Incorporating Augmented Reality into Consumer and Industrial Technology

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ABSTRACT

This paper will discuss the usage of augmented reality and the current methods of implementation. The paper will also cover technologies that are used, as well as challenges with them. Current implementations of Augmented Reality will be discussed, as well as prototypes and future uses for Augmented Reality.

Keywords
Augmented Reality, Wearable AR

1. INTRODUCTION

Reality is what exists around us. It is what we interact with on a day to day basis. Augmented Reality (AR) is using computers to produce an interface that integrates with that existing reality. This is in contrast to Virtual Reality (VR) which uses computers to produce an interface in a completely virtual environment, where the user's entire surrounding are replaced with a virtual one. The key difference is that AR overlays virtual objects onto reality, while VR creates it's own virtual space. An example of an AR device is the Google Glass, which projects content onto a small lens. An example of VR is the Occulus Rift. The Rift completely obscures the users view and instead displays a virtual environment through a pair of goggles.

The field of AR is very new, so a precise definition does not yet exist. There are many interpretations on what does and does not constitute as AR, but for this paper I am defining AR as technology that adds to and interacts with reality without completely replacing it. This includes technology such as glasses with micro displays, but does not include non interactive media.

These are four components that all AR systems have in common. My paper will be structured around discussing the methodology and challenges associated with each of these components:

1. How output from the device reaches the user. (Method of Display)
2. Where the system processes information. (Computational Concerns)
3. Synchronizing the content with the surroundings. (Overlay Synchronization)
4. How the user interacts with the device. (Methods of Interaction)

There will be two main classes of device discussed in this paper; portable and non portable devices. Portable devices include anything that a person could reasonably carry, such as a set of glasses, or a smartphone. Non portable devices include anything that is not easy to move around. This category includes cars with AR displays as well as larger devices that have AR *integration* such as a household appliance. *Integration* is a term that I use to mean the incorporation of one or more AR components into a device that is not currently using AR technology. This can also mean the repurposing of existing hardware for the use of the AR application. For the purpose of usage explanation I have also split the technologies into two more categories, consumer and industrial as shown in Figure 1. Consumer technologies are those that are for private use, while industrial are for use in a workplace setting. These are not mutually exclusive and some technologies fit into both categories.

Types of Augmented Reality Devices	Consumer	Industrial
Portable	AR smartphone applications	Helmet Heads Up Displays
Non-portable	Automotive Heads Up Display	Architectural Models

Figure 1: Table showing the the split between personal and commercial, as well as portable and non-portable

2. BACKGROUND

This section will go over the technologies behind AR, starting with the methods of projecting and displaying the AR content. This section includes integrated displays, heads up displays, retinal projectors, environmental projectors, and three dimensional projection. Following that will be a section on computing and challenges associated with it, including device size and whether off-site computing is a viable alternative. The next section discusses the synchronization of the displayed content with the environment, methods including three dimensional grid coordinates and GPS locators. The final section covers the interaction between the user and the device, including methods such as gesture control, touch control and haptic feedback.

2.1 Methods of Projection and Display

Display and projection has been a challenge since the birth of AR technology. Currently there is very little variation in technology allowing users to view AR. Most projection based systems are limited by the medium they project onto. These systems overlay content onto the environment or a clear medium. This contrasts an integrated display which, instead of projecting overlaying content, displays both the image of the environment and content on a single screen. Larger non-portable devices can use a projector separate from the viewing device, though many keep them together for the sake of simplicity. Three types of projection that will be discussed are integrated displays, projector displays, and retinal projections.[22]

An *integrated display* is when the projection and display are combined in a device. Examples of this are smartphones and tablets, since the device contains the display there is no need for separate projection. An AR application on a smart phone takes video from the smartphone's camera then uses the AR application to project an overlay across the video as seen in Figure 2.[16] This is an easy way to produce a simple AR application due to the relatively small amount of processing power needed, as well as not requiring specialized equipment to use it. Two downsides to these methods are the difficulty of displaying content due to device size, and dangers to mobile users from being unaware of their surroundings.

Figure 2: An image of a smartphone overlay marking the names of mountain peaks in the Alps.

Another common form of augmented reality is in the form of a *Heads Up Display* (HUD). This uses some form of glasses or goggles to project the display to the user. An example of a HUD is Google Glass which displays the content by using LEDs shining onto a small crystal in front of the right eye. The crystal is clear so the users vision is not obstructed, while still capturing the projector's image. These can either be stand alone, such as Google Glass, or part of a larger display system, such as CastAR. The HUD is useful because it can be built into existing headgear such as the aforementioned glasses or safety goggles. The heads up display is also useful for the actual interaction between the device and the environment, being able to easily display content to the user in relation to their surroundings. [12]

Retinal projection projects the image directly onto the users retina, fooling the eye into thinking the image is actually existing in reality. This type of projection works very well for HUDs due to being able to remove a medium from the device by projecting straight onto the eye. These displays avoid projected images blocking the users field of view by projecting the images into the peripheral vision of the user. There are fields of view where the eye can recognize text, shape, and color as seen in Figure 3. The retinal projector takes all of these field of view into account and displays the image outside of the recognizable field. These images only activate when the user focuses on the item, then bringing it into view. [12]

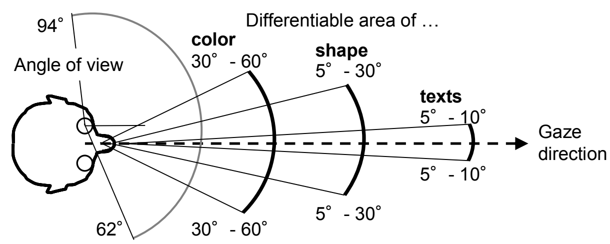

Figure 3: An image of the fields of view of the eye. [12]

Another type of projector display is a *environmental HUD*. Environmental HUDs require suitable physical surfaces to project onto, as the content is displayed directly onto the environment. This technology works quite well in a consumer setting and the environmental projection method could be implemented in industrial settings, as the projector can be built into current safety equipment such as helmets or safety goggles. [21]

The most advanced and difficult technology to use is *three dimensional (3D) projection*, and in depth details are lacking as there has not been much work done with this interface. This creates a virtual 3D object into the environment that can be viewed without the use of other devices, however this is by far the most difficult method to perfect due to its complexity. A full 3D projection differs from worn AR devices in that it is projected directly into the environment, instead of a medium such as glass or the eye. The projection is similar to a hologram, which is a single still image that is a record of a field of light, not an image formed by a lens. The difference is that holograms are still images, while 3D projection can move or be interacted with. The largest challenge is how to display the content, as 3D projection must project the content directly into the air to be feasible for use. There are methods to simulate a 3D projection using an inverted pyramid of material, but this method is not viable for most uses due to the size and cumbersome nature of carrying around a small pyramid.[4]

2.2 Computational Concerns

One of the largest hurdles to integrated AR is where the computing are performed. In non portable devices space is not as much of a concern so the processing can be added to the device with few issues. In portable devices the challenge is to maintain appropriate size and weight. Wired connections are an option on portable devices, though they limit both portability and usability by hampering freedom of movement, especially with multi-user devices.

In automobiles AR can easily be implemented due to the large amount of space available, both for the display and the computer. Most newer automobiles already have computers built in so adding more processing power to the existing computers is a viable strategy as well. For more portable technology the choices for computing are limited significantly. One of the options is *integration*, in the case of smartphones it is using the phones computer and built in camera to run AR applications. This is more difficult for wearable technology such as glasses as both the projector and the display must be attached to the frame, leaving little room for the processor. This option is almost exclusively limited to smartphones and tablets due to the computing power already being incorporated into the device. [23]

Another method is outside computing, which is where the computations are not made on the wearable device, but instead streamed wirelessly from another location. The other location could be almost anywhere as long as a connection could be made, some examples for consumers are a smartphone that the user is carrying or their desktop computer in their home.[23]

In the industrial setting the wireless transmission is easier due to the localized area that the device is operating in. As long as there is a wireless network that provides coverage it would possible to have computation done in a concentrated area and transmitted to the individual workers. [24]

2.3 Overlay Synchronization

Creating AR technologies requires interaction between virtual objects and the user's environment. This involves overlaying images over the user's surroundings to simulate objects or display information. Most devices created specifically for AR use a projector that displays the content onto a medium. The real challenge is getting the projection to overlay in the correct location in relation to the environment.

Both portable and non-portable devices have different methods available to to this. With non portable devices fixed positions can be used to determine where the user is in relation to what they are trying to interact with. This is achieved by creating axis along lines in the environment and registering the coordinates of the intersections of these lines to determine position. The system then calculates where the objects should be positioned in relation to the surroundings based on the coordinate locations of visible objects.[8]

Two methods that are currently being used have some significant problems in accuracy. The two existing methods of positioning are GPS and marker based systems. GPS based systems use a GPS built into the device to estimate position in relation to it's surroundings. While this can provide a rough idea of the location and of known nearby objects it does not work well indoors and also has difficulty pinpointing the altitude of objects. However this method does work well for rough overlays and outdoor application not requiring precise positioning.

The second method is the Marker based system, which uses markers placed in the real world as landmarks for the AR system to determine its position. This can work quite well for determining position and the more markers that are place the more accurate the positioning is. This does require markers to be placed quite frequently if accurate positioning is required, making this method unattractive for outdoor use due to the sheer number of markers necessary.[16]

2.4 Methods of Interaction

The ability to interact with augmented reality is nearly as important as being able to view it. A few ways to interact with AR are, interacting directly with the display, interacting through gestures, interacting through eye movements, and interacting with a haptic feedback controller.

In portable systems, *interaction with smartphones* is the simplest due to the touch screen. The touch screen allows the user to directly interact with the displayed image. Stepping up in complexity there is *gesture controlled AR*. Gesture controlled AR is controlled by movements that signal the system to execute a specific command. [19] This has an added layer of complexity because the software must be able to identify the gestures that the user is making with accuracy. Getting the tolerance for the gestures can be a major hurdle to overcome. If the tolerance is too low then the user will need to make the exact gesture with no error to execute the command. With the tolerance too high the user could accidentally execute commands.

Another form of interaction is an *eye controlled interface*. This is mostly used in wearable headset devices, due to the nature of the controller. The eye control method is similar to the gesture control method, but it uses the motions of the user's eye instead of hand gestures. This works by tracking the eye movement and when the eye is focused on part of the image that the user wishes to manipulate the sensor sends the execute command. As with gesture control this is difficult, but the difficulty lies in a different area. With the gesture control the challenge was having the tolerance of the movement just right so the actions would trigger when the user commands. With the eye controlled system the challenge is detecting what part of the image the eye is focused on. In the retinal projection that was referenced in section 2.1, a sensor detects the position of the eye and determines what it is focused by the angle at which it is pointing. There are specific angles at which the human eye can recognize text, shape, and color. The retinal projection puts the images outside of all of these angles so it is nearly unnoticeable until looked at directly. [12, 25]

Using non portable systems allows for a more robust gesture control interface due to the system being able to read motion from the user's entire body not just the parts usually visible on portable AR, the hands and arms. A *full body gesture control system* works by identifying the hands, head and feet and estimating the 3D pose the person is in. From there it can identify what gestures the user is making. [13] *A mouse and keyboard* is also an option to a non portable AR device. This works by having a projected icon controlled by the mouse used to manipulate the image the same way as if it were on a screen.

Another method that has promise is a *haptic controller*. [14] A haptic controller works by providing constant feedback to the user by sensing the amount of force the user is exerting into the device and replying with a roughly equal amount of force. This allows the user to feel as though they are moving the haptic device, while the device remains is a roughly fixed position. This is useful for manipulating AR projections because the the user can perform actions with a minimal amount of space required.

3. CURRENT AND FUTURE TECHNOLOGIES

3.1 Consumer

The consumer market has a nearly endless supply of opportunities for implementation of AR. Starting with existing technologies and products there is smartphone AR. Smartphones have a variety of AR uses as they are a commonly owned device that provides an integrated display and computing. A few examples of applications that have been developed for smartphones that incorporate augmented reality are Golfscape GPS Finder [3], an app that lets your smartphone camera display the distance to the hole on a golf course, as well as hazards along the way. Wikitude World browser is another AR application that uses the camera of the smartphone. When the camera is pointed at the user's surroundings, a popup will appear with links to the web pages of local businesses, menus of restaurants, and more all added by users. [7] Then there is Sky Map, an application that identifies constellations when pointed at the night sky. [6] These are a few examples of AR applications that have made their way to smartphones. [16]

Moving on to the more complex technologies there are wearable AR devices, the most prominent of which in recent years is Google Glass. Google glass is a HUD based headgear that uses a projection onto a small glass lens. Although this device was not a commercial success, it paved the way for wearable AR devices and helped garner support for other companies investing in AR. Many lawmakers were concerned about the safety of AR headset users and bystanders, fearing that the distractions caused by the AR headset could lead to injury among both. There are also numerous privacy concerns with many worried about the possibility of unwelcome filming in public. [15, 22, 23] Following Google, Microsoft has been developing the Microsoft HoloLens, which may end with the same fate as Google Glass if views of the safety and security of wearable AR do not change in the future.

Entertainment is another market that is seeing AR rise in popularity. There are many products that are in development or released that deal with the entertainment side of AR as well as having a commercial use such as CastAR. CastAR uses a one by one meter mat with connected goggles that project a 3D image over the mat. This has a variety of uses from games to architectural models. What is unique about the CastAR is that each user can be shown a different image, providing a means for everyone to have different content displayed to them.[2] This could be used to develop unique new board games that are asymmetrical for the players.

Video games are another field that is likely to adopt AR in the near future, rather than players wearing VR headsets to immerse themselves in a world, AR gaming attempts to do the opposite, bringing video games in to reality. By wearing an AR headset players could experience a game in a real world location, something that is currently being done by the Japanese company Nintendo with their upcoming game Pokemon GO. This game has the players travel around the real world to catch virtual "Pokemon". This is game is the first of its kind using interactive AR to participate in a game.[5] With 3D games becoming popular and AR technology always improving, it is only a matter of time before AR is more widely adopted by the entertainment industry.

There have also been many prototypes developed by researchers to find new ways to augment existing technology with AR. The uses are varied and many of the prototypes have used existing technology to create the experience for the user. The Magicbook is a book that can be read normally without any equipment, however when wearing the goggles a three dimensional image is projected over the page. showing the setting for the current event happening in the text. The user is able to view the images from any angle.[9] Another technology is an augmented map using a smart phone. This works by holding a smart phone over a physical map, with the screen displaying additional information about what is currently being viewed.[18]

Moving on to concepts for future technologies. These are devices or software that are starting to be explored, but do not yet have a market product. Automobiles are a promising candidate for AR integration, given the available space for the display, processing, and projection. While in theory the windshield is a perfect place to display information, in practice the display is limited to a small area directly over the dashboard. Unless the entire instrument cluster is made into AR, there is very little room to add images without obstructing the drivers view. In theory, AR in autos could replace nearly all of the functionality of the instrument cluster, freeing up space that can be used for more displays or simply improving the drivers field of view.

Some possible features are built in GPS and navigation systems as shown in Figure 4. There are also possibilities for side window augmentation, displaying points of interest such as street names and housing numbers. Localization is another feature that may be useful for drivers in a foreign country as signs along the road could be translated into their native language. This is only viable at low speeds however as the automobile is usually moving too quickly to make effective use of these pop ups. [20] Augmenting autos with AR is not without concerns however, there are similar safety issues with autos as with wearable devices. Drivers distracted by a HUD could be much more dangerous that any other form of AR users.[15] This could be mitigated by having safety features built into the AR in autos, such as a warning for blind spots as well as warnings for approaching traffic.

Figure 4: A mock up of a windshield displayed HUD in an automobile. [1]

Documentation of consumer products is another interesting use of AR, with the paper documentation being automatically converted into a 3D image. This could assist customers with assembly of goods, such as furniture and other devices. AR can also be used to create a step-by-step tutorial, showing exactly what to do to assemble each piece. Annotations can be easily added for parts as well. This could also be used to assist in repairing broken items, with animated diagrams showing exactly how to replace certain parts. AR can also be used to make exploding diagrams, reversing the assembly process by showing the removal of each part from its final position by moving it along one or more axis. An example of how this technology could be used would be an interactive furniture diagram, with each step being shown on a virtual furniture set.[17]

3.2 Industrial

Industry has a large variety of uses for AR as well, many involving safety measures in dangerous working conditions. Factory workers surrounded by large robotics moving at high speeds have a very dangerous occupation, though this can be made much safer with the addition of HUD. Many workers in industrial environments are required to wear safety equipment such as helmets and safety goggles already, so adding an AR HUD would be quite feasible.[21] Some of the features the HUD could provide would be markers for where the automated factory robots move, indicators of dangerous situations, such as a hazardous materials spill, or to provide useful information, such as the level of oxygen available in oxygen tanks. In the case of maintenance, workers could look at a cutaway of the machine being maintained and have any areas where problems have occurred in the past highlighted.[17]

Machines in industrial settings tend to require bulky controls, with augmented reality however the controllers can be replaced by an AR controller linked to the machine that does not require physical controls at all. This could allow the machine operators to be off site, or at least not in as dangerous conditions, while having a full range of controls available to them. There are also applications for productivity assistance and training for newer workers with augmented reality. Hands on tutorial programs with augmented reality could significantly improve the speed at which workers reach maximum productivity, as well as reducing mistakes that could lead to industrial accidents causing injury.[10, 24]

Architectural planning and floor plans are also a way to implement AR into industry. Creating models of the building in an AR setting instead of creating an actual model can result in a more portable and easily changed product. These 3D models can be superimposed over a paper floor plan, similar to the magicbook, projecting a 3D image over the pages. Retrofitting existing buildings with new equipment is also much easier thanks to full scale models being projected with AR. This allows the planners to organize the new equipment around the existing space much more easily. An entire mock run through of the production process can be done in AR, making sure there are no complications with the positioning of the machinery. AR modeling can also help with designing workstation in industrial settings, with a field of view projection showing what someone in a specific position will be able to see. This can be used to create more ergonomic work spaces for technicians, improving their productivity by limiting the amount of movement that is required to view the station. [11]

4. CONCLUSIONS

There will be many opportunities to integrate AR technology due to continued advances in the field. Whether or not the technology will be widely adopted will depend on more than just the technology, though the current climate seems favorable. There seems to be a trend in mainly portable AR devices in the consumer markets with devices like Google Glass being produced, which for the first widely available device of its kind did not fair that badly. Many AR applications on smartphones have been developed lowering the cost of entry in using AR technology. Prohibitively expensive new technology puts a major dampener on the willingness for consumers to adopt the devices created with the technology, but hopefully AR applications will give a jump start to interest in AR technology and help to expand its adoption.

In the industrial settings AR is also trending more towards portable devices, though it is the integration of AR into existing safety features that is getting much of the attention. I believe this will be the most widespread type of AR in an actual factory or construction environment, though in other industries there is plenty of room for other types of AR. Three dimensional mock ups of prototypes and architectural plans are two applications that have been explored, with prototypes being developed. I can see this expanding in the future, especially if AR is widely adopted in the consumer markets.

As for the types of AR I do not see full 3D projection being viable in any products in the near future unless there is a large leap forward in projector technology. I would guess that laser projectors onto a medium, most likely glass, will be most prevalent in AR technology for the foreseeable future. For any AR device where is is applicable, eye tracking seems to be the best option as it requires less freedom of movement to control the device. Gesture control is viable for non personal AR devices or non wearable devices.AR technology has all that it needs to be successful, platforms to use it, a low cost of entry, and relatively high public interest.

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