The History, Development and Future of Computer Input/Output Methods

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Abstract

This paper reviews the history, current state, and future of input and output methods, and the factors leading up to their invention. The paper hopes to explain what the current trends in development are and what new applications they may allow.

The paper summarises the history of a selected set of computer interaction devices, from punch cards to the mouse and keyboard, and goes on to investigate the devices in popular use today. Using the knowledge about the factors that lead up to the creation of previous and contemporary devices, the paper goes on to present two possible future methods that follow the same trend of development; gesture control and brain-computer interfaces. A number of solutions are covered, aimed towards those with need of assistive devices.

The report concludes that the interaction method development has become highly user-centered, and goes towards a higher level of abstraction between the user and the machine. It also shows that advances in technology not necessarily replace the previous technology, but rather broaden the spectra of applications where computers are used.

Input and output devices and methods is a broad subject and this paper does not assume to present a complete coverage thereof. It rather presents a deep enough coverage of its most prominent aspects in the field, in order to see the general patterns.

Abstract

Denna artikel granskar historiska, nuvarande och framtida användargränssnitt, och de faktorer som driver deras utveckling. Artikeln avser att förklara vilka de nuvarande utvecklingstendenserna är, och vilka nya tillämpningar dessa tillåter.

Artikeln sammanfattar en utvald uppsättning användargränssnitt från hålkort till mus och tangentbord, samt undersöker de gränssnitt som är i populärt bruk idag. Genom att använda kunskapen om tidigare och samtida enheters utveckling presenteras två möjliga framtida gränssnitt som följer samma utvecklingstrend; gestigenkänning och gränssnitt mellan datorer och den mänskliga hjärnan. Artikeln behandlar även ett antal lösningar för personer med handikapp, i behov av särskillda hjälpmedel.

I artikeln dras slutsatsen att utvecklingen av användargränssnitt i allt högre grad blivit användarcentrerad, och eftersträvar en högre abstraktionsnivå mellan dator och människa. Den visar också att de nya gränssnitten inte nödvändigtvis ersätter de tidigare, utan att de snarare kompletterar varandra och breddar uppsättningen användargränssnitt som används.

Användargränssnitt för datorer är ett brett ämne och denna artikel avser inte presentera en fullständig redogörelse av dessa. Den avser snarare presentera en tillräckligt bred täckning av dess mest framträdande aspekter, i syfte att se generella mönster.

Contents

1 Introduction

The history of computers is arguably short, but has already seen many advances. Its history is intertwined with that of the input and output methods it uses; changes in the way we use computers have altered the way we choose to interact with them, and vice versa.

Today the classical way to use a computer is with a computer terminal, that is using a mouse and keyboard. Although this is a working configuration on a desktop, it does not cope with the demands of the mobile devices currently growing in popularity. Touchscreen technology used in mobile devices have not lead to mobile devices taking the place of the traditional computer. Instead, it has broadened the spectra of applications for computers, bringing them into our everyday life. This inspires us to investigate the history leading up to todays dramatic changes in computer usage, in the hopes of better understanding the challenges in computing today and to get a glimpse of the interaction methods of tomorrow. Understandably, a large variety of devices have been developed over time and cannot be exhaustively covered in this paper.

The devices covered in the history section are some of those devices which can be said to have had a big impact on the development leading towards the computer keyboard and mouse. Among contemporary input methods, touchscreens are covered due to their recent popularisation, as well as speech recognition as it is a field which have seen great advances lately and shown great promise for the near future. The possible future input methods covered in this article are gesture control and thought control, as these methods have the potential to greatly reduce the friction in human-computer interaction compared to contemporary methods.

A set of special devices are covered in this article. These are mainly focused on techniques that are not overly specific in the nature of the disability they address, and can be used by a large set of people. This includes gaze communication devices, and techniques developed for the blind.

The roadmap of the paper is as follows. To start off with, we investigate the history of the terminal interface in chapter 3. In chapter 4 we summarize the history of contemporary input methods and analyse their effect on our relationship toward computers. In chapter 5, we explain some of the technologies currently in development and attempt to predict the impact they could have on our future use of computer technology.

2 Problem Formulation and Purpose

It is apparent that the history of the modern day computer is relatively short and that it has seen rapid development since their introduction. During this time, a broad variety of in- and output devices and methods have been developed, and likewise, a broad range of methods are currently under development. In this maze of devices and approaches, it can be difficult to grasp how these changes have lead up to the contemporary methods in use today, and what can be expected even in the near future. The purpose of this paper is to stake out the paths leading up to some of the devices used today, and to look ahead at where these paths might lead us in the future.

This also raises some questions on what factors lead up to new devices and methods being popularised. Does new ways of utilising computers lead to new interaction methods? Or does novel interaction methods enable us to use computers in new ways, and if so, how can we expect computers to be applied in the future?

Besides the familiar devices and methods for interaction, there are also special-purpose devices designed towards those who for some reason cannot use the traditional methods of interaction. As the role of the computer in modern day society is increasing, in some cases having become a necessity, it is an important issue to ensure that all groups in society are able to take part in this development. What alternatives exist now and do they compare to the traditional devices? Does the rapid development lead to assistive devices falling behind in development, or does it in fact mean the opposite?

3 History

In 1946, the ENIAC computer was completed for the United States Army and it has been argued whether ENIAC is to be seen as the first digital computer[26], or if this title actually belongs to the ABC[1] computer (1942). Regardless, the history of the underlying computer interfaces used is longer than the history of computers themselves.

Already in the beginning of the 18th century Basile Bouchon started using perforated paper to control the textile looms used for weaving. To control the cords of a warp, thick paper rolls were punched with patterns of holes, each column corresponding to a cord. The cords were then raised or lowered, depending on whether the paper was punched or not. In this manner Bouchons machine managed to automatise part of the weaving process, and allowed for more complex weaving patterns. Although punched cards were first invented in the 18th century, they were used as means of interaction both by the ABC and the ENIAC right at the beginning of modern computer history, and they saw continued use until the late 1980's [5].

3.1 Herman Hollerith and the Census Problem

By the end of the 19th century, the Bureau of the Census in the United States had a problem. The Census is the agency in charge of keeping records of the population, and due to heavy immigration, the amount of data and complexity of the system was rapidly increasing. At that time, the Census was performing a population count every ten years - a process taking several years to complete. In 1889, the director of the Census advertised a competition for the 1890 census tabulation system. The winner of the competition was Herman Hollerith, a former employee of the census bureau, with his electric tabulating machine.[5]

Hollerith's tabulating machine was a success, and the contract was renewed for the 1900 census. In order to expand the customer base of his tabulating machines, Hollerith founded the Tabulating Machine Company in 1896. His company was one of three companies that in

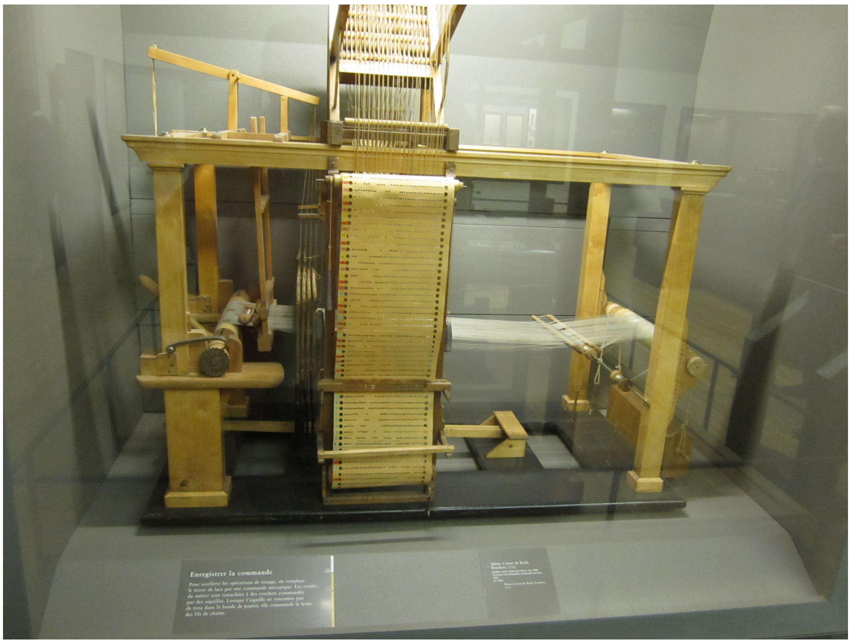

Figure 1: A Bouchon loom exhibited at the Musée des arts et métiers in Paris.

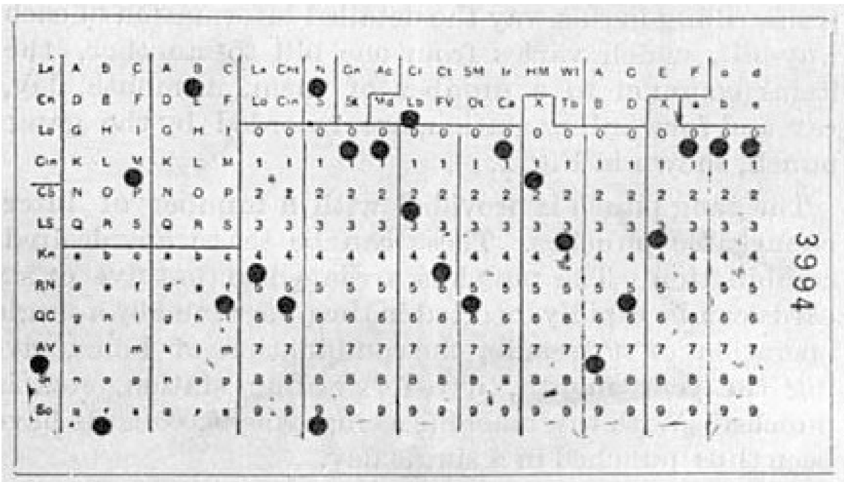

Figure 2: A punched card used in the 1890 Census, published in the Railroad Gazette 1895.

1911 merged to form the Computing Tabulating Recording Company (CTR) - later renamed IBM[50].

Punched cards were the most commonly used data medium until the 1950s, and were commonly used until the mid 1980s when they had become obsolete by the *computer terminal*[5].

3.2 The Teleprinter and the Terminal

In 1901, Donald Murray developed a *tele-typewriter* or *teleprinter*. His idea was to simplify the work of telegraph operators, by using a typewriter keyboard. The operator would type on a typewriter, where every letter corresponded to a pattern of holes punched into a punch card. The information on the punch card was then transfered over the already existing telegraph lines and reproduced at the receiving end, again on punch cards[35].

This method of typing to punch cards was used by early computers, and are known as *computer terminals* but the term computer terminal is not exclusive to punch card-based typewriters. Though punch cards were the main method of data entry and data storage, alternative methods began to emerge in the early 1960's.

In the 1960's, output devices had become more advanced and in the end of the 1960's, the first attempts were made to replace printing with a *computer monitor*. This method of combining a typewriter-style *keyboard* with a monitor is what constitutes a computer terminal. One of the earliest computer terminals was the Datapoint 3300 by the Computer Terminal Corporation[38]. Using the Datapoint 3300, the user could control a *cursor* by moving it up, down, left and right on the screen.

Later computers with microprocessors allowed program and working memory to be shared and for computer programs to read data from the memory itself. To input data into the memory, punch cards could still be used. However, since all the data was stored electronically the data could as well be entered direcly into the memory. This removed the need for punched paper to be used as a middle step. The data previously transmitted via telegraph lines could be used to connect the typewriter directly to the computer memory. The initial disadvantage with this method was that memory was limited and expensive. Thus, the use of punch cards declined in favour of the computer terminal, in step with computer displays becoming more available[5].

3.3 Pointing devices

The first computer *mouse* was developed in 1965 at the Stanford Research Laboratory and is attributed to Doug Engelbart. Engelbart also proposed applications for the mouse, such as using multiple tiled *windows*, which became widely used in early graphical computer interfaces. Although invented in the 1960's, it was not commercially available until 1981 when released as part of the Xerox Star system[31]. Xerox soon got competition by the Apple Lisa (1983) and the popular Apple Macintosh (1984).

Figure 3: The first mouse prototype by Engelbart 1865.

The introduction of the mouse allowed the users to move a pointer on the display that could be used to interact with the computer. A ball underneath the mouse gave relative

Figure 4: A series of mice from the Apple company from different era. The first Apple Macintosh was supplied with the Macintosh mouse (closest in the picture).

Cartesian coordinates when rolling the ball on a surface.

The mouse laid the ground for the WIMP (Windows, Icon, Menus, Pointer) graphical interfaces used today[45]. The graphical user interface was invented by XEROX, and the Star system is wildely recognised as the first commercially available product with a graphical interface.

As the displays became smaller and smaller and with the introduction of flat screens the portable computers were introduced. To keep these computers portable the mouse had to be built into the computer itself. This lead to a different kind of pointing devices, which are described in the following section.

4 Current

Several input devices in this paper such as the keyboard and the mouse, are still wildely used today but can be seen as historical devices. This is justified by the fact that they remain largely unchanged – if not in their physical design then in the fashion they are used. On the other hand, a number of other input/output devices that can be seen as recent have a long history behind them. Although *touchpads*, *touchscreens* and *speech recognition* techniques were researched as far back as the 1960's [9][4], they have only now began to see commercial use and have likely still not reached their "peak".

4.1 Touch devices

Touchscreen devices have become increasingly popular during the last years, following the breakthrough of *smart devices* running specialized operating systems such as the Apple's iOS and Google's Android. The technology used in these devices however, have evolved over a much longer time.

One of the first mentions of touchscreens was by E.A. Johnson in 1965, describing a touchscreen and identifying some potential uses in a short article, less than a single page[21]. Some of the earliest developed systems came in the beginning of the 1970's. Early prototypes are the PLATO IV[9] in 1972, see figure 5, and a transparant touchscreen was developed and put to use by CERN in 1973[8].

Figure 5: Student using the PLATO IV.

The initial uses of touchscreens were point-to-select systems used in for example ATM machines or cash registers in restaurants and were relatively non-demanding on the screen performance[9]. There were also early attemps to make *PDAs*[1]. The first products to enter the market were the Palm Zoomer and the IBM Simon. The Simon was a mobile phone without any physical buttons, having only a touchscreen working area. Beyond regular telephone capabilities, it could also manage information such as a phonebook and be used for drawing and taking notes. Due to this, it is sometimes refered to as the first *smartphone*[9].

Smartphones have seen much development since the release of the Simon, and today it is estimated that more than a billion people use smartphones[32][33]. This is largely due to the recent popularisation of the iOS and Android operating systems.

This increase in the number of touch-based devices has changed the way in which we interact with computers, and the new operating systems specifically designed for smartphones have a fundamentally different approach to computer interaction.

The classic WIMP approach requires the user to find the cursor on the display, move it to the desired location and click the mouse button to interact, or use the keyboard to input data. The touch screen on the other hand gives the user the ability to point directly at the desired item at the screen to activate it. An on-screen keyboard appears when it is needed, allowing the computer to show only what is relevant at that point of time. This has made computers so portable that they can be used in almost any context and in a user-friendly way.

One of the big breakthroughs that has allowed the touchscreen to be used as an independent input device by a computer, is the introduction of multi-finger gestures. While early touchscreens could only handle one action ("left mouse button"), the use of multi hand gestures removes the need for icons. Instead the functionality can be reached by pinching or swiping fingers.

A common application of smart devices is to read e-books. On a traditional computer, the user typically reads the e-book as a document, with all pages following each other from top to bottom. On a *tablet*[2], the e-book can be made to look like a book, see figure 7. The act of swiping a finger from right to left triggers the book to turn the page, similar to what one would do in a physical book. This could be done with another gesture, for example by

[1] Personal Digital Assistant

[2] A smart device, typically with a larger screen than a smartphone

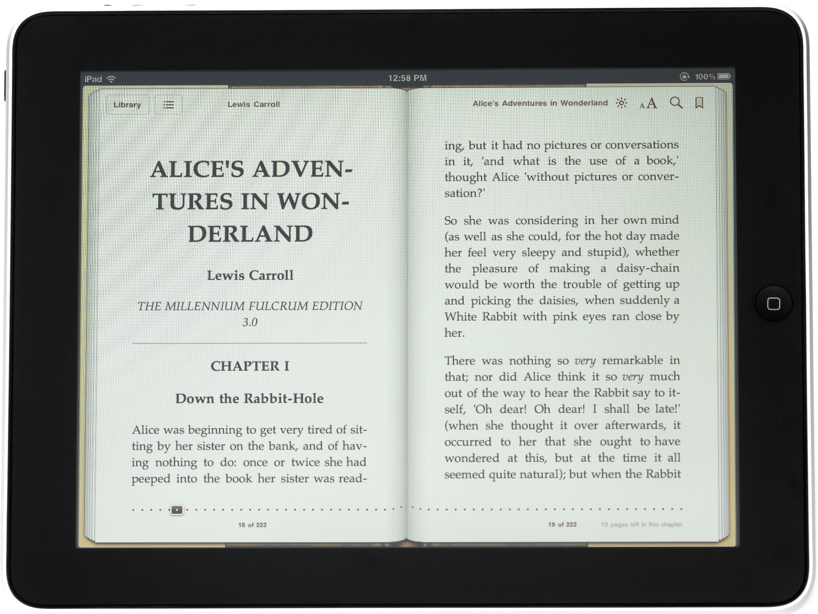

Figure 6: Apple Ipad showing iBooks, with the book Alice's Adventures in Wonderland.

drawing a circle on the screen or triple-tapping, but these approaches are not be as intuitive as the swipe-gesture. This example shows that this type of interaction is not fundamentally more user-friendly, but it *can be* if used in the right way.

4.2 Voice recognition

Voice recognition is another input method that has become increasingly popular in the last years. This input method uses speech recognition by analyzing input from a microphone. Once the spoke word has been analysed, it can be used in several ways.

One ambition is that of providing real-time subtitles to spoken text, for example to aid those with hearing disorders. As an input method, the sound input can be parsed by the computer and then trigger a predefined action. This type of speech recognition has recently seen big progress, and is growing in popularity. For example, in the past years Microsoft presented an English to synthesised speech Chinese translator, working in real time and Apple has introduced the *Siri* speech recognition system in their handheld devices.

While computers have only recently become powerful and cheap enough to make speech recognition broadly available, its history is much longer. The first working implementation was introduced by Bell Labs in 1952[11]. It could not analyse sentences, instead single words were compared to a small dictionary, the numbers 0 to 9, spoken by a single speaker[**?**]. The user was also required to make a small pause between every word for the system to recognize them.

Other systems analysed *phonems*[3] in the spoken text. Early phonem-based techniques could only recognise a subset of phonemes; RCA Labs in 1956 could recognise ten phonemes, spoken by a single speaker, Fry and Denes at the University College in England could recognise 4 wovels and 9 consonants. More notably, they were the first to incorporate statistical information in the analysis[**?**], something that now is fundamental in speech recognition. By analyzing speech at this low level the system becomes less dependant on pauses and dialect in speech.

In the 1980's, the use of *Hidden Markov Models* was introduced in speech recognition[39].

[3]Phonemes are the smallest building blocks of the language and consist of the individual sounds used to construct words and sentences

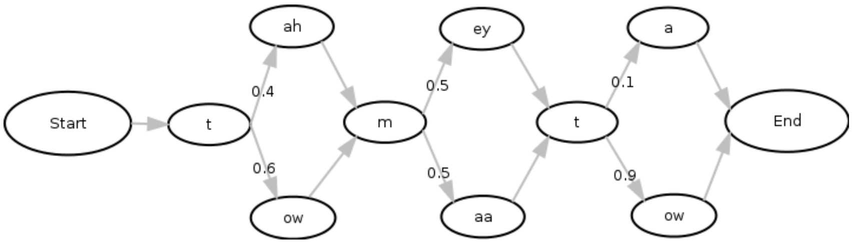

Figure 7: A model describing the statistical values of phoneme input of the word *tomato*. The model contains american and british english pronounciations, with a small statistical favor of the british accent.

The Markov Models use previously gathered statistical data to with some certainty guess which phoneme the user is saying, and the chain of phonemes considered to be correct are then matched to a phoneme-word database to decide which word the user has spoken. The context of the word is also taken into account to prevent homonyms of the desired word to be entered instead. The Markov Model Speech Recognition systems “learn” the users voice and speech patterns by using the data from corrections to alter the statistics used to decide which phoneme was spoken.

Most speech recognition software today use Hidden Markov Chains for speech analysis[17], but recent research has shifted focus towards the use of a type of artificial neural network, called Deep Neural Networks (DNN). Neural networks have been used for speech recognition since the late 80’s[49], but the use of DNN is the first that has been shown to have substantial benefits over the use of the traditional markov chain approach.

An ongoing research collaboration around DNN exists between the University of Toronto, Microsoft, IBM and Google. Late 2012, Microsoft publicly demonstrated their work with speech recognition – a system that can translate spoken English into spoken Mandarin in real time and in a voice similar to that of the speaker. In conjunction with the demonstration, Microsofts chief researcher Rick Rashid says about DNNs: “While still far from perfect, this is the most dramatic change in accuracy since the introduction of hidden Markov modeling in 1979”[40].

Speech recognition can be used in many applications. One of these include the the automatic texting of television programs. Another application, which is the main task of the Siri interface, is to respond to short queries by the user, about for example the weather, the current time, web searches and booking systems. This removes the need for the user to interact through a traditional interface, and allows for certain automatisation.

5 Future

Admittedly there is no way of knowing with certainty what the future has in store, and this is just as true when it comes to technical development. On the other hand, knowing what the prominent factors are, one can more easily predict this development. It can be seen that the history of input and output devices has actually not had a tight connection to that of computer processing power and memory, although the lack of which can delay the popularisation of such devices. Some examples of this are mentioned above; the computer terminal gained in popularity first when computer memory became more easily available and the use of neural networks gained in popularity again in the 1980’s when processing power had increased. According to the well-known Moore’s law, the number of transistors and hence chip performance doubles approximately every two years, further leading us to believe that this is not the main issue.

Development rather aspires to ease the interaction either by making devices more portable and available or to remove the obstacles present in the interaction. This is well exampified by the “Google Glass” project currently under development. The glasses are worn like traditional glasses, but have a built-in display where the glass traditionally would, and is

Figure 8: Leon Theremin operating a theremin in 1927.

controlled by speech commands. This way, the system aims to provide both higher portability and more natural interaction with the user.

Taking this trend of portability and user-centered interaction into account, this section will cover two possible interaction methods likely to grow in popularity in the future; the use of gesture based systems, and systems to control devices directly by thought.

5.1 Gesture control

Gesture control is a means of interaction that uses either hand-gestures or full-body gestures to control and interact with a device. In a way, this form of control aims to immitate human-human interaction by removing the need of physical interaction with a physical device. Possibly the first such system was the *theremin* developed 1919/1920 by Leon Theremin, see figure 8. The theremin is an electronic musical instrument, operated by hand gestures. Depending on the position of the hands in relation to the antennas, sounds of different frequencies can be generated[44].

This is an early example of how hand gesture control can be useful and intuitive in *certain* contexts. There are several areas where gesture control can be useful. Separating the user from the machine can be useful to protect the physical machine from abuse, as the system is worked from a distance. During a presentation, a speaker can avoid the obstructing act of changing slides manually, instead using hand gestures to signal this command. If the session is filmed, hand gestures could easily notify the camera to focus on a certain area on a blackboard, screen or object being exhibited.

Hand gestrures are often useful in the same settings where voice recognition would be useful, but does not suffer from the disadvantage of being sensitive to noise and does not break the user's flow when communicating[46]. Tracking mouth movements can also aid in speech recognition, allowing speech and gesture to be used in combination[25][41].

Several difficulties involved with gesture recognition are currently under study. To be able to recognise gestures the systems depend on a camera which needs be positioned where it can catch the relevant movements of the subject and must also have a rather high resolution and frame frequency in order to cope with the speed of human movement. Furthermore, this must be combined with fast and accurate algorithms to detect and track movements reliably. Besides the technical issues, there is the issue of ease-of-use. A technique that aims to provide a natural interface such as that of regular human interaction must be quite tolerant – the input must be done on the terms of the user.

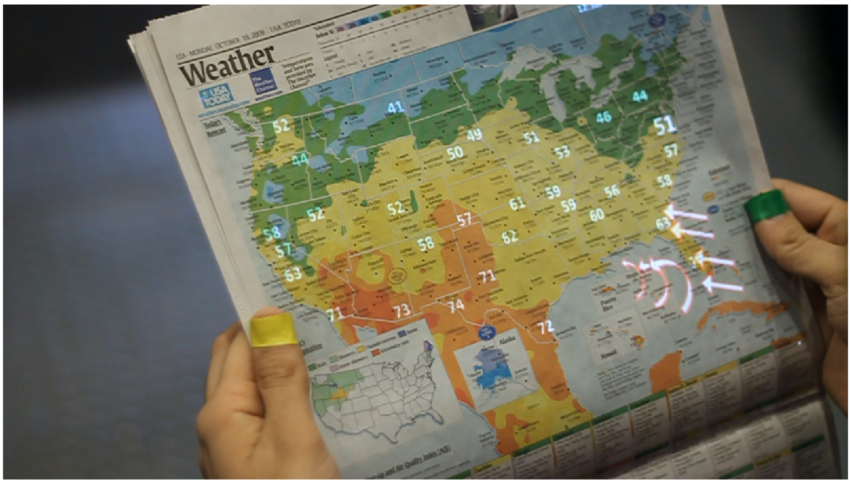

Figure 9: The SixthSense interacting with a newspaper augmented with weather data.

An example of a gesture based system is the *SixthSense* developed at the MIT Media Lab, a mobile system which utilises a mini-projector. The camera and the projector hang around the neck of the user similar to a pendant. The camera recognises the users hand-gestures to perform the requests, and can optionally use the projector to project data onto a surface. What is especially interesting with the SixthSense is its user-interface. In a traditional system, the user interacts with a user-interface against the computer whereas the goal of the system is to use the user's normal setting – the physical world[28]. Ideally, the user would interact with objects as in a natural way with the computer aiding when appropriate. An example of such an application can be seen in figure 9.

5.2 Brain Computer Interfaces

Since the early 1990's there has been a lot of research on Brain-Computer Interaction (BCI) systems[24]. These systems uses brain reading techniques to use brain activity as input to a computer.

Brain-computer interaction methods can be divided into *non-intrusive*, *partially intrusive* and *intrusive* technologies[51]. Non-intrusive technologies are technologies where the brain activity reading equipment is placed on the outside of the persons head. This requires no surgical procedure and is therefore the easiest and safest method for scanning brain activity. The drawback is that the readings are usually more imprecise than intrusive methods, since the readings are distorted by the skull. However some methods[12] have been developed that give readings comparable to more intrusive approaches.

The partially intrusive methods require electrodes to be placed inside the persons skull, but outside the grey matter of the brain. This approach removes the distortions caused by the skull, but require surgical procedures that can be dangerous for the patient. The intrusive methods are methods where electrodes are placed into the grey matter of the subject. This gives the highest accuracy, down to neuron level, but can cause tissue scarring on the person, since the body tries to get rid of the foreign object.

The history of brain activity reading started in 1924 when Hans Berger discovered the electrical activity of the brain and the first EEG equipment was constructed[16]. This equipment enabled the reading of electromagnetic activity in the brain. During the 60's and 70's more research on this area has allowed the implantation of electrodes in the brains of monkeys (see figure 10), which were able to control a robotic arm[14][23].

Brain-computer interfaces have have mostly been used for controlling prostethic devices for persons that have become blind, have lost limbs or lost control of their motor functions[24], but have in later years also been able to decode pictures from the brain activity[29]. During the last years BCI equipment has become cheaper and more available to the public

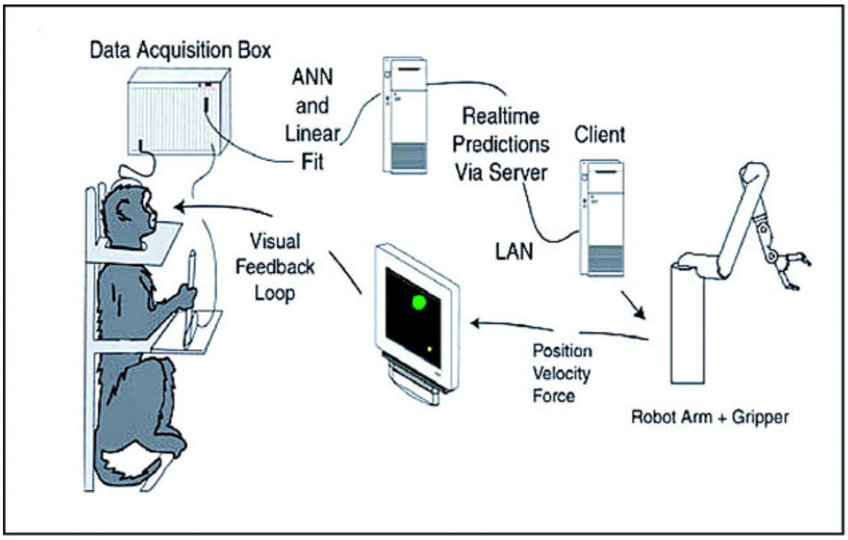

Figure 10: A schematic picture of a BCI system used on a monkey.

market[51]. The input is however still very sensible to disturbance, if the user looses focus. To broaden the usage areas of BCI systems more research is needed to ensure stable communications.

The use of BCI comes with a number of ethical questions, the most important of which are side-effects from intrusive BC interfaces, mind reading and mind control. Mind reading could be used for many purposes, some of which are of a questionable ethical nature. Examples of possible applications that might be controversial are neuromarketing to gather data on the neural effects of marketing, or the use of brain readings in interrogation[43][30].

Mind reading can interfere with the the persons privacy, if the mind reading goes on outside the users will, but on the one hand mind reading can be a help or even the only way to communicate for persons that have lost all motor skills and possibly also the use of the eyes.

BCI has the potential to further spread the utilisation of computers in our every-day life, examples of ongoing research are its use in computer gaming[**?**] and thought-controlled cars[15]. What the future applications could be depends on how well limitations within these techniques can be overcome, it may be that it can replace other interfaces altogether.

6 Special-Purpose Devices

Computers today are used for the most diverse set of tasks. They have become such an integral part of our society that people with handicaps that prevent them from using computers are at risk of getting left out of large parts of society and from work opportunities. While the computers themselves are indifferent towards handicaps, the input and output devices may present the user with accessibility problems.

The obstacles for people with impaired vision are mostly concerned with output devices, since most output devices rely on graphics like bitmap-displays or status LEDs. This can be circumvented with accessibility tools, such as the Apple *VoiceOver* solution described below. But input methods may also present problems, for example the touchpads used in modern mobile phones.

For people with reduced motor skills, the obstacles lie mainly in the use of input devices and come in many different degrees. The standard computer mouse can be too sensitive for some users, while for other users both the mouse and keyboard may be unusable. Below, some of the most prominently used special-purpose devices are described.

Devices aimed towards aiding people with reduced motor skills come in different types, depending on which problem they are designed to solve. In some cases the use of hand-controlled devices is an issue, which has led to research on alternative keyboard solutions. In 1997 [22] a foot-controlled keyboard was described for persons having atleast one foot. It consists of an arched set of keys centered around the heel of the foot, used for typing. This kind of input device is aimed at amputees and persons with cerebral palsy. This demonstrates the specific nature of some existing solutions. Other methods are designed to be more general, allowing usage of persons with several types of disabilities, such as gaze communication, see below.

A set of devices currently in research are designed to aid persons that have lost most of their motor skills. An example are devices controlled using eyes or facial features which do not require any other movement. These devices are called *gaze communication devices*. Devices that use gaze communication are often designed to allow persons who have extensive motor skill handicaps to rely on facial features and actions for controlling the cursor on the display, like nose tip and pupil movements for cursor movements and blinking for performing click actions[36][3].

Since computer output is mainly dependent on displays, the implementation of special computer interfaces for blind or vision impaired persons is needed. One such solution has been the introduction of tactile braille displays. These displays consist of a bit matrix, where each bit can be raised or lowered to generate braille text. This creates a computer interaction interface that removes the barrier of vision from computer use. Previously these systems have been adapted for command line interfaces, in the last few years however, there has been research on Braille Window Systems, enabling interaction with graphical user interfaces through tactile displays[37][42]. These interfaces work in a way similar to touchscreen devices, in that they move the control of the user interface from a separate input device to the output device. Tests show that users find these systems efficient, however, they require some time to get accustomed to.

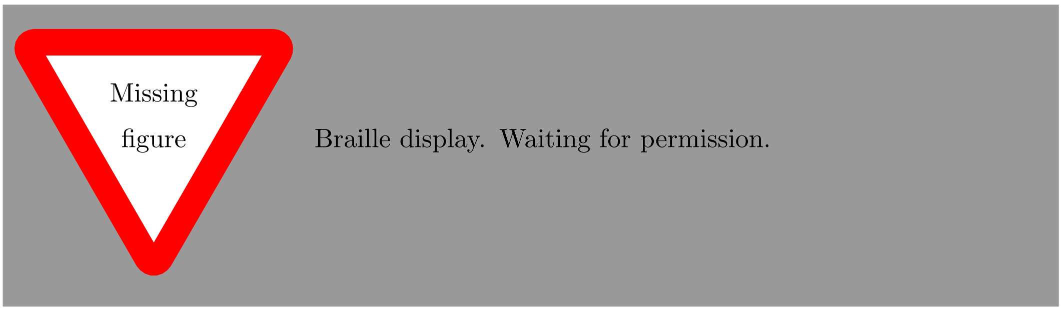

Figure 11: A tactical braille display.

Most smart devices today have some kind of input method to aid blind users or users with impaired vision. The VoiceOver solution reads the selected virtual key out loud. The user then selects the key by double tapping that postition on the display[2].

Advances in regular interaction technology can also contribute to the development of special-purpose devices. An example thereof is the Perkinput method[6]. The method allows the user to enter text in a much faster pace when handling touchscreen devices in comparison to text-to-speech methods, used in VoiceOver and other similar solutions. The method allows the user to enter *Braille*[4] letters directly by tapping fingers on the display.

The Braille alphabet is built using a 2x3 *bit*[5] *matrix* where each letter has certain *bits* ”up” or ”down”, see figure 12. In the Perkinput system, using two hand Braille input the user taps up to six fingers on the display - each finger representing a bit in the Braille letters. The letters can also be entered using only one hand by first entering the left column with three fingers, followed by the right column with the same fingers.

[4]Writing system used by the blind.

[5]The elevations used in Braille letters are known as bits, but differ from the familiar bits used in computer systems.

$$\begin{array}{ccc} \begin{array}{cc}\bullet & \circ \\ \bullet & \circ \\ \circ & \circ\end{array} & \begin{bmatrix}1 & 0\\ 1 & 0\\ 0 & 0\end{bmatrix} & 110000 \\ \text{(a)} & \text{(b)} & \text{(c)}\end{array}$$

Figure 12: Three representations of the Braille letter B; the regular representation (a), a matrix representation (b), and a binary representation (c).

For entering letters using two hands, the user uses three fingers on each hand. Each finger represents one of the bits in the Braille letter. To enter the letter B, having binary representation 110000 using two hands, the user would press the first two fingers on the first hand only, representing only the first two bits as 1:s.

To enter the letter B, using one hand, the user would press the two first fingers to represent 110, and then do a one finger swipe to represent the remaining 000.

The input rate of this special-purpose method is evidentially faster than the iPhones standard input method[6], and two handed Perkinput is more than twice as fast. This comparison shows the difference a special-purpose device can make in the effectiveness of computer use related to adapted standard input methods.

7 Results

The earliest computer interaction devices were not initially designed for computers nor to make computers user-friendly. Instead existing technologies were directly taken and modified in order to function within their new setting. In contrast, the computer input devices in use at the time of this study are designed to make human interaction with computers as simple and easy as possible.

The typewriter-based *terminal* was one of the first input device specifically designed for computers. It removed many of the earlier problems associated with programming and running calculations on the computers of that time. Although this device was very different from the earlier input devices, the underlying technology was still based on the previous technology, punched cards. It abstracted away technicalities that slowed the user down. In contrast, the development of pointing devices was not related to the previous systems, but instead a result of the introduction of bitmap displays, capable of displaying data in a different way than previous computer displays.

The big difference between these important inventions is the type of impact they had. The terminal allowed the user to communicate with the computer more conveniently than before, but still in the same style. The mouse instead changed computer usage altogether, being instrumental in the window-based systems introduced in the 80's. The impact of touchscreens is in a way similar to that of the mouse, in that it has lead to a new type of graphical user interfaces. Importantly, as these systems are mostly mobile devices, it has not only changed the way we use the computer but also *how* and *when* we use them.

There has been an apparent change in the focus of computer input devices from machine-centric methods, in which the user has to adapt to the computer, to a clear user-centric approach. While the pointing devices were developed to handle input to the new graphical output methods and not specifically to ease the overall computer experience. This laid the ground for the creation of computer interfaces that were more accessible to users without technical background and allowed the computers to move into the homes and offices of regular citizens. This mass-market opportunity created the necessary foundation for focus on more human-centric interfaces that we are still feeling the effects of today.

The two contemporary input methods discussed in this paper, speech recognition and touchscreens, behave very differently in practice, but they share the same underlying idea - to remove the hurdles in the interaction between man and machine. The touchscreen has evolved as the next step from computer-mouse-keyboard interaction to direct interaction with the data the user is interested in. This allows the user to manipulate the data using fingers and the learning curve for users is drastically reduced when the computer interacts with the user in a more intuitive way.

Speech recognition fulfills the same goal in easing the interraction between human and computer, but instead of doing it physically it is done by reacting to the spoken language in the same way the user would speak to another human. The idea is to make the computer understand the user on the user's own terms. The development of speech recognition systems has required research in cognitive psychology and mathematical (statistical) models rather than in computer science, which reflects the previously mentioned change of focus towards user-friendliness.

Skriv om cognitive psychology i current

The future devices discussed in this paper, gesture input and brain-computer interfaces are taking an even larger step away from previous computer input devices, in that they completely remove the computer as an entity in our workflow. Instead they let us focus on the task at hand without even reflecting about that there is actually a computer doing all the work in the background. This will allow the introduction of computer assisted processes in completely new parts of human lives, and has shown great prospects in the field of medicin. But this technology comes with important ethical issues; it could be used to access private information, possibly without the subject even being aware of the intrusion.

The special-purpose input methods in current use make up a large selection of devices,

test-text

Computer interaction for people with different kinds of handicaps are often dependent on special purpose devices, depending on the nature of the disability. As computer output most commonly use displays, they only pose a problem for users with low eyesight or blindness, and the existing solutions are either tactile or hearing-based. The input devices on the other hand are much more diverse in their designs, as they need to adress a larger set of disabilities. Two main categories of special-purpose input methods are devices to aid people with reduced motor skills, and people with reduced or no eye-sight. Additionally, for persons with reduced motor skills, there are different methods available depending on how much motor skills is assumed.

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kommentar om altern-ativ

For a person that has reduced motor skills in the hands only, the use of the standard keyboard and mouse can be difficult or impossible. There are solutions where a special designed keyboard and mouse designed for use with the feet can overcome this problem. For persons that have more extensive reduction of motor skills the use of such devices might also be a problem. There are numerous different approaches to solve this. One of the most interesting is the use of eye movements to steer the computer. This approach makes use of cameras to track the users eye movements and act as a pointing device, which is also used to control an on-screen keyboard.

For persons that have reduced eye sight the use of Braille input can be used to overcome computer use problems. There are numerous approaches with redesigned standard equipment like Braille keyboards, and speech feedback. There are also some completely different approaches that are more user centric, as an example the Perkinput system that uses the fingers on a touch surface (touch screen) to input Braille characters.

As illustrated by the case study of the Perkinput system, not all special purpose devices rely on specially designed hardware, but may rely on the software that handles these input devices. The Perkinput system allows the user to use the standard interface of the smart phone or tablet, but use a fundamentally different method of inputing text that is handled by the software that ease the process of data input into the system.

8 Discussion

Computers have gone from being blackboxes that take specially formated input and produce computer-formatted output that has to be interpreted by a human, to become more and more integrated with the regular life. It has also evolved from complex systems that require professional training to seemingly simple devices usable even by a child.

During this transformation different trends can be observed over time. The first trend was the process of making computer input faster while still retaining the underlying structures, the second was to make computers available to larger groups of people by making them simpler to use, and the third, and current trend, is the process of removing the computer as an entity and making it transparent to the user.

The first trend had no intentions to change the nature of computers at all, and did not do so in any extensive way. The introduction of keyboards and terminals were simply a way to speed up the process of computer input/output and were mostly technology-driven.

The second trend, making computers accessible to larger groups of people, set in motion a large scale research and development cycle in both academic and commercial sectors which changed the focus from large main frame computers to desktop computers which introduced the user-centric approach to computers. The current trend in human-computer interface development displays an even larger focus on making the computers transparent to the users.

Since the progression towards a more human-centric development began, many different input devices have been introduced and are being used for tasks previously performed at a terminal-type computer. However, these systems do not necessarily replace the previous computer systems, instead the spectrum of computer interfaces in use is broadening. The concurrent use of different kinds of interfaces means that each individual interface is becoming more and more adapted to its context of use. The act of typing moderate or long pieces of text is tiring on a touchscreen device, being too slow and lacking the physical feedback of a real keyboard. On the other hand, inputing small amounts of data on the go is an activity that is made more cumbersome by a physical keyboard and it benefits heavily from the compact form of a touch screen device.

Examples of this concept can be seen across the field, where desktop and laptop computers are being replaced in areas were new technology is more suited, while they still remain in areas were new input systems have yet to outperform the previous systems. It is also evident that some of the current systems are outperforming eachother in different areas. An example is that voice recognition has become more and more used in simple query-based tasks, with technologies like Apple's Siri voice recognition system, where touchscreen-based systems in smartphones were previously prominent.

With the mainstream systems getting more and more diverse the division between special-purpose devices for persons with disabilities and standard devices will probably become less important, since every device will have a different design and ways of accessing the data. As this process continues, these devices will become just another device in the myriad of available devices.

In summary, computers have gone from a technology-centric design with a unified interface, to a large number of context-specific interfaces designed for more and more diverse tasks. With the these interfaces the computers themselves become such an integrated part of the process they are part of that they become invisible to the user. It is likely that this trend will continue and that computers with custom-designed interfaces will appear in almost every aspect of our lives. This will likely reduce the terminal-type computer, which has dominated the market for over 40 years, from an all-purpose system to the typewriter on which it is based. The gap created will be filled by better suited and transparent devices more adapted to perform the current and future tasks computers will be used for.

9 Proposed Future Work

write me!

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