2023 Mobile Computing Systems Programming Assignment 1

Exploring the Augmented Reality Frontier : Understanding Development Tools, Devices, and Application

Video Youtube Link: https://youtu.be/qx3fzMHzHuA

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1 Abstract

This essay aims to provide a comprehensive exploration into the multifaceted world of Augmented Reality (AR). Divided into three key sections, the essay first focuses on illustrating the significance of APIs and platforms such as ARKit and ARCore, emphasizing their role in shaping AR experiences, their inherent functionalities, and limitations. The second part turns its attention to the significant AR devices in the market like HoloLens 2, Magic Leap 1, Google Glass Enterprise Edition 2, Nreal Air, and Apple Vision Pro, highlighting their unique capabilities, target use-cases, and technological advancements. The final section presents a comparative study the real-world applications of AR across multiple sectors including healthcare, education, and entertainment, detailing both current adoption and future possibilities. Through these sections, the essay aims to offer a 360-degree view of the AR ecosystem, from its foundational technology to its practical applications and the devices that bring it to life.

2 Introduction

Augmented reality (AR) is a technology that provides users with a real-time view of the physical world while superimposing or adding virtual computer-generated information on top of it. [1] This additional information may include images, text, animations, or other interactive elements that enhance the user's perception and interaction with the surrounding environment, which means AR combines real-world and virtual elements, allowing users to perceive and interact with them at the same time, as shown in Figure 1.

Figure 1: What is AR

In general, the concept of augmented reality is closely related to the idea of merging virtual objects with the real environment. This integration makes virtual objects appear to co-exist with the physical world as if they were part of a real existence.

However, the goal of augmented reality is not just to embed virtual elements into the user's view, but to simplify the user's interaction with the world around them by seamlessly blending virtual information. It provides users with a deeper understanding of their environment, enabling them to interact with real and virtual elements in a natural and intuitive way. Whether in education, entertainment or travel, augmented reality creates a whole new experience for users. The diversity of AR devices enables them to function in these different usage scenarios, whether it is smart glasses, mobile devices, or head-mounted displays, creating a richer experience for users. The differences between these different devices also lead to the diversity of AR development technologies. Developers need to develop according to the characteristics of different devices to achieve the best user experience. Therefore, the differences and discussions of AR development technologies cannot be ignored.

3 Topic and critical analysis

3.1 AR SDK

By integrating cognitive technologies with AR, images gain immersive appeal, enhancing understanding in the digital age. This extensively utilized technology enables organizations to vividly depict products, services, processes, and more to users. AR apps are adopted by companies to enhance user engagement and effectively illustrate subjects. Industries developing AR apps consistently enhance user experiences, offering innovative methods for showcasing digital content to brands and SMEs. [1]

Now, the choice of cross-platform products is small. Some of the most popular cross-platform engines on the market like Unreal Development Kit, Unity, Godot, Engine, Cocos2D, and others. Unity is the optimal environment for implementing augmented reality technology in software. As a high-level platform for apps and games, it offers a robust editor with a graphical interface and a mobile-optimized graphical engine, streamlining development.[2]

SDK (Software development kit) – a set of development tools that allows software professionals to create applications for a specific software package, software basic development tools, hardware platforms, computer systems, game consoles, operating systems, and other platforms. The SDK takes advantage of each platform and reduces integration time [3]. As a developer, you can use SDK on multiple platforms, here we use Unity 3D, for Unity allows the user to export the source code to mobile device platforms, such as Android, iOS, and Windows Phone, which enables a more complete investigation of the AR frameworks.

3.1.1 ARCore

ARCore is Google's AR platform that allows a user's phone to perceive its surroundings, interpret the real world, and interact with information through various APIs. ARCore is mainly designed to work on various Android phones running Android 7.0 and later.

3.1.2 Vuforia

Vuforia SDK is an AR toolkit for mobiles. It employs computer vision to recognize real-time planar images and 3D objects, enabling developers to overlay virtual objects in the camera view[4]. Supporting diverse 2D/3D objects and virtual buttons for occlusion, it also allows real-time target selection and configuration. Vakaliuk and Pochtoviuk make a comparison with different development tools and come up with a conclusion that the most optimal environment for developing a mobile application is Vuforia. [5]

3.1.3 ARKit

ARKit, the AR application development kit, was introduced by Apple in June 2017 for iOS devices. The latest iteration, Apple ARKit 6, unveiled at the Apple Worldwide Developers Conference (WWDC) in 2023, boasts several groundbreaking features. Notably, the ultra-wide camera in the iPad Pro (5th generation) now offers expanded face tracking, with the TrueDepth camera capable of tracking up to three faces at once. Additionally, AR projects can be pinpointed using location anchors at specific latitudes, longitudes, and altitudes. [6]Furthermore, the Depth API, harnessing the power of the LiDAR Scanner, when combined with 3D model data from Scene Geometry, enhances virtual object occlusion, making interactions even more realistic.

This section presents a detailed survey of different software and tools required for creating an AR experience. The section outlines hardware devices used in AR technology and various software to create

	Developers	Platform	Features	AR Component	Constrains
ARCore	Google	iOS, Android	ARCore support Motion tracking with SLAM and Inertial, Depth Understanding, Light Estimation. Good for gaming.	SLAM + Inertial for Tracking and understanding the environment Integrated Display	AR Tracking isn't consistent, Not stable on old devices
ARKit	Apple	iOS	Instant AR (Using Lidar) and Good AR rendering devices. Good supports for old devices. It has tracking, display and development environment to develop AR app.	Motion Tracking, Camera Scene Capture, Advanced Scene Processing	Only for iOS and iPad OS Charges per app distribution
ARToolKit	Open-Source	Linux, Windows, MacOS X	-C and C++ Language Support for AR, JARToolKit for Java Support. Processing happens in real time.	-Tracking Library Supports -Video See Through (VST) -Optical See Through (OST)	Can be used only with image markers
Vuforia	Unity	iOS, Android	-A complete SDK for AR application development. -Supports many languages for AR development for API -Most widely used (with Documentations)	-Marker less (vision-based) -Marker based tracking (Fiducial) -Calibration Library	Paid license is required for advance AR features
Wikitude	Wikitude	Windows, Linux, iOS, Android	It is an SDK that can help to build an AR app without any other tools needed for Android, iOS, Windows, and Linux.	-SLAM -Image Tracking -Calibration Manager -Geo AR -Inertial	Paid license is needed for the app development
MS HoloLense	Microsoft	Windows 10	Augmented reality headset for running AR apps	-Vision Based Tracking -OST Display -VST Display	Old platform

Table 1: Comparison for SDKs

	Traditional State	**Impact of AR**	**Outcomes**
ARCore	Operated by Google, Limited to Android initially	Extended support to iOS, Uses SLAM + Inertial for enhanced AR experience	Enables better gaming experience but may be inconsistent on older devices
ARKit	Exclusive for Apple devices, Advanced AR capabilities	Introduced Instant AR using Lidar, Ensures better rendering on older devices	Boosts iOS and iPadOS AR ecosystem but has app distribution charges
ARToolKit	Open-source, Multi-platform, Relied on image markers	Introduced JARToolKit for Java support	Offers real-time AR processing but is limited to image markers

Table 2: A summary of the evolution and impact of different AR platforms.

an AR experience. It further elaborates on the software libraries required and covers bother the aspects of the commercially available tools. Table 1 provides a stack of software libraries, plug-ins, supported platforms, and standalone authoring tools.

3.2 AR Device

Back in 2014, Google announced a new project called "Google Glass". It was the first AR smart glasses for the consumer market. The impact of this announcement was huge, as the pioneer of all AR devices, Google Glass has drawn attention globally. However, the device failed due to many reasons, but one of them was the camera on the device, it was a threat to privacy. [7]Since then, many companies have started entering the AR device market, and with the development of the entire industry, many companies have started to focus on the industrial sector instead of the consumer market. [8]

Comparing AR devices is important in understanding the rapidly evolving landscape of the augmented reality industry. As AR thrives in diverse sectors – from education, healthcare, and manufacturing to entertainment – identifying the strengths, limitations, and unique features of each device ensures optimal alignment with specific user needs and industry applications. By drawing these comparisons, we not only facilitate informed decision-making for potential adopters but also stimulate innovation and growth within the AR ecosystem, driving developers to refine, iterate, and craft devices that push the boundaries of immersive technology to best serve its varied customers. In this section, we're going to compare the key features and advantages of different AR devices, based on their current models available in the market, to give the users a general idea of AR device evaluation.

3.2.1 HoloLens 2

The HoloLens 2, developed by Microsoft, is an optical see-through head-mounted display (OST-HMD). It is primarily aimed at enterprise applications in sectors such as healthcare, education, and manufacturing.[9] The device incorporates ergonomic improvements over its predecessor and uses waveguide display technology.

At its core, the HoloLens 2 features a second-generation custom-built Holographic Processing Unit (HPU 2.0) for low-energy, real-time computer vision. The HPU is located at the front of the device and supports various computer vision algorithms, including head tracking, hand tracking, eye gaze tracking, and spatial mapping. Supporting the HPU is the Qualcomm SnapDragon 850 CPU, part of the System on a Chip (SoC) located at the rear of the device. The HoloLens 2 is equipped with a depth camera, an RGB camera, and four grayscale cameras, along with an Inertial Measurement Unit (IMU). It also includes a microphone array with five channels.[10]

A notable feature is its eye-tracking system, which uses two infrared cameras to capture a detailed view of the user's eyes. This data can be accessed through platforms like Unity 3D using the Mixed Reality Toolkit (MRTK) or the API for the Universal Windows Platform (UWP).[11]

In terms of optics and display, the device uses three-stack diffractive waveguides to combine real-world light with virtual imagery. It projects virtual content at a fixed focal distance, usually between 2 meters and infinity. The device offers a standalone experience, relying on voice and hand gestures for navigation. Additionally, the front portion of the display can be lifted, which is useful during extended use. However, the device is susceptible to interference from bright lights and sunlight, affecting the clarity of virtual objects. Its optical design has a 40 percent transmissivity[12].

3.2.2 Magic Leap 1

Magic Leap 1 is an optical see-through head-mounted display (OST-HMD). It is designed for a range of applications, including entertainment, design, and interactive learning. The device employs waveguide display methodologies and emphasizes natural user experiences.[13]

Magic Leap 1 uses three-stack diffractive waveguides to merge real-world light with virtual content. It projects this content from a 2D micro-display positioned near the user's eyes but outside their direct field of view. Collimation lenses adjust the projection, making it appear at a comfortable distance.

One distinguishing feature is its dual focal plane technology, which allows it to project two virtual images at two different focal planes: one at 0.5 meters and another at 1.5 meters.[12] This feature has potential implications for reducing common AR issues like the vergence–accommodation conflict.

The device package consists of the lightwear (the headset), the lightpack (a processing unit), and a remote controller. Unlike some AR devices, Magic Leap 1 requires a controller for navigation. It is incompatible with prescription glasses; users with vision impairments will need to use contact lenses or purchase prescription inserts.

In terms of image quality, the device has superior color contrast and reduced light sensitivity. Its optics block 85 presents of external light, allowing for 15 presents transmissivity. The device has a field of view of 50 degrees and a per-eye resolution of 1280 x 960 pixels. It also includes eye tracking with a latency of 8 milliseconds and offers six-degree freedom multi-sensor SLAM capabilities.[14]

3.2.3 Google Glass Enterprise Edition 2

The Google Glass Enterprise Edition 2 (Glass EE2) is an optical see-through wearable device intended for industrial and professional applications, notably in logistics, manufacturing, and healthcare. It builds on the hardware improvements and design features of its predecessor.

In training contexts, particularly emergency room settings, the Glass EE2 operates within a dual system: a supporter-side desktop system and a trainee-side wearable system. The desktop system provides an interface for video conferencing and message transmission to the trainee-side system.[15]

The trainee-side system includes the Glass EE2, Bluetooth earphones, and a small mirror. The built-in speakers in the Glass EE2 are less effective in noisy environments, making the addition of Bluetooth earphones crucial. The device has a front camera capable of shooting up to 1080p at 30 frames per second and facilitates two-way communication.[14]

Running on the Android Oreo 8.1 operating system, the Glass EE2 features a touchpad for navigation and supports direct transmission of texts and images without server intervention. However, the front-facing camera has limitations in capturing objects directly below it, which is addressed by attaching a lightweight plastic mirror to the device.[13]

In terms of display capabilities, the Glass EE2 has a broad Field of View (FoV), making it suitable for professional scenarios requiring a larger viewing area.[14]

3.2.4 Nreal Air

Nreal is a company that focuses on the consumer market of AR smart glasses, This company was founded in BEIJING back in 2017, and this company is now called Xreal. In 2022 they publish their second-generation AR smart glass, which is Nreal Air. Nreal Air is a lightweight AR smart glass that only weighs 79g, and it looks like normal sunglasses. [16] It is an entry-level product, so the Nreal Air cannot function by itself, it must connect to a phone or a computer. For the display, the Nreal Air has two 1080p OLED displays from Sony one for each eye, the brightness comes to 400 nits. It also has two built-in open-ear speakers. However, this device does not come with any cameras, which means this device won't be able to support hand tracking or any other services that require a camera.

The Nreal Air only has 3 degrees of freedom, which means that it only tracks rotational traction, not translational. For FOV this device only has 46 degrees, which is not good enough for an AR device. When connected to a phone, the phone is the controller of this device, when connected to a computer, the keyboard, trackpad, or mouse is the controller. What this device does is provide you with a big virtual display, allowing you to have more screens when the space is limited, for example in a café, subway, or airplane. In casting mode it has a 130-inch virtual screen, in AR mode it can support up to three 201-inch virtual screens, but the fluency cannot be guaranteed.

3.2.5 Apple vision pro

The future of Augmented Reality (AR) is going to be Mixed Reality (MR), and Apple Vision Pro is a product that will explain what is MR. Virtual Reality (VR) consists of no real objects or persons, but MR consists of both real and virtual objects or persons. By the definition of VR, the Vision Pro is a VR device since it is not an optical see-through device, but the video see-through capability makes it an AR device, so the ability of Vision Pro to perform both AR and VR tasks makes it an MR device, according to one of the many definitions of MR. [17] Unlike most AR or VR devices on the market the Vision Pro is a stand-alone computer that can function without pairing to a phone or a computer, this is a new representation for mobile computing.

Apple Vision Pro doesn't have any controllers, smart glasses on the market normally would have a built-in trackpad or use an external device or controller to help navigate the pointer. However, Apple decided to use the user's eye, voice, and hand to control this device.[18] Except for the two main cameras for the video see-through system, there are additional 2 down-ward facing cameras, 2 side-ward facing cameras, and different sensors just to keep track of your hand. four infrared cameras and many infrared illuminators are used to keep track of your eyes. The movement of your eyes control the movement of the point, and your hand act as a button, to perform a click just put your thumb and forefinger together. The way that the Vision Pro switch from AR to VR is simply to spin the digital crown, it allows the screen to display the need of the real-world accordingly. The display on the Vision Pro consists of two 4k OLED screens, one for each eye. The combination of the cameras and the screen makes the streaming of the real world to the screens, look like seeing the real world by our own eyes.

The Vision Pro has an outward-facing screen that displays the user's eye when in the AR mode, when in VR mode the screen will display some patterns. This feature is unique in the industry. This feature allows the user to chat with someone else nearby without taking off the vision pro, and the one who is chatting with the vision pro user won't feel like talking to someone with no eye contact. [19]

The landscape of augmented reality (AR) devices is varied. Each device comes with its own set of unique features, limitations, and use cases, catering to specific market needs. Thanks to breakthroughs in computer vision, optical technologies, and human-computer interaction, AR devices are continually pushing the limits of what we can achieve in an augmented reality setting.

	Sensory Array	*Optics and Display*	*Field of View (FoV)*	*Resolution*	*Interaction*	*SLAM Capabilities*	*Unique Features*
HoloLens 2	Depth, grayscale cameras, IMU	Three-stack diffractive waveguides	52 degrees	1268 × 720 pixels per eye	Voice, hand gestures	6-DoF multi-sensor	Spatial mapping, gesture navigation
Magic Leap 1	Depth, GAM, GPS	Three-stack diffractive waveguides	50 degrees	1920 × 1080 pixels per eye	Controller	6-DoF multi-sensor	Dual focal plane technology
Google Glass Enterprise Edition 2	GAM, GPS/GLONASS	Not Mentioned	80 degrees	640 × 360 pixels per eye	Touchpad, voice	Not Mentioned	Two-way communication, light and large FOV
Nreal Air	proximity sensor	Not mentioned	46 degrees	1920 x 1080 pixels per eye	connected device	3-DoF	sunglass outlook
Apple vision pro	cameras, infrared illuminators, LiDAR scanner, depth	three-dimensionally formed laminated glass	Around 100 degrees	more than 4k pixels per eye	eye, hand, voice	6-DoF multi-sensor	capable of AR or VR

Table 3: Comparison for AR Devices

As the world tilts further toward digital and remote ways of living and working, AR devices present an exciting opportunity for seamlessly blending our virtual and physical worlds. As such, gaining a comprehensive understanding of the current capabilities and shortcomings of AR devices is not just helpful but essential for both developers and consumers as we march toward a more augmented reality.

3.3 AR Application

3.3.1 Education: From Rote Memorization to Experiential Learning

In traditional learning, students memorize facts, figures, and theories. Most of them use textbooks and blackboards, which can make learning boring. However, as Hwang et al. (2016) [20] noted that the use of augmented reality (AR) in schools and universities is changing the way we teach.

One widespread use of AR is to add digital information to real places. This connects real-world environments with digital learning materials. For example, students can use AR to see them more realistically instead of just reading about science topics. For example, biology students can see detailed parts of human cells as if they were observing them up close. Through augmented reality, they might also see a model of the solar system on a classroom table or gain a clearer understanding of how plants make food through photosynthesis[21], although these ideas may appear in books Very abstract becomes more precise and easier to understand. This new way of learning isn't just about making things look cool; It can help different types of learners, especially those who learn best through observation or practice. It also encourages students to explore topics rather than just actively listening or reading.

Another exciting use of AR in schools is its integration with problem-based learning (PBL). According to research[22], this teaching method shows how AR can improve students' learning and how they feel about learning, especially in physics.

PBL provides students with solutions to real-world problems rather than just providing them with facts. The goal is to help them think critically, solve problems, and retain information better. Adding AR to this approach makes learning more hands-on, making hard-to-see concepts visible and interactive. The use of augmented reality in the teaching of subjects such as physics represents an exciting change in education today. Studies such as Fidan and Tuncel (2019) [22] show that this new approach can improve learning outcomes and how students feel about their education. However, it is crucial to use AR wisely and ensure that it complements, rather than detracts from, the basic principles of good teaching.

3.3.2 Gaming: Beyond the Screen to Real-World Interaction

For decades, the gaming world was synonymous with screens, be it arcade displays, televisions, or handheld devices. Gamers would dive into fictional worlds, but always with a tangible barrier—the screen. Nilsen (2004)[23] explored the motivations behind AR games. He employed four dimensions to evaluate a game: physics, mental, social, and emotional. Using ARTOOLKIT, they developed an AR version of the classic game "Worms". This game was showcased at the HIT Lab's Virtual Worlds Consortium meeting in February 2004. Although attendees expressed great enthusiasm for the prospects of AR games, the player experience was not optimal due to technological constraints. However, it still represented a significant attempt to integrate AR technology into the gaming domain. With manufacturing processes and chip technology advancements, powerful personal computers and mobile devices have become ubiquitous. More and more sensors are integral in most smartphones. In 2017, Pokémon Go emerged as the first globally popular AR game, introducing the concept of AR to the world through gaming. This introduction dismantled the screen barrier, weaving the virtual and natural into a unified tapestry. Rauschnabel et al. (2017) [24] analyzed that gyroscopes and accelerometers ensure that the AR elements (like Pokémon) appear fixed to real-world locations, moving seamlessly as the player moves. Infrared sensors enhance AR games by determining depth and proximity, ensuring a deeper immersive experience.

Drawing on the four quantitative standards for gaming mentioned in Nilsen's (2004)[23] study, mobile outdoor augmented reality games, spearheaded by Pokémon Go, have significantly enhanced user experiences in both physical and social dimensions. These games have broken free from the constraints of traditional gaming input devices. AR-powered games extend the gaming arena from digital landscapes to physical neighborhoods. Pokémon Go encouraged players to walk out, explore their surroundings, and interact with both virtual creatures and real-world players. This evolution was not just about a game anymore but a social phenomenon. Games have transformed from isolated experiences to community events and real-world interactions.

3.3.3 Tourism: Traditional to User-centric

Although AR has been widely used in mobile applications such as entertainment and education, some studies also believe this technology still needs to be well used [25]. For example, more research must be done on user-centric AR application design. Hence, translating users' psychological and behavioral metrics into relevant technical designs and using them for mobile AR tourism applications in urban heritage tourism is a new direction of application [26]. In 2001, AR was first used in cultural heritage and became an exciting area of research [27]. Furthermore, mobile apps for the tourism industry have been emerging, but only a tiny fraction of tourism apps are being used regularly [26]. Therefore, user-centric AR applications for the tourism industry remain a novel direction. The general idea of such applications is that when the user scans a specific tourist attraction with the camera, the attraction will be recognized, and the user can view relevant information on the interface. "User-centric" means the application's usability will be a significant consideration. It is also possible to recommend nearby attractions that may be of interest based on the user's preferences. Users can get more interactive in this type of app than in previous travel-related apps, which leads to a better travel experience. Some studies have confirmed the close relationship between cultural heritage tourism, entertainment, and education. Cultural heritage tourism attracts tourists and fulfills local people's social, cultural, and entertainment aspirations [28]. Therefore, the use of AR in the tourism industry is a promising application direction, as it can drive the development of the entertainment and education industries at the same time.

There are several aspects to consider when implementing this type of application, and since tourists are generally familiar with social networking applications and use them daily, making this type of AR tourism application accessible to their social networks is considered very valuable. Therefore, future applications should be linked to established social media giants rather than developing new social platforms [26]. The idea is effective and inexpensive but also more likely to raise some privacy concerns, such as how to share and store user information without leakage. In addition to data privacy, some users care about the safety of the mobile device itself. For example, holding up the phone in front of them for an extended period to stay at a particular POI (point of interest) to access information through an application is an easy way to grab the phone. In addition, the availability of the network while traveling is also an issue to be considered, and the feature of offline content is proposed [26]. Offline content is also beneficial in getting users to visit more attractions [29].

There are other aspects; for example, when it comes to traveling, foreign tourists need to be considered, so the application needs to support multi-language, and of course, considering the usability, the application needs to support the navigation function as well. However, with the combination of multiple functions, the difficulty of development and maintenance will increase accordingly. At the same time, when displaying information related to the location, it is necessary to consider the problem of coverage and overlapping, the amount of information to be displayed to not dazzle people, and how to guarantee readability needs attention. In addition, considering the need to combine with GPS, if the attractions are located in the city, especially downtown, ensuring the accuracy of positioning will be difficult. Therefore, SLAM (Simultaneous Localization and Mapping) technology has been proposed, which can continuously construct a model of the surrounding environment for tracking purposes without relying on GPS sensors [26].

Given the current lack of design guidelines and heuristic rules related to this application, the following research directions need to be further explored: first, finding effective ways to realize and ensure

	Traditional State	Impart of AR	Outcomes
Education	Rote learning, Textbooks, Blackboards	Enhanced visualization, Intuitive understanding, Problem-Based Learning with AR	Addresses varied learning styles, Fosters curiosity, Transformative classroom dynamics
Gaming	Screen-based interaction, Isolated experiences	Blends virtual & real, Uses sensors for immersive experience	Promotes physical activity, Encourages social interaction, Transforms gameplay dynamics
Tourism	Limited to basic information, non-interactive, and not user-centric.	AR integration leads to more interactive, user-centric designs. Apps can recognize tourist attractions, providing relevant info and recommendations based on preferences.	Enhanced tourist experience, more engaging apps.

Table 4: A summary of the impact of AR in different sectors.

seamless integration of desired domain-specific functionalities to support a positive user experience. Second, context-based information filtering in AR views to better fulfill user needs. It is also possible to adaptively present content from the user's surroundings in the AR view by experimenting with different graphical variables and visual cues (Smith & Brown, 2022) [30]. Future research should also continue to emphasize user-centric approaches to AR application design. Conducting thorough user research, including usability testing and collecting user feedback, can provide insight into how users interact with AR interfaces in real-world scenarios, helping to develop more intuitive and user-friendly AR experiences. As AR technology becomes more integrated into everyday life, research should address ethical issues related to privacy, data collection, and user consent. How to provide valuable AR experiences while gaining user trust and ensuring user privacy needs to be explored.

The way forward will be oriented towards practicality rather than simply gimmicks (Han et al., 2019) [26]. While breakthrough innovation is essential, the ultimate goal should be to create AR apps that genuinely improve the user experience and bring them into everyday life.

4 Conclusions and Future Directions

4.1 Conclusions

With the rapid development and popularization of augmented reality (AR) technology, we are now at a turning point in information technology. After our in-depth research on AR device SDK development and application, we have to admit the diversity and complexity of this field. There is no one-size-fits-all solution for developers. On the contrary, the technologies and tools in this field are constantly evolving, and at the same time, they also bring great opportunities and challenges to relevant practitioners.

The three areas studied in this article are software development kits, operating devices, and practical applications. These three are complementary to each other. Choosing the right equipment and development tools for a specific application scenario is important. For example, an AR application designed for industry may need to run on a device with higher graphics rendering capabilities, while an application designed for medical or educational purposes may focus more on user interaction and data accuracy at the programming level. AR-based games are divided into indoor games based on AR headsets and outdoor games based on mobile phones, such as Pokémon Go.

4.2 Future Directions

Faced with this rapidly changing field, future research directions are diverse. First, as new AR devices emerge, they will provide more powerful performance and real-time computing capabilities. In addition to hardware developments, software and development tools will undergo dramatic changes. With the integration of advanced technologies such as artificial intelligence, machine learning, and cloud computing, the possibilities of AR applications will be further expanded, evolving from simple graphic overlays to more complex and intelligent interactive experiences.

Augmented Reality is gradually transforming into a multidisciplinary and interdisciplinary research direction. The convergence of evolving technologies, diverse devices, and innovative applications paints a promising future for AR. AR brings a new perspective to our interaction with the world from theory to real-world application.

5 Appendix

5.1 External Links

Description	URL
Demonstration Video	https://youtu.be/qermcMn7x1M
Overleaf Report	https://www.overleaf.com/read/ngkphxvxfpyr
Presentation Slides	https://www.canva.com/design/DAFsvFKTHGg/9oBI2Y2znUtR5-xUCKNJUA/edit?utm_content=DAFsvFKTHGg&utm_campaign=designshare&utm_medium=link2&utm_source=sharebutton

5.2 Team and Contribution

Team members and Contributions

- **Zhiyuan Wang**
  - Contributions:
    * Completed the AR SDK part for the report.
    * Video production and editing.
    * Organized team members, scheduled meeting times, recorded meeting content, and planned the overall progress.
- **Wei Zhao**
  - Contributions:
    * Video production
    * transform report from Google Doc to Overleaf(Latex)
    * Application parts for gaming and education
- **Yangang Chen**
  - Contributions:
    * Video production, footage editing
    * Video structure planning
    * Device parts for the report
- **Hongyi Tang**
  - Contributions:
    * Abstract & Device parts for the report.
    * Related Video production.
- **Lin Xi**
  - Contributions:
    * Introduction & Application parts for the report.
    * Video production.

Bibliography

[1] Jeevan S. Devagiri, Sidike Paheding, Quamar Niyaz, Xiaoli Yang, and Samantha Smith. Augmented reality and artificial intelligence in industry: Trends, tools, and future challenges. 207:118002.

[2] Fabio Arena, Mario Collotta, Giovanni Pau, and Francesco Termine. An overview of augmented reality. 11(2):28.

[3] A. Lisovitckii. 8 best-augmented reality sdks for ios and android in 2017. 2017.

[4] Xinqi Liu, Young-Ho Sohn, and Dong-Won Park. Application development with augmented reality technique using unity 3d and vuforia. 13(21).

[5] Tetiana A Vakaliuk and Svitlana I Pochtoviuk. Analysis of tools for the development of augmented reality technologies.

[6] Yunqiang Chen, Qing Wang, Hong Chen, Xiaoyu Song, Hui Tang, and Mengxiao Tian. An overview of augmented reality technology. 1237(2):022082.

[7] Abdulla Alsharhan, Said A. Salloum, and Ahmad Aburayya. Technology acceptance drivers for AR smart glasses in the middle east: A quantitative study. *International Journal of Data and Network Science*, 6(1):193–208, 2022.

[8] Laura Simone Gebelhoff. Management from the NOVA School of Business and Economics.

[9] Arrigo Palumbo. Microsoft hololens 2 in medical and healthcare context: State of the art and future prospects. *Sensors*, 22(20), 2022.

[10] Dorin Ungureanu, Federica Bogo, Silvano Galliani, Pooja Sama, Xin Duan, Casey Meekhof, Jan Stühmer, Thomas J. Cashman, Bugra Tekin, Johannes L. Schönberger, Pawel Olszta, and Marc Pollefeys. HoloLens 2 research mode as a tool for computer vision research.

[11] Sebastian Kapp, Michael Barz, Sergey Mukhametov, Daniel Sonntag, and Jochen Kuhn. ARETT: Augmented reality eye tracking toolkit for head mounted displays. 21(6):2234.

[12] Giulia Zari, Sara Condino, Fabrizio Cutolo, and Vincenzo Ferrari. Magic leap 1 versus microsoft HoloLens 2 for the visualization of 3d content obtained from radiological images. 23(6):3040.

[13] Junling Fu, Alberto Rota, Shufei Li, Jianzhuang Zhao, Qingsheng Liu, Elisa Iovene, Giancarlo Ferrigno, and Elena De Momi. Recent advancements in augmented reality for robotic applications: A survey. 12(8):323.

[14] Jiaqi Xu, Derek Doyle, and Fernando Moreu. State of the art of augmented reality capabilities for civil infrastructure applications. 5(5):e12602.

[15] Hyoseok Yoon, Sun Kyung Kim, Youngho Lee, and Jongmyung Choi. Google glass-supported cooperative training for health professionals: A case study based on using remote desktop virtual support. Volume 14:1451–1462.

[16] Tse Yi Hong Benjamin. Augmented reality–revolutionary technology or just a fad?

[17] Maximilian Speicher, Brian D. Hall, and Michael Nebeling. What is Mixed Reality? In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pages 1–15, Glasgow Scotland Uk, May 2019. ACM.

[18] Ethan Waisberg, Joshua Ong, Mouayad Masalkhi, Nasif Zaman, Prithul Sarker, Andrew G. Lee, and Alireza Tavakkoli. The future of ophthalmology and vision science with the Apple Vision Pro. *Eye*, August 2023.

[19] Jan Egger, Christina Gsaxner, Xiaojun Chen, Jiang Bian, Jens Kleesiek, and Behrus Puladi. Apple Vision Pro for Healthcare: "The Ultimate Display"?

[20] Gwo-Jen Hwang, Po-Han Wu, Chi-Chang Chen, and Nien-Ting Tu. Effects of an augmented reality-based educational game on students' learning achievements and attitudes in real-world observations. 24(8):1895–1906.

[21] Hsin-Kai Wu, Silvia Wen-Yu Lee, Hsin-Yi Chang, and Jyh-Chong Liang. Current status, opportunities and challenges of augmented reality in education. 62:41–49.

[22] Mustafa Fidan and Meric Tuncel. Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. 142:103635.

[23] Trond Nilsen, Steven Linton, and Julian Looser. Motivations for augmented reality gaming. *Proceedings of FUSE*, 4:86–93, 2004.

[24] Philipp A. Rauschnabel, Alexander Rossmann, and M. Claudia Tom Dieck. An adoption framework for mobile augmented reality games: The case of pokémon go. 76:276–286.

[25] Julie Carmigniani, Borko Furht, Marco Anisetti, Paolo Ceravolo, Ernesto Damiani, and Misa Ivkovic. Augmented reality technologies, systems and applications. 51(1):341–377.

[26] Dai-In Danny Han, Timothy Jung, and M. Claudia Tom Dieck. Translating tourist requirements into mobile AR application engineering through QFD. 35(19):1842–1858.

[27] Faculty of Technology Creative & Heritage, Universiti Malaysia Kelantan, Bachok, Malaysia, Fatin Norsyafawati Mohd Sabri, Nik Zulkarnaen Khidzir, Ahmad Rasdan Ismail, and Khairul Azhar Mat Daud. An exploratory study on mobile augmented reality (AR) application for heritage content. 4(6):489–493.

[28] Naai-Jung Shih, Pei-Huang Diao, and Yi Chen. ARTS, an AR tourism system, for the integration of 3d scanning and smartphone AR in cultural heritage tourism and pedagogy. 19(17):3725.

[29] Meredydd Williams, Kelvin K. K. Yao, and Jason R. C. Nurse. ToARist: An augmented reality tourism app created through user-centred design.

[30] Zornitza Yovcheva, Dimitrios Buhalis, and Christos Gatzidis. Overview of smartphone augmented reality applications for tourism. 10(2).