for people suffering from paraplegia, eye tracking is a great gift.
For those, who do not carry such a burden, any kind of gestures can be used to interact with a computer. This is the other major application of camera-input. A piece of software recognizes the body and translates (more or less distinct) movements into commands. The *Perceptual Window* [3] and the *Magic Board* [3] are such systems. It is obvious, that one needs space to perform such actions. Space, especially in mobile computing, not always available.

3.3 touching events

Being a more compact and accurate user interface, touchscreens are widely accepted, today. Since the dawn of the multi-touch surface, not only pointing, but also performing more complex two-dimensional gestures has been possible. One basic fortune of touchscreen interfaces is the direct access to the GUI. The user does neither need to learn hotkeys, nor use a mediating mouse-like device to indirectly control a cursor. Gestures like those for zooming, rotating and scrolling are easy to learn and freely combinable.
In the year 2005, Jefferson Y. Han introcuced the groundbreaking technology of frustrated total internal reflection (FTIR) [4]. It allows very precise recognition of multiple touch-events on a transparent surface. Being both very scalable and much cheaper, than other multi-touch solutions, it triggered an avalanche of new (mostly mobile) computer devices.
These handhelds often entirely lack a physical keyboard. A virtual keyboard can be displayed and directly accessed on the screen. This makes keyboards dynamically con-

figurable in both size and layout. The major problem here is, that the user does not very much tactily "feel" the keyboard, what makes touch-typing very hard to learn. Yet, there are ambitious efforts in developing tactile multi-touch. For example Wayne Westerman and Apple Inc. recently released a patent[5] which describes a virtual, tactile feedback keyboard. Nevertheless the problem, that whenever touching the screen for interaction, the user, moving his hands in the line of sight, partly hides content, remains.
As already mentioned, the greatest achieve of modern multi-touch surfaces is it's inspirational effects to other, well established devices.

3.4 fusioning ideas

In the last year, Microsoft Corp. presented five prototypes for their new mousy, ah, I mean mouse-like human input devices [6]. From the user's perspective, they all do very much the same thing. While gross motors still require the user to slide the mouse over the table (or any other solid, planar surface), fine motor manipulactions are much more flexible. These mice's buttons are replaced by a multi-touch surface. This allows the performing of more complicated motions, just as those, commonly applied to multi-touch screens. As the paper says, one could also connect particular areas of the mice's surfaces with programmable functions, replacing the many special buttons, covering modern standard mice.
But the first multi-touch mouse introduced onto the market, is not a Microsoft product, but Apple's *Magic Mouse* [7]. It is an ordinary two-button mouse with a multi-touch surface on top. The user may perform various gestures with his fingers. This includes predefined actions like zooming, rotating or scrolling (replacing the mouse wheel).
Besides multi-touch, there are other promising technologies like the ferromagnatic input device[8], introduced, just as Mouse 2.0, during the *22nd annual ACM symposium on User interface software and technology (UIST '09).* It uses the same technology, found in the pick-ups of electric guitars. First of all, magnetic field is established. Then magnetic deflexions, caused by the placing and moving of ferromagnetic objects in the field, are messured. This allows not only the application as multi-touch surface, using pads of (unfortunately intransparent) ferrofluid. As every magnetic object adjoined, influences the magnetic field, even a modular, user-specific design of custom interface devices is possible.
Another technology introduced at UIST '09 is the *PhotoelasticTouch* [9]. It uses the effect of photoelasticity, what means that certain transparent, rubberlike material, when applied pressure to, changes the polarization of light, passing through it. The device in principle is built of three basic layers. At the bottom, there is an ordinary LCD. Topmost,

a camera is mounted. The photoelastic material is set up between these. There are also several polarization plates needed. The light, LCDs usually emit, is non-polarized. That means light waves, which oscillate in any orientation orthogonal to their direction of propagation. Polarizing light means filtering all those of its components, that do not match one particular orientation. Photoelastic material may, when squeezed, distort a light beam's polarization. Another polarzation plate, in front of the camera, lets only pass the non-distorted light. So, speaking figuratively, when pressure is applied to the photoelastics, the camera recieves another image, than it would expect to. The kind of the touch event is calculated from the difference of the expected and the recieved image. Knowing the material, a pattern recognition software can compute not only the position of the deformation, but also the amount and even the direction of the applied pressure.

3.5 brain-computer interface

To complete the presentation of promising human interface devices, we will take a quick look at brain-computer devices [10]. Most of these input devices are equivalent to those used in medical and psychological electroencephalography (electrodes, applied to the user's head, measure brain activity). There is also the efford of using functional near-infrared imaging (fNIR) as brain-computer interfaces [11].
Of course there are much more devices, but listing all of them, would surely go beyond this document's borders. Yet, the selection above should provide a broad overview of what is currently happening in human interface research.

4 Evaluation

4.1 the users' needs

Before evaluating any input device, we have to look at, what the user actually needs. Unfortunately, there seem to lack any research results on this topic. So, for a start, we have to classify the input devices' properties.

4.1.1 efficiency

The first category is efficiency, describing, how fast a user can perform an intended (possibly very complex) task. There is a common measuring method, called *Fitts's law*[12], named there for historical reasons. It's basic principle is gauging the times, a proband needs to point to or click at a button, in a certain distance from the cursor's current position. Although serving well in testing and comparing pointing devices, it looses more and more of it's significance. New devices, for example those, based on multi-touch, are hardly evaluatable that way. A device's fine motor capabilities, which are becoming more and more important in man-machine interaction, can not yet been measured properly in a standardized way. Therefore, and for the reason, that I do unfortunately not have of the described devices at hand, my performance evaluation, is based on the description of the devices' capabilities. Instead of an empirical analysis, we will take a look at what the devices are capable of and what they lack.

4.1.2 universality

Tough, the new technologies reveal a huge field of highly specialized interfaces, our focus is on general purpose computing. The user may neither be restricted in what tasks are possible nor significantly handicaped with a certain device. Independently from personal skills or cultural background, all tasks should be performable at about the same level of lavishness. As a negative example, writing text with a mouse, joystick or gamepad is very exhausting.

4.1.3 ergonomity

The expense of user input, concerning effort, is not the only point. A user interface device should also satisfy certain needs in ergonomity, allowing dexterous, non-insanitary or health-promoting working [13].

4.1.4 learnability

Nevertheless, even the most innovative interface is useless, when nobody can handle it. The user's investment in learning how to interact with a new interface should be as low as possible. Interfaces generally refered to as "intuitive" simply apply a lot of what the human has already learned in interacting with the physical world and make software visually react like expected.

4.1.5 mobility

Another condition, input devices have to meet in the field, is mobility. A user interface system must do well in all the issues above independently from whether used in office, on the sofa or even in the underground.

4.1.6 expense

For being successfully sold on the open market, the basic technologies, used in devices, should be of low manufacturing costs. And of course, design also has a certain importance in selling products.

4.2 in how far the needs are satisfied

Validation of particular devices very much needs empirical methods like questionnaires and testing under under laboratory conditions. Unfortunately, as writing this, I severely lack such methods. Therefore, the following evaluation contains some hypotheses, not proven, but conscientiously made.

First of all, the keyboard again. It's major advantage, besides being very cheap, is it's efficiency. Not only in the obvious application of writing text, but also, when used in combination with a commandline interface like the unix-shell, one can quickly input very accurate and powerful commands. Unfortunately, the typing takes a lot of time to learn, especially when writing Chinese, Japanese or Korean (CJK) symbols. Also the many different commands and their effect must be memorized. Visual work like drawing or arranging objects is quite stressful. As one can see, the keyboard obviously lacks of good qualities in universality and learnability. Even though great improvements in ergonomity, the excessive use of keyboards, but also mice, may still cause diseases like carpal tunnel syndrome [14]. Using mice is only designed useful as an extension to the keyboard. Standing alone, such pointing devices have very low efficiency. It is impossible to perform multiple tasks, namely pointing and clicking, at the same time. The accurate and fast usage of a mouse in daily work needs almost as much training, as using a keyboard. In matter of mobility, both of them are too unwieldy or (in case of the mouse) depend to much on a plain surface to operate on.

Graphic tablets go one step further. They increase efficiency, by directly sending the digitally encoded, additional information of how much pressure is applied with the pen, to the computer. Not only presenting the user a third dimension (besides vertical and horizonal position), they are easier to use for fine motors. The human capability of handwriting is transfered as is. Besides drawing, the input of symbols (like in CJK text input) is very intuitive. Also in issues of ergonomics graphic tablets seem to outrun mice [15]. The main problem, again, is mobility. One also sees the input data only virtually on the screen, not also on the tablet. This cognitive transfer must be learned anyway.

The probably most intuitive device is the touchscreen. The user can directly access functions. The technology of FTIR even made it ready for low cost mass-implementation.

Multiple touch events can be performed and - more important - recognized at the same time. This makes (more or less intuitive) gestures be part of the user's input. For the first time, there is an even reasonable replacement for the good old keyboard. Still the planar surface is very uncomfortable for touch-typing. Great efforts are being made and is quite probable, that soon, there will be more tactile touchscreens [5]. Modern multi-touch screens made the input and output device be no longer segregated. The user's brain therefore does not have to perform any areal translation. Yet, there are disadvantages. For example, while performing input, the user partly blocks the line of sight to the visual output device. Another minus is, that the input area still is a only two-dimensional, planar surface, which is currently unable to recognize what grade of pressure is applied with the fingers.

The limits of screen-mounted multi-touch technology lead to the idea of integration in other devices. As mentioned above, Microsoft Corp. introduced some new mice, that give the user control of more than one cursor [6]. The position of the fingertips is recognized and translated into five independent cursors. These five are the so called "touch cloud". That cloud can be shifted just as a traditional mouse's pointer by movements of wrist and arm. Compared to traditional mice, this improves performance, with only little more expense in learning. Also the technology used in the prototypes, is not especially expensive. The ergonomic problems of traditional mice (e.g. causing carpal tunnel syndrome) are still present in this innovation. Further ergonomic issues, like the devices' handlings, for example, can not be rated here. As these new mice seem to aim at desktop work, they are not as mobile, as, for example, multi-touch screens.

These problems of mobility and ergonomity also concern Apple's *Magic Mouse*. Moreover the flat, aerodynamic design does not fit the user's hand well [17]. The gestures (shortcuts to GUI operations) support the interaction with the computer, but can not replace the keyboard. Also, holding only two mouse buttons, it restricts the user in matter of using it as an ordinary mouse. [16] Moreover, accidentially performing a touch gesture, while shifting the mouse - and vice versa - is quite likely.

Tough also immobile, by requiring a top-mounted the camera, the use of photoelastic material [9] in user interfaces is an interesting idea. The user's interaction with the rubber-like material has very high informational troughput. As already mentioned, the system recognizes the amount and direction of pressure, applied to the material. With some kind of relief, one can imagine the user tactily sensing a virtual keyboard or other reference points. Besides the lack of mobility, there is the problem, that the camera always needs a clear line of sight between the camera and the area around the event of deformation. Besides the lack of mobility, no non-transparent object (like the user's

hand) may block the camera's line of sight to the deformed material. Also the prototype, using a high-speed camera is probably quite expensive.
The probably most promising application of basic technology is the ferromagnetic input device [8]. Though only in the space very near to the device, it allows three-dimensional user input. Ferrofluid pads, used as touch surface are even pressure sensitive. The most interesting idea in ferromagnetics is the freedom in designing a custom interface. Think of a 3D modelling software, shipped with the input device, allowing the user to build his own prefered interface from smaller magnetic elements. These prefabricated elements could be assembled like Lego bricks. Ergonomity is literally hold in the user's hands. As always, there are problems. Including this technology in other devices, brings up the problem of shielding the electronic circuits from malfunction or being even damaged by the magnetic field. I also guess, that all the metal makes the device quite heavy. Furthermore, magnetic effects are highly damped. In times of power-saving technology, this device seems a bit misplaced.
Last but not least, the brain-computer interface. The efficiency of the interface itself still is very low. Also it needs high attention, training and personal calibration [18], to communicate with a computer by using EEG. This is but relativized by the fact, that the user does not need anything else but his brain. Imagine the effects for physically handicapped people or even patients in vigil coma. But also when still equipped with two healthy hands, the user is free to perform any other task independently. Nowadays' major disadvantages in direct interaction with the human brain is, that we do neither know very much about it, nor do we have imaging methods with both high spatial and temporal resolution [10].

For a better image, take a look at *table 1*, giving an overview over and summarizing the text above. The devices are rated as either *good* or *bad*, according to whether they have great advantages or disadvantages in the related field. When a particular device does either have both advantages and disadvantages to the same extent, or could not be sufficiently examined, it is rated as *neutral*.

	efficiency	universality	ergonomity	learnability	mobility	expense
keyboard	good	good	bad	bad	bad	good
mouse & co	bad	bad	bad	neutral	bad	good
graphic tablet	bad	bad	neutral	good	bad	neutral
touchscreen	neutral	good	good	good	good	neutral
mouse 2.0	neutral	bad	neutral	neutral	bad	neutral
magic mouse	neutral	neutral	neutral	neutral	bad	neutral
photoelastics	good	neutral	neutral	good	bad	bad
ferromagnetics	good	good	good	neutral	bad	neutral
brain	bad	bad	good	bad	bad	bad

table 1 - overview over the evalution

5 Conclusion

5.1 what to keep an eye on

The modularity of the ferromagnetic device could revolutionize the way, interfaces are designed. Also the combination of multi-touch with other technology is promising. I am also looking forward to what tactile virtual keyboard Wayne Westerman and Apple Inc. will come up with. And of course, what technological advance will be made in brain-computer interaction.

5.2 what remains after all

The current research seems to focus on distinct, innovative technologies. It all looks a bit like people coming up with ideas for new interface devices over and over again, having no actual target. Maybe one should ask the users, what they want, instead of first developing something and then explaining the users, how they can solve problems, they had not even been aware of. Some sociocultural studies could possibly enlighten where human interface design should lead.
Another major issue is the great effort made in coming up with the ultimate device, instead of thinking about how to connect multiple highly specialized devices to a bigger, modular input and output system.

5.3 the perfect device - dream or reality?

One day we might be able to communicate with computers just using our brain, without special concentration. But even if not so, there could be a input system, consisting of many interconnected input devices, each one perfectly dedicated for the particular task, it performs best in. This system still should be affordable for anyone and must not be insanitary to use. I guess most of us don't think of evolutional, population-wide obesity and amyotrophia, as something we should try to achieve.

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References

[1] Brad A. Myers. A brief history of human-computer interaction technology. *interactions*, 5(2):44–54, 1998.

[2] Willie Walker, Willie Walker, Paul Lamere, Paul Lamere, Philip Kwok, Philip Kwok, Bhiksha Raj, Bhiksha Raj, Rita Singh, Rita Singh, Ro Gouvea, Ro Gouvea, Peter Wolf, Peter Wolf, Joe Woelfel, Joe Woelfel, W. Walker, P. Lamere, P. Kwok, and Sun Microsystems. Sphinx-4: A flexible open source framework for speech recognition, 2004.

[3] James L. Crowley, Joëlle Coutaz, and François Bérard. Perceptual user interfaces: things that see. *Commun. ACM*, 43(3):54–ff., 2000.

[4] Jefferson Y. Han. Low-cost multi-touch sensing through frustrated total internal reflection. In *UIST '05: Proceedings of the 18th annual ACM symposium on User interface software and technology*, pages 115–118, New York, NY, USA, 2005. ACM.

[5] Wayne C. Westerman. Keyboard tactility arrangement on a smooth touch surface, 2009. United States Patent, U.S. Class at Publication: 345/168; 340/407.2; 345/173, December 24, 2009.

[6] Nicolas Villar, Shahram Izadi, Dan Rosenfeld, Hrvoje Benko, John Helmes, Jonathan Westhues, Steve Hodges, Eyal Ofek, Alex Butler, Xiang Cao, and Billy Chen. Mouse 2.0: multi-touch meets the mouse. In *UIST '09: Proceedings of the*

22nd annual ACM symposium on User interface software and technology, pages 33–42, New York, NY, USA, 2009. ACM.

[7] Magic mouse - the world's first multi-touch mouse. Website, 2009. Available online at http://www.apple.com/magicmouse/ visited on January 26th 2010.

[8] Jonathan Hook, Stuart Taylor, Alex Butler, Nicolas Villar, and Shahram Izadi. A reconfigurable ferromagnetic input device. In *UIST '09: Proceedings of the 22nd annual ACM symposium on User interface software and technology*, pages 51–54, New York, NY, USA, 2009. ACM.

[9] Toshiki Sato, Haruko Mamiya, Hideki Koike, and Kentaro Fukuchi. Photoelastictouch: transparent rubbery tangible interface using an lcd and photoelasticity. In *UIST '09: Proceedings of the 22nd annual ACM symposium on User interface software and technology*, pages 43–50, New York, NY, USA, 2009. ACM.

[10] John P. J. Pinel and Paul Pauli. *Biopsychologie*, pages 136–141. Pearson Studium, 6., aktualisierteauflage edition, 2007.

[11] Erin Treacy Solovey, Audrey Girouard, Krysta Chauncey, Leanne M. Hirshfield, Angelo Sassaroli, Feng Zheng, Sergio Fantini, and Robert J.K. Jacob. Using fnirs brain sensing in realistic hci settings: experiments and guidelines. In *UIST '09: Proceedings of the 22nd annual ACM symposium on User interface software and technology*, pages 157–166, New York, NY, USA, 2009. ACM.

[12] I. Scott MacKenzie. Fitts' law as a research and design tool in human-computer interaction. *Hum.-Comput. Interact.*, 7(1):91–139, 1992.

[13] Ulrike M. Hoehne-Hueckstaedt, Sandra Keller Chandra, and Rolf P. Ellegast. Ergonomic requirements for input devices. In *HCI (17)*, pages 216–224, 2007.

[14] Mircea Fagarasanu and Shrawan Kumar. Carpal tunnel syndrome due to keyboarding and mouse tasks: a review. *International Journal of Industrial Ergonomics*, 31(2):119 – 136, 2003.

[15] Global Ergonomic Technologies. Comparison of postures from pen and mouse use, June 1998.

[16] Roman Loyola. Apple magic mouse. Website, 2009. Available online at http://www.macworld.com/article/143489/2009/10/magic_mouse.html visited on January 26th 2010.

[17] Jason Chen. Apple magic mouse review. Website, 2009. Available online at http://gizmodo.com/5386202/apple-magic-mouse-review visited on January 26th 2010.

[18] Benjamin Blankertz, Michael Tangermann, Florin Popescu, Matthias Krauledat, Siamac Fazli, Márton Dónaczy, Gabriel Curio, and Klaus-Robert Müller. *Computational Intelligence: Research Frontiers*, pages 79 – 101. Springer Berlin / Heidelberg, 2008.