AR evolution towards smart contact lens: A hit or a miss?

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ABSTRACT

The capacity to see augmented and mixed reality content or to take photographs and recordings (or both) with Google Glass was an incredible thought. Be that as it may, everyone hated the geeky look of wearing everything that apparatus all over. Imagine a scenario in which everything was contracted and devised into a contact lens point of view application. There is a considerable measure of patents signed for the next smart contact lenses by various industry-driving organizations. This paper will begin with a concise survey of the past and ongoing progressions in AR and then center around the advancement and results from innovations intending to address critical issues related to these displays. The reason for this study is to envision the possibility of augmented reality in point of view application in the future contact lenses by understanding the evolution of current head mounted AR sets and the way people react to such a gadget and its useful implications. The findings are very important from a stand point of knowing where AR research is currently focused on and the smart contact lens application drawbacks and limitations. It is found from this study that there is a greater deal of the surrounding factors which needs to be dealt with to move forward with this argument to have a smart contact lens implemented in future. Will this be a hit with respect to usage for the common individuals of next generation, or be a miss like the Google glasses or other heads-up and head-mounted displays which did not flourish?

Author Keywords
AR – Augmented Reality; VR – Virtual Reality; MR – Mixed Reality; Smart Contact Lens.

INTRODUCTION

There's an analogy which we can identify with about where we are today with immersive computing: we're investigating the cave of conceivable outcomes. It's tremendous, with numerous branches and potential ways ahead—and it's for the most part unclear and dark like the cave. While there are flashes in spots, it's difficult to see exceptionally ahead. In any case, by doing research, building models, making products, and in particular perceiving how individuals utilize and advantage from these advances, we light up extensive parts of the cave and see all the more unmistakably where this leads to and progress thereafter.

From our present vantage point, it very well may be difficult to perceive how all this unfolds. What is clear, however, is that it will lead to something acceptable. Currently, we can idealistically believe and trust that immersive computing will, in time, change our lives to improve things. We're as of now observing looks of that today, helping kids investigate a greater amount of the world from their classrooms, giving writers a chance to convey their audience to world occasions, and empowering artists to make unimaginable artwork. At some point, we'll think about how we at any point got along without computing that works like we do, computing that is naturally mindful, that shows data to us in context, and that looks, feels, and carries the present reality.

Near-eye displays are poised to enter the consumer market. However, emerging devices present one of two restrictive solutions: either narrow-field-of-view displays, located in the periphery of a viewer's visual field, or bulky designs held in place with tight straps. These compromises are necessary to achieve lightweight, eyeglasses-like form factors, with the former, or to obtain widefield-of-view, immersive experiences, with the latter. Commercial near-eye displays have not yet met these demands with thin, lightweight designs [13].

While the normal contact lens is just used as a passive way for enhancing one's vision, a smart contact lens actively provides solution to a complex problem, let's say. There are three main domains of applications where we can use such a smart contact lens and the first is augmented reality. We have seen how Google Glass did not best fit the needs of people. Which throws a thought of what could be the next step to not make another device like that and better the usability. Integration of a display into a contact lens would be a great challenge.

While the smart contact lens is in the improvement stage, it might turn out to be one of the cutting-edge AR devices using RF, RFID, Nano and display technologies. The upcoming bionic contact lenses will be mostly outlined with integrated embedded technology, LEDs, and a wireless communication antenna. The focal points should be on both close objects and distant ones in the real world at the same instance. Applications are currently focused in the military and medical fields and should soon be out for commercial use.

MOTIVATION – MIXED REALITY

AR, VR and MR can catapult us from the information age into the knowledge age. It is going to totally revolutionize the way we perceive things in different fields. The challenges and advantages are for us to tackle. Very expensive experiences and very expensive things become inexpensive, replicable, shareable. Mixed reality will let us learn, feel, remember and process new ideas in a more experiential and deeper way. Humans are hardwired to learn by doing, and AR will let us do that when mind and body feels it was real in any mixed reality state. It is known that after two weeks the human brain remembers 10% of what it reads, 20% of what it hears and a 90% of what it does or simulates [22]. Instead of cracking open a text book and trying to learn complicated theories, we can experience and learn through mixed reality and learning would get faster and deeper. The ability to become more fluid and less rigid is something which mixed reality help us achieve. The time between the original idea and mass adoption is now momentary. The typewriter was invented in 1714 and but it was 150 years before the first model became available. VR/AR/MR took a third of that time. It is beneficial to be curious than be fearful of the unknown. AR can bring digital information to us in the context of the real world, right where it is more accessible and useful.

What if we could change the way we see our world and the way we work to move it forward? What if we could bring our visual two-dimensional interactions into our three-dimensional reality? Today we can bridge these worlds with mixed reality in the modern workplace. Giving people the power to achieve things that were once impossible. Enabling different use cases with endless possibilities. Information workers have been well supported over the past three decades but there is a lot more that we can do to achieve more. We can solve problems faster by collaborating remotely anywhere, anytime. We can give business insights in the context of our work. We can transform the way we see and interact with the information. It really unlocks the possibilities for the way the information worker can be productive.

No matter where you work or what you do, collaboration is the key to success. When challenges arise, you need the right people with the right expertise. But bringing people together is not always easy and travel is not always an option. By bringing digital content and mixed reality annotations into your world and connecting people across devices, you can get the help you need to solve difficult problems faster.

Mixed reality will profoundly change the way we work, giving everyone tools to make an even greater impact and empowering us all to achieve more.

BACKGROUND – HISTORY OF AUGMENTED REALITY

The first occurrence of the concept of AR was introduced in the year 1901 when L. Frank Baum's "The Master Key" [7] imagines a sort of Augmented Reality. L Frank Baum is best known as the author of the Wizard of Oz series. The Master Key was an Electrical Fairy Tale, portrays the adventures of a 15-year-old kid who explores different avenues regarding power and incidentally contacts "the Master Key of Electricity," experiencing a Demon who gives him different gifts. One of these endowments is a "Character Marker".

"It consists of this pair of spectacles. While you wear them everyone you meet will be marked upon the forehead with a letter indicating his or her character. The good will bear the letter 'G,' the evil the letter 'E.' The wise will be marked with a 'W' and the foolish with an 'F.' The kind will show a 'K' upon their foreheads and the cruel a letter 'C. Thus, you may determine by a single look the true natures of all those you encounter." [7]

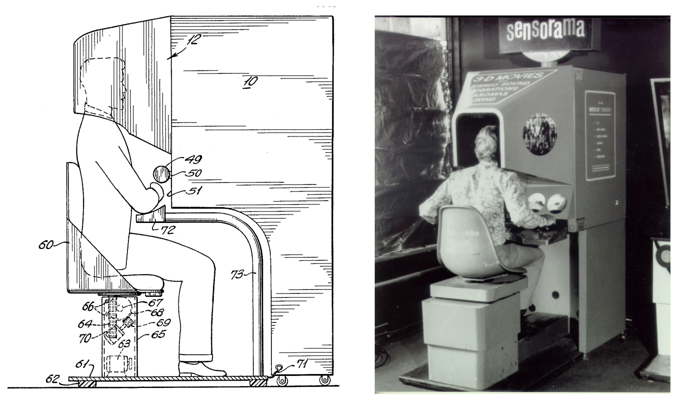

Figure 1. Morton Heilig's Sensorama.

AR was first accomplished, to some degree, by a cinematographer called Morton Heilig in 1957 [12]. He invented the Sensorama [Figure 1] which conveyed visuals, sounds, vibration and smell to the user.

The invention generally relates to a simulator setup, more particularly it was used to stimulate the senses of an individual to simulate an actual experience realistically. There was no computer controlling it. However, it was the principal example of an endeavor at adding extra information to an experience.

Vannevar Bush's "As We May Think" [16] stated that the future computers would not be room size machines but what you can carry around as wearables, taking a photo and linking the picture and text together, more precisely talking about the hypertext and the web. His accessors, like Douglas Engelbart or J. C. R. Licklider, talking about intelligence amplification, intelligence augmentation, basically talking about mobile systems, not just desktop systems. As they were working in the 60's, they had to dedicate themselves making a decent desktop system. Engelbart's demo actually shows video conferencing instances and hypertext; till date being the mother of all demos. People forget his original paper, 8 years earlier. If we take a closer look at reading it from a sense of wearable computing, it shows the essence of where he was envisioning the future at that time.

One other thing to mention here is in 1957, a guy by named Upton designed something called cued speech with a glass display, looked very similar to the augmentation concept of today's glass wearables. There was 6 LEDs embedded in the lens to help people who are deaf for better lip reading. Only 20% of English is actually in the lips, the rest of it comes from the sounds we make, how our voice box work. The idea was to imply from what you can see observing the lips, process it using a digital signal processor, and send it to the display to the person's line of sight making different LEDs light. This derived a relation of what the person opposite was saying at that point in time. We can relate this to AR today where most of them do not know about, rather everyone knows Sutherland's Sword of Damocles as the first experiment towards head mounted display as it was much easier to relate to VR.

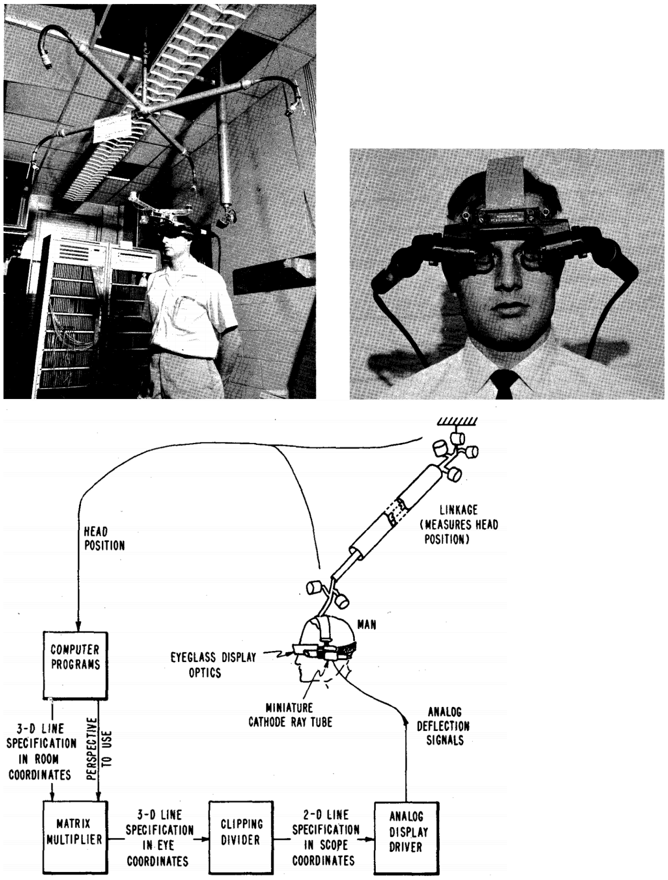

Figure 2. Ivan Sutherland's Head Mounted Display.

After that point in 1968, Ivan Sutherland the American computer researcher and an early Internet influence, created the head-mounted display [Figure 2] as a sort of window into a virtual world. He and his student Bob Sproull made the principal VR/AR head mounted display (Sword of Damocles) that was associated with a computer and not a camera. It was a substantial and alarming looking contraption that was too overwhelming for any user to serenely wear and was suspended from the roof. The user would likewise be strapped into the gadget. The computer-generated graphics were exceptionally crude wireframe rooms and articles. The innovation utilized at the time made the development unfeasible for mass utilization.

The fundamental idea behind the three-dimensional display is to present the user with a perspective image which changes as he moves. Psychologists have long known that moving perspective images appear strikingly three-dimensional even without stereo presentation; the three-dimensional display described in this paper depends heavily on this "kinetic depth effect" [9]. Their main arguments about perspective presentation, clipping, hidden-line algorithms, and programs to display curved surfaces in stereo, form one of the most exciting educational experiences and has been the basis for many experiments [9].

In 1975 Myron Krueger, an American virtual reality computer craftsman built a progression of experiences which he named "artificial reality" in which he created environments that respond to the users in it. The projects named GLOWFLOW, METAPLAY, and PSYCHIC SPACE were movements in his exploration which at last let to the advancement of VIDEOPLACE innovation. This innovation enabled its users to control and cooperate with virtual articles and continuously in real-time. He said "In the long range it augurs a new realm of human experience, artificial realities which seek not to simulate the physical world but to define arbitrary, abstract and otherwise impossible relationships between action and result. In addition, it has been suggested that the concepts and tools of the responsive environments can be fruitfully applied in a number of fields." [14]

Steve Mann, a computational photography scientist, gave the world the concept of wearable computing in 1980. Mann's custom-built EyeTap headsets have been interceding his own reality for a considerable length of time, and he joined Meta to help convey the innovation to other people. Obviously in those days these weren't "computer generated reality" or "augmented reality" on the grounds that augmented experience was authored by Jaron Lanier in 1989 and Thomas P Caudell of Boeing coined the saying "augmented reality" in 1990.

The main legitimately working AR system was most likely the one created at USAF Armstrong's Research Lab by Louis Rosenberg in 1992. This was called Virtual Fixtures and was an unbelievably mind-boggling robotic framework which was intended to make up for the absence of high-speed 3D designs handling power in the early 90s. It empowered the overlay of tactile data on a workspace to enhance human efficiency.

There were numerous different achievements in augmented reality since then till date; the most prominent of which include: Bruce Thomas building up an open-air portable AR game called ARQuake in 2000, ARToolkit (a design tool) being made accessible in Adobe Flash in 2009, Google declaring its Google Glass in 2013, Microsoft declaring AR support and headset, HoloLens in 2015.

CONTEMPORARY – PRESENT DAY AR SYSTEMS

Consider the possibility that smart glasses did not make you resemble a techno cyborg. That is actually what Intel is making. These smart wearable glasses are called Vaunt and they seem to be completely different from the expectations. The best part of these glasses is that they look like normal glasses and is really light on the head, weighing about 50 grams. It has a tiny red monochrome projector that shines an image on a holographic mirror, which then bounces it directly into user's eyeball so that there is no requirement for focus. It is a very low power laser which is at the very bottom end of a class one laser. If the user is not looking directly into the display, it completely disappears to avoid distraction. The other new element is that there is no tapping and swiping like in Google Glass. There is no camera and is meant to be non-intrusive, not annoying in social situations. This is a prototype project from Intel's new devices group. They need to be fitted according to the inter-pupillary distance (IPD) so that the distance can actually align to the line of sight. Basically, it is intended to look like a heads-up display (HUD). Intel is trying to show only contextually important information. Providing a level of behavioral AI to the system that figures out what to show and when.

Microsoft's HoloLens [8] remains the most noteworthy watermark by a margin over other predecessors, it's as yet the sole independent holographic computer. In any case, after some time all gadgets will begin looking increasingly like HoloLens. HoloLens brings holograms into your real world. Using transparent lenses and understand spatial sound and an understanding of your environment. Holograms look and sound like they are actually a part of the world around you, that being mixed reality. With HoloLens, holographs are viewed through the holographic frame centered in the middle of your view. This preserves your peripheral vision so that you can move freely and connect and collaborate with people around you. Holograms and mixed reality don't block out when you can see and hear, this enables you to engage in digital contents and tools alongside the objects in your real world. Holograms can be locked in a physical location. So, you can walk around them, or they can travel with you. You can even hear them in 3D with spatial sound. MS HoloLens is the world's first most untethered self-contained holographic computer. With the mixed reality experience of HoloLens, you can stay in the real world and interact with real people as you simultaneously explore 3D in actual three dimension.

Spatial mapping brings the real world and virtual world together. The HoloLens scans your environment creating a map or mesh of your room allowing the hologram to be placed on the surfaces it finds. You can then use this information to set the mind model on a table or pin up report to a wall like a virtual pin board. As the spatial map is stored, the HoloLens will remember the locations of all the physical surfaces and holograms the next time you launch the particular application. To interact with the holograms, the HoloLens uses gaze gesture and voice inputs. Gaze similar to the mouse controls the gesture, move your head around and the cursor follows, centered in your field of view. Selection is done through gestures. The HoloLens sensors tracks specific movements of your hands and by using the air tap gesture, you can select particular areas. Voice commands allow easy engagement with the holograms.

DISCUSSION

The overall solution is not to replace hand held devices by glass or lens, it is to have user relevance on specific tasks. There are certain detailed tasks which can never be replicated on a glass or lens which otherwise is simple on a mobile phone or a desktop computer.

There are specific areas we would need to concentrate on while designing these devices, power and heat, privacy and interface. Most people concentrate on the interface, but there is equal amount of research and importance required for the other areas as well. All these areas here have ethical issues. Society has a set of moral and end up with a social norm that people agree to. Here research with employing the systems, is the right way to go about to establish norms and look into the usability and get people acquainted with it [17].

"Privacy has been a hot-button topic for some time now. But so far, its impact on a field where its relevancy is obviously high - ubiquitous computing - has been rather minimal. Only a small amount of work has so far been accomplished in the area of ubiquitous or pervasive computing. Privacy by Design principles need to be applied to these systems, a comprehensive set of guidelines for designing privacy-aware ubiquitous systems" [17].

"What lies at the intersection of privacy protection and ubiquitous computing is easy to imagine: the frightening vision of an Orwellian nightmare-come-true, where countless "smart" devices with detailed sensing and far-reaching communication capabilities will observe every single moment of our lives, so unobtrusive and invisible that we won't even notice! Ron Rivest calls this the "reversal of defaults": "What was once private is now public", "what was once hard to copy, is now trivial to duplicate" and "what was once easily forgotten, is now stored forever." Clearly, "something" needs to be done, as nearly all work in ubiquitous computing points out, yet little has so far been accomplished." [17]

Let us talk about how Google Glass was designed [15]. In google glass you need to first tap a side module which runs from the temple to your ear and the display triggers and to see the display, you will have to adjust your line of sight which is slightly above the line of sight. You can adjust it to see everything. There was your timeline with a row of cards and you slide front and back on the side module to browse through those cards. Cards on the right of the home screen are from the past.

One thing that happened when Google started making Glass is that they wanted no barriers between you and the world around. The computer is taking a secondary role. Hence, whatever you are doing in the real world, whether it is conversing with someone else, or if you are walking down the street, or day dreaming on a park bench. The interface reflects that there should be no barriers between you and the world around you.

The display was mounted high so that the person in front of you can see both pupils and when the display is off, it gets transparent. This was done very much on purpose in Google's design to make sure there are no conversational disturbance between you and the person you are speaking to. There are social cues for the world to recognize that the Glass is being used. The people or the world around the user also needs to be a part of the design. As a matter of fact, in Google glass your conversational partner can actually view what is on the screen if the person takes a closer look into your screen. This was made to encourage participation and use of social gesture.

On the other hand, glass appears like a rear-view mirror of your car. It was designed for quick glances and short interactions staying out of the way and it easy to ignore when you do not need it. That is the whole point of this technology to be there when you need it and gone when you don't.

Glass design was created in such a way that it does not block your sight or your hearing. They used bone conducting transducer from behind the ear skull bone instead of having the sound directly inputted to the ear drums. For hearing impaired users, it was a revelation when they could hear Glass speak to them, as compared to normal hearing they do not have any interference from the rest of the world and it's only the bone conductance sound.

The Glass prototype enabled all day texts, time, calendar, web search, occasional snapshots or ten second videos, restaurant suggestions, etc. or 50 minutes of recording video or 20 minutes of hangouts(teleconferencing) with respect to battery life. This was not a design to replace broadcast camera.

SMART CONTACT LENS

Contact lenses will get smarter but full-fledged displays and medical sensors are still in very early stages. Charging objects is something which you normally associate with an electronic device. In few years, we might be charging the smart contact lens.

Google claims their smart contact lenses are painless non-evasive and accurate way for people suffering from diabetes to keep their blood sugar level under control. Patients with diabetes need to check their blood or glucose level many times. The design works by putting a minuscule sensor, a hair thick antenna, and a chip of the size of a piece of glitter between two contact lenses. The sensor in contact with the tear naturally found on the surface of the eye can take readings of glucose levels once per second. The lens then can communicate to an external device and receive the power it needs wirelessly.

As per Sony's patent [18], sensors in the lens can differentiate among willful and automatic blinks. (This was an element of Google's Glass model, which could take a photograph when you winked.) When it distinguishes a conscious blink, it records a video. Sony's contact lens is said to be powered by piezoelectric sensors that convert movements in the eye into electrical power. It would include a great degree of little forms of a considerable number of parts of an advanced digital camera - an auto-centering focal lens, a CPU, an antenna and even a storage.

The contact lens as indicated by this patent has an image pickup function and can perform predetermined image pickup control as per blinking or the like of the user. This makes it conceivable to make an intelligent contact lens, in this way surprisingly enhancing usability for the user.

Samsung's patent was documented in September 2014 [19], despite everything we haven't seen any comparable gadgets make it to the market. It's not exactly certain whether the lenses are for real, or only an idea to clutch for what future awaits. However, Samsung likewise has trademarked the name 'Gear Blink' in the US and South Korea, around a similar time the patent was recorded. So, it's conceivable that the organization is not having just a thought about making this device a reality.

GAP

Ordinary contact lenses have achieved a mature state at this point. From their inception, research endeavors were centered around expanding their comfort, performance, and simplicity of manufacturing. However, their motivation hardly redirected to different applications other than vision correction [21].

There is certainly immense amount of engineering and complex fabrication process required to make a stand-alone smart contact lens design which does not need any external module to be carried always along like most of the contemporary AR modules. With all of the electronics integrated into the lens itself, it is going to be quite a challenge to implement everything in one. There has been considerable research but none of the smart contact lens applications have been able to go beyond having just a few pixels in terms of the display.

Our eyes are not intended to concentrate on things that are as near to them as contact lens seems to be, and on the off chance that we put a display at that distance, it would certainly have a blurred image. As we try to increment the size of display area and field of view which is a prerequisite of genuinely vivid AR, the measure of optics required to make it work increase geometrically, and inevitably we will wind up with something extremely immersive, however exceptionally enormous sized like the majority of the head-mounted displays. This gap of not having enough research especially for AR should be known or further actualized through research and Nano-technology advancements.

VISION FOR THE FUTURE

Thad Starner, Professor of Interactive Computing at Georgia Tech, in his keynote talk [15], shows how wearable computing help people by being closer to the body. He says it will help the user pay attention to the real world as opposed to retreating from it. Technology can be calming that mediates interruptions instead of adding to them. Enabling micro interactions, allows the user to perform tasks more quickly and resume back to the flow of his life.

He also states with respect to micro-learning that over 9% of deaf infants are born to hearing parents. Most of those normal hearing parents will not know how to sign well enough to actually teach their children. That means by the time the kids get to elementary school, they have neither spoken language or sign language. It turns out that learning to sign or speak a language is what causes short term memory to develop. So, he deduces that it is better for infants to learn sign language whether or not they can hear. There is also considerable research on using mobile device, improving test scores of students as compared to desktop computers. This shows that wearable mobile systems can aid impairments and make life better for growing individuals.

The key towards micro interactions, like things that are fast to do, will lets us also perform seamlessly and concentrate on tasks which we are currently doing. The idea is supposed to be driven towards putting the devices close enough where your sensors are, like to put the user interface where your eyes are and sound at where your ears are.

There is also one of the applications Google Glass used for visually impaired users, which scanned the image of the object or an article that they were holding and the question they asked by talking and fetched the information over the web from a dedicated server answering their questions.

There is also another concept in Google Glass design on concentrating on the non-dominant eye by having the glass in front of that and the dominant eye to concentrate in front world view. This would not work for all users as it may cause strain and other problems. This can be avoided in contact lens designs as this is not specific to a particular eye, but the problem would arise when the images of two eyes do not meet at the focal point as they have to superimpose to make a clear image.

I feel the best way to go about is to have micro interactions which is shorter than using cell phones and stays up only when the user requires it. The average smartphone user interacts with the cellphone about 150 times a day and it takes about 23 seconds to retrieve a handheld phone and get to a specific interaction, which can be greatly avoided by use of a contact lens AR display. There should be a conscious choice to put the technology out the way of the user by limiting the interactions to very important things and not overwhelm the usage of it.

With AR, a superimposed display comprising of virtual objects, for example, content and pictures, enable a person to expand the connection between real and the virtual world. Be that as it may, AR, for the most part, requires a projected coordinated display integrated to a device. In any case, most usage are not lightweight and may be too diverting in crisis circumstances looked by Fire Fighters or paramedics for example. One conceivable method for defeating these obstacles is employing the display significantly closer to the eye and integrating it into a contact focal point. Such a contact lens display goes for a greater mixture of the man-machine interface and would seek after an upgrade of the real view, instead of feeling as only an add-on. Unmistakably, regardless of these underlying outcomes, a smart contact lens for AR applications will even now require huge measures of research. However, overlap in the required supporting innovations for example the biomedical applications, it can fill in as a long-haul driver while the more transient applications are created on the way.

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TABLE OF CHANGES

Location of Change	Type of Change
Abstract	What did I find through this study? was added as a note.
Introduction	Added what is immersive computing (VR, AR, MR)
Motivation	Citation included and referenced
Discussion	Citation included and referenced
Gap	Reframing the full piece after moving the relevant sections to the right places in the paper (History & Discussion). Concentrated on the gap according to the review comments.
References	Added reference 21 and 22