Augmented Reality Glasses
State of the art and perspectives

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Abstract—**This paper aims at delivering a comprehensive and detailled outlook on the emerging world of augmented reality glasses. Through the study of diverse technical fields involved in the conception of augmented reality glasses, it will analyze the perspectives offered by this new technology and try to answer to the question : gadget or watershed ?**

***Index Terms*—augmented reality, glasses, embedded electronics, optics.**

I. Introduction

Google has recently brought the attention of consumers on a topic that has interested scientists for thirty years : wearable technology, and more precisely "smart glasses". However, this commercial term does not fully take account of the diversity and complexity of existing technologies. Therefore, in these lines, we wil try to give a comprehensive view of the state of the art in different technological fields involved in this topic, for example optics and elbedded electronics. Moreover, by presenting some commercial products that will begin to be released in 2014, we will try to foresee the future of smart glasses and their possible uses.

II. Augmented Reality : a clarification

There is a common misunderstanding about what "Augmented Reality" means. Let us quote a generally accepted definition of the concept : "Augmented reality (AR) is a live, copy, view of a physical, real-world environment whose elements are augmented (or supplemented) by computer-generated sensory input".

It must not be confused with Virtual Reality, which consists in presenting to the user a completely alternate reality, simulated from scratch.

The concept of augmented reality is part of a wider one, which is mediated reality[1]. It defines not only the fact of superposing computer-based information on real images, but also the modification of those said images. For example, Steve Mann, "father of wearable computing", imagined a smart welder mask which could shadow the welding arc.[2]

Therefore, devices such as Google Glass can not be defined as ARG ("Augmented Reality Glasses"), but should be refered to as "ubiquitous computers" as they consist more of a complementary screen than of a device capable of altering reality before presentig it to the user. This difference being now clear in the reader's mind, following lines will focus on augmented reality devices and the technical challenges they must face, which include optics, electronics, real time image processing and integration.

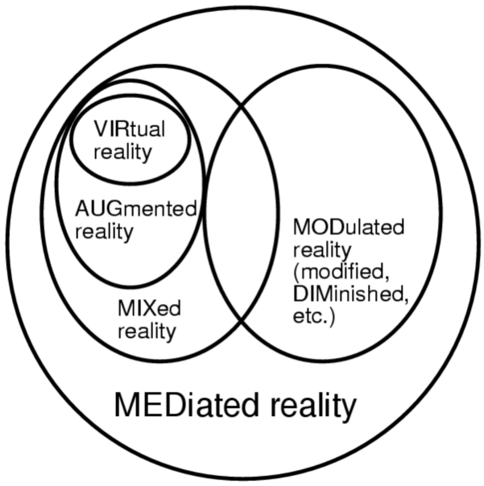

Fig. 1. Different kinds of Mediated Reality

III. Optics

Optics are the core challenge of augmented reality glasses, as they need displaying information on the widest Field Of View (FOV) possible, very close to the user's eyes and in a very compact device. Moreover, the images must be displayed so as to appear far from the user, in order for the eye not to be forced to accommodate, which would be a source of discomfort and ocular fatigue. Therefore, all devices rely on an optical system which is in charge of forming images at infinity. A number of systems have been designed by industrials to achieve this goal. Here are three of them which give a good outlook on the main technologies used so far.

A. Heads Up Diplay

Heads Up Displays (HUD) aim at superimposing computer-created images on user's FOV. Today, they rely on two main different opical systems which are presented in the next lines.

1) Classical systems: Though not fully accurate, the figure 2 shows the principle of most basic HUD which corresponds to the system used in Google Glass. It consists of several core components :

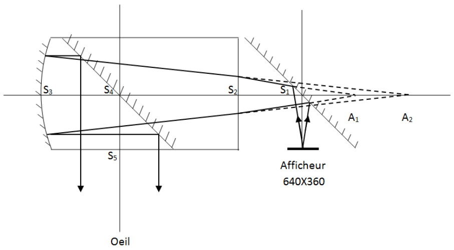

Fig. 2. Google Glass optical system principle

- A compact, very dense source display
- A magnifying system in charge of giving the image a satisfying size
- A system charged of placing the image at infinity. Here both these operations are processed by the parabolic mirror placed on the left
- A beamsplitter (an optical component that lets a proportion of light go trough and that reflects the other part) which allows the superposition of light coming from the display on the user's field of view.

However, this system uses classical optical components that are difficult to integrate in a limited space. Besides, the unavoidable use of a beamsplitter at an angle of 45 degrees does not allow a wide FOV with limited dimensions. Hence the interest of another system, used for example by a French company, Optinvent, in their ARG : diffraction based see-through video glasses.

2) Diffraction based systems: Diffraction based systems use a light guide which is in charge of carrying the image from the output of the collimator to the user's FOV. Until recently, it was almost impossible to use for commercial purpose as technology was both expensive and fragile. An innovation called "Clear VU" has recently made it wearable and affordable.[3]

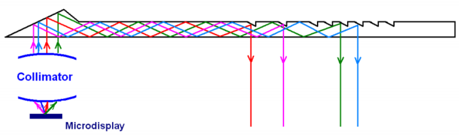

Fig. 3. Optical guide used in Clear VU

The principle of this technology is depicted on figure 3. The image created on the microdisplay is collimated and the ray beam is then guided through the device by Total Internal Reflection, before being impressed on the eye through a set of micro-mirrors. The turning point achieved by Clear VU is the realization of this system in molded plastic. It allows the microdisplay and the collimator, which remain the biggest unavoidable components to be placed more discreetly. Therefore, it partial answers the challenge of integration, compactness and design.

However, both these systems do not fully answer to the ambitions of mediated (and augmented) reality as, though allowing the system to display information, it can not alter the reality seen by the user. This can be done by chosing a more complex optical system, know as EyeTap.

B. EyeTap

EyeTap is the name of a system imagined and designed by Steve Mann's team which is based on the same principles that HUD.[4] However, this system includes a complementary component named "amerac" as well as a camera so that the system sees what the user sees, as one can see on figure 4. These two added components, linked by some processing blocks that allow focus and zoom control, allow the superposition of perfectly synchronised artificial rays of light on natural ones, which enables a much better mixing of added informations and reality.

Moreover, by replacing the beamsplitter by a two-sided mirror, user gets isolated from direct ambient light and reality can be mediated before being presented to them; e.g., a very lighted zone of FOV may be shadowed artificially.

Therefore EyeTap is much more powerful than simple HUD and can fully answer the challenges of mediated (including augmented) reality. However, it seems much more complex as far as technology is concerned. Besides, both HUD and EyeTap use a physical display which is both energy-consuming and difficult to integrate in compact devices. Hence, some new technologies draw the interest of scientists and industrials, among them Virtual Retina Displays (VRD) which appear to be a very promising alternative to the use of a physical display.

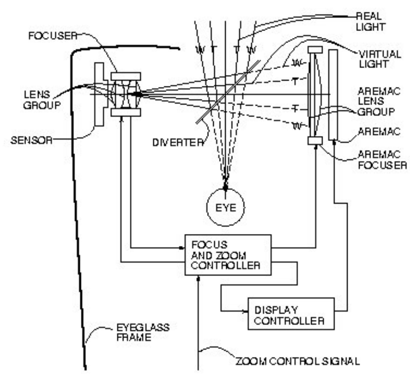

Fig. 4. Eyetap functionnal diagram

C. Virtual Retina Display

Functionnal diagram of the system is presented on figure 5.

The principle of VRD relies on a system which uses a photon source - typically a laser - to impress what could be called pixels directly on the user's retina. It therefore involves a scanning system which is in charge of pointing the laser to each point of the retina at high speed.[5]

Therefore, VRD is likely to be able to answer the problematics of compactness, optical aberrations and even power consumption. As such, VRD seems to be the future of ARG, as

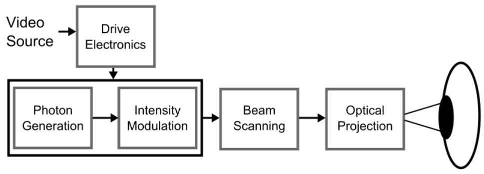

Fig. 5. Virtual Retina Display functionnal diagram

far as optics are concerned. However, this is so far an unready technology, but it is very likely that ARG will soar when VRD will be perfectly mastered.[6]

IV. Electronics and integration

Until the announcement of the Google Glass Project [7], in 2011, the different Augmented Reality Glasses (ARG) products could easily be divided into two categories : Head-mounted displays and Heads-up displays. The former regroups the different devices able to display a 2D or a 3D image on the whole user's field of view, while obstructing the wearer's vision, whereas the latter regroups the devices displaying images while still allowing the user to view his surroundings.

The first group could achieve a better screen resolution, while severely impairing the view of the wearer's whereabouts. However, both device types had something in common : they were not designed to interact with the wearer. Simply put, they were output devices with no responsiveness to stimuli, merely some kind of exotic monitors. However, with the arrival of smartphones and the mass adoption of them, just about everybody now carries enough computing power all day long to give a new start to Augmented Reality Glasses.

We will first try to identify what are the necessary functions to enable that user interactivity on an embedded device, and then try to break down two different approaches being currently explored by two industry leaders, namely Google with their world famous Glass project, and Samsung with their upcoming Spectacles.

A. *Features*

The main concept of the smart glasses revolves around a few principles. First of all the device has to have a way to superimpose information onto the wearer's field of view, without being too intrusive, which we treated in the optical part. But the core idea resides in the interaction with the user, which is a field where breakthroughs are currently incoming. Interactivity means computing and thus electronics. We can then deduce a very crude concept schematic of the electronics driving the device, as described in Fig.6.

As we can see the display system consists of a display driven by a processor, which is tightly coupled to a memory. That display system exchanges real-time information with a single or maybe more remote devices, providing more content for instance. An interesting part is that two different companies came up with two different designs, with different devices acting as those components presented in Fig.6.

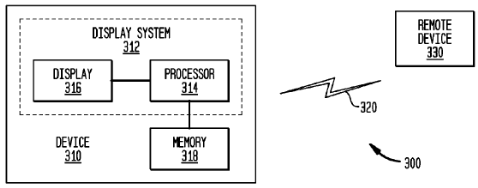

Fig. 6. Basic Electronic Schematic of a typical interactive ARG

B. *Fully embedded solution :* Google Glass

Google is currently building their Glasses as a standalone Android device. Most of the computing will be done on-board, and the hardware will be built accordingly.[7]

Their architecture resembles closely to the one of a common smartphone : a TI System-on-Chip (SoC), the OMAP 4430, based on a 1.2GHz dualcore ARM processor with a dedicated multimedia hardware accelerator, drives the display. That chip was even used for a 2011 Google/Samsung phone, the Galaxy Nexus.

Connectivity is ensured by WiFi and Bluetooth to maximize compatibility. On-board sensors include a 9-axis sensor, the MPU9150 by Invensense, comprising an accelerometer, gyroscope and magnetometer and accounting for a total orientation awareness of the device, but also a GPS chip, a touch pad and microphone for user interaction, and headphones. The whole system is powered by a 570mAh Li-Poly battery, giving a 5 hour "normal utilization" time between charging.

Reusing a well-known architecture is a good way to market a product early. The design constraints on Augmented Reality Glasses are indeed very similar to smartphones'. However, a glasses frame is even narrower than a typical smartphone casing. Fitting all the electronics inside it has thus been an engineering issue. To overcome it, Google has used mainly two feats : Package on Package (PoP), and flexible PCB.

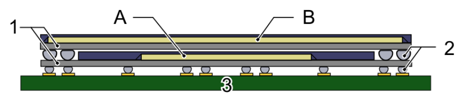

Fig. 7. Package on Package chip stacking

PoP is a common technique for highly integrated electronic designs. In Google glasses it is used for interfacing the SoC and its SRAM. The principle is quite simple : different chips are stacked and connect vertically instead of conventional routing, as described Fig.7.

Flexible PCB allows the electronics to fit in the curvy frame. On the glasses it is mainly used to route different parts of the circuit, but the inertial sensor has been fitted there too, thus giving more room on the small board for big chips such as the 16GB flash memory and the SoC.

The main design issue is the very small battery life. Having integrated everything on the device enables indeed a very broad compatibility (even for non-Android users), but it very much hinders usability : some early-access users report a running time of "about 45 minutes" while intensively using the device features. A 570mAh battery seems rather small compared to a 2000mAh standard smartphone battery, which we have seen share common circuitry, and thus have a comparable power consumption. This makes energy consumption a very acute problem of this Augmented Reality design.

C. *Partially remote solution :* SAMSUNG SPECTACLES

SAMSUNG has deliberately chosen a different path than GOOGLE's. Their full design is not public yet, but a design patent has been filed in Korea in October 2013. Few information is now available as the news is recent, but as seen from Fig.8, the main difference resides in a visible micro-USB cable hanging from the back of the frame. As this is just a design patent, its internal workings are not public yet, and this might just be an exploratory architecture. However we will try to explore the idea of using a wired connection to a smartphone in order to use the remote computing capacity, and bigger power supply it provides.

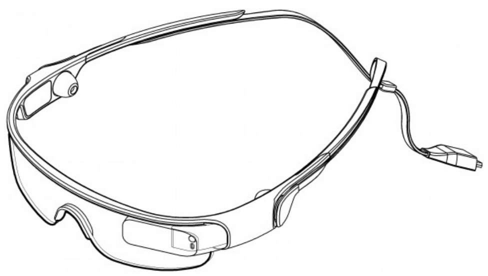

Fig. 8. Samsung's new design for ARG

If SAMSUNG's glasses are to be wired to a smartphone, there is minimal need for embedded electronics in the glasses' frame : The Display processor (Fig.6) could be reduced to a really small, power-effective display driver, with probably a small graphics processing unit to offload the smartphone as much as possible, for direct video feed encoding, for instance. However the electronics would need to be less complicated, as the need for RF communication would not be as strong for instance. Therefore, that solution has little need for onboard computing, and thus would be more energy-efficient in itself.

That architecture has yet to overcome two obvious issues : No internal battery means a lighter device, of course, but also a reduced smartphone battery life, which is already an issue. Therefore it is merely displacing the issue from one device to another. However, the lesser need for active on-board RF communication and processing would also diminish the power consumption.

Also, physically wiring that device to the user's smartphone seems rather outdated in our all-wireless world, and that would very likely be a drawback from the consumer's point of view. Besides, feeding power from the smartphone to the glasses requires special compatibility characteristics, as USB is an asymmetrical standard (host and device paradigm). Not all the smartphones would be natively compatible, which could also be very problematic.

V. THE FUTURE OF SMART GLASSES

It is nevertheless interesting to see that those two industry leaders have led different paths to achieve the same functionality. However, we will now try to discuss a few social issues that may arise from a wide adoption of that technology.

In a time where the question of privacy in connected media is more sensitive as ever, strong concerns are arising about those technologies, which all comprise an on-board camera able to record footage : will we ever be able to walk the streets unrecorded by the other citizens, or by a nation? Adding to that the possibility of embedding eye-sensors on GOOGLE glasses is almost certain, it is not too far-fetched to imagine that someone gaining unwanted access to my ARG could know where I am, what I am looking at, with whom I am, and what I am currently looking at, and that as long as my device is powered.

S. Mann, a AR and wearable computing pioneer and enthusiast, offers however an interesting point of view regarding the privacy issue in a recent paper [8]: Seeing as more and more states deploy a nationwide surveillance system — a la Big Brother sometimes — enabling each and every citizen to record and then broadcast true footage of important events would discourage information manipulation and thus guarantee freedom of information.

A potential privacy concern is not really critical as long as there is little motive for people to try to break in a system. However, seeing as personal metadata is a (often legal) and lucrative business (especially for GOOGLE), and as spamming is its illegal counterpart, and as lucrative, we can again easily imagine the issues raised by wearing those devices. Publicity, legal or not, would also be lucrative and very annoying when displayed on your whole field of vision.

Then, as for all connected devices, and moreover on the sensitive ones such as ARG, special concern should be put in designing a secure platform from the bottom up, to prevent data theft. That issue will probably gain in momentum as more and more objects become connected ones.

VI. CONCLUSION

At the lights of the current state of the art of ARG, and the different problematics that are still to resolve, both technical and ethical, here is how we can conclude :

ARG currently constitute a soaring technical and commercial field. It is likely that we will see them increasingly invade our everydaylife in the coming years, just as smartphones have done in the past ten years. Unpredictable issues will undoubtedly arise, and why not from the public health side : asymmetric vision because of having only one screen strains the eyes, and that could become a problem.

However, despite the technical challenge that ARG represent and their obvious interest for bleeding edge technologies, one may even doubt of their relevance for personal use : a simple complementary screen could seem to be nothing more than a useless gadget, whereas a complex, powerful augmented reality system could offer too many possibilites for a common daily life.

On the latter, though, one should not forget developers' ability to innovate, empowered by increasingly simple and powerful APIs. So, to sum everything up, ARG is likely to be a watershed point concerning one's approach to information and relationship towards their whereabouts, enabling them to receive always more data, always faster. If that is desirable, though, is hard to say.

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