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Mass-Market Augmented Reality: The Difficulty behind its Integration and the Path to Success

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ABSTRACT

The failure of Google Glass changed the path of augmented reality (AR), delaying its integration into a mass market by years. Google Glass contained numerous technical limitations that companies are still facing today. The product also showcased the social issues that come with the technology. Shared privacy concerns among many cause consumer reluctance, with information tyrants such as Google leading and largely controlling AR development. In addition to privacy concerns, health concerns steer people away from the technology. Worse yet, the many negative connotations associated with AR give it a stigma that causes major social limitations. Without normalization of the technology, people will not be interested in investing large sums of money in a product centered on convenience rather than purpose. This lack of purpose and perceived unknowns, combined with the pragmatic elements of low battery life and glitchy, bulky design, makes the technology unappealing. Companies today are attempting to circumnavigate these problems in multiple ways. Some are attempting to create a product with a centralized purpose that solves a problem. Others are using already established industries such as the smartphone or gaming market to sell a more manageable product. Some companies have abandoned the idea of selling AR products and are instead using it as a service.

Augmented reality is a field that still must develop due to its initial setbacks, compelling companies to become creative with the technology's usage. The consumer market is not adapted to wearable AR, making normalization necessary for further progression in the field.

Google Glass: The Initial Rise and Fall of Augmented Reality

Upbringing

From a think tank composed of Google's executives, Google Glass was born. It was one of a hundred different futuristic ideas that the company came up with and quickly gained attention from many executives, including Google's then-CEO Eric Schmidt. Schmidt recruited entrepreneur Sebastian Thrun in 2009 to build the product, resulting in the next three years of Google Glass' life being spent in the shadows. Thrun created a lab known as "Google X" to house the project. X would later become a research facility, owned by Alphabet, holding the name "The Moonshot Factory." The main goal of the facility is to create revolutionizing technology that seeks to have a "10x impact on the world's most intractable problems, not just 10% improvement." Many other established individuals in the industry joined the project, notably Babak Parviz and Astro Teller. Babak Parviz, a current Vice President at Amazon, is often credited with being the creator of Google Glass. Astro Teller would later become the CEO of X, as he still leads research into eccentric technologies (Bilton).

Google Glass began its trek into the public spotlight when Sergey Brin, one of Google's co-founders, joined the lab. He had different beliefs about the product. Some of the employees of X believed that the project should take on more of a public eye. Until then, and for about another year after, a majority of employees at Google had no

knowledge of the project. There were countless debates around the approach of Google Glass. Some believed that it should be marketed and curated for daily wear, whereas others believed it should be used for special occasions such as a wedding. All of this debate was spurred before there was a truly finished product. Google Glass was still a prototype with limited functionality and questionable battery life. Still, Brin believed that the best approach to Google Glass was to take it outside of the secretive lab X (Bilton).

Abrupt Rise to Fame

In April 2012, Google released a video titled "Google Glass: One Day…" The video spends 2 minutes and 30 seconds going through what a day would look like with Google Glass. It shows off the technology's ability to receive and send messages, provide Google Maps, and take pictures. It gave a promising look at what Google Glass could be, but still sent the wrong message. The technology was not at the robust level shown in the video, as it was unable to last a whole day. Certain tests showed that the technology sometimes lasted only an hour. This suddenly created a time limit, as there was only so long that the public would wait before losing interest in the product. The glasses claimed to be able to perform a plethora of actions. This included taking photos/recordings, searching using Google, translating between languages, providing directions via Google Maps, marking calendar events, and even video calling with others. It even promised an extensive user interface where an individual could move their head to interact with the technology, instead of having to use their hands. These assurances excited consumers, as it vowed to be a near replacement of the phone. Solutions to it being a distraction were brought up, as the display only took up 5% of a person's total field of view. It seemed too good to be true, which it was (Steele). All of these promises had not been met and even the ones that were met came with bugs and glitches. This caused pressure to continue to build, as engineers worked against the clock to meet these demands.

The pressure was further accelerated by a stunt held at Google I/O in 2012 when Brin planned a live hangout between skydivers wearing Google Glass and the stage. It showed the skydivers jumping from a blimp and landing outside the stadium. This just furthered the interest in Google Glass, while providing the engineers with no real time to create a product ready for consumer integration. Everybody wanted a pair, but there were none available. Google attempted to continue riding this hype, posting more and more about the project. Another video, titled "DVF [Through Google Glass]" showed people the day in the life of a runway model. It allowed people to see the view of someone walking down the runway, and that person's day before and after the event. This included getting ready for, going to, and leaving the event. It showed a new perspective of just what Google Glass could give, without it seeming heavily staged or influenced. The technology promised the world at someone's fingertips. Advertising did not come solely from inside the company, with tech reviewers such as Robert Scoble sending their praise towards the technology. Mr. Scoble even posted a headshot of himself in the shower, wearing the glasses, captioned "Yes, Google Glass survives a wet shower. You thought I was kidding when I said I would never take them off." Magazines also believed in the glasses, with Time Magazine naming it one of the "Best Inventions of the Year." It spread throughout social media and television alike. From YouTube to comedy shows, Google Glass was everywhere. Still, no product could meet such high expectations (Betters).

Finally, Brin and his associates decided that this level of popularity was not beneficial to the development of the product. Their first attempt at limiting the exposure of Google Glass was through Glass Explorers. This was a group of journalists and testers who would pay $1,500 to test out the product. This meant that it could enter the world, but not as a fully commercialized product. This was created in hopes of dousing the hype around Google Glass, buying developers more time to create a working product. These methods had the reverse effect, as they only increased demand for the product. With it being available to only a select group, those not selected wanted to get their hands on the product. The desire for Google Glass only continued to grow, as it was one of the first products that was truly augmented reality. Companies such as Oculus were being founded at the same time, and these types of technologies were finally getting attention. At the front of this attention was Google Glass, pioneering the industry of augmented

reality and setting a standard for what the technology could be. It certainly set a standard, but not a positive one (Bilton).

The Collapse

The facade of Google Glass could only last so long. Eventually, people caught on to the fact that Google Glass was still only a prototype. Consumers had gotten sick of the flashy advertising and hype around the project, as its limitations were exposed. Some of the Glass Explorers began to test the product, only to discover not-so-favorable attributes. The first issue, and debatably most jarring, was the battery life. Alongside this, the technology was not smooth. It was filled with many bugs, glitches, and inconsistencies. Interacting with certain parts of the technology proved to be more difficult than expected. There were issues surrounding privacy concerns. Google, a corporate titan, did not have the best reputation for its data privacy usage. Concerns elevated over what Google Glass could see. Since the technology could take pictures and record videos, the potential for spying was limitless. If someone were to gain access to an individual's glasses, they could steal a plethora of information. These recording features led to it being banned from many different areas: bars, movie theaters, and casinos. Unlike many devices, Google Glass puts the privacy of others at risk just as much as the user. Since the glasses could theoretically record an individual's daily life, anybody involved in that daily life would be under surveillance. Most people do not want their actions constantly caught on camera. This concern was voiced by both individuals and corporations. Companies do not typically want people recording on their property, with department stores such as Walmart typically banning or discouraging people from recording while on their premises. User concerns reached the point where a new term was coined: "Glasshole." This was used to describe many of those under the explorer project, specifically those using the technology in obnoxious ways. This turned the fashionable and hip device into an annoyance, where the image of the technology flipped. Suddenly, nobody was cool for wearing them and any desire around them had faded (Betters).

The final breaking point for Google Glass was not even around the technology itself. It came from a scandal between Sergey Brin and Google Glass's marketing manager, Amanda Rosenberg. Mr. Brin, a married man, was reportedly having an affair with Rosenberg. News of the affair made international headlines, and soon Brin and his wife of ten years divorced. Rosenberg became the face of the ill-fated Google Glass. From here, it became impossible for Google Glass to recover. Reports were everywhere around both Mr. Brin's affair and the limited capabilities of the current glasses. Once people learned what the glasses could do at the time, the price point seemed too steep. For a short period of time, it was seen as a fashion item, with runways during the New York Fashion Week in 2012 showcasing the glasses in different colors. Many of the leads behind Google Glass also wore the glasses in public, furthering their fashionability. Once they stopped being shown on runways, and individuals including Mr. Brin no longer wore them, the small level of influence it had plummeted (Bilton).

The technology had gone from a sexy and innovative pair of glasses that could replace the phone, to a malfunctioning and unappealing run-of-the-mill technology in a few short months. This is where Babak Parviz went to Amazon and many of the engineers moved on to different projects. Google Glass rode on the hype, carrying itself far past its abilities. On January 15th, 2015, Google officially announced the cancellation of the Glass Explorers. Two years later, there was an attempt to restart the project. By 2019, the Glass Enterprise Edition 2 was announced. These glasses were aimed at the enterprise market, instead of the consumer market. It could be used by businesses to gather information on the job in real-time, instead of having to use a phone or computer for tasks (Steele). There were noticeable upgrades on this device and the entire advertising campaign was rebranded, but it was not enough. Competitors including Microsoft's HoloLens did not carry the same stigma that Google did. Also, people still imagined the glasses would be what Google Glass had originally promised. This caused Google Glass V2 to have little success, with Google announcing that they would stop selling the technology on March 15th, 2023 (Bilton).

There are many to blame for the failure of Google Glass. But in the end, it came down to the technology itself. It was too soon and lacked a clear sense of purpose. People had not seen augmented reality, at least in this way, before. This could have paved the way for all upcoming wearable technologies. Instead, it highlighted many of the

issues that augmented reality companies are still battling today. It brought up privacy concerns, battery issues, bugs, errors, and even the typical ugliness of glasses. It shined a light on many of the problems while dimming many of the positives. Google Glass is not remembered for what it could be: a technology that replaces the phone and allows a user to have a flawless integration between real and augmented life. Rather, it will be remembered for doing too much too quickly and forgetting to master one or two areas. It did not get the technology right and it did not make clear the product's purpose. This made a recovery impossible, as it is difficult to change the public's opinion. No matter how useful the Glass Enterprise Edition 2 was, people were not interested in a Google-led augmented reality device. It seems that this effect has spread past Google, with many people not being interested in any AR wearable device. This requires companies to work around the social limitations of AR, while also creating a product not plagued with technological limitations. The failure of Google Glass had an adverse effect on the AR industry, but that does not mean that companies are not attempting and succeeding in overcoming these obstacles.

Social Limitations

Augmented reality comes with a lot of baggage. There are many concerns with the technology. Many see the features as obtrusive, with part of someone's field of view being blocked. This can lead to safety concerns, especially when combined with glitches. If the technology was to somehow block an individual's field of view, they could die. Beyond accidents, there are also concerns about Electromagnetic Field (EMF) waves causing radiation damage. These concerns may not be enough to steer people away from the technology, but they act as a deterrent to a product that is not needed. AR Glassware has typically been advertised as a replacement for the phone. The main issue around this is contentment with smartphones, with most individuals having no issues with using a phone. It serves any purpose they may need, but it does not get in the way of their daily life. Wearable AR, however, can be both distracting and annoying. This is especially true with the typical brute design of glasses, making them unfashionable to wear daily. AR glasses can cause further disturbances to a person's environment that go beyond style choice.

Supposed Health and Safety Concerns

During the peak of *Pokémon GO's* popularity, a game utilizing AR through a mobile app, there were genuine concerns about the app being distracting. People were trespassing, walking into traffic, and even crashing to catch whatever Pokémon appeared in front of them. This issue is not contained within *Pokémon GO*. Any augmented reality that can be used in public, particularly while driving, can be dangerous. Identical to how a phone can attract the attention of an individual at the wrong times, AR can as well. The difference between the two is that AR is typically in front of the user and cannot be easily stowed away. If someone were to receive a notification while driving, it would be significantly more distracting than receiving one from a phone (Boghossian et al.). One of the many concerns around Google Glass came from the risk of distractions. The company claimed that the technology would only take up 5% of a user's field of view, but people were still concerned that it could be eye-catching. Similar to how a small text message from a phone can be distracting, full-on AR displays can be much worse.

Health concerns are also prevalent, with worries around AR causing anything from nausea to radiation poisoning. The worry of nausea typically relates to virtual reality, as the body being fully engulfed in a virtual field can disrupt the positioning of the real body. For augmented reality, the nausea concerns are relative to that of a smartphone. There has been real concern around radiation, however, with EMF waves being emitted from the technology. EMF waves, a type of non-ionizing radiation, are used to send signals across radio waves. This means that it is in any type of technology that receives or sends signals, from a remote-controlled car to a radio tower. Non-ionizing radiation is not the stereotypical type of radiation, as it cannot manipulate or damage the structure of DNA in a way that ionizing radiation can. It can, however, shake atoms due to heat emitted from the radio waves. There is no conclusive evidence showing that EMF waves can be dangerous at the level in AR (*EPA)*. No long-term studies have been done, due to

AR not existing for long enough. Still, without any evidence to support that EMF waves can be harmful, many argue that it is not a limitation. If there was conclusive evidence about the danger of EMF waves, these health concerns would be technical limitations. They fall under social limitations, however, due to the limitation being misinformation. Many companies that are attempting to sell EMF blockers, or those simply against AR, broadcast misinformation in a way to scare those away from AR. With some people believing that EMF waves are harmful, companies are forced to convince consumers that this is not the case. Convincing consumers does not end with these issues, as many people remain concerned about how their data will be used.

Privacy Concerns Via Company Use

Concerns around privacy can stem from internal or external factors. When it comes to social limitations, the issues surrounding privacy are internal. Internal factors revolve around the use of data commercially. With many AR devices using facial recognition, such as face filters, the camera will record a user's face. Many are concerned about where these recordings are being stored, and if they can be accessed by people at the company. There are also concerns about the data collected. The possible data collected varies based on the product, but the fact remains that AR typically needs to store multiple forms of data. These concerns may seem illogical to many, due to the amount of data collectors that people already use. The difference is that owning a phone and searching on the web is a necessity for most. They acknowledge that they must give up their data, but also understand that the data collected will be safely stored. Google promises that they do not sell any data and only use the information for targeted advertising ("Google protects your privacy"). AR also has the potential to store forms of data that other software does not, such as voice recordings.

One of the biggest challenges to augmented reality technology is that there is not a clear existing need for AR in the mass market. When it comes to technologies that store data and have willing participants, it is typically because the technology is already established. It would be difficult for many to stop using Google's search engine. It would not be difficult to avoid AR glassware or other AR software that does store data. Few people want their data saved, with the majority of people being neutral on the topic of data collection. Still, there is no reason to give away any more data unless necessary. With AR products not currently necessary, the privacy concerns that come with the intrusive technology can be overwhelming. People argue that this is not the case, as many individuals continue to give up more of their information. The difference between individuals continuing to purchase items such as Amazon's *Alexa* and AR is how established the product is. People already understand what Amazon's *Alexa* offers and the privacy risks involved. Without AR being widely available, it is easy to imagine all the ways one's privacy could be compromised or violated. Many companies have yet to explain what their AR does, making it easy to conjure images of what data could be stolen. This is why a company must define the purpose of its product, as the human mind tends to wander and apprehension and fear take hold.

Lack of Centralized Purpose

When breaking down the abilities of AR glassware, specifically Google Glass, it becomes apparent that the product does not provide a solution. It certainly provides a convenience, as hands-free access to messages, directions, and even a calendar can be appealing to many. Still, every ability listed under different AR glassware already exists in another way. People can simply use a smartphone to check their messages, directions, and calendar alerts. These criticisms apply mainly to the wearable technology aspect of AR. Products that offer a service or are built into another technology do not typically foster this issue. This is because wearable AR is the primary form to which people are forced to devote time and money. An app such as *Pokémon GO* does not require the user to pledge funds to use the AR parts. It is not a continuous part of an individual's day, whereas it typically is with wearable technology. A new player on the AR scene, Vuzix, has a new wave of AR glassware that does the exact opposite. Vuzix's Ultralite is labeled as "An OEM reference design for the ultimate smartphone accessory." It claims to offer a display that will present a "smartphone's alerts, messages, and custom applications content heads up in front of your vision ("VUZIX ULTRALITE OEM

PLATFORM℠").” This technology may be convenient, but it is still only an accessory. Many will be unwilling to pledge hundreds or even thousands of dollars for a technology that cannot stand alone. There are instances of AR relying on pre-existing technology, such as *Pokémon GO* with video games, but those do not typically involve large amounts of money. Once a product becomes costly, it needs to serve a distinct purpose. This is especially true when looking at unproven and incomplete industries.

Unfashionable and Stigmatized

At the launch of Google Glass, there was an impressive level of advertising directed toward turning the product into a fashion item. Google was able to successfully grab the attention of consumers for a while, but people eventually realized how unattractive and bulky the technology is. Due to the technology required, it is difficult to make a sleek and comfortable wearable device. Companies such as Vuzix promise their newest eyewear will weigh in at 38 grams, but this is yet to be seen (“VUZIX ULTRALITE OEM PLATFORM℠”). Typically, the temple arms of AR glassware are large and distracting. When an item is not fashionable, people will be against wearing it every day. The typical unattractive and plain-looking features of AR, similar to many other issues around AR, apply only to wearable technology. When it comes to software, there are fewer criticisms regarding the look of the product.

There is yet to be direct evidence of AR’s ability to be extremely successful and purposeful. The technology is commonly used, but rarely on its own. There are many software developers for AR, but they are not only AR developers. CXR.Agency is a software development agency that has used AR to create filters, games, and even display ancient pottery designs on new pottery (“Projects.”). All of these do have a focus on AR, but they do not brand the products as augmented reality products. This is a key difference between many companies. The technology itself does not seem to be a problem, rather the advertisement of the technology. Many believe that AR’s failure only comes from the technical and social limitations around health and privacy, rather than the public’s actual perception of the technology. This is not the case, as terms like “Glasshole" developed out of annoyance around these technologies. Previous backlash and the futuristic abilities of AR steer many people away from the name of AR. The concern that younger generations are becoming progressively more reliant on technology is growing. It seems that people have accepted technologies that simply use AR, but not AR technologies. This makes it seem that the biggest issue is the idea of the unknowns and past missteps of augmented reality. By simplifying what the technology does and offers, people seem to accept the technology. This implies that a stigma remains around augmented reality and only time can begin to break down this stigma.

Technical Limitations

Battery Life

Both the software and hardware applications of AR require immense battery power. When companies promise to create a pair of AR glasses that can replicate the phone, concerns around its battery life are immediately brought up. Current-day smartphones are built to last the entire day. This is possible due to the size of a typical phone, allowing for a much larger battery than that of AR glassware. The designers of AR glassware, such as Google Glass, are working with a heavily constricted frame. They must fit all necessary technology, including the battery, inside the frame of the glasses. Google Glass promised a technology that could be used every day, but initial tests showed that its battery life was all of an hour. Without a battery that can last at least a day, glassware turns from a convenience into a nuisance. Nobody wants to become reliant and familiar with a technology that will not make it through the day. Companies claim to have solved this issue, but they are currently just claims. Vuzix’s new glasses, the Ultralite, can supposedly last 48 hours. This is due to it being a Bluetooth device connected to the phone, rather than a standalone technology. Even if this is the case, many individuals do not want another version of the smartwatch. There are arguments that AR

being connected to the phone is positive, as it can rely on a previously established technology. While it is true that relying on a previously established technology can be beneficial, it still must be unique. *Pokémon GO* relies on the already-established game market but is unique enough to receive interest. If technologies such as the Ultralite do manage this, they can be wildly successful. If not, they will be disregarded as another wearable technology with no unique purpose.

Battery drain does not only apply to AR glassware, as all types of AR will have a strain on the battery and performance of the technology being used. In the case of *Pokémon GO,* the AR features of the app caused heavy strain on the phones used. With *Pokémon GO* being the only app running, the phone loses around 30% an hour. When background apps are running, this number jumps up to 45%. Oculus' most recent portable VR headset, the *Quest 2,* has a battery life of 2-3 hours. Microsoft *HoloLens* has a battery life of 5.5 hours (Conditt). All of these devices have a level of battery drain that is not sustainable for daily use. *Pokémon GO* was able to ignore this issue due to its popularity, as people would carry portable chargers to play the game. For other less popular devices, this battery life proves to be a large scare. One of the solutions is for the AR to have a larger battery, but this leads to the technology being unattractive and bulky. For some, such as Microsoft's *HoloLens,* this is not even an option. The battery is already large enough, to the point where increasing size decreases efficiency. Many aspects of AR turn into a tradeoff, with battery power being one of them. A company can decide to keep battery usage as low as possible, but this will require decreased speed and increased weight/size of the product. Battery life will only continue to improve, but it currently poses a problem to many AR products and services.

Privacy Concerns Via Errors

With internal issues for privacy falling into social limitations, external issues fall into technical limitations. External issues, when it comes to privacy, are attacks from hackers attempting to gain information. This can be a major issue, on both an individual and wider scale. On the individual scale, people can accidentally install malware leading to someone gaining access to their information. It is also possible for a hacker to gain access by breaching the servers of a company, allowing them to compromise countless accounts. With tech leaders such as Google storing user information, people seek to gain access to this information. This can be deadly, especially for AR products. With AR glassware being a display, an individual having access to that display is an emergency. The person could project the wrong directions on Google Maps, leading an individual into a trap. There are numerous risks around the manipulation of a user's heads-up display (HUD). Regardless of the way of the breach, there are real concerns about the potential dangers involved. On top of the manipulation of the HUD, hackers could have access to the user's visuals and audio.

The main issue around AR from a privacy stance is the sheer amount of data it has the potential to collect. Even if companies pledge to not collect data, that does not guarantee the user's safety. There is no surefire way to protect all user data. With this being the case, the amount of data that AR devices can hold will always concern users. The only solution is to continue strengthening firewalls and limiting what data is gathered. Unless the data must be collected, it should not be. The implementation of alerts to show tampering must be created. There will always be privacy concerns, forcing companies to manage these concerns as best as possible. The easiest way is to create a closed product: one where there is no data sent out. This is not possible for *Pokémon GO* or Vuzix's Ultralite, but it could be for Google's new translation glasses. It would be possible for Google to not collect any user data, removing any privacy concerns. This is not always viable, but it must be addressed. Limiting user and customer concerns in any way possible is vital, especially when considering other technical limitations.

Spatial Recognition Misplacement

The seemingly largest technical limitation stems from the juxtaposition of the virtual and real world. This limitation is known as spatial recognition misplacement and takes place when object detection fails to perfectly judge the location of an object. Object detection, especially when involved in AR, typically struggles with depth perception. This issue

is similar to an individual with one eye, as it is noticeably harder to grasp how far away an item is without multiple angles. When object detection is working with one angle, its accuracy struggles. This is what tends to create a small disconnect between the real and virtual world. It is currently impossible to perfectly integrate virtual objects alongside real objects and make the two indistinguishable. Object detection is not solely at fault for AR's inability to be indistinguishable, as there are many cases where the graphics are not up to par. Still, object detection is the initializing factor around spatial recognition misplacement. To understand the uphill battle that object detection faces, one must first understand the process of object detection.

Object Detection: There are commonly two methods used: Convolutional Neural Networks (CNNs) and Vision Transformers (ViT). CNNs are a neural network that can recognize patterns, allowing an object to be run through it for pattern recognition. Vision Transformers can also recognize patterns but do so in a different way. CNNs will look at an entire image, whereas ViTs break down the image into defined segments. This makes ViTs typically faster, as they do not have to scan through an entire image at the same time. The tradeoff comes with its decreased accuracy in comparison to CNNs. Through this, an ultimatum is born: increase speed and lower accuracy or decrease speed and improve accuracy. The best algorithms use a combination of both, such as You Only Look Once (YOLO). There are two types of object detection: one-stage and two-stage. Two-stage object detection will first generate a region, typically through a Region Proposal Network (RPN). This is used to locate the area an object might be (region). The second stage will then classify the object in the way talked about under general description. One-stage object detection skips region proposals and detects all samples. YOLO is a one-stage algorithm. This is typically faster, as it does not have to run through a neural network twice. At the same time, since it does not first generate a region, there can be a noticeable decrease in accuracy (Colmenares).

For the process of object detection, feature extractors are repeatedly used to reduce the amount of data consumed. Feature extraction is used to reduce raw data by editing the number of variables in said data. When it comes to object detection through deep learning, large data sets are required and therefore many variables are used. This slows down processing, and even though more variables mean a higher accuracy, it takes too long. By using feature extraction, some variables will be combined and others deleted to turn them into features. There are different levels of features. Low-level features are edges/corners. The second level of feature extractors takes these edges and turns them into shapes. The third and final level, high-level features, will classify objects into subjective terms such as tree or cat. Simply, high-level feature extraction is how machine learning sees it. There is objectivity to what is an edge, but that is not the case for items such as a cat. They can differ greatly and can take many shapes, which is what object detection will typically struggle with (Colmenares).

For feature extraction, feature descriptors are implemented. A commonly used feature descriptor is Scale-Invariant Feature Transform (SIFT), which will search for keypoints in an image by looking at individual regions instead of the whole image. When it comes to this process, there are four steps: Scale Space Construction, Keypoint Localization, Orientation Assignment, and Keypoint Descriptor. Scale Space Construction, the first step, typically applies Gaussian Blur to the image to remove noise. Gaussian blur will slightly blur the image, removing any unnecessary minor details and only leaving shapes/edges. The image is not just blurred at one level but instead is turned into 20 different images. There are four octaves of images, with each octave having 5 images in the set. The first octave will have the least blurred images and the 5th will have the most. To simplify the image even more, Difference of Gaussians (DoG) will be used. DoG will turn each octave into 4 images, instead of 5, by subtracting an image from the previous image. This new set of images will be used for Keypoint Localization. This is the process of finding the local maxima and minima of the images. As shown in the figure below, this is done by comparing every pixel to 26 nearby pixels. 9 of these pixels come from the previous image in the octave, 9 from the next one, and the last 8 from the bordering pixels. Any key points that have low contrast or are close to an edge are eliminated.

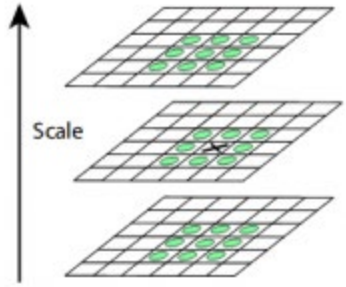

Figure 1. Singh, Aishwarya. "SIFT Algorithm | How to Use SIFT for Image Matching in Python (Updated 2023)." Analytics Vidhya, 9 October 2019. www.analyticsvidhya.com/blog/2019/10/detailed-guide-powerful-sift-technique-image-matching-python/.

The next step is Orientation Assignment, where an orientation will be assigned to each keypoint to make them invariant to rotation. Both the magnitude and orientation are calculated by taking the differences of surrounding pixels. Magnitude is the intensity of a pixel, whereas orientation is the direction. A histogram is created of this data separated by degrees (0-360). Wherever the histogram peaks are the orientation, with another keypoint being created if there is another peak. Finally, the Keypoint Descriptor will give descriptions of keypoints. A 16x16 block around the keypoint will be taken and then divided into 4x4 blocks. Magnitude and Orientation will be calculated for each block. Features from different images will be matched, typically training and testing data, to determine what an object is. This is seen in the figure below, where two different orientations of the Eiffel Tower are matched (Singh).

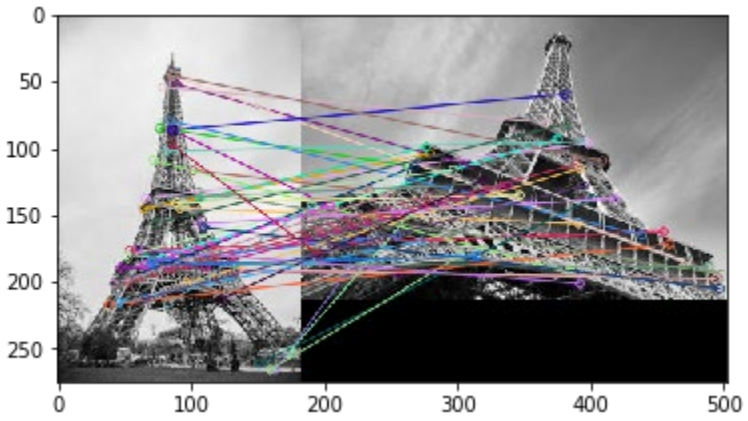

Figure 2. Singh, Aishwarya. "SIFT Algorithm | How to Use SIFT for Image Matching in Python (Updated 2023)." Analytics Vidhya, 9 October 2019. www.analyticsvidhya.com/blog/2019/10/detailed-guide-powerful-sift-technique-image-matching-python/.

There are countless feature descriptors, all able to extract features in their own way. Issues typically evolve from a lack of testing data. This can be from a blurry camera, glare, or just an image with high noise. All of this can decrease the accuracy while making the algorithm take longer to compute. The noisier the image, the less effective DoG is. Without effective object detection, many AR features will falter. This makes it debatably the largest issue with AR, as it is reliant on the performance of spatial recognition. Without a great depth perception, objects will not

be properly overlaid into the real world. If Vuzix wants to have a text message appear, or if Niantic wants a Pokémon to be in the middle of the screen, object detection needs to be able to determine where the targeted area is. If this process is not strong, people will not be as interested in the technology. One of the biggest interests in AR is its ability to integrate virtual aspects smoothly into the real world. Without that smooth transition, a major selling point of AR will disappear.

Attempted Solutions to Counteract Current Limitations

There is a solution to every problem. Companies have been forced to find new ways to advertise augmented reality, as the industry is no longer a blank slate. These companies are facing uphill battles, as they must attempt to change public opinion on AR. This has led to many different methods being implemented. Three of the most prevalent methods have been to define the purpose, improve familiarity, and direct focus on a service rather than a product. Defining the purpose makes it easier for consumers to understand what they are buying. Improving familiarity helps with making people feel comfortable purchasing the product. Changing the direction of AR from a product to a service helps in the process of removing current biases around AR.

Centralizing and Defining the Purpose

Previous AR technologies have attempted to do everything. This applies to both software and hardware in the industry, as initial uses of extended reality attempted to create fully virtual worlds. Instances of AR hardware, such as Google Glass, looked to revolutionize how the world communicates. Even today, companies tend to be extremely broad in the applications of their AR technology. This makes it difficult for consumers to grasp what is being offered. Vuzix does a surprisingly good job at presenting what the glasses will do, but still uses terms such as "much, much more" ("VUZIX ULTRALITE OEM PLATFORM℠"). This can overcomplicate and confuse the consumer, reducing interest in the product. When a consumer does not fully understand a product, sees a high cost, and has a bias against AR, selling will be challenging.

Companies have learned from their mistakes or the mistakes of others. A major method that is being used to increase consumer interest in AR is by simplifying it. Instead of attempting to offer everything, companies are leaning towards solving one problem. A necessity for this method is to create a technology that is not a convenience, but rather a need. It may not be a need for everyone, but it must be a need for someone.

Google's Translation Glasses: Google, being at the forefront of the failure of Glass, has been able to learn from past mistakes. Because of this, the company has moved past the idea of displaying information like a phone. Instead, they are attempting to create a pair of glasses that can translate any language. These glasses will provide subtitles of translations, using Google Translate, allowing the user to understand other spoken languages. Alongside this, the glasses will be able to provide subtitles of already spoken languages as a way for the product to be used as a hearing aid ("Breaking down language barriers"). This provides a precise technology that can solve a problem. It is not a convenience for many, as it has real-world applications. Google Translate may already exist on the phone, but it is not plausible for having a lengthy conversation. Without a substitute for fluid conversation, these glasses can move beyond a convenience and instead offer a solution to a problem. Whether it provides a convenience or a solution, it is a concise technology that explains its exact purpose. It still is vaporware but has the potential to become a commonly accepted and used technology.

Showrooms: Showrooms are a relatively new technology but have amassed quite an interest. The term itself may not be common, but it can be seen as trying on clothing, seeing furniture in a room, or customizing a car online. Many e-commerce websites, such as Amazon or Wayfair allow the user to see how a piece of furniture would look in their

room. The same exists for clothing, with companies allowing individuals to virtually try on clothing. Past e-commerce, many automotive manufacturers will allow shoppers to customize cars on their websites. This process has the user choose a car and proceed to customize the color, wheels, interior, engine, and much more. If they are satisfied with their final product, they have the option to purchase the customized vehicle. These showrooms have a precise purpose that solves a problem. Before their existence, people would have to order a product and hope that it will fit on them or the room. The problem was even larger for the automotive industry, as it was nearly impossible to customize a car and see its appearance before ordering. With the addition of these simple products, people can feel more comfortable and inclined to make the purchase.

Reliance on Established Industries to Foster Comfortability

Every new technology, especially when it comes to software, is reliant on other technology. Some, however, can forge their own path. This can be seen with Google's new translation glasses, as they offer a unique service unaccustomed to many. These technologies are typically groundbreaking, but that has not always been true for AR. Due to the advanced features of AR, many individuals felt completely unfamiliar with the products. Without this familiarity, it became increasingly difficult for companies to sell their AR products. Certain companies have used the idea of familiarity to their advantage, developing AR software that combined what people were already accustomed to. Some people believe that this method is not beneficial, as they claim that it removes AR's ability to establish its own industry. This is not necessarily the case, as AR's industry and uniqueness revolve around its ability to integrate into many other technologies. Companies such as Niantic Games are looking to showcase how AR can help current technologies, which is where AR currently thrives.

Niantic Games: As gaming advances, so does the technology. Niantic Games was one of the leaders in creating AR mobile games. Their first main success was *Pokémon GO,* a game where people can go and catch Pokémon throughout the world. The core functionality of this game was not based on AR. It was only certain features that included levels of AR. The most notable one was the ability to have Pokémon appear in the world, through the user's camera lens, while they are being caught. Other features attempt to combine the real world with the fake, such as PokéStops. *Pokémon GO* was one of the most popular mobile games of all time, having over 600 million total downloads (Clement). Downloads have dropped drastically since its inception, with 228.27 million downloads in the 3rd quarter of 2016 and only 11.4 million in the 3rd quarter of 2022. This was expected due to the large number of initial downloads. With over 600 million downloads, *Pokémon GO* is one of the most popular games of all time. Niantic has found success using this formula multiple times, later creating popular games such as *NBA All-World* and *Marvel World of Heroes.* This success was brought on through a revolutionary idea in the gaming industry: augmented reality video games. There had been virtual reality implemented into gaming, but Niantic paved the road for the augmented versions. Virtual reality struggled to gain popularity at times due to how unfamiliar it was to the gaming industry. AR, on the other hand, was extremely familiar. There was still a disconnect between the game and real life, allowing people to feel more comfortable playing the game. With *Pokémon GO* feeling familiar to players, but still offering a spice, it was a huge hit. This would not have been possible without the AR features in the app. *Pokémon GO,* and other Niantic games, were able to find the perfect mix between familiarity and the unseen.

Face Filters: Many different companies implement the use of AR face filters for a range of reasons. Face filters are AR effects plastered onto the face using object detection. Social Media apps such as TikTok offer filters that can simply be described as "silly" or "fun." Other companies use face filters for more professional or product-based use, such as L'Oréal's *Modiface.* This product would allow people to try on different shades of makeup by simply directing the camera at their faces and scrolling through different shades. Amazon allows people to try different hair colors using these filters. Even though face filters are new technologies, they have a level of familiarity that many other use cases of AR do not. People are used to putting on makeup, dyeing their hair, or putting masks on. These filters are of

such a simple design, as well as seemingly inconsequential, making their normalization easy. Face filters are never the only part of a product and are typically not a large part of a product. Because of this, people have gotten completely accustomed to the idea of face filters. It is not uncommon to see these filters used throughout all types of social media, with people even forgetting that they have them on at certain points.

Use of augmented reality as a Service, rather than a Product

The majority of the AR use cases mentioned above have been a product, instead of a service. That is what a majority of AR has been, with companies selling their products, whether it be a game or accessory. Software developers have begun specializing, or at least using, AR in their commissions. Companies such as Groove Jones and CXR.Agency are software development companies using AR alongside previous technologies. They can be commissioned to create varying projects, from an AR advertisement to an entire game. This does not mean all their products even use AR. CXR.Agency uses AR for some projects, whereas Groove Jones has a much heavier focus on it. Both, and many other companies, have taken advantage of the growth of the AR field. Instead of attempting to create their product, they simply create products for others.

Both CXR.Agency and Groove Jones have countless use cases from Fortune 500 companies to small businesses. CXR.Agency created a marketing campaign for Max's (formally HBO Max) new movie *Charm City Kings,* where they included an AR face filter in the campaign. This project had a relatively low level of AR use, which contrasts starkly with many of their other projects. In another project, they built an AR app that would allow individuals to see the inside of different apartments/houses for sale. They would be able to walk through a 3D model of the house and experience what the house was like without being there ("Projects."). Still, a majority of CXR.Agency's previous projects implemented a relatively low amount of AR. This contrasts with Groove Jones, which has created technologies such as Toyota's Virtual Showroom. This is where people can customize and possibly order a car of their own making, following the guidelines and limitations of the car manufacturer. They have also made multiple 3D billboards for Times Square, where it looks as if the billboard is popping out of the screen ("Featured Work."). All of this helps to bring AR into the world. When people look at many of these products, their first thought is not about the AR used in them. With more people interacting and experiencing AR, it is possible that there will be growing acceptance of the technology.

Conclusion

Through the rise and fall of Google Glass, issues were exposed around the integration of these technologies into the mass market, with limitations ranging from social to technical. The fact is that many people do not want to stand out and break the "norm," but wearable augmented reality tends to have the reverse effect. There is currently no necessity to have AR glassware, as the world is already convenient enough. With a hefty price and an overall poor battery life, the technology is not practical enough. Certain aspects of AR have already proven themselves with consumers, whereas other use cases have yet to resonate. The products that are working do not typically build their entire design around AR and instead use it for added benefits. Technologies such as Niantic's *Pokémon GO* do not run solely on AR and only use it to improve the user experience. This can be compared to fully virtual reality-based games that do not bring in as much attention, due to their heavy focus on the virtual field. It seems that most of the consumer market does not want to always be plugged in, wearing a device that gives them constant updates right in front of them. The disconnect between the phone and real life is much more appealing than the disconnect between AR and real life.

This does not mean that the AR industry is lost, or even that the associated wearable technology should be abandoned. It simply shows where the current consumer interest lies. The computer was not as popular 50 years ago as it is today. It solved a problem for only a few while debuting at a cost unaffordable to the majority of consumers. That, compared to the computers of today, is night and day. There are use cases of AR that have been wildly successful.

Pokémon GO is one of the most well-known mobile games in history. Almost every automotive manufacturer has a showroom allowing interested customers to customize a car. Numerous clothing and furniture brands allow the user to "Try it On" through AR. Real estate is another exploratory market for AR. Many of these implementations are currently successful and will continue to be successful. Certain use cases have worked well, but the industry still must wrestle with current customer bias and usage patterns. When these products continue to advance, the stigma around AR will begin to crumble. Some may argue that the consumer market is simply not interested in AR, but that can be disproven by the viral adoption of *Pokémon GO.* Once AR technologies become an everyday part of people's lives, they will be more accustomed and welcome to the idea of wearable versions. There may be many social and technical limitations, but none are hard limits and can all be navigated with due time. Remember, the mobile phone started out the size of a brick, weighed around four pounds, had no more than 30 minutes of charge time, and cost thousands of dollars. Every invention worth anything has failures that lead to eventual success. Google Glass' missteps, limitations, and exaggerations should be studied to better understand the perils and path of invention.

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