An Analysis of Augmented Reality's Effects on Society

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Dear Claire Avery,

During this work term (Engineering 04W), I was employed with Cadence Design Systems as a Full Stack Developer with InspectAR. This was my first work term with Cadence, as well as in this role. I was supervised by Nick Warren, the co-founder of InspectAR; who is now a lead software engineer at Cadence.

InspectAR, a subsidiary of Cadence Design Systems, manages an extensive range of projects. I gained exposure to many of these projects, including testing releases and organizing components, amongst other full stack roles.

The enclosed work report titled "An Analysis of Augmented Reality's Effects on Society" resulted from a need to analyze augmented reality's growing influence and impact on industry and society. New technologies can greatly affect people's lives, which means that an in-depth understanding of all potential aspects of the technology's reach need to be studied in order to minimize possible damages and maximize benefits.

If there are any questions concerning this report, I would be pleased to discuss them with you.

Yours truly,

Anna Behm

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Executive Summary

InspectAR, a groundbreaking tool developed by Cadence Design Systems, harnesses the potential of augmented reality to redefine electronics hardware tasks. It revolutionizes processes like collaborative debugging, inner component visualization, and component lookup, effectively addressing challenges in hardware development. InspectAR's innovation transforms printed circuit boards into interactive platforms, significantly enhancing the hardware development lifecycle. Augmented reality seamlessly merges digital and physical realms, enhancing real-world experiences by overlaying virtual elements. It does so through the power of computer vision, utilizing both a camera to view into the real world, while also overlaying the digital aspects into the area through computer algorithms. Ethical implications include issues such as privacy concerns, potential addictive behaviours when applied to entertainment, reality distortion, bias amplification, and cybersecurity vulnerabilities. To prevent ethical implications, involving experts such as psychologists and sociologists during development could mitigate adverse effects, particularly with addictive tendencies and biased algorithms. Moreover, there is positive potential of augmented reality in education, healthcare, and accessibility, underlining the need to harness its benefits for societal betterment. Striking a balance between innovation and ethical mindfulness will pave the way for a harmonious coexistence of augmented reality's technology with human experiences. In summation, augmented reality's transformative potential spans various industries, enhancing experiences and reshaping the way humans interact with their surroundings. The case of InspectAR exemplifies the impactful fusion of augmented reality with practical applications in electronics hardware development. As augmented reality evolves, it introduces new vistas and challenges, urging stakeholders to approach its advancement responsibly while keeping ethical considerations at the forefront.

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List of Acronyms

Augmented Reality - AR

Electronic Design Automation - EDA

Machine Learning - ML

National Aeronautics and Space Administration - NASA

National Football League - NFL

Nonfungible token - NFT

Printed Circuit Board - PCB

Quality Assurance - QA

Quality Control - QC

Software Development Lifecycle - SDLC

User Interface - UI

Virtual Reality - VR

Introduction

Augmented Reality (AR) stands at the crossroads of society and technology, reshaping how we perceive and interact with the world. By seamlessly blending digital and physical realms, AR enriches our experiences by overlaying virtual elements onto our surroundings. This technology influences education, work, entertainment, and navigation, offering immersive learning, streamlined tasks, and enhanced shopping experiences. AR's ability to merge reality and virtuality creates intuitive interactions and benefits such as improved learning, precise work tools, and remote collaboration. As AR becomes an integral part of our lives, it opens up a new realm of experiential possibilities, bridging and sometimes blurring the gap between imagination and reality.

InspectAR is a groundbreaking tool designed for electronics hardware tasks, redefining the way we interact with Printed Circuit Boards (PCBs) through augmented reality. It offers a dynamic experience that enhances collaborative debugging, inner component visualization, and component lookup, addressing challenges in hardware development. By seamlessly integrating the physical and virtual realms, InspectAR transforms PCBs into interactive boards, making it an essential tool for modern electronics development.

As InspectAR’s technology is reliant upon the development of AR, it is important to study this technology in depth to allow for further breakthroughs within their product development and design. However, one should also consider the potential ethical usages of such technology to ensure that no user is negatively affected by such advancements. There have been

many studies completed on the field of AR, due to its rapid advancements and numerous applications. These studies include topics such as education, manufacturing, and medical technologies, among others. Within this specific research paper, AR will be studied from mainly the manufacturing and electric fields due to its involvement in InspectAR's technology.

The purpose of this report is to research and discuss the many uses of AR, as well as how it is utilized within InspectAR's technology. It has been authorized by Nick Warren, the co-founder of InspectAR, as well as Claire Avery, a co-operative coordinator for the Faculty of Engineering at Memorial University of Newfoundland. This paper will include an in-depth analysis of many items including InspectAR's technology, AR's history, technological background, usages, limitations, and ethical implications. Limitations to this research paper include that not all AR information across the spectrum is available in the literature as it is a continually developing technology. Also, many companies do not wish to reveal their AR technologies or applications until they are fully developed, implemented, and financially incentivized. Through this report, the reader will obtain a greater understanding of this technology as a whole and within InspectAR.

InspectAR

InspectAR, under Cadence Design Systems, is an AR platform that caters specifically to the complex requirements of electronics hardware tasks. Its primary objective is to transform the conventional process of working with PCBs into a dynamic, interactive experience that enhances various aspects of the hardware development lifecycle. Whether it's in the realm of tele-engineering, where remote collaboration and problem-solving are paramount, or the collaborative process of design, where multiple stakeholders need to synchronize their efforts, InspectAR proves to be an indispensable tool. It facilitates collaborative debugging, allowing multiple experts to collectively identify and rectify issues on a PCB, streamlining the troubleshooting process.

One of the most remarkable features of InspectAR is its ability to provide inner layer visualization. This means that even the intricate inner components of a PCB, which are usually hidden from plain view, can be visualized and analyzed using the power of augmented reality. Additionally, the platform serves as a powerful component lookup tool, aiding engineers in quickly identifying specific elements on the board and accessing crucial information related to them. One of the standout features of InspectAR is its ability to transform a PCB into a live, interactive board. This means that users can manipulate and engage with the board in a tangible way, selecting components and obtaining vital information about them. Hovering over a component reveals its reference designator, and with a simple click, users can access detailed design-specific pinout information. Even flipping the board over is a seamless experience, as all the overlays adjust to match the orientation of the design. Furthermore, InspectAR plays a

pivotal role in the net searching process during the manufacturing and testing stages of a PCB's development. It enables hardware teams to swiftly trace connections and pathways, simplifying the complex task of identifying and addressing network-related issues.

In the broader context of hardware development, InspectAR addresses a significant industry challenge. The trends in hardware product manufacturing have created bottlenecks in testing, debugging, and reworking. Traditional tools have struggled to adapt to this evolving landscape, lacking the ability to interpret physical objects with the precision of a human. This is where InspectAR truly shines. By leveraging a combination of camera technology and manufacturing outputs from electronic design automation (EDA) tools, InspectAR transcends this limitation.It's important to note that InspectAR achieves this without requiring specialized augmented reality glasses. This democratizes the accessibility of the platform, making its benefits attainable with common hardware. Furthermore, the possible discomfort of wearing eyewear for hours in a work day is eliminated, providing a more friendly and comfortable ergonomic environment. In addition, fewer hardware needs (i.e., AR eyewear) may decrease costs. With just a few clicks on a component, engineers and designers can access datasheets, supplier information, and design-specific pinout details, streamlining the entire testing and debugging process [1].

One project at InspectAR that was completed this semester included testing the application for errors before being released to the public. To complete this task, one must obtain the newest version of the application, open it, and attempt to complete every task that is available. Such tasks include testing the sign in page, dashboard scenes, overlays, calibration

types, and more. An employee would not only test these areas once, but numerous attempts with different credentials, file sizes, as well as physical boards to ensure the best software quality. This type of testing is empirical to ensure the proper functional quality from the user's perspective, encompassing its features, performance, user-friendliness, and absence of defects. Besides testing, there is also Quality Control (QC), which is used to ensure that the product meets the pre-set requirements before it is released to the public [2]. Testing and QC are part of an overall process named Quality Assurance (QA), which is used in the Software Development Lifecycle (SDLC) to ensure that the final product aligns with the expectations. QA creates processes and standards of quality to catch and fix any potential errors in the product [3].

Another aspect of being a full stack developer at InspectAR is to update User Interfaces (UI) regularly to ensure that the customers receive the best product for their needs. Specifically, one project included compartmentalizing different components of HTML administration pages into .tsx files. This included languages such as HTML and TypeScript. In this job, the employee translated deliverables from a UI designer into functional code blocks, to test that the given HTML files worked and displayed correctly on webpages. This type of development focuses on both functional and non-functional qualities; as it requires testing the UI, as well as implementing proper coding practices. The non-functional qualities encompass the system's underlying characteristics and architectural aspects. This type of software quality includes factors such as the maintainability and comprehensibility of the code, the efficiency of operations, and the security measures in place [2]. In between large projects such as the ones mentioned above, developers also investigated separate bugs that customers brought to light. One such bug that was fixed included being able to progress into another step without completing required inputs.

The secret to InspectAR is rooted from a desire to alleviate the challenges and frustrations often encountered in electronics work. It was founded by engineering graduates from Memorial University of Newfoundland, and originated from a Capstone project. This initial venture into creating an AR-based solution for electronics work quickly evolved into a full-fledged business endeavor.

In essence, InspectAR emerges as a groundbreaking solution that not only embraces the potential of AR in the field of electronics but also addresses practical challenges faced by hardware teams. Its ability to seamlessly merge the physical and virtual worlds, coupled with its focus on enhancing collaboration, troubleshooting, and information access, positions InspectAR as a trailblazing tool in the realm of electronics development.

Augmented Reality

What Is It?

Augmented reality is a groundbreaking technology that seamlessly blends digital elements like visuals, sounds, and sensory cues with our physical world. It is accessible through devices such as smartphones, tablets, webcams, and specialized eyewear. Its increasing popularity is evident in mobile computing and business applications, presenting diverse opportunities across industries. AR's primary goal is to enhance our understanding of reality by accentuating specific features and extracting insights from the environment, making it a powerful

tool in the era of data analysis. Unlike Virtual Reality (VR), AR supplements our surroundings instead of replacing them, resulting in practical applications that seamlessly integrate with daily life. In retail, AR transforms shopping by enabling customers to visualize products in their personal spaces before purchase, bridging the gap between online shopping and in-store experiences. Similarly, healthcare professionals employ AR to explore intricate 3D images of human physiological and skeletal systems, revolutionizing medical education. AR's advantages are twofold: for users, it offers interactive, immersive encounters that amplify enjoyment and comprehension, while businesses benefit from enhanced brand awareness and increased sales through impactful marketing campaigns and product visualization [4]. With the evolution of technology, wearable devices like smart eyewear could take AR to the next level, further blurring the line between the virtual and real realms, promising a future where reality and technology seamlessly coexist to reshape industries and redefine user experiences.

History

AR technology was pioneered in 1968 when Ivan Sutherland developed the first head-mounted display, and the term "augmented reality" was coined in 1990 by Boeing researcher Tim Caudell. Over the past 50 years, AR has transformed content consumption in the real world. Key milestones include Myron Kruger's 'Videoplace' in 1974, which used projection and camera technology for interactive experiences, and Louis Rosenburg's 'Virtual Fixtures' in 1992, aiding military tasks. Julie Martin's 1994 theater production blended acrobats with virtual objects, while Sportsvision introduced the iconic yellow yard marker in National Football League broadcasts in 1998. National Aeronautics and Space Administration (NASA)

incorporated AR for spacecraft navigation in 1999. In the 2000s, Hirokazu Kato's ARToolKit allowed developers to create AR software. Sportvision enhanced their graphics on the Skycam system in 2003, and Esquire Magazine used AR to bring pages to life in 2009. Volkswagen's MARTA app offered step-by-step repair instructions in 2013, showcasing AR's cross-industry potential. Google introduced Google Glass in 2014, a wearable AR device with internet connectivity. Microsoft's HoloLens, a sophisticated AR headset, debuted in 2016, and IKEA's AR app, IKEA Place, revolutionized retail by enabling virtual previews of home decor in 2017 [5].

Furthermore, Apple Vision Pro was recently unveiled; an AR spatial computer within wearable goggles. It effortlessly integrates digital elements into the real world, all while ensuring users remain engaged and connected with others. The Vision Pro establishes an expansive platform for apps that introduces a completely three-dimensional user interface guided by the user's gaze, gestures, and voice. It enables users to interact with digital content in a manner that mirrors its physical existence within their surroundings [6]. AR has significantly expanded since its discovery, and has made its way into a multitude of fields. As mentioned before, InspectAR utilizes such technology to aid with debugging of circuits, whereas Apple is utilizing it to revolutionize the way humans interact within their surroundings. There are numerous applications of such technology, and the growth of such products can greatly support our lives.

Technical Background

AR is typically used with devices like smartphones, tablets, or smart glasses. AR software harnesses the power of computer vision technology to identify objects when the device's camera is focused on them [7]. Computer vision involves utilizing the camera to capture images from the surrounding environment, which are then interpreted and referenced using a machine learning (ML) algorithm. For instance, when the camera focuses on an object like a ball, the pixels in that image serve as a reference for identifying similar objects. Subsequently, when capturing an image of another ball, the algorithm draws from this reference to determine if the object corresponds to a box [8]. After viewing the object, the data retrieval process then begins within the cloud, where information about the object is obtained. The magic happens when this data is projected back onto the real world in the form of a three-dimensional augmented experience. This combination of the digital and physical realms creates an interactive experience that's both captivating and immersive.

What sets AR apart is its ability to deliver real-time data visualization and control through touch, voice commands, and gestures. For instance, within an AR environment, users can interact with digital overlays to initiate commands or access information. As users move, the AR display dynamically adjusts to their surroundings, presenting new information while concealing outdated content. This flexibility proves especially beneficial in industrial scenarios where distinct users can access customized AR experiences for the same object. A pivotal component in this fusion of realities is the "digital twin," a cloud-based three dimensional model that acts as a conduit between the physical object and the AR environment. This digital twin

collects data to ensure the AR software displays up-to-date and accurate information on the actual object, thus bridging the gap between the tangible and virtual seamlessly [7].

"The Cloud" refers to remote servers accessible via the Internet, housing software and databases. This eliminates the need for users to manage physical servers or run applications locally. The cloud enables universal access to files and apps across devices since data processing and storage occur on remote servers. By adopting cloud servers, it helps with global operations, offering consistent access to resources. Furthermore, multiple virtual machines can run on one server, expanding cloud capabilities and enhancing cost-efficiency. Cloud services encompass infrastructure, applications, tools, and data storage, classified into various service models [9].

The combination of computing vision, ML, the cloud, and advanced computing techniques work together to create one of human kind’s great advancements. Not only does it create breakthroughs such as InspectAR, but many other products, positively impacting our lives.

Usages

As mentioned above there are a multitude of usages for AR. Besides InspectAR, Nonfungible tokens (NFTs) are one usage of AR. They stand as distinctive digital assets that symbolize ownership of a specific item or content. The integration of AR technology brings life into NFTs, empowering users to visualize, interact with, and present their digital collectibles in the tangible realm. This merging of AR and NFTs is set to revolutionize the concept of digital possession and create novel avenues for artists, creators, and collectors alike [10].

In the realm of gaming, AR technology's adoption has been swift, offering players captivating and immersive encounters. Notable examples like Pokémon Go have eloquently demonstrated the potential of AR gaming by utilizing the player's camera, GPS, and gyroscope to guide them towards locations where virtual elements are artfully superimposed onto the real world. As AR continues its march of progress, the gaming industry is destined to witness a surge of ingenious and immersive AR games that elevate player experiences to unprecedented heights [10].

While AR technology continues its rapid evolution, businesses across industries must embrace its potential to stay competitive. Retailers can enhance customer experiences and reduce returns through AR-based virtual try-ons, as demonstrated by companies like RTFKT, acquired by Nike. AR also holds promise in education, offering engaging learning experiences, and in healthcare for remote consultations and data visualization. Real estate can leverage AR for remote property tours, exemplified by companies like Ouse Token. Apple's investment in AR, seen with products like Apple Glasses, underscores future trends. AR's appeal lies in its ability to blend the difference between the digital world and reality. By storing AR-created digital objects as NFTs on the blockchain, a new digital economy could emerge, allowing customers to express themselves through unique digital wearables [10].

Ethical Implications

Augmented reality technology has the capacity to revolutionize various facets of our lives, altering the way we learn, work, and engage with our surroundings. However, like any emerging technology, AR also presents significant ethical considerations and apprehensions. In terms of privacy concerns, AR technology possesses the ability to accumulate extensive user data, encompassing location, behaviour, and personal preferences. This data can be harnessed for targeted advertising, but simultaneously, it triggers concerns about user privacy, as users might not be fully informed about the extent of data collection and its subsequent utilization. In a world where personal information is often taken advantage of and sold to the highest bidder, it is very important that users are aware of how their data is being used. Developers should create requirements for user safety, as well as placing agreements for certain data usage if user information is needed.

There is also potential for AR technology to create addictive behaviors, potentially leading users to become excessively reliant on it [11]. The scope and negative effects of human addiction are widely apparent over many areas such as alcoholism, drugs, gambling, and other addictions. This is a significant issue because it could lead to users neglecting other essential aspects of their lives. Such overdependence could have adverse implications for mental and physical well-being, as well as interpersonal relationships. Addictive technologies already pose a grave threat to our society and relationships, and whether it be alcohol, drugs, food, or technology, all addictions should be taken seriously. There have already been stories of people hooking themselves up to intravenous line (IV) machines in order to continue gaming for large

periods of time without breaks (Personal Communication, Omar Faruk, August 22 2023). This example shows the extent addicted individuals will reach to appease their addictions. Addictions are serious issues that need to be considered in the creation and releases of products, so that the creators are bringing good into the world rather than more harm to people's lives. This highlights that it is very important to incorporate sociologists, and psychologists, among other professionals, to minimize the potential harm of the products. Without proper research, many individuals could end up abusing themselves to stay within the AR, which is certainly possible considering some game enthusiasts already utilize IV machines. Businesses need to prioritize their user's health over their monetary profits; people's lives are much more morally important than paychecks.

Furthermore, AR technology blurs the boundaries between reality and the virtual world, which can impair our ability to differentiate between the two domains. This reality distortion might result in confusion and disorientation, particularly in scenarios where safety is paramount [11]. Especially in scenarios where technology can create addictions and other severe psychological issues, distorting the line between reality and the virtual world is extremely dangerous. Individuals with a proclivity for certain psychological disorders may not be able to discriminate between what is actually happening and what is imaginary, which could be even more dangerous with people that have issues finding this difference normally.

Another issue is that the manner in which AR technology presents information has the potential to perpetuate pre-existing biases and stereotypes. Augmented reality could exacerbate discrimination and marginalization, particularly affecting vulnerable communities [11]. Although

one may think that technology cannot have biases, it is dependent on the data that is inputted by humans. This allows human bias and error to enter the algorithms, which can increase bias and discrimination, even when it was not intended. Therefore it is important to consider all use cases of the technology from the start to ensure that no users would be discriminated against.

The reliance of AR technology on wireless networks and cloud-based services exposes it to cybersecurity threats such as hacking. This jeopardizes users' personal data and compromises the security of the systems underpinning AR technology. Cybersecurity vulnerabilities also need to be considered, especially when the AR is utilizing confidential information within its programs [11]. The safety of user's information should be a priority for developers, especially when sensitive information could be taken from this technology.

In order to address these ethical dilemmas, it is imperative to establish protective measures that safeguard user privacy, advocate responsible usage of AR technology, and guarantee that its design and application do not perpetuate bias or discrimination. Additionally, an essential component is the education of users regarding the potential advantages and risks of AR technology, thereby enabling them to make informed decisions about its usage. Furthermore, psychologists and sociologists should work with the developer at all points of development to make sure that there are no negative impacts of the publicized technologies.

Results

With the above analysis, one can take away, both positive and negative results. Some positive effects of AR include that of heightened creativity, such as creating new ways to create and showcase art. AR can also increase efficiency, as seen with InspectAR's application which tracks PCBs and provides overlays and information. Through this application, users do not have to search for specific parts or how components are connected, this saves not only time, but also money. Furthermore, with other applications of AR, like the Apple Vision Pro, users can entertain themselves with face filters, watch movies without a projector or television, amongst many other possibilities. However, AR can also have negative effects on society; including creating addictions. Addictions often worsens mental and physical health as well as interpersonal relationships. The line between the real and virtual world is blurred with AR, as it is a mix of both realities. This may confuse users and increase disorientation, especially amongst those who are prone to psychological disorders. Besides mental health, AR could perpetuate further biases and stereotypes through human error with initial data sets. These biases could become integrated into decision making of the technology, which can gravely affect users within minority groups. Another negative effect includes that of user data privacy; as the data for this technology is stored on the cloud, it could open more avenues for potential hackers to steal personal data.

Conclusion

In conclusion, AR holds the potential to reshape the way we perceive and interact with the world, bridging the gap between reality and virtuality. It enriches various facets of our lives, from education to entertainment, offering immersive experiences that enhance learning, streamline tasks, and transform industries. As AR technology continues to evolve, it introduces a

new era of experiential possibilities, where imagination and reality converge. InspectAR, a pioneering tool in electronics hardware tasks, exemplifies the fusion of AR with practical applications. It revolutionizes the process of working with printed circuit boards, facilitating collaborative debugging, inner component visualization, and streamlined component lookup. By seamlessly integrating the digital and physical worlds, InspectAR emerges as a trailblazing solution that addresses challenges in hardware development and enhances collaboration and troubleshooting. As the adoption of AR advances, it is vital to delve into its technology for further breakthroughs. AR has many different applications, from gaming, NFT viewing, to online shopping, and still the number of products utilizing AR grows still today. However, ethical considerations are paramount with the growth of any new technology. Privacy concerns, addictive behaviors, distortion of reality, bias propagation, and cybersecurity vulnerabilities are all critical ethical implications that have been brought to light. The evolution of AR, as seen in InspectAR's innovation, signifies a transformational journey that augments human capabilities and redefines industries. As humans harness AR's potential, the future is being shaped where technology and humanity coexist harmoniously.

Recommendations

As can be seen above, there are many applications of AR technologies, and it is important to ensure that the safety of all users is prioritized. One question to be asked includes that of proper legislation - should AR be regulated by the government or self regulated in the industry? There are many positives to AR, however one should never look over the pitfalls. Therefore, it is recommended that all products with this new technology should be reviewed at all points of

development, not only by technical professionals but also psychologists and sociologists, to limit the possibility of harming users. However, there are also many recommendations of positive outcomes from this technology. For example, AR can be used to complement education and mitigate risks, whether it be in practicing surgeries or obtaining a pilot's license. AR would allow the user to practice their work in a safe space, and in other industries can aid in specific tasks such as overlaying files onto PCBs. Not only would AR help in education, but it can also be recommended to help with medical technologies, such as for people with disabilities. AR glasses could create real-time subtitles, provide better views for the blind, and more. There are a multitude of applications for AR, and although it is important to get the technology to those who need it, it is also equally as important to analyze every possible error to ensure the best product for all users.

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