# Wearable Augmented Reality Systems

## Past, Present and Future of Augmented Reality Head-Mounted Displays

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# Abstract

This thesis deals with wearable headsets that are based on the technology of Augmented Reality. There is a definition of Augmented Reality and it is compared to Virtual Reality in order to accentuate the differences between them. In addition, a glimpse into the history of Augmented Reality devices is given. Furthermore, functionalities of currently existing types of head-mounted displays, such as video and optical see-through monitors, as well as projective and retinal displays, are explained.

This paper also introduces a choice of products, which are attempting to establish themselves on the market at present or in the near future, such as Google Glass and META.01. Moreover, there is an outlook on potential future developments in this area, such as bionic contact lenses, or the mergence of Augmented Reality with ubiquitous computing. Changes in terms of the embedded technology and the usability of the devices, as well as the interaction with virtual objects, are broached, so that they become part of the daily routine of people and suitable for the mass-market.

Ultimately, the main fields of application for Augmented Reality apparatuses in the future are addressed. One use case is the navigation of car drivers and pedestrians. This technology can also be applied to support workers during the accomplishment of complex tasks in the industry, such as repairs of technical machines. Augmented Reality headsets will not only facilitate the everyday lives of people, but will also be utilized to save lives in the future, for instance when it comes to perform a surgery. It can also be used to envisage architectural structures and push the gaming industry to a new level. In the future, advertising in virtual spaces will play an important role as well.

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# 1 Introduction

Anyone interested in movies, will probably be familiar with the two science fiction films "Minority Report" and "Terminator". In those two blockbusters, the concept of Augmented Reality has been taken up and implemented accordingly to the ideas of the stage directors and producers. Thereby, the protagonists were equipped with high-technology gadgets or special computer interfaces.

In Minority Report, Tom Cruise is able to retrieve, select and shift multimedia-based, virtual information that is displayed onto a transparent, head-up glass pane, simply by moving his hands, which are covered with special data gloves, in front of him.

Before Arnold Schwarzenegger accepted the office to become the governor of California, he was known as the Terminator from the movie of the same title. Through his bionic eye, the main character's actual field of view is superimposed with consecutively updated information.

What was costly staged science fiction by James Cameron in 1984, has become reality, Augmented Reality, so to speak. Humanity is closer to this futuristic technology, than the majority estimates.

This thesis deals with the past, present and future of Augmented Reality head-mounted displays and brings out, which changes in technology are required to establish such devices in the daily routine of humanity.

# 2 Definition of Augmented Reality

Augmented Reality (AR) characterizes a form of human machine interaction, which provides the opportunity to extend the real environment with additional, virtual information, which provides an insight into a broader perspective for human users. (Azuma, 1997, p. 356) Therefore computer-generated information is displayed into the viewer's field of vision, for instance by means of a head-mounted display.

Other sub-categories of this technology are, on the one hand, Mobile Augmented Reality, where the created information is superimposed through the view of an handheld device, such as applications of an Smartphone. On the other hand, there is Spatial Augmented Reality, where virtual objects are projected directly onto the surfaces of the real environment by the means of a projector placed in specially designed rooms. (Raskar, Welch, Fuchs, 1998, p. 962)

The illustration of images is done in real time and context-dependent, that is to say the appropriate information for each object is displayed. (Tönnis, 2010, p. 2) In best case, no difference between the real and the augmented reality is recognizable for the viewer. To ensure this, it is important that the overlaid information is displayed on the accurate position.

As Augmented Reality is a fusion of real and virtual world, it brings new technical possibilities in many application areas, whose are pointed out in another chapter of this thesis.

## 2.1 Comparison to Virtual Reality

Virtual reality (VR) is a three-dimensional surrounding area entirely created by computer, which is regarded as real by the observer. The viewer is completely immersed in the artificial world by means of a head-mounted display and the user is able to interact with the virtual scene. (Azuma, 1997, p. 356)

Although both technologies share the key element of interaction with the virtual objects, the biggest difference to Augmented Reality is that in Virtual Reality the viewer is completely in an synthetic world and is unable to see his or her actual surroundings. In contrast, in Augmented Reality the real environment can, in addition to the superimposed or composited virtual information, be perceived as well.

The result is a continuum, defined by Milgram, where both levels of reality - reality and virtuality - are merged, which is called "Mixed Reality". (Milgram, Takemura, Utsumi & Kishino, 1994) The Augmented Reality system interacts closer with the reality, while the virtual reality has little or no relation to the real scene.

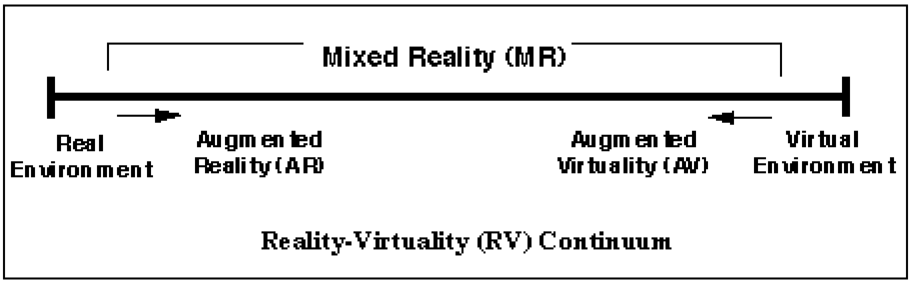


*Figure 1.* Milgram's Reality-Virtuality Continuum.

# 3 Head-Mounted Display Technologies

Generally, there are four different methods available to visually integrate virtual elements into the real environment using various wearable devices: video and optical see-through, which are currently applied the most, as well as projections. A promising technology for the near future represent retinal displays. Those methods are explained in detail and their advantages and drawbacks in technical and usability matters are pointed out in the following sections.

## 3.1 Video See-Through

Video see-through is closely related to virtual reality, since, in this case, the real scene is recorded by video cameras mounted on the wearable device. This video feed will be displayed on one or two, mostly liquid crystal display (LCD) based, monitors that are placed in front of the eyes of the beholder, so that a immersed and closed-view is emerging. In addition, the virtual elements superimpose the digitized data on the opaque displays. (Edwards, Rolland, & Keller, 1993)

As the data of virtuality and reality is stored separately, brightness and contrast between the computer-generated elements and the reality can be accurately matched, so that a smooth, unobtrusive transition occurs. Contents may be easily installed in or removed from the digitized stream, because the exact pixel coordinates can be calculated. Another advantage includes that, in contrast to optical see-through, no or lower cognition delays arise between virtuality and reality. To adjust the lag of time resulting during the display of AR elements, the procedure is to temporally delay the recorded video feed as well. This is a relatively low priced technology of wearable devices. (van Krevelen, & Poelman, 2010, p. 3)

A main problem of video see-through is that, due to the digitized image, the real scene, as well as the virtual elements, are displayed in the reduced resolution (180,000 to 240,000 pixels) of the mounted monitor. Moreover, the visual field of the user is constricted (about 30 degrees horizontally) and distorted at times, which has to be offset. (Azuma, Baillot, Behringer, Feiner, Julier, & MacIntyre, 2001, p. 35) A further disadvantage is that many wearable systems have a fixed lenses and therefore the focal distance cannot be adapted. Additionally, safety issues may be given, if the video see-through device runs out of power. By reason of the closed-view, the user would be unable to see the real surroundings any more. As the camera does not coincide with the actual position of the eye of the viewer, but rather is mounted at a distance to it, this may lead to an disorientation of the user based on the parallax. (van Krevelen et al, 2010, p. 3) The gap between the monitors can also differ from the user's interpupillary distance (IPD). These problems may provoke inconveniences regarding the viewer's eyes, such as increased strain or tiredness, because the user awaits another visibility field than he really receives. This so-called simulator sickness primarily appears during rapid motions of the user's head. (Bimber, & Raskar, 2006, p. 4)

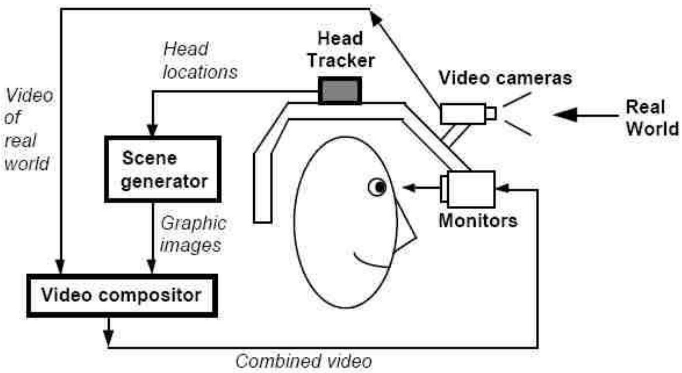


*Figure 2. Video see-through device.*

## 3.2 Optical See-Through

A further procedure is optical see-through. Such displays permit a direct view on the real scene by the use of a tilted, semitransparent mirror in front of the eyes of the beholder. Monitors that are mounted above the so called combiner, superimpose the real image holographically with virtual information on the units, which partly reflects the beam. (Rolland, & Fuchs, 2000, p. 287)

Since optical see-through preserves the view on the real environment, there is given no lack in terms of details. By contrast with the previously explained technology, only the generated images are impaired by the lower resolution of the resource or the monitors. An energy loss of the device has, unlike video see-through, no significant negative impact on the visual field. There is a easy and cost-efficient way of producing it, because no camera for recording the reality is required and therefore this method only has to edit the virtual objects. Another main benefit is that the positioning of the camera does not cause any eye-offset. (van Krevelen et al, 2010, p. 3)

To be able to superimpose the virtual image on the exact position, a complex calibration and tracking of the head of the user are necessary. The mounted mirror diminishes light intensity and contrast of the viewer's field of vision, as the reflected beam takes a disturbing effect. Due to this fact, optical see-trough is less qualified for application outdoors. Another disadvantage is that, on borders of mirrors of optical see-through devices, clipping errors of the AR elements can occur. As on the one hand these approaches provide an instant look on the real environment, but on the other hand the superimposed images are registered within a short delay of time, it leads to visual troubles. These distortions must be removed by rectifying the virtual elements, in such way as to fit the reality. Furthermore a focal problem occurs because of the different depth levels of the actual surroundings and the digital data. As the eye of the beholder has to either switch the focal point between the real and image plane regularly or to blur one of it, this may lead to perceptual disturbances. (Bimber et al, 2006, p. 4)

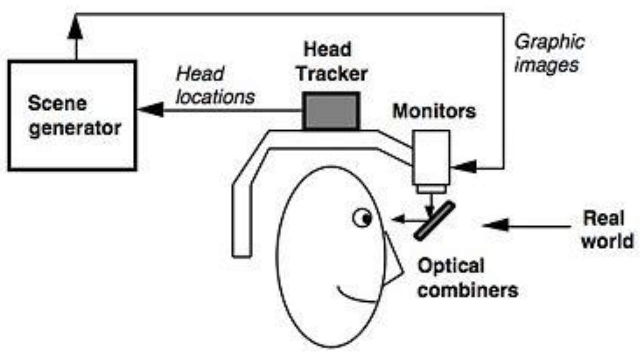


*Figure 3. Optical see-through device.*

## 3.3 Projective

An AR environment also can be created with miniature video projectors that cannot only be mounted on a room's ceiling, but also on the head of a person. Here, virtual objects are projected on the physical items by employing two semi-transparent mirrors to blend the projections in the visual gaze of the observer. By using a special retro-reflective material consisting of a multitude of micro corner cubes to cover the desired objects, the cognition of the projection can be increased in contrast to light-diffusing grounds. Thereby the projection ray is deflected with a beam splitter along the axes of coordinates until it attains to a suitable surface. From there, the beam is reflected back along its arrival angle in direction to the human eye. (Azuma et al, 2001, p. 35)


*Figure 4. Reflection of retro-reflective material.*

By means of this technique, the virtual environment can be applied to diverse and larger surficial areas without having to install supplementary parts that could strain the view. Since the modulated light is reflected back to the eye, maladjustments regarding the interpupillary distance and therefore disorientations based on the parallax can be avoided. Besides this major advantage of such systems, every user is able to experience different virtual elements on the same surface, as they only can be seen by the wearer of the head-mounted device him- or herself. Due to the fact that the head-tracking can be automated via cameras, the problem of having to manually calibrate the projectors each time the user, who is wearing the projector, varies the distance to the screen, can be solved. (van Krevelen et al, 2010, p. 4)

However, projector based devices generate problems regarding a reduced luminosity, resolution and contrast of the projected elements created by the scene generator, especially if there are poor light conditions in the utilized setting. Hence, real surroundings might mask up the computer-generated images. Therefore it is not suitable for outdoor application. To achieve reasonable results, high-quality technical equipment and specifically designed areas are needed, which will cost a pretty penny by contrast with video see-through for example. (Bimber et al, 2006, p. 5)

## 3.4 Retinal

The disadvantages of having to mount displays on the head of the user are eliminated by the development of retinal scanning displays (RSDs), where the computer-generated picture in the form of modulated light is projected directly on the retina of the beholder using a low-powered semiconductor laser and a beam splitter. (Azuma et al, 2001, p. 35)

Therefore, a larger visual field can be generated compared to the monitor-based method. It creates a brighter and high-contrast virtual image, as well as a superior resolution and a minor wattage. The technical potential is only diffraction limited and restricted because of optical errors in the luminous source. In addition, the relatively simple built-in elements causes the device to be cheaper and lighter regarding the weighting. For these reasons, this is the best technology to be used outdoors. (van Krevelen et al, 2010, p. 4)

In the future, lasers might be replaced by custom-built light-emitting diodes (LEDs), an automatic refocus will be possible, where there is a definite focal distance nowadays. As in the early editions only red light could be emitted, the implementation of full-colour stereoscopic images will be on the market by combining the separately modulated beams of the RGB colour-space. (Bimber et al, 2006, p. 4)

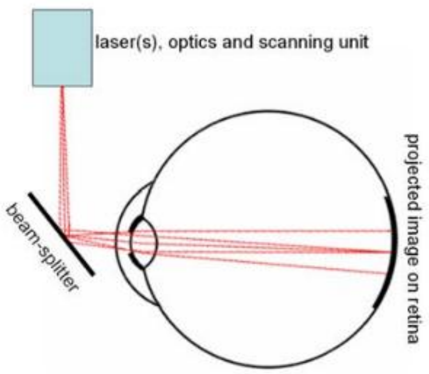


*Figure 5. Retinal display.*

# 4 The Past

Having the intention to "persuade the human senses with virtual experiences by advances in computer technology", Ivan Sutherland published an essay in 1965, entitled "The Ultimate Display". (Sutherland, 1965, p. 506 - 508) This happened some years before the introduction of Personal Computers. In cooperation with students of Harvard University and University of Utah, he designed and developed an optical see-through display thereupon. It was a stationary system with a helmet and a semi-transparent display. This made possible to illustrate simple 3D computer graphics in real time, which could be viewed, depending on the perspective of the observer because of an integrated positioning unit. This development of the first head-mounted display (HMD) until 1968, can be considered as the birth of Augmented Reality, because the real environment was enriched with virtual elements for the first time.

Since the late fifties, there was an extensive research by the defence industry, such as US Air Force and NASA. As jets demanded faster reaction times of pilots, visual systems for simpler navigation and sighting devices were put to the test. As a result, the modern head-up display (HUD) evolved, which was developed by a French test pilot in 1975 to overlay the pilot's field of view with flight and position data. This was the first successful implementation of Augmented Reality with a practical benefit. (Wolski, pcwelt.de, 2012)

In 1992, the term "Augmented Reality" was used for the first time, when the physicist Tom Caudell published a paper in which he described the use of "Augmented Reality" in aircraft to assist workmen in the cabling of Boeing aircraft. (Caudell, & Mizell, 1992, p. 659)

As the technology advanced, predominantly when mobile computers with good performance were available, so that the user is independent of permanently installed computer systems, other projects emerged in this area. Examples are a GPS-based appliance to navigate visually handicapped people, and a wearable AR device, called MARS, that provides tourists with information through 3D graphics on their sightseeing tours. (Höllerer, & Feiner, 2004 p. 1)

In Japan and America, several workshops and symposia were held on Mixed and Augmented Reality. After the involvement of Europeans, especially Germans, the previously independent associations merged. Hence, the International Symposium on Mixed and Augmented Reality (ISMAR) takes place in one of the primary participating continents since 2002. Annually, challenges and solutions, regarding these fields of activity, are reviewed. (van Krevelen et al, 2010, p. 2)

# 5 The Present

Since the early development of head-worn devices mainly for military purposes to pilot fighter jets, numerous aspects have changed in terms of the appearance of such systems. In the past developers had to either choose between investing in technical facilities to accomplish acceptable results, which lead to heavy-weight and cumbersome devices, or to focus on an adequate wearing comfort, though thereby the technical supply gets the short end of the stick. Nowadays the aim is to integrate these devices in the daily life and use of the people and to make it suitable for mass production. Prototypes tend to an ergonomically designed, comfortable and smaller body housing, to enhance them not only on a technically, but also on a usability basis. A number of companies currently are researching and have wearable headsets that embed Augmented Reality optics within an ordinary pair of spectacles in their works.

In the subsequent chapters the current technical possibilities in the field of Augmented Reality are exposed on the basis of the probably best-known device brought to the market, named Google Glass, as well as a competitive product from the US company META. Since the world premiere of Glass Google, wearable devices of several other companies, who pick up the concept of augmented reality glasses, were announced too. Such examples are the Italian start-up GlassUp or the Smartphone-Gadget Vuzix Smart Glasses M100. However, most of them turned out to be not more than just knock-offs or simply not suitable for everyday use of the masses.

## 5.1 Google Glass

Google Glass is a lightweight head-worn device that is built like a normal pair of eyeglasses, but a 640 x 360 pixels prism display is sited in front of one of the user's eyes, instead of the regular lenses, to superimpose virtual data in the visual field of the beholder by means of a mini-projector. (Rivington, techradar.com, 2013) It is based on the technique of optical see-through displays.

Bruce Sterling has characterized the functional range of this invention in an E-mail to IEEE Spectrum, a technology magazine, very accurately: "Google Glasses are more like a head-mounted unit Android, and there's not much in the way of live interaction with 3-D virtual images." (Ackerman, 2013, p. 29) As he commented, the appliance does not effectively take advantage of what Augmented Reality stands for. The real environment seen by the beholder cannot be overlaid with suitable images or charts. It has rather embedded the components of an Android Smartphone with its dual-core processor and 1 gigabyte memory chip.

The device can, on the one hand, be controlled and navigated via voice commands through an integrated headset with microphones, or, on the other hand, with a touchpad on the side of the plastic frame. In addition, there were also some experiments with head gestures. Sounds are perceived by bone conduction, so that there is no need of ear-phones.

In an interview with IEEE Spectrum, Babak Parviz, head of Google's Project Glass, said that those glasses should serve two main purposes: firstly, it is designed to provide a communication tool via pictures and videos to their users and secondly, it should also be an aid to access information and thus to answer questions of all kinds very quickly. (Parviz, spectrum.ieee.org, 2012)

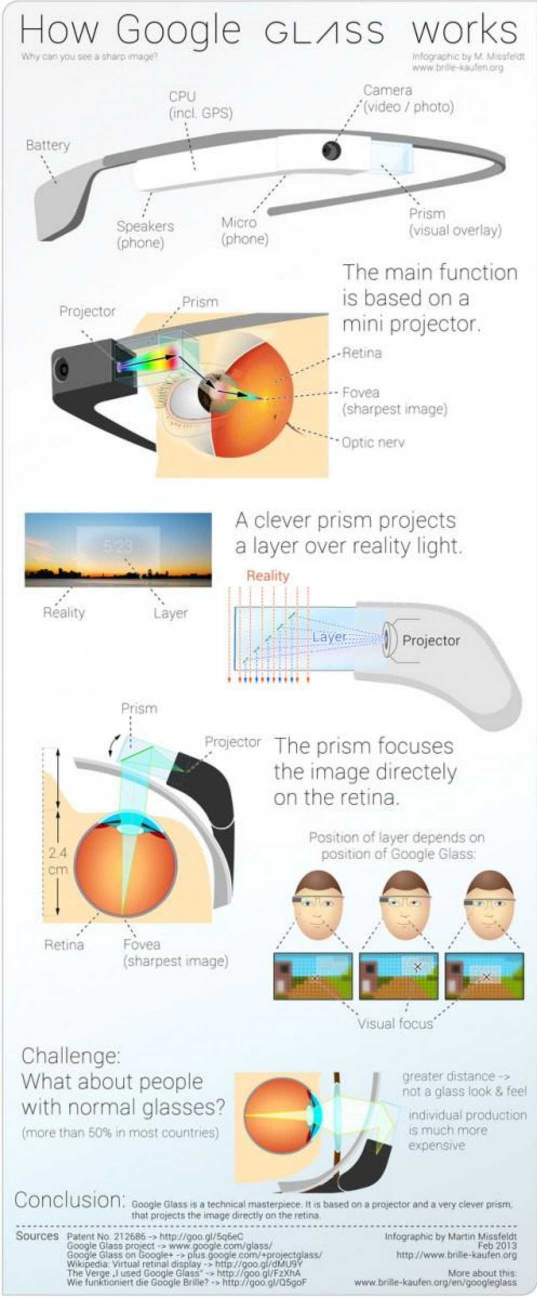


*Figure 6.* Google Glass.

Therefore Glass is equipped with a 16 gigabyte flash memory capacity, a camera for 5 megapixel photos and 720p videos. Visual and audible recordings can also be immediately stored in the cloud or shared on social media platforms with others. As Google Glass can be used as a stand-alone version, it provides WIFI, GPS and Bluetooth for such purposes. However, when using a special app, named "MyGlass", a connection to a Smartphone can be established and afterwards data can be exchanged. That is why telephone calls can be made or text messages as well as emails can be displayed in front of the user's eye. Dictating answers represents also a feature. This device gets an unique character by installing various apps, such as a navigation software, an Augmented Reality travel guide or a software for instant translations. (Rivington, techradar.com, 2013) Moreover, Babak Parviz's statement punctuates that Google wants to remain to its roots as a search engine in some degree.

A main drawback of this product is the low battery life, which is, depending on the workload, limited to approximately 6 hours. A further issue is the currently relatively high sales price of about $ 1,500. Both could avert that Google Glass might establish itself as an everyday object of many people in the near future.

It would not be a product of Google, if the data privacy protection would not have been called into question. Glass is considered to be another way to spy on their users, because nobody exactly knows what the enterprise does with the collected data. Personal information may be disclosed to third parties. There are also raised concerns over a prospective misuse and the privacy of the customers, as everybody could be stealthily filmed or photographed at any time in public. (Ackerman, 2013, p. 29) However, up to this time, no law is enacted to work against it. Questions regarding road safety or social graces and acceptance also remain unsettled. At least, no advertising is planned for Google Glass. (Parviz, spectrum.ieee.org, 2012)

## 5.2 META.01

Glasses, which seamlessly display virtual objects into the real field of vision, are currently rudimentary applied for industrial purposes. However, these models are expensive. Henceforth, an emerging company from New York, consisting of some students from Columbia University, wants to achieve a breakthrough with a product at a more favorable price for about $ 667. They are supported by experts like Steve Mann, considered as the "father of wearable computing", and Steve Feiner, a well-established specialist in the field of Augmented Reality and 3D. (futurzone.at, 2013)

Unlike the alternative developed by Google, META.01, which is introduced under the name of Spaceglasses on the Internet, meets the criteria of true Augmented Reality glasses much more than most of the competitors'. It facilitates a natural interaction with stereoscopic virtual objects that appear in the real field of view. The user can operate through gesture control via hand waves to move or manipulate those graphical superimpositions. In addition, digital content such as videos, can be anchored to real surroundings. (futurzone.at, 2013)

Two transparent liquid-crystal displays, each with a resolution of 960x540 pixels that are actuated via HDMI, and the use of two projectors including respective mirrors provide the creation of three-dimensional illusions within a visual field of 23 degrees per eye. The rendered contents are also translucent, so they do not completely cover other people or the real environment. A module, similar to Microsoft's Kinect, consisting of an RGB camera that records in 720p, as well as an infrared camera with a resolution of 320 x 240 pixels is installed for depth measurement. Both are activated via USB and capture the position and movement of objects or hands, so that the wearer can interact with virtual items. Finally, an accelerometer, a gyroscope and a compass detect the orientation and position of the goggles. (spaceglasses.com, 2013)

*Figure 7.* META.01

To be able to work with the META.01, a Windows PC is required. In the future, it may be replaced by a Smartphone. After the glasses were connected, apps, which are based on the Unity 3D engine, can be downloaded and utilized. The ambition is to replace the use of computers or laptops in a long-term. Application areas could be architecture offices or design laboratories, as well as gaming. With those Augmented Reality wearables, the user can play conventional games, such as chess or laser tag, and also computer games, like Minecraft, at present. More applications are estimated with the publication of the API for external developers. (Zubovsky, hackthings.com, 2013)

The first generation of this eyewear is visually not very appealing. Because of its weight of 300 grams, the device seems a bit clumsy. The end customer's version is intended to be slimmer and more elegant and should be worn like a conventional pair of spectacles. (trendsderzukunft.com, 2013)

# 6 The Future

Augmented reality is not yet technically mature as experts have thought a few years ago. Current examples of use turn out to be more like gimmicks or marketing strategies for the broad masses, usually in terms of mobile applications for Smartphones, instead of being a truly valuable extension, which can be sustainably established on the market. The recently awakened interest and the immense hype regarding head-mounted devices arises from more affordable powerful and small-sized hardware. While not all technical hurdles have been mastered yet, a rudimentary useful application is already possible. However, today's products and techniques, such as Google Glass, are just the tip of the iceberg of what may be possible in the future. It is time for Augmented Reality to leave laboratories and niches behind and take steps towards everyday technology.

In this regard, three sections are addressed that will entail major modifications in the upcoming decades: the compression of the components to small surfaces to the point of a total invisibility of the applied hardware, as well as the way of interaction with the digital world. Looking ahead, this could implicate that Augmented Reality becomes a fundamental technology.

## 6.1 Bionic Contact Lenses

As technology continues developing expeditiously, Augmented Reality may obtain its intention to supplant handheld, mobile devices and wearable computers will become commonplace in leisure and labour of many people. This breakthrough should be achieved through reduction of costs and dimensions of the embedded component parts, such as cameras, computers, sensors and the composition of those, whereas the speed of data processing, as well as precision and resolution of virtual superimpositions is increased.

Ergonomic, stylish and small-sized apparatuses, which resemble a regular pair of spectacles, are an intermediate step at most. With substantial progress in miniaturization and nanotechnology, Augmented Reality technology will be brought closer to the human eye, in such a way as the technical may merge with the biological attributes. As a result, imperceptible contact lenses with implanted electronics or possibly even bionic eyes supersede head-mounted optics to prompt the beholder with additional, digital information directly on his or her eyeballs, non-constraining by drawbacks of eyeglasses or other head-mounted displays.

Researchers at the University of Washington in Seattle assisted by Finnish engineers accomplished to imprint a light emitting diode (LED) onto a contact lens to visualize a single, remote-controlled image point when it is worn. To turn conventional polymers into an Augmented Reality device, "we integrate control circuits, communication circuits, and miniature antennas into the lens using custom-built optoelectronic components", Babak Parviz, the team leader, explained. (Parviz, spectrum.ieee.org, 2009) In order to neither distract the gaze, nor harm the eyes of the wearer because of toxic materials or high temperatures, the fabricated hardware is as organic and minimized as possible and semitransparent. The LED is powered by an external battery, whose electricity is transmitted via radio frequency, as well as the processed, displayable data is sent from a separate device, such as a Smartphone. To cope with the problem that the human eye is not qualified to bring objects into focus that are closer than 15 centimeters, a Fresnel lens was applied. By the use of this, the focal length could be shortened and the aperture could be enlarged. A contact lens consisting of an array of 16 LEDs is currently on the drawing board. The final aim is to highly expand the number of diodes installed, so that more detailed output can be generated, with a simultaneous decrease of power consumption. (Parviz, spectrum.ieee.org, 2009)

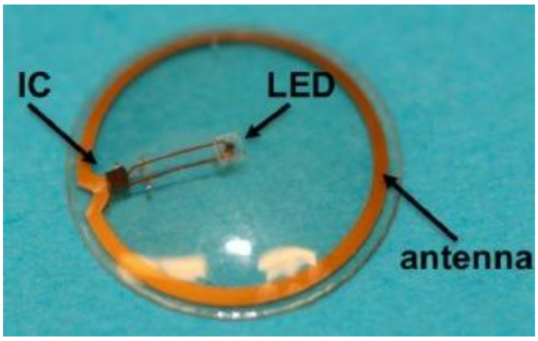


*Figure 8.* Bionic Contact Lens.

Another approach to this subject area was chosen by a team based at the laboratory at Ghent University in Belgium. They have recently developed a contact lens embedded with a curved LCD display. Unlike LED technology, where the display is restricted to a small, centrally arranged area on the lens and therefore to a small range of pixels, with this method the entire surface can be equipped with pixels to display more detailed, virtual images. To be able to model the LCD display in a smooth spherical shape, special conductive polymer films were used. So far, the prototype is incapable of showing more than basic patterns, which only can be noticed externally, rather than by the wearer him- or herself. (Plafke, extremetech.com, 2012)

However, both laboratory experiments have the potential to evolve into functional and valuable head-up displays as a commercial product for a broad populace.

## 6.2 Ubiquitous Computing

"Humanity has left the Information Age and entered the Shift Age. The Shift Age is one of those inflection points or times when much of humanity will change how we live, how we think, how we interact with each other and what we do." These words are coined by David Houle, a futurist and author of a book entitled "Entering the Shift Age". (Houle, davidhoule.com, 2012) In this environment of change, Augmented Reality technology could play a decisive role.

The next step to that effect is not only the downsizing of hardware, but also to make the computer, which is an interface between the real world and digital information, as inconspicuous as possible. So technology will only take a back seat and virtual data will become a more natural part of the real environment. This could lead to a merging of both levels, which will ultimately change the definition of reality.

According to Amit Singhal, senior vice president in charge of search at Google, "Computers will no longer be devices we turn on, but will be so integrated into our everyday environment that we can ask them to do things without ever lifting a finger." (Miller, nytimes.com, 2012)

With this statement, he refers to a paradigm that is called Ubiquitous Computing, which was introduced in an essay named "The Computer for the 21st Century" by Mark Weiser. (Weiser, 1991) It represents a further step towards permanent networking, which means that computers will not be visible casings any longer, but people will be surrounded by a pervasive network without perceiving it, such as electricity. Therefore, technologies are required to maintain Augmented Reality permanently. People are "always on", and the point is to provide the appropriate information and course of action from terabytes of data available in the cloud at the right time and place. Personalized information that is beneficial in the current scene, will be intuitively augmented without having the user to demand it. Such preparation of data is known as Push Augmented Reality. (Phillips, businessrevieweurope.eu, 2012)

Research centers are already working on sensors that are able to recognize the context of a situation the beholder is in and automatically react thereupon. Google could be cited as an example. (google.com/landing/now) They have developed a similar intelligent aid, which springs into action unasked. Today's state of the art is Pull Augmented Reality, where the user requests required information on his own. (Phillips, businessrevieweurope.eu, 2012)

## 6.3 Thought Control

Augmented Reality's aim is to create a human interaction with the invisible computers that is as natural as possible, so that they merge with the actions in real life. Therefore, technology and functionality of the already existing voice and gesture controls will continue to improve. Advanced eye and accordingly head tracking will be able to register movements of the hands or even the entire body at a higher level, so that virtual objects could be manipulated with increased accuracy and reduced latency.

During a prolonged use of gesture control to navigate through the digital world, the so-called "gorilla arm" effect could arise. (Carmody, wired.com, 2010) In doing so, the user gets exhausted of all the hand motions. That is the reason why this alternative form of computer interaction will not displace standard methods in the near future. A keyboard might still be the fastest way for writing texts for example.

Another approach could be brain computer interfacing (BCI), if it is technically mature enough. Thought control is currently in an early stage of development, although there were already successful experiments with the steering of a helicopter model. While bringing the mind into focus, the user's brain waves can be measured by electrodes and transmitted to EEG apparatuses. A computer converts the signals to control overlaid Augmented Reality items. (Nordqvist, medicalnewstoday.com, 2013)

Objects may be created by mentally visualizing the final product in the future. Afterwards, the virtual image could contingently be realized with a 3D printer.

# 7 Fields of Application

After Augmented Reality devices are technically mature enough to establish as a commercial product in the market, it can not only facilitate the everyday life of its customers, but also save the lives of them by detecting events of sudden danger. Augmented Reality could be employed in nearly all fields of everyday life, as well as an aid in industrial fabrications and medical care in the future. Some examples are still in the testing phase, others already moved mainstream. With further technological progress, scenarios, considered as futuristic these days, could be opened up. The major application areas are discussed in the following chapters.

## 7.1 Navigation

The utilization of augmented reality as a navigation guide for drivers and pedestrians is probably the most famous of all application purposes. The target location is entered via user input and the current position is determined by GPS coordinates. The marked directions are superimposed on the actual road scene.

Concerning automobiles, Augmented Reality may also be integrated as a head-up display in windshields. Driving-related data, such as directions, speed, road conditions, traffic signs or potential sources of danger like pedestrians or corners that are difficult to observe, is displayed in the field of vision. Information transferred from a linked Smartphone could also be part of it. As the driver is not obliged to shift the attention off the street, car rides are made safer. (Mendoza, business.inquirer.net, 2013)

Until realization, some technical challenges regarding GPS determination still have to be eliminated. This applies to both, insufficiently available geographical material for pedestrians, and the positioning inaccuracy.

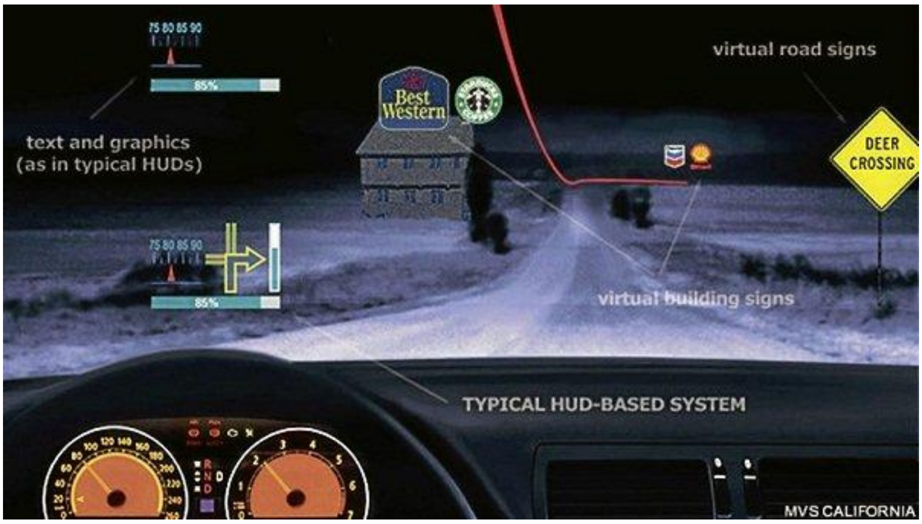


*Figure 9.* Aumgented Reality Windshield.

## 7.2 Medicine

Computer-aided surgery (CAS), which is extended by Augmented Reality technology, is an important and future-promising procedure in the domain of healthcare management, since the success rate of surgical interventions can be increased due to this visual guidance. The outcome of this is that many patient's lives can be saved or at least improved.

*Figure 10.* Augmented Reality in Medicine.

This technology provides the opportunity to extend the physician's sensory perception during surgeries. Previously recorded scans of computed tomography (CT) or magnetic resonance imaging (MRI) can be virtually superimposed on the body of the patient. (Tang, Kwoh, Teo, Sing, & Ling, 1998, p. 49)

Because of visual information, such as the position of bones, ligaments, organs or veins, as well as instructions of handles, medical operations can be performed more accurately and efficiently. Especially in sensitive and delicate areas, like during a brain surgery, this form of computer-assisted extension of cognition is a useful guidance for doctors.

Besides this application, Augmented Reality could be deployed as a training tool in the form of a medical simulator for students to learn how to handle diverse disease patterns.

## 7.3 Industry

The manufacturing and maintenance of modern machines, such as cars, is increased in its intricacy, not least because of the rising complexness of the embedded systems and components. Due to frequently changing purchase behaviors of consumers, development times have to be reduced. Nevertheless, in order to permit shortwork as well as reliable and high-quality commodities, mechanics will work by dint of Augmented Reality devices, which take a supportive role during tasks.

These special binoculars display step-by-step instructions depending on the worker's field of activity, for example to enable the repair of an engine. Not only the next step of the procedure is visually shown in the user's sighting field, but also necessary information about the used tool. It may also be possible to highlight the object that has to be manipulated and visualize the movement that needs to be performed, so the mechanic only has to imitate it. (Regenbrecht, Baratoff, & Wilke, 2005, pp. 48-49)

By the use of such an Augmented Reality system, installation and service can be done more flexibly and efficiently. Workload also requires less of time than would be necessary in personal contribution. Moreover, the industry expects less rejects owed by human failure. Money that otherwise has to be invested in skill enhancement of manpower, can also be saved and used for different purposes.

Augmented Reality technology, integrated in welding helmets to assist employees during their production of weld seams, is already established in some factories. (Aiteanu, Hillers, & Gräser, 2003)

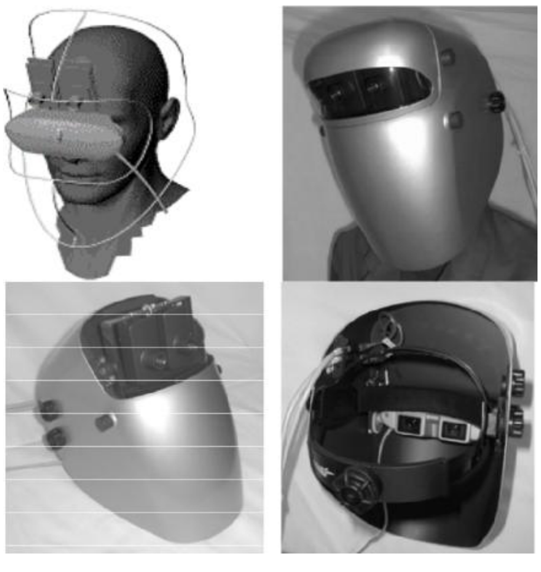

*Figure 11.* Augmented Reality Welding Helmet.

## 7.4 Architecture

Architectural visualization is concerned with the visual presentation of architectural designs and existing architectural structures. It is mainly applied in the field of interior design and the planning of complexes of buildings. The use of Computer Aided Design (CAD) in architecture offices and design laboratories has become standard long ago to facilitate the planning process. (Thomas, Piekarski, & Gunther, 1999)

Computer-generated models of buildings, statues, or furnishings are rendered in 3D and may be projected directly into the accommodations or the landed property of the client by means of an Augmented Reality device in the future. They will be suited to the preferred position in due consideration of the angle of view.

Interminable measuring of the estate to be designed becomes redundant, since the scheme can be adjusted directly on the spot to the conditions or demands of the customer. This has the benefit that the impact of the modification immediately occurs before the architect's and client's face.

Augmented reality is also intended to be a tool for collaboration. The responsible architect can do a walk through the simulated design. Furthermore, multiple designers or architects are able to interact with the same virtual model.

## 7.5 Tourism

As tourists are commonly culturally very interested, they would like to experience and learn as much as possible about the points of interest of their whereabouts. In online databases, a variety of digital information about such places is available. However, gaining access to this data, for example via Smartphone, is cumbersome for tourists during their expedition.

Using Augmented Reality technology, detailed, location-based and personalized information can be retrieved from the user at the moment when it is required without having to shift his attention away from the scene. A variety of multimedia contents, such as texts, photos, videos or 3D animations can be provided from online sources.

Therefore, the real environment, which may consist of a historical building, monument or an artwork in a museum, can be rigged with context-sensitive information, such as facts and figures. Moreover, the sight could be superimposed with an image that shows, how it looked back in history. (Fritz, Susperregui, & Linaz, 2005)

Another way Augmented Reality can be useful in tourism is the preparation of translations. Warning and information signs, as well as the menu in a restaurant, can be augmented with the appropriate text in the tourist's mother tongue in real time.

## 7.6 Advertising

Over the past years, traditional advertising media, like banners, went out of date, so experts are seeking after new opportunities for product commercialization. Augmented Reality is a paradise for marketing and advertising. To customize, locate and integrate the advertising and shopping experience into the real environment of the consumers is a huge claim and aim for sales promoters. It is more important to segment the market and focus on the target group of the specific product than to reach the masses with advertisements. Augmented Reality enhances the virtual reality with advertising that is not only personalized and therefore valuable, but also adapts to the surroundings and even takes place within it.

John Havens (Havens, mashable.com, 2011) has dealt with the question of who actually has the rights on digital spaces, named as "Virtual Air Rights". Currently, nothing prevents divers companies from claiming the same virtual ad space for themselves in order to visually overlay advertisements. However, this will probably turn out to be a copyright infringement in the future.

## 7.7 Entertainment

Games containing aspects of Augmented Reality are currently booming. However, they are predominantly developed for mobile applications at present, as the wearable technology is not yet mature and affordable enough for mass production. Therefore, a Smartphone and an installed app of the desired game are required for gaming.

With increasing miniaturization and performance enhancement of the hardware, especially in terms of battery life, Augmented Reality equipment gets more and more portable. For this reason, games can be relocated outside, like back in the day. The real environment becomes the scene of a three-dimensional game.

One of the first Augmented Reality games on the market that are based on the use of head-mounted displays, is the first-person shooter "ARQuake". (Piekarski, & Thomas, 2002, p. 36) It combines Augmented Reality and Gamification in a revolutionary way. Thereby, an existing game engine was expanded with Augmented Reality components. In this game, the player moves freely in the actual surroundings and has to shoot at monsters appearing from nowhere. A very natural way of interacting with the virtual opponents is provided by the use of a physical gun made of plastic.

*Figure 12.* ARQuake.

Another field of application for Augmented Reality are sporting events. These days, game-related, virtual markers, like the first-down line in American Football, or the insertion of the driver's names in Nascar, are only visible on TV. With the use of Augmented Reality glasses or contact lenses, they should also be superimposed on the field in the stadium for the spectators. The data material normally processed in television production, will be placed at the viewer's disposal for those purposes.

# 8 Conclusion

The future of Augmented Reality in our society strongly depends on the development of data spectacles. Glass Google currently draws a lot of attention on this technology, and therefore many other manufacturers will follow. Due to an increasing manufacturers' competition, the embedded hardware will continuously advance, as each business concern wants to offer the product of best quality. Therefore, a steady market for Augmented Reality glasses could evolve.

If a majority of people applies such devices in their everyday lives, possibly in conjunction with ubiquitous computing, a further step towards permanent networking of humanity will be done. However, this may create doubts regarding data privacy protection, as it already crops up nowadays, using the example of Google Glass.

In the future, people have to accept that the data cloud will store all conceivable personal information about everybody linked to the network. The evolution towards a "Big Brother" society with mass surveillance will be inevitable, but the privacy advocates could potentially be appeased by informing them, what their data is used for and if it is distributed to third parties. In addition, the network has to be made safe in order to avoid hacker attacks and error-proneness.

However, it remains to be seen, whether humanity is ready for this pioneering step towards Shift Age.

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