Overview of XR in a Manufacturing Environment

Mike Doiron
Zohair Mehkri
Flex. Ltd
Milpitas, CA

Abstract
The Augmented Reality and Virtual Reality market is expected to cross $44 billion by the year 2025 according to various industry experts. This exciting new technology is not exactly new, but has cutting edge potential that can change the way that we live our lives and especially how we do business. While there are many types of hardware and software out in the market, few are looking at addressing manufacturing environments. Due to the various types of "Realities" such as "Virtual Reality", "Augmented Reality", "Mixed Reality" and others, we will refer to any type of reality as "XR" where "X" is a variable. For this paper, we will focus only on Augmented Reality and Virtual Reality, while only mentioning some others. Virtual Reality refers to a computer-generated simulation of an environment that can be interacted within a seemingly real or physical way. Augmented Reality refers to viewing the physical environment whose elements are overlaid on top of what you are seeing live. We will discuss how both of these technologies can be used in a manufacturing environment and the key applications we have identified to use these for. In addition to the applications that we have identified, this paper will also cover the market, technology, different types of devices, software, as well as advantages and limitations that exist today.

Introduction
Augmented and Virtual Reality is technology that has been around for decades, however, it is now gaining a lot of popularity in the media for several reasons. Augmented Reality is a technology that projects computer generated graphics into a person's field of view using a variety of different components such as micro-projectors, light sources, displays and waveguides. The goal of this technology is to enhance the user's perception of reality using computer generated sensory input such as audio, video, graphics and others. The first functional Augmented Reality systems were conceived by the United States Air Force in the early 1990s. The first Augmented Reality system, named Virtual Fixtures was developed by Louis Rosenberg at the USAF Armstrong Labs. Since three-dimensional graphics were slow in rendering speed, Virtual Fixtures used robots which were controlled by a human exoskeleton. A binocular optics setup was used so that the user's view of the robot arms appeared to be in the same location as the user's physical arms. It was from this early system that most interactive hardware and software in the market today is based off of. Today, there are various components of hardware that enable a user to see computer generated graphics in their field of view. Since there are many forms of Augmented Reality display technologies, the major 2 types of optical hardware will be covered in this paper. The first is commonly referred to as "optical combiner", an optical combiner is essentially an optical device that combines a computer generated graphic with the real world light. The combiner works like a partial mirror, it is redirecting the generated light (that is coming from either LED, OLED, or other light source) as well as selectively allowing real world light to hit the eye. Various setups of optical combiners can be seen in Figure 1 below:

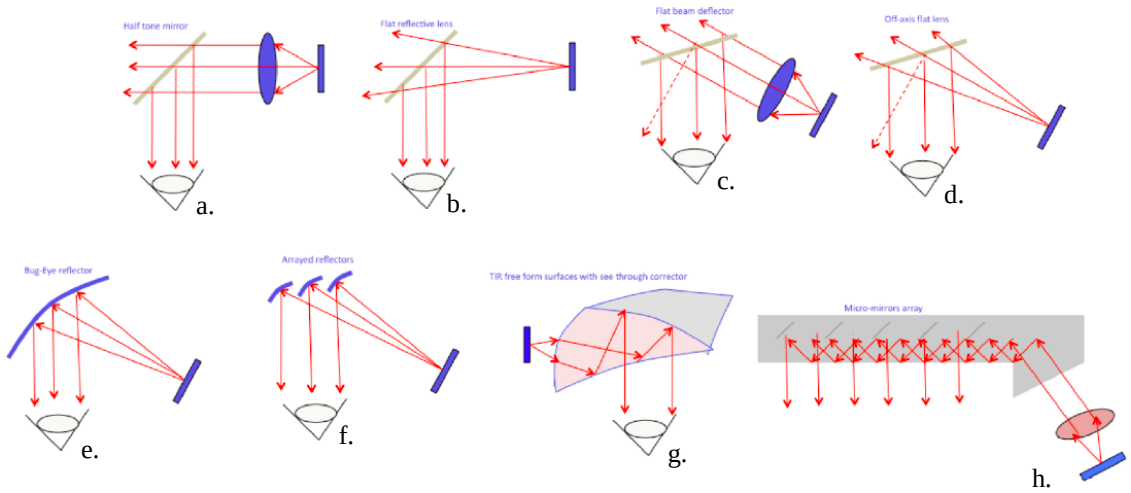

Figure 1 - Various types of combiners: a. Half tone mirror, b. Flat reflective lens, c. Flat beam deflector, d. Off-axis lens, e. Bug-Eye reflector, f. Arrayed reflectors, g. TIR free form surfaces with see through corrector, h. Micro-mirrors array [1]

The second type of optical hardware is commonly referred to as a "waveguide", waveguide grating, and holographic optical element are also among the terms that can be used to describe it. A waveguide essentially behaves similar to a light pipe, a medium in which light can pass through. However, in this case, the pipe is a thin sheet of plastic or glass that is designed and set up in a diffractive pattern that allows the light to bounce through and into your eye by progressively extracting a collimated image using the principles of TIR (total internal reflection).

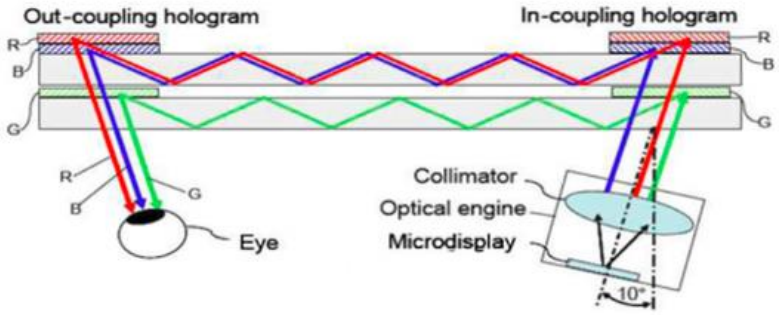

Figure 2 - An illustration of a waveguide [1]

By using this type of setup, Augmented Reality headsets have been able to display various types of information to the user. Today, there are several companies in the market who are using similar setups as above in addition to some proprietary technology to achieve the best looking display for customers. However, there are still many hardware and software limitations that are limiting widespread adoption which will be covered later in this paper.

Virtual Reality is a technology that allows a user to be immersed in a computer-generated environment through usage of a combination of headsets, physical environments, sounds and other equipment that help simulate a user's physical presence in a virtual environment. Virtual Reality and its existence has a much-disputed origin due to the fact that components of Virtual Reality have been around for decades. For this reason and for the sake of simplicity, the year 1968 can be referred to as the start of Virtual Reality since it is in this year that Ivan Sutherland, a computer scientist developed the first head mounted display with the help of his student, Bob Sproull. The head mounted display was a device that comprised of a stereoscopic display that displayed output from a computer program which comprised of a wireframe room. The perspective of the wireframe room would depend on the positon of the user's gaze, thus creating the illusion of an immersed environment. The device was so heavy that it had to be suspended from the ceiling and was attached to a mechanical arm that held it in place, due to this elaborate setup, this head mounted display was referred to as the Sword of Damocles. Today, many of the components have advanced in terms of technology but overall are similar in function. The major components of a Virtual Reality headset are:

- Sensors: Usually head and body tracking and/or location sensors that are for user experience as they reduce the latency of the image refresh to match viewer's movements
- Motion Controllers: Location controllers that allow users to track their motions or gestures intuitively
- Displays: Usually a HD or high resolutions OLED (or equivalent) screen that displays the content to the user
- Lenses: A piece of plastic that allows the viewer to have a wide FOV (Field of View)

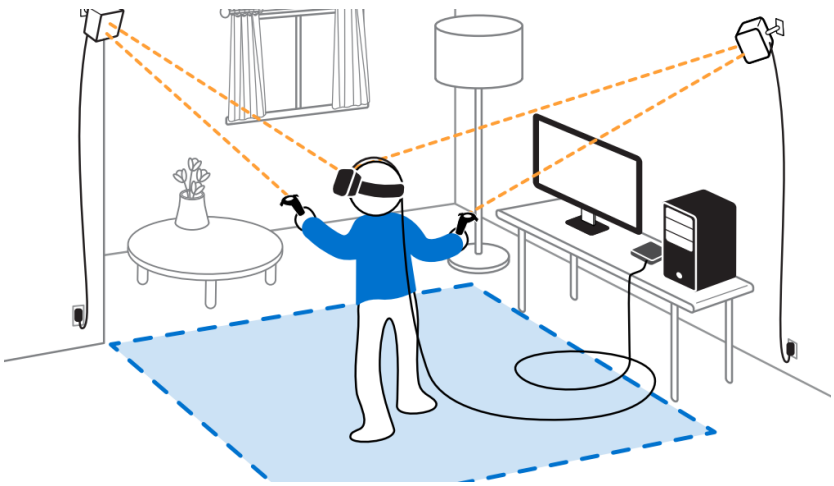

Figure 3 - Room layout of a typical Virtual Reality setup [2]

Figure 4 - Various components of a Virtual Reality headset [3]

As can be seen above, a Virtual Reality headset works by having a user view a LCD, OLED or other type of display through a stereoscopic lens setup that gives the user the sensation of being immersed in an environment. This allows for applications that either require a user to be immersed in an environment or enhance the user's experience. However, there are still hardware and software limitations that are limiting widespread adoption which will be covered later in this paper.

Due to the fact that these immersive technologies are both supplemental and useful, both Augmented and Virtual Reality are fast growing markets and technologies. Industry reports indicate that the average selling price for an Augmented Reality headset in 2016 was over $1500, this price is expected to be less than $600 by the year 2025, a 61.3% decline. [4] As the average selling price of this hardware drops, it will naturally be more affordable and therefore more accessible to a larger market. In 2016, a total of 145,000 units of Augmented Reality were sold worldwide, this number is expected to increase to 47 million by the end of the year 2025, a 90.1% Compound Annual Growth Rate. Due to these figures, naturally, as more people start to own and use Augmented Reality headsets, the global use and sale will drive up the total value of the market. Industry reports indicate that the global sales of Augmented Reality will exceed $27 billion by the year 2025 with a 71.1% Compound Annual Growth Rate. Virtual Reality has a similar trend according to industry experts. Today, the average selling price of a Virtual Reality headset is $350, this price is expected to drop to $221, a 36.9% drop. There are many factors as to why the selling price of a Virtual Reality is low today and as to why there will not be a significant drop in price, the drivers for these reasons will be covered later in this paper. As with any technology, the price reduction will increase market penetration. In 2016, 3.7 million Virtual Reality headsets were sold, this number is expected to be 78 million by the end of the year 2025, a 40.5% Compound Annual Growth Rate. This will drive up the total value of the market $17.2 billion by the end of the year of 2025.

Market and Applications

Both Augmented and Virtual Reality are being used to supplement various areas of daily life, however, there are some major industries that are adopting the technology faster than others. Below, a chart shows the various industries that are currently using Augmented and Virtual Reality for various applications.

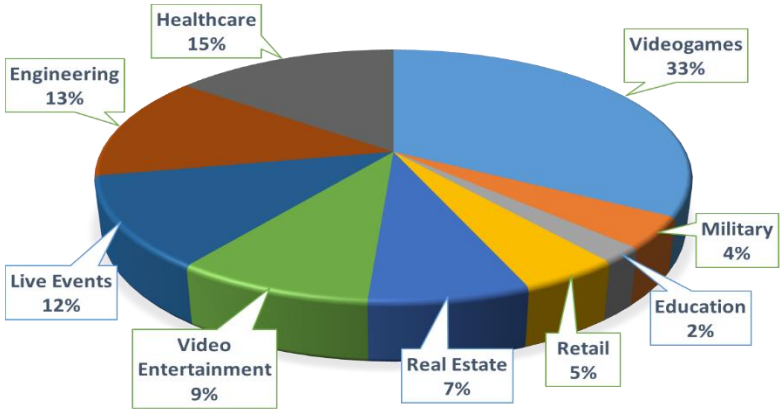

Figure 5 - AR/VR Overall Market [4]

For each of the above markets and applications, Augmented Reality and Virtual Reality offer a different value to that segment. The offerings and main applications are below:

- Video games: The video game industry currently owns the largest portion of the market share at 33%. The video game industry is embracing the use of immersive experiences. Software companies are now creating games that allow a user to wear a Virtual Reality or Augmented Reality headset and physically move through a game environment. This demands greater content generation due to the fact that an entire environment needs to be created, in the past, a game had a set path that all users had to follow in order to play; today, gaming companies need to generate content complete environments and provide gamers the freedom to move around and select their own paths in a game. Due to the fact that the video game industry is now heavily involved in the Virtual and Augmented Reality market, it has increased the demand for software programmers, graphic designers, content creators as well as the other functions that are required to create a video game. Due to the increase in sophistication and immersion of gaming, this has given rise to another sector of hardware startups that are focusing on creating hardware for gamers who are in an Augmented or Virtual Reality environment. Products such as controllers, vests, exoskeletons and headgear for a gamer to wear while playing have increased in the market and more and more companies are focusing on integrating the experience between hardware and software than ever before in the gaming industry. It is safe to believe that the gaming industry will drive some of the technological advancements in this industry going forward and will be one of industries that massively adopts this technology in the future.

- Healthcare: The healthcare industry owns 15% of the market share, following the videogame industry. Currently, the healthcare industry is being able to act as a good use case for Augmented and Virtual Reality due to the reason that healthcare professionals are testing how to improve their job functions using the technology. As an example, medical schools and training programs are using Virtual Reality to train students about operating environments and what to expect in various different medical situations. Virtual Reality is also being used to teach students about various parts of the human body, allowing students to see 3D graphics instead of traditional 2D pictures. Augmented Reality has played a role in training due to being able to help walk students through various medical procedures step by step by augmented instructions that are projected into the field of view of the user. Not only are students using this technology but established professionals are also benefiting by being able to have Augmented Reality headsets aid them in surgery as well as capture data, pictures and video to be analyzed for later study, record keeping or training purposes. As Virtual and Augmented Reality matures and penetrates the market more, healthcare will be a prime customer in the use of this technology.

- Engineering: The engineering industry currently owns 13% of the market share, following the healthcare industry. The engineering industry is one of the industries that will help drive some of the innovation and advancement of the technology due to the various applications that have been identified in engineering environments and the hardware and software requirements for those applications. Main applications for the engineering industry include remote assistance, training, design and others. A detailed overview of the various engineering and manufacturing applications will be covered in the next section of this paper.

- Live Events: The live events industry currently owns 12% of the market share, following the engineering industry. In recent years, live events have been more adventurous in trying out new technologies for the benefit of the organizers as well as the attendees. Technology such as RFID, NFC, mobile applications and others have been deployed by organizers to help add value and ease to the process of planning and execution for live events. Virtual and Augmented Reality are the same case when it comes to live events trying technology. Today, concerts, trade shows, and other events are mainly using Virtual Reality to give demos or show certain aspects of an offering to an attendee. Augmented Reality is being used by some to provide more information about an event or to assist users with information about the venue, scheduling or auxiliary information that pertains to a certain event. Although various experts believe that Virtual Reality will be widely used in live events going forward, safety, technology and other concerns might limit the widespread adoption for this industry. Augmented Reality however, might be an option that live events take an advantage of from an end user perspective, for either the organizers or attendees.

- Video Entertainment: The video entertainment industry currently owns 9% of the market share, following the live events industry. The video entertainment industry will also be one of the sectors that helps drive technology due to the reason that the use cases related to it demand higher performing hardware and software. Video entertainment is mainly being looked at from content creators of feature films as well as the video streaming market. Production companies are exploring the concept of being able to have a user experience a video in 3D, which enables the viewer to feel immersed in a movie as well as view any part of the 360 environment that they please. Some of the challenges faced are; being able to shoot a full video in 360, controlling the viewers gaze so they follow the story, as well as the venue for viewing the video. Shooting in 360 demands for advanced cameras as well as other filming

equipment that allows for 360 recording video and audio, this also puts stress on the post production and special effects team due to those teams having to account for full 360 environments as opposed to a single frame. Being able to control what the user is looking at is also a challenge, since viewers might not always focus on the scene that requires them to follow along with the story, so content creators will need to produce content which can keep a viewer paying attention to where they want. Most experts believe that Virtual and Augmented Reality video entertainment will take place in the home of the viewer as opposed to venues such as move theaters and halls due to factors such as safety as well as the amount of capital investment required to obtain and maintain hardware and software. As more video entertainment producers start to create content in this technology, a hardware and software advancement will be seen in terms of graphics, sensory input / output as well as overall usability and comfort.

- Real Estate: The real estate industry currently owns 7% of the market share, following the video entertainment industry. Real estate will be one of the industries that will serve as a good use case for both Augmented and Virtual Reality due to the applications that the industry is looking at. Some real estate firms are taking 360 video of homes and properties and uploading them to their website or host client for viewers to be able to immerse themselves in using their own Virtual Reality headset. Others are using Augmented Reality to supplement property tours or provide additional information to prospective buyers or clients. Contractors, renovators and construction firms are also experimenting using Virtual and Augmented Reality for aspects such as interior design and floor planning. Moving forward, the real estate industry will be a good use case for the technology.

- Retail: The retail industry currently owns 5% of the market share, following the real estate industry. Retail will be a driving industry regarding content creation as well as overall software due to the reason that the applications used by the retail industry will be very customer focused. Some retail companies are experimenting using Augmented Reality to provide product experiences to customers before purchasing the product. This is allowing customers to virtually "try before you buy" products that they are interested in. Since retailers want to have customers use this technology to sell the product, many retailers who use this technology will try to have the content be visually pleasing, technically easy to access and easy to use. This will call for retailers to develop software with aesthetics in mind, which will drive the need for software to have graphic design capability, the need for the technology to be easy to use and access and will drive software to be simplified but in terms of usage and in terms of creation.

- Military: The military industry currently owns 4% of the market share, following the retail industry. Interestingly enough, the military contributed much to the early development of Augmented Reality technology but has not adopted it as widely as other markets have. This is mainly due to the hardware and software limitations that the technology currently presents. Today, Augmented and Virtual Reality is mainly used in the training of soldiers and military personnel. Many Air Force students first learn about flying through Virtual Reality pilot simulators before they sit in a real plane. Other branches of the military mainly use simulators and training programs to train new students of the environments that they will face when in the field. Studies are also being done on how to deploy this technology in the field or while soldiers are in combat. As this technology matures, it is likely that the military will increase its adoption.

- Education: The education industry currently owns 2% of the market share, following the military industry and is currently the smallest sector for use. Augmented and Virtual Reality is mainly being used for teaching and training students of a certain discipline, as noted similarly to the healthcare section above. Virtual Reality and Augmented Reality present their own benefits in the area of education. Virtual Reality has the advantage of immersing the student in an environment, allowing the student to learn through more than just their sense of sight or listening. Augmented Reality presents the advantage of being able to guide a student in real time about the subject that the student is trying to learn. As the technology starts to mature and more content is created, it is likely that many levels of education will deploy the use of this technology to train students.

The applications listed above capture the main essence of the state of the market use cases today. For manufacturing and engineering, Augmented and Virtual Reality provide a value that will likely streamline processes, improve workflow and optimize operations for the industry going forward. After working with various industry professionals and technology experts, the company has been able to recognize six main areas of study for Augmented and Virtual to be used. These six main applications are; remote assistance, work instructions, logistics/manufacturing, business development/design, people and resources, and service and repair. These applications are the major components of the "engineering" industry market share as mentioned above.

- Remote Assistance: Remote Assistance is the ability of two or more users located in different geographic locations to connect wirelessly and communicate through both video and audio. Users who desire assistance, information, or to share an experience in real time can use this application to do so. One of the users will utilize a camera to stream both audio and video to another user who is able to see what the user who is streaming is looking at. This

phenomenon is referred to as SWIS or See What I See. This enables the user who is watching to have a sense of what the user on the other side is experiencing. Today, some remote assistance software applications offer the ability to have the user who is watching to send media, messages, and even annotate on the live view of the user who is streaming the video. The advantages of this application are still being discovered but at this stage a few early advantages have been identified. For one, the use of this application can save on travel costs, since users are able to stream audio and video and show someone what they are seeing, the user who is remote does not have to travel to the location to physically view what the other user wants to show. Another advantage is the passing down of tribal knowledge, as the experienced workforce starts to retire, the newer workforce needs to gather the experience from the earlier workforce. The ability to send video, audio, media and annotation helps this process. As the technology of Augmented Reality matures, remote assistance will be one of the most common applications that this technology is used for, especially in manufacturing environments.

- Work Instructions: Work instructions are used to assist a user in performing a certain action in a specified way. In the assembly or disassembly of a product, certain steps in a specific order are required to complete the action, thus, it is very important that the user who is doing this action follow the instructions. The advantage of using Augmented Reality in this case is that a user can have the instructions appear in their field of view which allows for hands free operation rather than having a user look back and forth between the operation and instructions. In addition, it allows for a greater quality of work instructions since the ability to use graphics and other software can help with the animation of the steps and therefore can add an extra layer of explanation to the process for the betterment of the user. Lastly, the use of Augmented Reality headsets that have video recording ability allow for users to record sessions and processes for recordkeeping, analysis as well as for training. Today, this application is being deployed on mobile devices and tablets since Augmented Reality headsets are not fully mature. As the technology of Augmented Reality matures, work instructions will be one of the most common applications that this technology is used for, especially in manufacturing environments.

- Logistics/Manufacturing: The logistics and manufacturing application refers to the ability to use Augmented and Virtual Reality in the areas of warehouse logistics and manufacturing shop floor. Virtual Reality can be used to show environments and train new hires in what to expect when entering new environments. Augmented Reality can help in logistics by aiding users in picking applications, which is usually referred to as “Directed Picking” in the industry. Today in most warehouse environments, picking is done manually by having people follow pick lists and order forms. By using Augmented Reality, pickers can follow the directions on their heads up display as well as follow the order in which the pick lists go. By using integrated barcode scanners and other hardware, Augmented Reality can allow for a hands-free experience for pickers in warehouse environments. Augmented and Virtual Reality enable pickers to follow optimal paths, not miss any picks as well as use both of their hands for picking as opposed to one as is today. For manufacturing, Augmented and Virtual Reality also pose a great advantage in the terms of being able to locate and identify various parameters on a shop floor. Today, information is displayed at set locations in various areas of a shop floor and only displays information that is deemed to be key by management, such as yield, UPH, inventory etc. However, with using Augmented Reality, a user who is walking the shop floor can view any information that is important to them by choosing what they need on their headset. Virtual Reality can also be used to aid in line set ups, changes as well as viewing the line in Virtual Reality from an office or other offsite location.

- Business Development/Design: The business development and design application refers to the ability to use Augmented and Virtual Reality in the areas of using the tools to sell goods or services as well as use it for designing various things like products, manufacturing lines or anything else related to the industry. Augmented Reality can be used for business development by incorporating it into part of the selling process, for example, visitors to a manufacturing area who are there for a tour can use an Augmented Reality headset to add content to their field of view and learn more about the environment that they are in. Augmented Reality can be used for design in the sense that a user can overlay a design in their environment that is designed to scale and see how it fits and works in their environment without having to have a physical model. Virtual Reality can be used for business development to give virtual tours of a factory or an environment without having to have the visitors travel to the factory or environment physically. Since Virtual Reality is immersive, a virtual tour for business development can allow a user to be completely immersed and therefore experience how the environment is. Virtual Reality for design can be used for collaborative design. For example, having two design engineers collaborate over different geographic locations on the same design can allow for a reduction or even elimination on travel cost.

- People and Resources: The people and resources application refers to the ability to use Augmented and Virtual Reality for training, onboarding, and other human resource related activities. For training, Augmented and Virtual Reality can be used to train people on how a certain company performs certain tasks, it can be used for teaching

corporate culture or company policies so that team members who are new or need to be refreshed can be engaged better by using a more interactive and immersive experience. For onboarding of new employees, Virtual Reality and Augmented Reality aid in the area of easing transition. For example, manufacturers can use the technology to show new hires how their manufacturing environment is like and how they perform certain operations. This can help new hires feel more at ease when they enter the real manufacturing operations since they are now more used to what the operations are like and not surprised by their environment.

- Service and Repair: The service and repair application refers to the ability to use Augmented and Virtual Reality to assist in servicing and repairing operations. Augmented Reality can be used in service and repair by helping field technicians perform repair, service, maintenance, preventative maintenance and/or other service and repair operations by having instructions or procedures displayed in the technician's field of view that will aid the technician in completing the action hands free without having to refer to a written text or flip through various manuals and books. Virtual Reality can be used by teaching field technicians to learn repair, service, maintenance, preventative maintenance and/or other service and repair operations by learning on virtual equipment rather than on physical equipment. This allows newer technicians to learn on equipment without damaging or affecting real capital.

Advantages and Challenges

The applications for this technology are wide and useful, and there are many advantages to using both across the industry. Some of the main advantages of Augmented Reality are the following:

- Mobility: The ability to have headsets that can be easily transported or carried poses as a great advantage for technology such as this. People are able to carry the headsets with relative ease. As Moore's Law acts more on this technology, the market will see even more mobile form factors that will make it easier to carry and most likely use.

- Hands Free: Headsets that display real time data and information to the user will have a positive effect on the safety and efficiency of the user. For example, in logistics applications, a user does not have to carry any physical paperwork or pick list, but rather can use voice or gestures to go through the list of tasks that are needed to be performed while being able to use both hands.

- Visual Alerts: The ability to present immediate reminders or alerts in the field of view of a user allows for immediate actions to take place. This can help in environments where a user is required to perform certain actions at a certain time or can also help combat fatigue, noise, inattention or busy environments.

- Multimodal: Most headsets today respond to multiple forms of inputs and outputs. The ability for a user to be able to use voice commands, taps, gestures or head movements increases productivity as well as allows users to interact in different ways with the hardware and software.

- Always On: The ability for a headset to stay on and record data for the length of its battery life poses an advantage in the sense that it allows for analysis of the data as well as displaying and actions based on what it is recording.

As can be seen above, Augmented Reality can provide much value to users and can greatly improve efficiency for users. However, the technology is still maturing and therefore there are some current disadvantages to the technology.

- Comfort: Today, most of the Augmented Reality headsets are not comfortable for everyday or all-day wear. Due to the number of components that are needed to make the technology operate properly, the headsets can be heavy and cause fatigue to the user due to the weight of the headsets.

- Battery Life: Most of the headsets in the market today cannot last more than a few hours without needing to be recharged. This is a challenge for applications in a manufacturing environment due to the fact that hardware that is needed by the user needs to be able to last at least a full shift to be able to be used. As other components of the technology become more powerful and energy efficient, and as batteries advance, we expect this issue to be addressed in the future.

- Processing: Today, the processing speeds and internal computing power of Augmented Reality headsets are not that high, causing heavy applications or multitasking to take a long time or not being able to be performed at all. As more powerful processors and auxiliary hardware is developed, the challenge will be addressed, and headsets will be able to perform faster.

- Field of View: Today, most headsets have a field of view that ranges from approx. 15- to 25 degrees. This field of view is good for notifications and alerts; however, it is not ideal for viewing designs or for things that require you to

see a large amount of graphics together. This creates a limited view for the user and causes them to have to back up or look around to try to piece a scene together. As optics technology advances, this will be a key area that needs to be addressed.

- Cost: As with any new technology, cost is a driving factor for adoption, if the cost is too high, it is less attractive for consumers to purchase it and use it. Today, Augmented Reality headsets carry a very high price tag, with the majority of them being well over a thousand dollars. This is barrier for entry for most corporations as well since buying in mass volume is not financially feasible.

- Privacy: Since the majority of Augmented Reality headsets incorporate cameras or recording devices, privacy is a major concern for public use. The ability for users to take pictures or record video at any time while wearing glasses poses a risk of anyone taking pictures or video of anything. This causes discomfort for many people and will need to be addressed if this is to become the future of personal computing technology.

Augmented Reality has its own advantages and challenges that it faces but Virtual Reality is experiencing its own advantages and disadvantages for mass adoption. Some of the advantages for Virtual Reality are the following:

- Theoretical and Practical: Virtual Reality has opened up the world by being able to explain sophisticated theoretical ideas through the experience of immersion. By being able to experience a concept or thought through a virtual setting, users are able to grasp what is going on with more ease. For example, students are able to analyze virtual strands of DNA by entering into a virtual environment and by doing so they are able to learn about how it works in more detail. In addition to theoretical, Virtual Reality has also opened the door to being able to learn more about practical solutions. For example, medical students can learn about how operating rooms look and function just by wearing a headset and seeing how they are and how they feel.

- Sensory Input: By using various types of sensory outputs such as sight, sound and touch, a user can feel more immersed in an environment and therefore this provides a real-life scenario for a user. For example, the military can use Virtual Reality to help show soldiers in training common sights and sounds that they might run into in the field.

- Cost Savings: By being able to emulate another environment, the cost of having to travel to that environment can be saved. This has proven true for situations where users are shown various destinations through a Virtual Reality headset without having to travel there physically. For example, visitors to a manufacturing facility can tour other plants that are located around the world without having to spend the time and money required to physically be there.

- Safety and Complexity: By being able to be in a virtual environment, users are able to be in what would normally be unsafe or complex situations without having to worry about the danger or complexity of the situations. For example, automation engineers are able to look directly at robots operating on a product in a Virtual Reality environment without having to worry about personal safety due to the fact that the environment is not physical.

Virtual Reality can provide much value to users and can greatly improve experiences for users. However, the technology is still maturing and therefore there are some current disadvantages to the technology.

- Motion Sickness: The ability to wear a device that has screens very close to your eyes and is providing sensory inputs can fool the human brain pretty well. It is not uncommon for users to feel motion sickness after they have experienced a Virtual Reality environment. For some, this will never be cured but one way to help minimize this is to have the frame rates be increased.

- Safety: The safety of users is a current challenge that the technology is facing today as well. Since a user who is wearing a headset cannot see the world around them, they are more prone to environmental injury. This has been mildly improved due to some software solutions, but this needs to improve due to the fact that some users can possibly injure themselves.

- Frame Rate: One major challenge that Virtual Reality is facing currently is that the graphics are still operating at lower frame rates than ideal. This causes the user to feel disoriented due to the fact that their eyes are moving around a scene faster than the screen is able to render the graphics that need to be displayed.

- Portability: Most high end Virtual Reality headsets today require the need to be tethered to a computer for them to be able to operate. This limits many aspects of its full potential because it does not allow a user to walk around as much in a virtual environment due to the length of the cable. It also limits the ability to take the headset with the user if they want to travel somewhere. There are Virtual Reality headsets in the market that operate using a mobile

phone, however, the screen resolution technology and battery performances are still improving for this technology to be widely adopted and to be frequently used.

- Need of a PC: For high end Virtual Reality systems, a high-end computer is needed for it to work. High end gaming computers range in cost from over $1,000 to several thousand depending on the desired specifications. Even though the Virtual Reality system might cost several hundred dollars, the cost of the PC needed to run it will end up raising the overall price of the system significantly.

Conclusions

The Augmented and Virtual Reality market is a very interesting new technology that has many advantages that will make it valuable and at the same time there are a lot of challenges that will need to be addressed for this technology to be widely adopted. As these components mature, it is a reasonable assumption that the world will be seeing more of this technology in the years to come.

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Overview of XR in a Manufacturing Environment

Mike Doiron
Zohair Mehkri
Flex. Ltd
Milpitas, CA

Agenda

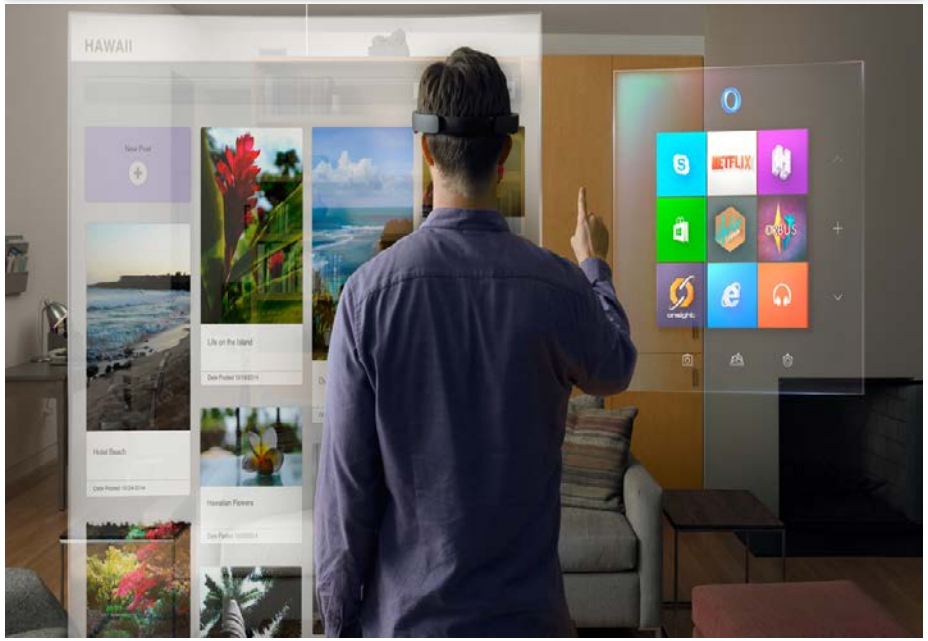
- Introduction
- How it Works
- Market and Applications
- Advantages and Challenges
- Questions

Introduction

- Various types of reality in the market:
  - *Augmented Reality*
  - *Virtual Reality*
  - *Mixed Reality*
  - *Informed Reality*
  - *Etc*
- *Referred to as “XR”*

Introduction

AR – Augmented Reality



Viewing the physical environment whose elements are overlaid on top of what you are seeing live

[1]

VR – Virtual Reality

Computer-generated simulation of an environment that can be interacted with in a seemingly real or physical way

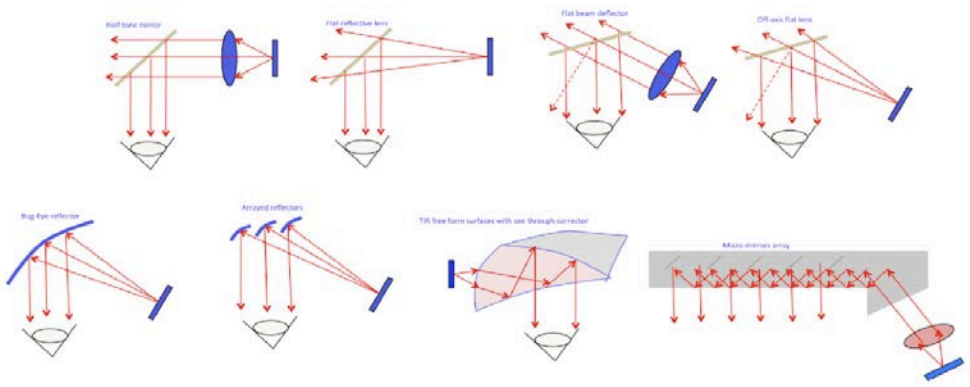
Introduction

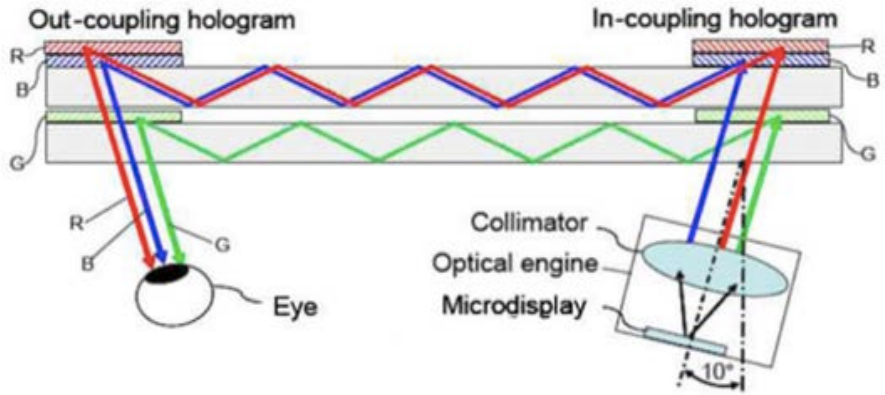
- The AR and VR market is expected to cross $44 billion by the year 2025
- The average selling price will be half the cost by 2025
- There will be 125 million more units in the market by 2025

[1]

How it Works – Augmented Reality

- An optical device combines a computer generated graphic with real world light. Like a partial mirror, it redirects the generated light and selective real world light into the eye.
- Other hardware is commonly referred to as a “waveguide”, waveguide grating, and holographic optical element behave similar to a light pipe. The pipe is a thin sheet of plastic or glass that is designed in a diffractive pattern that allows the light to bounce through and into your eye by extracting a collimated image using TIR (total internal reflection).

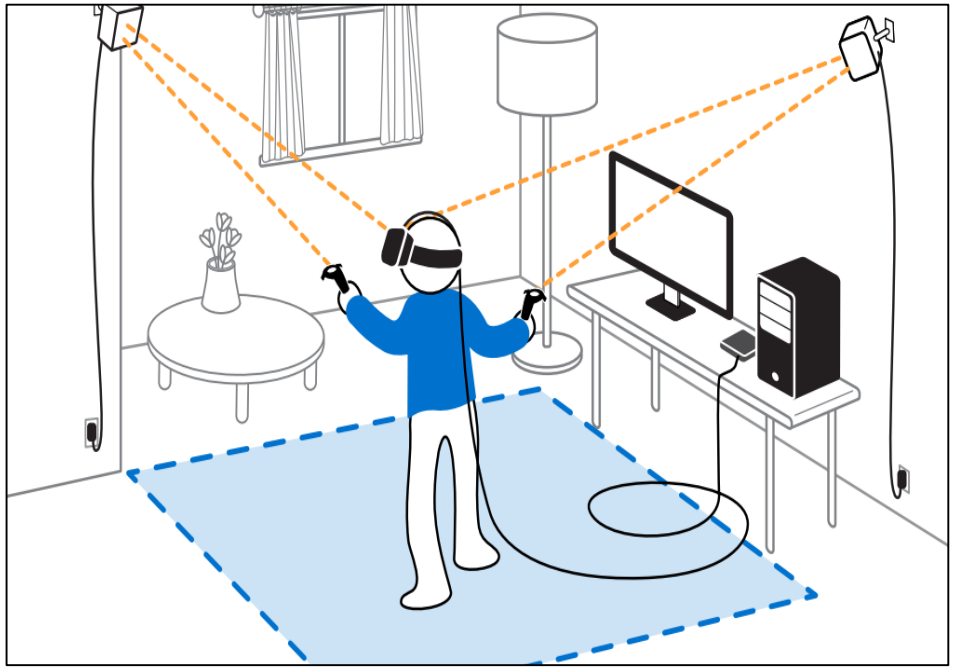




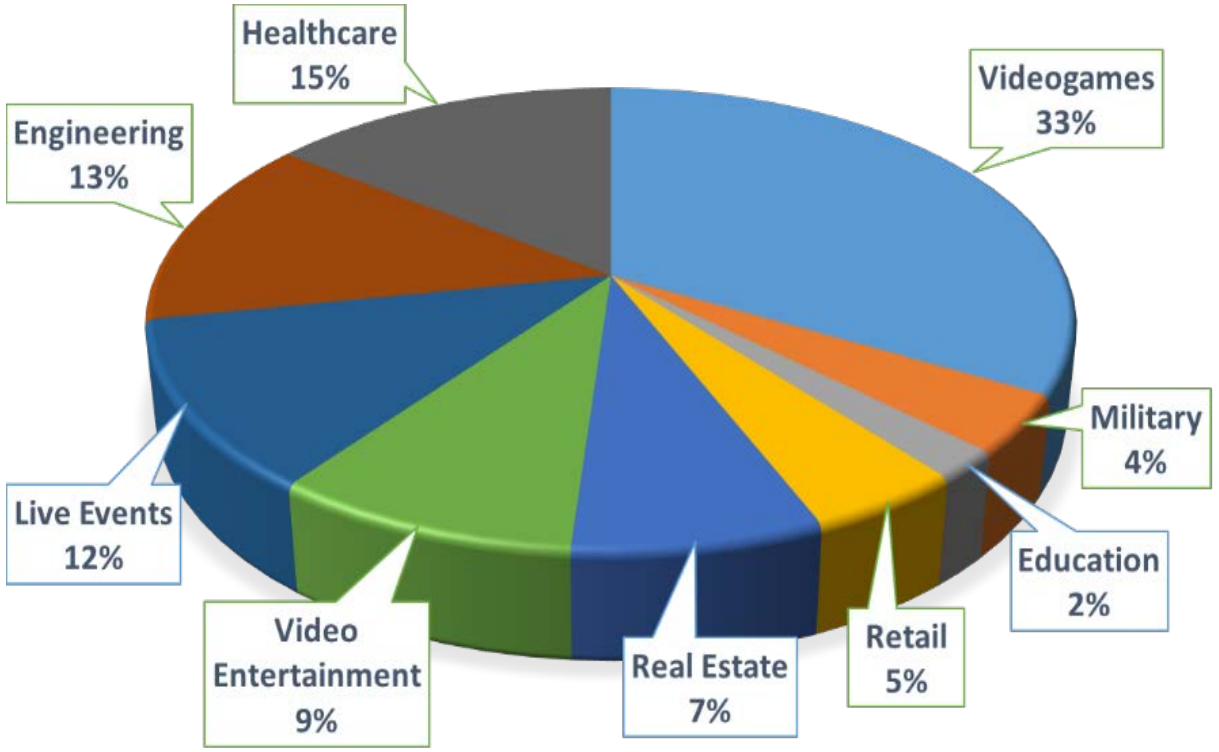
How it Works – Virtual Reality

- Works by having a user view a LCD, OLED or other type of display through a stereoscopic lens setup that gives the user the sensation of being immersed.
- The major components of a virtual reality headset are:
  - *Sensors: Usually head and body tracking and / or location sensors that are for user experience as they reduce the latency of the image refresh to match viewer's movements*
  - *Motion Controllers: Location controllers that allow users to track their motions or gestures intuitively*
  - *Displays: Usually a HD or high resolutions OLED (or equivalent) screen that displays the content to the user*
  - *Lenses: A piece of plastic that allows the viewer to have a wide FOV (Field of View)*

How it Works – Virtual Reality



Market and Applications



[1]

Market and Applications

Service and Repair

Remote Assistance

Work Instructions

Logistics/Order Fulfillment

Business Development

People & Resources

Advantages

Mobility

Hands Free

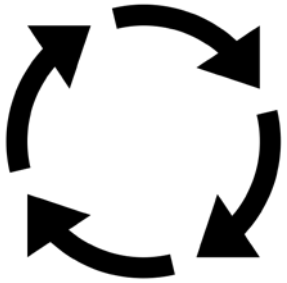
Multimodal

Always On

Visual Alerts

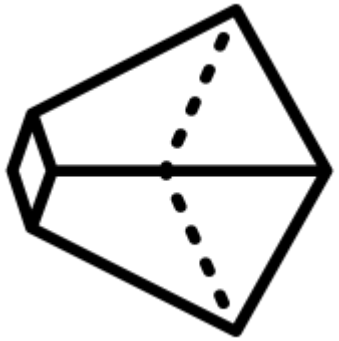
Challenges

Comfort



Processing

Battery Life



Field of View

Cost

Privacy

Conclusions

- The AR and VR market is expected to cross $44 billion by the year 2025
- There will be 125 million more units in the market by 2025
- Will enable manufacturing applications to become wider spread in the industry such as remote assistance and work instructions

Sources

- [1] Source: Goldman Sachs, Virtual and Augmented Reality, January 2016.
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Questions?

Zohair Mehkri

Zohair.Mehkri@flex.com