Smart glasses: technology and applications

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ABSTRACT

The maturing field of wearable computing aims to interweave computing devices into everyday life. This report focuses on smart glasses, one of the categories of wearable computing devices which is very present in the media and expected to be a big market in the next years. It analyses the differences from smart glasses to other smart devices, introduces many possible applications for different target audiences and gives an overview of the different smart glasses which are available now or should be available in the next few years. Interesting technological features of the smart glasses are highlighted and explained.

INTRODUCTION

Smart glasses are computing devices worn in front of the eyes. Evidently their displays move with the users head, which leads to the users seeing the display independently of his or her position and orientation. Therefore smart glasses or lenses are the only devices which can alter or enhance the wearer's vision no matter where he/she is physically located and where he/she looks. There are three different paradigms of how to alter the visual information a wearer perceives. Those three are introduced here.

- Virtual reality: The goal is to create a fully virtual world for the user to see, interact with and immerse into. The user sees this virtual world only, any other light sources are not affecting the eye. One significant difference to a simple screen is that the actions of the user affect the virtual world. In example movement affects what virtual content the user sees. A famous fictional example of a device creating a virtual world is the Holodeck from Star Trek.

- Augmented reality: The world is enhanced or augmented by virtual objects as seen in figure 1. The user can see the real world but also perceives virtual content created by a computing device and displayed by an additional light source which doesn't prohibit the perception of the real world. Interaction with those virtual objects is a way of communicating with the computing devices.

- Diminished reality: Objects are subtracted from scenes by filtering the light reflected or emitted by those objects towards the eye. This is most often used in combination with augmented reality to replace the diminished objects by some virtual objects.

Like other smart devices, smart glasses will often also have a camera. Significant differences to other camera devices are that the pictures or videos are taken from the users point of view, there is no need for the user to hold the device in his hands and the vision of the user is not occluded. This camera can see what the wearer sees at any time. In combination with eye tracking technology the devices can determine exactly what the wearer is looking at. This allows the device to get crucial information about the users interests, activities, surroundings and occupation.
Those fundamental differences to other computing devices are what makes smart glasses unique and interesting. They enable new applications which couldn't be as easily realized with other devices.

Figure 1: Reality is augmented with a virtual objec [7].

DEVICES

All the applications in the world are useless without the right hardware to run on. That is why an overview of different smart glasses which have been released recently or should be released in the next few years is provided. Those glasses are developed by different companies and often trying to achieve different goals and appeal to different consumer markets. Therefore they do not all stand in direct competition and should not be compared as such.

Devices with one display

There are smart glasses with a single display which is placed in the peripheral vision of the user. Those displays can be used to display information to the user. Unfortunately they can not be used to create a diminished or virtual reality because sight on one eye is not affected. They also can not be used to create an interactive augmented reality because virtual objects can only be seen in peripheral vision.

Google Glass

One example of smart glasses with one display is Google Glass which runs the Android operating system. Its specifications are the following

- Weight: 50g
- Processing: 1.2 GHz Dual-core ARM Cortex-A9 CPU, PowerVR SGX540 GPU, 16GB storage, 682MB RAM. That's roughly equivalent to the hardware of an IPhone 4
- Camera: 5MP still (2528x1856 pixels) or 720p video. There is no flash
- Display: It is a color prism projector with a resolution of 640x360 pixels. See figure 3.
- Sensors: microphone, accelerometer, gyroscope and compass.
- Interaction: There is a long an narrow touch pad which supports swipe and tap gestures. The camera can be triggered by a button.
- Audio: There is a bone conduction transducer for audio. Sound reaches the inner ear in form of vibrations on the scull. Note that this technology is audible by the hearing impaired as well as persons with normal hearing.
- Communication: It has no cellular modem which means it can not make phone calls on its own. It does have Bluetooth and WLAN 802.11b/g

Google Glass is supposed to be used in combination with a smartphone and one of its main uses is to display notifications in a convenient and quick way. It is supposed to be priced similarly to a high end smartphone but there are no official announcements concerning the exact price or release date.

Brückner TRAVIS

It is visible in figure 2 that Google Glass does not have a very sturdy design and that it is made for consumers. It is not made for rough environments such as industrial sites or factories. One example of industrial smart glasses is the Brückner TRAVIS shown in figure 4. This device is a lot heavier than Google Glass because the processing is done in a embedded PC worn in a vest. It is controlled with six hardware buttons and its main applications are streaming video and displaying manuals to employees.

Reckon MOD

There are also many devices designed for use during sports. Similar to Brückner Travis they need to function in a rough environment but also should not be heavy. One example of dedicated sports smart glasses are the Reckon MOD seen in figure 5. The Reckon MOD are snow sports smart glasses. They can operate at temperatures from $-20\,^{\circ}$ to $30\,^{\circ}$, weigh approximately 65g and are water resistant. Interaction is done through a wrist remote. The main use of Reckon MOD is displaying maps and performance statistics.

Devices with two displays

Smart glasses with two displays can affect everything the wearer sees and could display 3 dimensional content. This makes it possible to create a virtual, augmented or diminished reality.

Both systems with two displays presented in this section need to be connected to a PC with a cable by which the virtual ob-

Figure 2: Google Glass developer version [8]

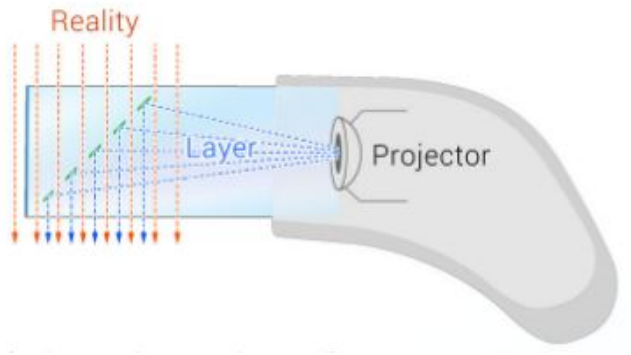

Figure 3: Google Glass display: A mini projector projects onto a semi reflective mirror which only affects light stemming from the projector [9].

Figure 4: Brückner TRAVIS [10]

Figure 5: Reckon MOD [11]

Figure 6: Cast AR [12]

jects are created. In the future similar devices could be wireless and worn outside. Those devices are interesting because they do not focus on displaying information but rather try to create an exciting visual experience.

Cast AR

An exciting new technology which is used to create a augmented indoor reality is Cast AR. It has a projector above each eye which projects onto a retro reflector with 120hz each creating a 3D image. A retro reflector is a surface that reflects light back to its source with a minimum of scattering. Nevertheless some of the light of each projector will reach the eye it is not destined for. To deal with this, Cast AR has active shutter lenses. The projectors are active in disjoint small time intervals. While the projector above one eye is not active the active shutter lens of that eye will stop any light from reaching that eye. This happens at such a high speed that the human eye can not notice. The result is a stereoscopic 3D image.

Cast AR tracks head movement and orientation using an infrared camera and infrared LEDs inside the retro reflector. The exact position is calculated by triangulation in hardware on the glasses. This makes it possible to adjust the orientation of the virtual objects with only a few millisecond delay to head movement. Many people can share one retro reflector each seeing a different scene or the same scene from different angles.

Another advantage of Cast AR compared to other smart glasses is that the eye focuses on items in a distance rather than a screen in front of the eyes. This makes it possible to use Cast AR for long time periods without eye strain.

One of the disadvantages is that the active shutter glasses filter a lot of light which makes the scenes appear darker. By increasing the brightness of the projectors its possible to make the virtual objects brighter, but it is not possible to make any real objects in the room brighter without changing lighting of the room which might disturb others.

Another disadvantage is the need for a retro reflective surface. Although these are very flexible, lightweight and not expensive they take up space and you can't see any virtual objects or scenes without one in the background. The price of Cast AR is expected to be around 200$

Oculus Rift

The Oculus Rift is a virtual reality solution which uses two displays placed in front of lenses close to the eyes of the wearer. There is one display in front of each eye, together they have a 1920x1080 pixel resolution on the newer prototypes. For Oculus Rift it is very simple to create 3D scenes because each display is only visible by one eye. Also brightness is not a problem because it only depends on the brightness of the display which may be adjusted. Oculus Rift tracks head movement using infrared LEDs like Cast AR but it also relies on a gyroscope and accelerometer. The advantage of tracking with a gyroscope and accelerometer is a very low latency, the disadvantage compared to the infrared solution is that over time errors accumulate and there might be orientation drift.[6] By combining both methods Oculus Rift implements precise low latency head tracking. As already mentioned Oculus Rift is used to create a virtual reality. No light from the environment reaches the eye. The advantage is that there is no need for any display surface in the room and the whole field of vision can be occupied by a virtual scene. Many users experienced a series of problems with the early prototypes of the Oculus Rift. Those problems and the solution approaches implemented by the newer prototypes are explained here.

Figure 7: Oculus Rift Crystal cove prototype [13]

- When the resolution of a display is not large enough the user might see spaces between pixels creating a view similar to seeing through a mosquito net. Because the displays of Oculus Rift are very close to the eye the screen door effect was a big problem with the early prototypes. Because the resolution of the newer prototypes is higher the screen door effect became less disturbing. It is to be expected that this will not be a significant issue in future iterations or the final product.
- Because of the delay from the moment the user moves his head until the images adjust to the movement and because of imprecision in head tracking, some users experience motion sickness. This happens when there exists a disagreement between the visually perceived movement and the inner ear's sense of movement. People react very differently to this problem and even with the newest prototypes with very little latency some people still experience motion sickness depending on which scene they are seeing.
- When looking at a screen for a long time many people experience eye strain. This happens when the eyes get tired of focusing on near objects. This problem is still present with newer prototypes.
- Graphical glitches, software bugs and lags are disturbing no matter what display technology used. However with Oculus Rift they are much more uncomfortable for the

user. With lags or loading screens the user looses the ability to affect his vision by turning his head which might lead to immediate motion sickness and disorientation. Those problems are very difficult to solve because software will always have bugs and hardware will always fail at some point.
- Even the newest Oculus Rift prototypes weigh around 0.5 kg which is not very comfortable for the user.

Although there are many problems with the prototypes of Oculus Rift it is a very promising technology which for many people creates very enjoyable experience even at prototype state. At least for those who are not very prone to motion sickness and the other issues mentioned above. The price of Oculus Rift is expected to be below 400 $ in the US.

We have reviewed different smart glasses and have seen some advantages and disadvantages each pair has. The choice of which smart glasses are more valuable to a user depends on the environment they will be used in and the applications that are supposed to run on them.

APPLICATIONS

In this section different possible applications that we can categorize as documentation, productivity, universal remote control, medical, education, entertainment, commerce and sports. The goal is to show how useful smart glasses could be. It is assumed that hardware to realize the applications will exist in the future.

Documentation

Pictures and videos taken by smart glasses are taken from the point of view of the user and can be taken hands-free without occluded sight. This is ideal to capture personal experiences of the wearer. In addition to pictures taken manually a device could also take pictures automatically. It could realize when the user is agitated or excited and take more pictures or even videos in those times automatically. All the pictures could be uploaded to create a documentation of the person's life.[4] This documentation could be used positively in many different ways. It could be used as a memory aid, to increase safety by creating visual evidence of crimes, as proof in court or simply for personal use. If many people used such a device for documentation, information of catastrophes and other major events would spread even faster due to the increase of pictures and videos taken in situations where the user might not have time to manually take pictures like an earthquake.

Productivity

Although there are already many solutions used for navigation, smart glasses could be used to create a better experience. In cars they could be used to highlight the way and propose a speed for the driver. In warehouses they could be used to navigate employees to the objects they need to transport highlighting those with some color.

Video streams could be used to ask experts or support questions while doing work. Imagine having to do a difficult maintenance task once a year. This could be done while being connected to an expert from that products company seeing exactly what you do, giving advice and in case something goes wrong maybe even being liable for damages. This is a lot cheaper than having an expert travel to once location.

Smart glasses could be used to track eye movement of employees. Analysing this data could help determine when a employee is overworked and needs a break or when a employee runs out of work and starts working slower.

Another possible application would be to augment construction sites with architectural plans helping in finding mistakes made in the planing phase and also preventing accidents like drilling through a water pipe.

Universal remote control

Smart glasses could be used as universal remote control. The user could spawn an augmented control of any compatible device at any time and use this to interact with the device through gestures. Examples would be an augmented television remote, music, heat, light, oven, security system or camera control. It would also be possible to remote control any computing device with a virtual display and a virtual or physical keyboard and mouse or touch interface. This could be realized by streaming video to the glasses and control information to the device. If the device which should be controlled has little computational power or the bandwidth is limited it would also be possible to only send the information to be displayed to the glasses and let the glasses create the visualization. Of course this would not be as convenient as using an actual desktop PC but it would enable the user to use the PC from remote location and use computing devices which do not have a screen or any physical interfaces. [1, 2]

Medical

At first the use of smart glasses for blind or visually impaired people might seem pointless. But they could be very useful in assisting those people as a sighted companion. Many blind people use a cane to get information about their surroundings. This method only gives information about items below the waist which doesn't prevent collisions with objects placed higher like tree branches. Smart glasses could warn blind people from such collisions. They could also be used for navigation by giving them information about the distance to predefined landmarks.[3] Another possible application would be to use the smart glasses as a seeing aid to create night vision or show objects in a distance.

Virtual reality has been used in physical therapy. Studies prove that the subjective pain sensation of patients during exercises can be reduced by distracting them with a virtual reality set up.

It would also be possible to have subtitles for deaf people. Speech recognition would have to improve and the glasses would have to be able to distinguish different voices. It would however be relatively easy to only recognize certain noises like a vehicle horn, somebody screaming: Watch out! or simple commands like turn around or come to me.

Education

Virtual reality glasses could be used to teach history by allowing the students to view historical sites not only through textbooks but in a virtual 3D world in which they could move around freely.

Those glasses could also be used to create simulations for training. Examples would be driving simulations, flight simulations, military training or surgery training. It is beneficial to be skilled in those activities in a safe environment where nobody can be hurt until the skills required to perform are acquired.

Entertainment

In 3D cinemas users wear glasses. By replacing those glasses with smart glasses the cinema experience could be improved. Personal subtitles could be introduced in the language of choice. Smart glasses could also be used for a virtual reality cinema experience. The users could determine what they see depending on their head position. The environment might be adjusted according to the conditions in the movie. For example when it is windy in a scene there could be a ventilator in the cinema creating similar conditions. Such a system would be very hard to recreate for someone at home therefore pirate copies would not create a similar experience to a cinema. This could help the industry in creating a lot more revenue.

Another big market would be virtual and augmented reality games. Especially augmented reality games could reach a broad audience than the people who play games today because they can be played outside and be based on interaction with other people in addition to augmented virtual objects. One example of such a game would be tennis with a virtual ball.

Commerce

Commercial billboards and advertisement posters could be enhanced with video. A movie billboard for example could be enhanced with a trailer of the movie if the user is wearing a compatible smart glass. Smart glasses with facial recognition software could help employees recognize customers and display information about them. Customers in stores could be given smart glasses to display information about products and to help them navigate through the stores quicker. At the same time the glasses could track their eyes gathering data about where they look. This data could be used to determine the value of advertising space. This data would then be used to sell the space at a more appropriate and maybe higher price.

Sports

During most sports one does not have a lot of time to devote to a computing device and it is impossible to use one's hands to interact with the device. These limitations make use of smart phones during sports very impractical. This is even true for endurance sports where you would have the mental capacity to interact with a smart device. Smart glasses are perfect for displaying information during a sport activity. The information that is useful for a person doing sports would be performance measurement, performance comparison, maybe navigation, notifications about weather or messages and so forth. The information can be displayed to the wearer in his peripheral vision without disturbing the sports activity.[5] The smart glasses could also be used to take pictures or video during sports activated by a speech command.

Custom software and sometimes hardware for each sport would be necessary as smart glasses for surfers would differ a lot from smart glasses for snow sports.

Conclusion

There are a lot of interesting applications which can only or a lot easier be implemented with smart glasses than with traditional computing devices. It is probable that there will be large investments into research and development of smart glasses because the entertainment industry, military and businesses can benefit from smart glasses and there might be a high consumer demand for them soon. The hardware that will be available in the near future still has its pitfalls and will probably need a few years and iterations to be fixed. Nevertheless the prototypes available today are very promising and it might happen that smart glasses will be a part of our future everyday life. Be it in cinemas, at the workplace, in our entertainment systems or as always connected companion device.

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