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AR Technology in Jewellery Display

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PREFACE

This dissertation was a project that demanded more time and effort than anticipated. However, it is now finally completed. The lessons learned from this undertaking encompass not only the acquisition and applying of new technologies but also the process of adapting to the changes these technologies bring to life.

I would like to express my gratitude to my super advisor, Ville Jääskeläinen, and extend my thanks for my family's unwavering support.

Helsinki, 01 Dec.2023
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Abstract

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In the era of social self-media, the landscape of buying and selling goods, and even visiting museums, has transformed with the introduction of digital technology. The use of Augmented Reality to display jewellery introduces novel presentation and expression, impacting physical stores and the traditional jewellery industry. Interactive Augmented Reality replaces the initial customization and try-on process, attracting users to engage interactively. The real feel of the try-on experience aids customers in making informed purchase decisions and enhances brand conversion rates. In this project, the selection of a suitable Augmented Reality platform is the primary challenge, followed by the integration of Augmented Reality Unity and Three-Dimensional models for seamless operation across multiple platforms. A comparison of AR Foundation, ARCore, Unity, and Zappar led to the joint use of Unity and Zappar as the construction platform. Due to the expected greater number of models compared to the final products, only a limited set was used as demonstrations in this project.

In this project, Zappar and Unity are predominantly utilized in conjunction with the physical cameras of computers and mobile phones. They facilitate real-time head tracking and positioning to display the Three-Dimensional models of jewellery.

Keywords: Augmented Reality, Unity, Zappar, AR Foundation.

Contents

List of Abbreviations

ADB	Android Debug Bridge
API	Application Programming Interface
APP	Application
AR	Augmented Reality
HUD	Head Up Display
MR	Mixed Reality
OAuth	Open Authentication
SDK	Software Development Kit
USB	Universal Serial Bus
UWP	Universal Windows Platform
VR	Virtual Reality
XR	Extended Reality
2D	Two-Dimensional
3D	Three-Dimensional

1 Introduction

Augmented Reality (AR) is a variant of a virtual environment or, more commonly stated, virtual reality [1]. Augmented Reality presents virtual digital information in a real environment in real time, helping users complete certain tasks and activities through the combination of reality and virtuality. Virtual digital information in AR conveys more valuable information to users through real-time interaction, such as mobile applications, the web, and so on [2].

Augmented Reality supports richer Three-Dimensional-level interaction methods and passively triggered actions. With the popularity of smartphones and AR, AR headsets tied to smartphones are becoming more and more popular. In the future, AR will be widely used in the four major consumer areas: social networking and communication, navigation, games, and sports and health. Augmented Reality adds a controllable data layer between the user and the real world, allowing virtual objects to interact with the real world and be displayed on a mobile phone or a computer screen. This data layer brings users not only the ability to view information but also, more importantly, a multi-dimensional interactive experience.

Among them, our most common Augmented Reality applications appeared: Pokemon Go, Snap Chat Lenses, Google Image Translation APP, human anatomy atlas, and Augmented Reality display in the jewelry industry.

W&Z Design Studio is a jewelry design and production company located in Helsinki. The challenge is to satisfy customers' demands in finding the right jewelry without leaving their accommodation. The company aims to start from the value attributes of jewelry and use new technologies to promote sales safely and effectively. With the emergence and popularization of Augmented Reality technology, it provides a solution: using Augmented Reality technology to display jewelry can give users a more detailed and accurate understanding of their wearing effect, showcasing not only the style and color of the jewelry but also its images. Simultaneously, when customers need to customize products, jewelry companies can display the wearing experience with the Augmented Reality model for customers to choose initially, without spending too much time and materials to complete a sample in advance. Moreover, Finland has a high internet penetration rate and online shopping usage rate, making it crucial to enhance customers' jewelry shopping experience without physical and geographical restrictions.

Customers select an item on the jewelry company's website or app, then point their smartphone or computer camera at the part they want to wear. As the camera changes angles, the jewelry in the picture appears as if it is worn on the body, showing different perspectives. Display, tracking, positioning, interface, visualization, and calibration technologies make up an Augmented Reality system. In smartphones, Augmented Reality projects information into the real scene (camera) based on the current location (GPS), direction of view (compass), and orientation of the phone (sensor or gyroscope). This study introduces the application of jewelry in the existing AR display and identifies the most suitable Augmented Reality application for this enterprise through comparative analysis.

In this project, the following platforms were compared and used: ZapWork Studio, Unity, and Universal AR (Zappar for Unity). The project also created a 3D mode build and integrated on the platform using Visual C, tested it, and ran it on different devices.

Currently, numerous companies have developed and promoted various AR platforms. For instance, designers, product managers, and professionals in the art industry without a coding background can use Adobe Aero and Apple's Reality Composer to quickly create AR content. For developers with programming knowledge, ARKit, ARCore, AR Foundation, Vuforia, EasyAR, and HoloLens can be used for development.

After testing and utilizing various AR platforms, this project opted for Unity and Zappar according to the company's low budget and trial operation needs. Code was written in Visual Studio to generate the applicable code and embed and debug 3D models of products. Finally, customers can scan the QR code of the product with a smartphone or electronic device for a virtual try-on.

This thesis is divided into 6 chapters. Firstly, based on customers' requirements for safely displaying jewelry while enhancing the social effect of the brand, it was proposed to use AR to virtually try on jewelry. The second chapter of the thesis briefly explains the development process of AR technology and the technical background of AR. The third chapter introduces and analyzes the current situation of existing brands such as Swarovski and Van Cleef & Arpels that have used AR jewelry for virtual try-on. The fourth chapter develops solutions and implementation plans based on the current situation and needs of customers. Chapters 5 and 6 present the operational results and analysis.

2 Theoretical and Background

As the use of VR technology predates the appearance of AR, the introduction of VR technology is a prerequisite. What constitutes VR? VR is a simulated environment produced by a computer, utilizing real-life data and electronic signals generated by computer technology, combined with various output devices. This allows people to have an immersive experience through audio and visual channels, entering the simulated environment [3].

So, what is AR? Augmented Reality is the merging of the digital and real worlds, involving real-time interaction and accurate 3D identification of virtual and real objects through digital visual elements, sound, and other senses using holographic technology, Mixed Reality combines AR and VR elements, digital objects, and real environment interaction. Extended Reality encompasses technologies of AR, VR, and MR.

- Augmented Reality (AR) - Interaction that adds digital elements to the view of the real environment.
- Virtual Reality (VR) -Transports the user into a virtual sensory environment through specially designed head-mounted displays and headsets.
- Mixed Reality (MR) - Incorporating elements of AR and VR, digital objects can interact with real-world environments.
- Extended Reality (XR) - Covers all types of technology used to augment our senses, including the three previously mentioned.

2.1 Brief Development of VR and AR

Figure 1, "The Development of VR," illustrates the timeline of VR development from 1960 to the present. In 1962, film cameraman Morton Heilig invented a simulator called the Sensorama, where users immersed themselves by poking their heads into the device. During this period, VR was primarily in the research and development stage, with no deliverable products.

In 1980s, the beginning development of 3D interactive technology took a significant step when Michael McGreevy and Scott Fish (NASA Ames Research Institute) introduced the virtual reality display system, HMD (head-mounted display), in 1985. Later, in 1996, Stéphane Cotin et al proposed the application of virtual technology to liver recovery surgery in hospitals.

Over the next decade, VR found increased use in the industrial field, contributing to product design and training for controlling large mechanical equipment. Applications extended to surface and subsea industries, incorporating force feedback arms for tactile feedback. Since 2010, the price of VR equipment has decreased, thanks to continuous innovation in industrial materials, making it easily accessible to ordinary people. This has allowed individuals to experience immersive gaming and video enjoyment from the comfort of their homes.

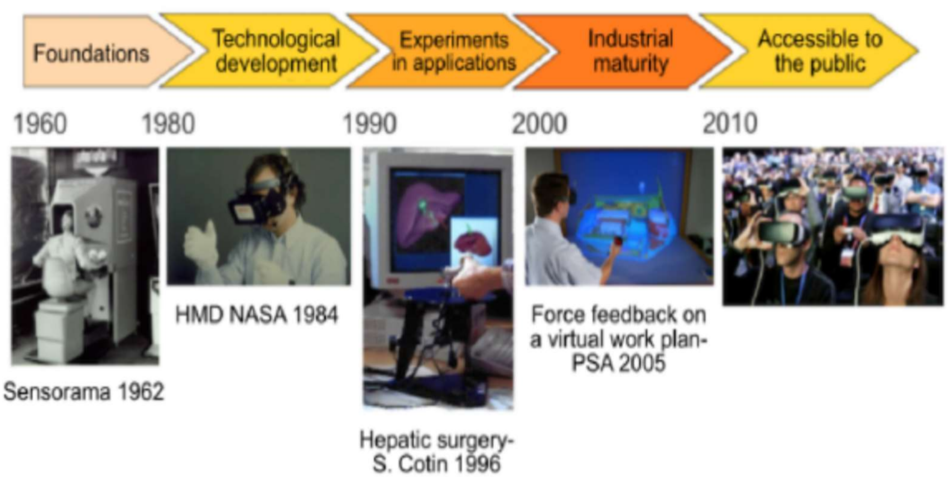

Figure 1. The development of VR [4]

Figure 2 illustrates the developmental trajectory of Augmented Reality (AR) from 1990 to the present, depicting a rapid evolution in a relatively short span. The roots of AR development trace back to Virtual Reality (VR). With advancements in industrial materials, technology, and the evolving demands of the consumer market, the AR landscape has matured significantly over time.

From 1990 to 2006, Augmented Reality technology was primarily implemented in scientific research and experiments within educational institutions and enterprises, with limited consumer-oriented applications. In 1990, Boeing employee Tom Caudel conceptualized Augmented Reality, initially applied during the assembly of aircraft. Six years later, Steve Feiner and colleagues at Columbia University pioneered the system prototype for Augmented Reality outdoor mobile equipment known as the Touring Machine. Further contributing to AR's progress, ARToolKit, an open-source Augmented Reality tool, was released in 1999.

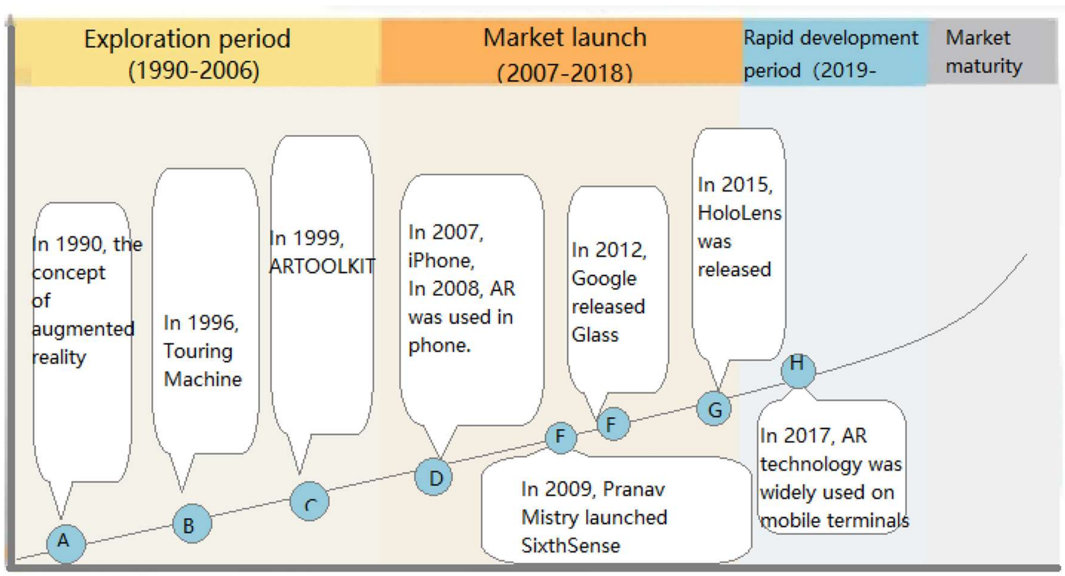

Figure 2. The development of AR [5]

Between 2007 and 2018, Augmented Reality technology entered a startup phase in the market, marking a period of exploration for the entire industry in terms of application scenarios. During this time, a multitude of Augmented Reality advertising services and hardware products emerged continuously. Key milestones in technology and product releases further fuelled this growth.

In 2007, Apple introduced the iPhone, a significant development that played a pivotal role in shaping the trajectory of Augmented Reality. The following year, in 2008, the Android system for mobile phones was released, contributing to the expanding landscape of AR-compatible devices. Additionally, in 2009, MIT student Pranay Mistry introduced the Sixth Sense, a wearable gesture interaction system.

Since 2012, AR has entered a period of rapid development. The release of Google Glass and HoloLens has directly promoted the commercial upsurge of wearable technology and AR technology [6].

2.2 Comparison of VR and AR

If we envision VR and AR as situated at opposite ends of the same axis, with the real world on one side and the virtual world on the other, their distinctions become clearer. AR, or Augmented Reality, is realized when virtual technology overlays on the real world. Conversely, VR, or Virtual Reality, emerges when the consumer disengages from the real environment and immerses themselves in a virtual world.

Figure 3 illustrates these two predominant environments, the real and the virtual. More virtual objects and experiences are immersed towards the other side of the axis. Gradually, it turns into AR by replacing more virtual objects with real ones. On the contrary, Augmented Virtuality turns more real items into virtual forms. In both ways, Mixed Reality is hybridized between real and virtual environments.

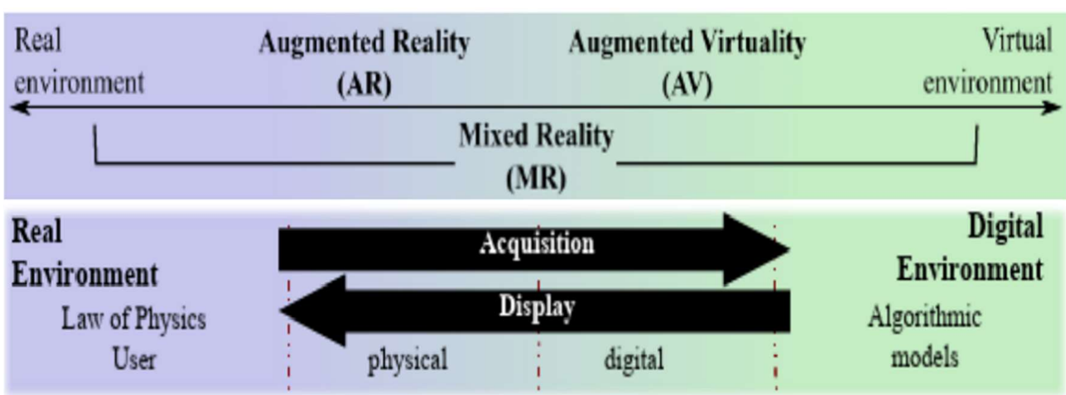

Figure 3. reality-virtuality continuum [7]

Conversely, Augmented Virtuality, depicted in the opposite direction, involves the transformation of more real-world items into virtual forms. In both scenarios, Mixed Reality emerges as a hybridization between the real and the virtual environments, creating a spectrum of experiences that blend elements of both worlds.

AR technology is an integration of various technologies such as computer graphics, human-computer interaction, human-computer interface, multimedia, sensing, network, and artificial intelligence. Utilizing computer simulation environments, AR seamlessly blends into these simulated environments, incorporating aspects like vision, hearing, touch, smell, and other senses.

Table 1, Comparison between AR and VR, highlights the distinct characteristics of each. VR, or Virtual Reality, constructs an entirely virtual world that doesn't exist in reality, perceivable only by the person wearing the device. On the other hand, AR involves overlaying computer-generated virtual electronic objects and additional electronic information onto the real-world scene, enhancing the user's perception of reality [8].

Table 1. Comparison between AR and VR

	AR	VR
Similarities	Simulate the environment with the aid of computer graphics.	
Differences	Realistic scene Virtual electronic object machine information.	All virtual objects and information.
	Environment is open.	Environment is closed.
	Display devices are different. No headset is required.	Headset is required.

2.3 The Technical Principle of AR

AR, or Augmented Reality, involves collecting relevant data using AR terminal equipment or cameras in the real world. This data collection process includes positioning and identification, extracting parameters for further processing. The devices involved in AR typically incorporate internal operating systems to ensure efficient operations and facilitate 3D registration.

Once the AR system has acquired the necessary data, it proceeds with rendering and overlaying 3D virtual elements onto the real-world environment. The final display is presented to users in various formats, allowing customization based on user preferences and requirements. This user-specified presentation can take different forms, enhancing the overall augmented reality experience.

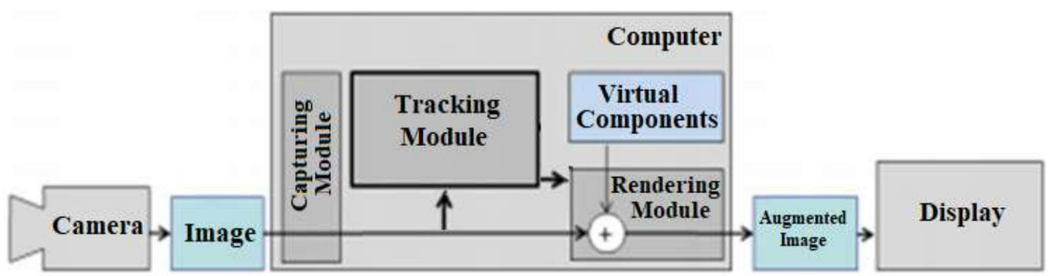

Figure 4. The technical principle for basic AR system [9]

As Figure 4 shows, the working principle of AR is mainly divided into three parts: the input part, the processing part, and the display part as output. In the input part, the Augmented Reality terminal or camera collected information and images from the real world, and the processor completed the three-dimensional registration of the virtual object in the real scene. In the processing part, while the AR system positioned the tracking camera to identify the real scene, it rendered the virtual model on the other side, and then formed a virtual scene. In the display part, the system displays the superimposed image in 3D, hologram, or square.

Figure 5 shows the frame composition of the AR system. The architecture of the layer framework of the AR system includes Concept and Theory, Implementation, and Evaluation. At the application level, it consists of two parts: hardware and software. The AR system's software is the tools and applications used to get AR up and running. Currently, there are general AR development software. Corresponding AR software and applications are also purposefully created according to the needs of some companies with special requirements. The software part mainly includes Agent-based AR, Knowledge-based AR, Interaction Design, and Contents Design. The hardware part roughly includes: Computing unit, Display, Interaction Design, Tracking, and Sensing.

Among them, the operation of AR requires a high-resolution lens and image platform to capture content and images. The better the resolution and clarity, the more realistic the resulting images will be. To ensure the consistency of the digital world and the current world, the sensors of the AR system need to capture the data information of the surrounding environment. When the AR system gets the information, it will use the software to send the information for processing. In order to ensure the normal operation of the entire system, system testing and detection must be done. Evaluation includes effectiveness and usability.

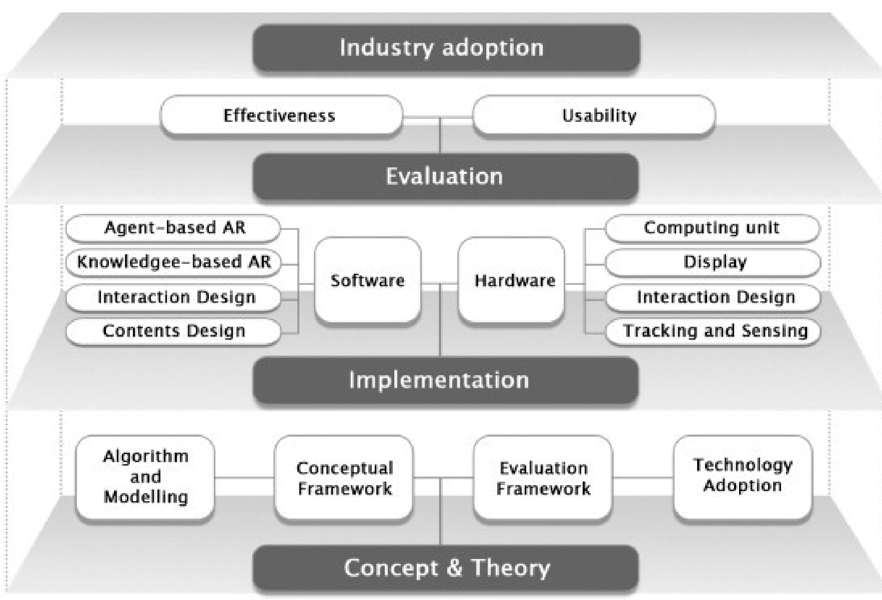

Figure 5. The architecture layer framework of AR systems [10]

2.4 Components of AR and Industry Chain

The AR industry chain is roughly divided into hardware, software, and application fields. On a component basis, the Virtual Reality, Augmented Reality, and Mixed Reality market are studied across hardware and software. Hardware mainly includes further research around projectors, cameras, displays, headphones, sensors, position trackers, and semiconductor components. The software sector includes the development and research of software associated with hardware in cloud-based services, software development kits, and content creation, but also includes the development of the underlying operating system, upper-level engine, and production tools. Research based on applied neighbourhoods encompasses areas such as advertising, education and training, retail, e-commerce, travel, games, entertainment, and sports, as well as medical training and education, patient care management, pharmacy management, and surgery [11].

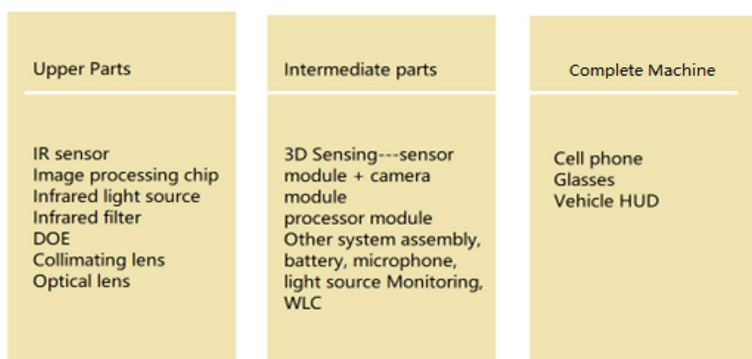

Figure 6． Components of AR [12]

In the hardware field, it is mainly composed of upper parts, intermediate parts, and the complete machine. Upper-level accessories include IR sensor, Image processing chip, Infrared light source, Infrared filter, DOE, Collimating lens, and Optical lens. Intermediate components and interactive technology modules are 3D Sensing-sensor module + camera module, processor module, imaging module (Glasses), other system assembly, battery, microphone, light source blue test, WLC. The complete machine consists of a mobile phone, glasses, and a vehicle HUD.

Among them, 3D Sensing in the middle is key to AR functional technology. This technology involves converting 2D cameras into 3D data, enabling applications like gesture recognition and face recognition. It utilizes sensors that consist of dot matrix projectors, flood sensing elements, and infrared lenses.

Figure 7 illustrated Hardware for AR. The primary products in the AR market encompass both hardware and software. Notably, software products are derived from hardware components. With the advancement of commercial maturity, AR devices are anticipated to become increasingly portable andmobile. The hardware for AR includes: Hololens, SmartEyeGlass, Camera, Smart phone. Figure 8 illustrated Software for AR. They are contained in Unity, Unreal Engine, Xenko, Android Development Studio, Vurofia, ARToolKit, ARKIT,ARCore.

APPENDIX A: AUGMENTED REALITY HARDWARE

Popular AR Hardware	*URL*
Microsoft Hololens	https://www.microsoft.com/microsoft-hololens/en-us
Epson BT (Series)	https://epson.com/moverio-augmented-reality
Sony SmartEyeGlass	http://developer.sonymobile.com/products/smarteyeglass/
ODG's R (Series) Glasses	http://www.osterhoutgroup.com/home
Meta (Series)	https://www.metavision.com/
Vuzix M (Series)	https://www.vuzix.com/
Atheer Air	http://www.atheerair.com/smartglasses
Recon Jet	http://www.reconinstruments.com/products/jet/
Intel RealSense Cameras	https://software.intel.com/en-us/realsense/
Recommended Hardware for Practice Development	
Any smart device supporting the minimum system requirements recommended by an AR plugin	
Any modern webcam attached to a PC supporting the minimum system requirements recommended by an AR plugin	

Figure 7． Hardware and software for AR [13]

Microsoft, Google and Apple, SONY INTEL, occupy most of the product market in the AR industry chain.

Recommended Development Software

Software	Type	Free or Paid	URL
Unity	Game engine	Free with paid features	https://unity3d.com/
Unreal	Game engine	Free with paid features	https://www.unrealengine.com/
CryEngine	Game engine	Free with paid services	https://www.cryengine.com/
Xenko	Game engine	Free with paid features	https://xenko.com/
Android Development Studio	IDE	Free	https://developer.android.com/studio/index.html
Visual Studio	IDE	Free with paid features	https://www.visualstudio.com/
Aurasma	Drag and drop	Free/paid features	https://www.aurasma.com/

Recommended Toolkits/Plugins for Augmented Reality Only

Name	Free or Paid	URL
Vuforia	Free to develop, paid features	https://www.vuforia.com/
Wikitude	Free to develop, paid features	http://www.wikitude.com/
ARToolKit	Free	http://artoolkit.org/
Augumenta	Free trial	http://augumenta.com/
Unreal4AR	Free/paid features	http://www.unreal4ar.com/
ARKit (iOS)	Free	https://developer.apple.com/arkit/
ARCore (Android)	Free	https://developers.google.com/ar/

Figure 8. Software and software for AR [13]

2.5 AR Technology Shows Jewellery Visual Try-on

Taking AR ring try-on as an example, Figure 9 illustrates the related algorithm and process of the AR ring try-on. The first step involves the 3D reconstruction algorithm of the hand, which retrieves the 3D vertex coordinates corresponding to the user's hand after collecting the input image. The second step is the AR layer algorithm. It involves calculating the 3D hand model based on the second step, obtaining the Transform matrix required for rotating the product to the correct position. The rotated model is then overlaid on the user's hand picture to achieve the final AR display effect.

The purpose of the ring try-on is to position the virtual ring on the user's corresponding finger, providing a realistic try-on experience. Compared to the palm imaging ratio on mobile phones, the finger knuckle area used for ring try-on is relatively small. It is essential to establish the vertex number of the try-on knuckle and the corresponding relationship between the front and back of the

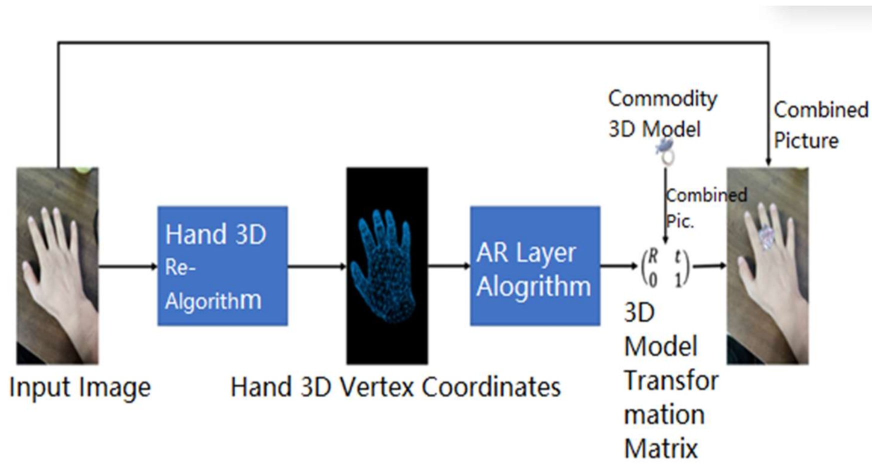

Figure 9. AR ring try-on Algorithm [14]

ring. The ring try-on must support both front and rear cameras, capturing the palm and the back of the hand, and ensuring an effective display under 360-degree rotation. Additionally, the ring should be rotated according to the local coordinate system, utilizing the Look Rotation function to determine the forward and up vectors and obtaining the corresponding rotation matrix of the ring [14].

2.6 Construct AR's APP

The technical architecture of the application (APP) project primarily consists of front-end and back-end technologies, storage, and APP cybersecurity.

1) The front-end technology of the APP is responsible for implementing the user interface and user interaction mode. Currently, HTML, CSS, and JavaScript are employed. HTML and CSS serve as fundamental technologies for constructing web pages, while JavaScript is a programming language utilized to process user input, execute animation effects, and communicate with back-end servers. Front-end frameworks such as React, VUE, and Angular offer robust tools and functionalities, simplifying the development of intricate user interfaces.

2) Back-end technology: The back-end technology is primarily responsible for processing business logic, managing data storage, and facilitating interaction with the front-end. It encompasses various components, including database management systems, server-side programming languages, and cloud services. Databases, such as MySQL or Oracle, as well as NoSQL databases like MongoDB, are employed to store product information, order data, and user details.

   Back-end programming languages like Java, Python, or Node.js are utilized for developing the back-end logic and handling business processes. Cloud service providers, such as Amazon Web Services (AWS) or Microsoft Azure, may be employed for deploying and scaling back-end services. Back-end programming languages and frameworks commonly include Java (utilizing the Spring framework), Python (utilizing the Django framework), or Node.js (utilizing the Express framework). Database technologies like MySQL, MongoDB, or PostgreSQL are integral to the process.

   Interaction technology between front-end and back-end: The interaction between front-end and back-end is usually carried out through API (Application Programming Interface).

   - RESTful API: Representational State Transfer, by using different methods of the HTTP protocol (such as GET, POST, PUT, DELETE) and URLs to define resource operation and access methods. JSON (JavaScript Object Notation) is a data exchange format for RESTful APIs.

   - GraphQL: GraphQL is a query language and runtime environment for APIs, which allows clients to obtain the required data by defining precise data requirements, avoiding the problem of over-acquisition or insufficient acquisition in traditional RESTful APIs .

- OAuth: Open Authentication is an authentication and authorization protocol. OAuth allows users to access APIs using authentication information from third-party applications while protecting users' sensitive information.

- WebSocket: WebSocket has real-time communication and push functions. WebSocket is a protocol that provides full-duplex communication on a single TCP connection, allowing real-time two-way data transmission between the server and the client.

- HTTPS: HTTP Secure is a secure transmission method to protect data as a communication protocol. HTTPS adds the encryption and authentication mechanism of the SSL/TLS protocol on the basis of HTTP to ensure the confidentiality and integrity of data during transmission.

3) Database management and security. Relational databases, such as MySQL, or document databases, such as MongoDB, are used to store user data and dynamic content. Data security is an important consideration in APP projects, and the following are some common security :

    - User authentication and authorization are crucial aspects of ensuring that only authenticated users can access sensitive information and perform critical operations. Employ secure authentication mechanisms, such as passwords, multi-factor authentication (such as SMS verification codes or fingerprint recognition), etc. The authorization mechanism should restrict users to operations within the scope of their designated authority.

    - Data encryption: Utilize appropriate encryption algorithms to protect sensitive data, such as user personal information and payment details, ensuring confidentiality during both transmission and storage.

- Input validation and filtering: Implement rigorous validation and filtering of user-input data to prevent security vulnerabilities like cross-site scripting (XSS) and SQL injection attacks."

- Secure network communication: Establish secure network communication through protocols like HTTPs to safeguard data transmission between the client and server, preventing cyber -attacks such as eavesdropping, tampering, and replay.

- Secure storage: Safeguard user data by implementing secure storage practices. This includes managing access permissions to databases and file systems, as well as employing encryption techniques for the storage of sensitive data.

- Safe error handling: When handling errors and exceptions, avoid disclosing sensitive information or system details to users to prevent information leakage and attackers using this information to attack.

- Security updates and bug fixes: Ensure the security of the application by promptly addressing and fixing known security vulnerabilities through timely updates and bug fixes.

- Security audit and monitoring: establish a proper logging mechanism to audit key operations to track and detect potential security incidents. Monitor application activity and performance to detect anomalous behaviour promptly.

- Security Awareness Training: Conduct security awareness training for development teams to educate them about common security threats and best practices to ensure they can write secure code and conduct proper security testing [15].

3 The Status and Cases of AR Visual Try-on

This section is divided into two parts. Firstly, the production and sales of jewellery represent a relatively specialized and traditional industry, with conventional display methods persisting. However, the advent of AR technology has breathed new life into the jewellery sector, introducing fresh and engaging display channels. Virtual imaging technology eradicates reservations about trying on finished jewellery. Customers have the freedom to explore and observe the wearing effect at their leisure. In the second part, we will briefly analyse the current utilization of AR by Swarovski and Van Cleef & Arpels.

3.1 The Benefits of AR Displays for Jewellers

AR display jewellery technology not only brings convenience to sellers but also to customers. For customers, the interactive display provides users with a different customer experience. While enjoying the new technology, customized users also participate in the jewellery redesign process. Generally, customers can try on a variety of jewellery in a short period of time, allowing them to make the right choice. Customers can try on jewellery remotely, changing the phenomenon of blind selection in the past and improving the accuracy of shopping.

For sellers, it is possible to create display models based on design drawings first and then make finished products when customers place orders, thereby reducing unnecessary inventory. Furthermore, the use of new technologies can increase the effective participation of customers, and the cost of model changes will always be much lower than the cost of constantly modifying the finished product.

Moreover, AR display improves the security of jewellery sellers. For the high-priced attributes of gemstones and precious metals, the utility of AR to display jewellery worn by potential customers can improve the safety of store operations while allowing customers to visualize.

Finally, the combination of the Internet and AR technology not only changes the traditional physical store business model but also enriches the online shopping experience.

3.2 Cases of AR Visual Try-on

Currently, many jewellery brands of various sizes are starting to use AR to display jewellery products and virtual workshop demonstrations. Product display is meant to promote sales more effectively. The introduction of a virtual studio is an in-depth promotion of corporate culture. When the user understands a series of processes from raw materials to transportation, design, processing, from origin to window display, the finished product is finally perfected through the joint efforts of countless people. This allows users to resonate with culture and life experience during the understanding process, fostering a sense of identity with brand values. This project takes the demonstration applications of Swarovski and Van Cleef & Arpels as examples.

Swarovski

Swarovski is a well-known jewellery brand mainly researching and developing man-made crystals known as crystal glass. It uses an app called Swarovski SPARKLE AR as a virtual jewellery display. At the same time, it also introduces an AR display used in the store. On the large screen, the Swarovski app will virtually display superimposed images of its own products so that customers can see themselves wearing the finished product. Customers can try on a variety of different styles of jewellery without physically wearing it. This can not only enhance perception but also increase entertainment for customers who come to the store in person, providing a more pleasant shopping experience.

Additionally, the Swarovski app also provides more product interaction functions. When customers use their smartphones to select a piece of jewellery, they can choose to watch the product from different angles. Simultaneously, they can also choose to read the introduction and basic information of the product, helping customers make clear comparisons and choices. The Swarovski app also supports social platforms, allowing customers to share virtual images of the jewellery they wear using smartphones and tablet computers. In an era where everyone can be a self-media creator, there are plenty of sharing and advertising opportunities [16].

Van Cleef & Arpels

Founded in France in 1906, Van Cleef & Arpels is a high-end jewellery company. The famous four-leaf clover theme comes from this brand. Van Cleef & Arpels uses an AR app called Van Cleef & Arpels VR. The Van Cleef & Arpels APP combines AR display technology and 360 photography technology to bring customers unparalleled virtual visual effects.

Like the function of the Swarovski APP, the Van Cleef & Arpels APP also uses AR displays in the store when launching the APP. AR virtual overlay processing technology allows customers to try on jewellery and display it on the large screen in the store, providing an intuitive visual perception. Simultaneously, the Van Cleef & Arpels APP has established an AR product catalogue. By scanning the catalogue with a smartphone, customers can virtually superimpose and display the appearance and basic information of jewellery from different angles.

What sets the Van Cleef & Arpels APP apart from other jewellery brands' apps is that it also created an AR display of the virtual studio to show customers the working environment and the production process of the product. Customers can use their smartphones to access a virtual studio, participate in space navigation, and interact with related products. The unique participation experience deepens customers' understanding and resonance of the jewellery creation process, providing customers with not only a sales act but also a more engaging experience [17].

Table 2 illustrated different from available systems, AR-Enable products information, a virtual show-room and purchasing via APP between Swarovski and Van Cleef & Arpels APP. Both applications are similar to each other except for Swarovski can't visually be tried on but can purchase from online.

Table 2. Comparison of the APPs

	Swarovski APP	Van Cleef & Arpels APP
APP Name	Swarovski Sparkle AR	Van Cleef & Arpels VR-AR
Available	iOS, Android	iOS, Android
AR-Enblad catalog	Yes	Yes
AR-Enblad products information	Yes	Yes
A Virtual show-room.	No	Yes
Buy via APP	Yes	No

4 Solution and Implementation

When installing Unity and Zappar applications for the project, one needs to tailor the installation selections according to the client's specific requirements. Typically, applications compatible with Windows, Android, Linux, and iOS systems are available. Choose and install them through Unity Hub as per the project's specifications. All required programs have been installed in this project, with the exception of the iOS series programs.

4.1 AR Development Platform Introduction

Apple's ARKit platform specializes in creating AR experiences for iOS devices, such as iPhone and iPad. ARKit uses advanced computer vision algorithms to track the device's position in real-time and overlay digital content onto the real world. Google's ARCore creates AR experiences for Android devices. ARCore uses advanced computer vision algorithms to track the device's position in real-time and overlay digital content onto the real world, similar to ARKit. Unity is a popular game development engine that can also be used to create AR experiences. It provides a wide range of tools and features that allow developers to create interactive and engaging AR experiences. Vuforia is an AR development platform that specializes in image recognition, allowing developers to create AR experiences triggered by specific images.

Target AR Platform	AR SDK	Development Platform	
		Window 10	Mac OSX
Android	Vaforia	Yes	Yes
Android	ARToolkit	Yes	Yes
Android	ARCore	Yes	Yes
iOS	Vaforia	No	Yes
iOS	ARToolkit	No	Yes
iOS	Apple ARKit	No	Yes
OS X Develop	Vaforia	No	No
OS X Develop	ARToolkit	No	Yes
Windows Desktop	Vaforia	(as UWP)	No
Windows Desktop	ARToolkit	Yes	No
Windows Hololen	Vaforia	Yes	No
Windows Hololen	MixedRealityToolkit	Yes	No

Figure 10. AR Platform, SDK and Systems [18]

Figure 10 introduces the applicable AR SDKs on different development platforms, which are used when installing different applications. Android and Vuforia, ARToolkit, ARCore can be installed on Windows 10 and Mac OSX systems. iOS and Vuforia, ARToolkit, Apple ARKit are only applicable to the MAX OSX system. Window Desktop and ARToolkit, Vuforia, MixedReality Toolkit can only be installed on Windows 10 systems. Before running the AR SDK on different systems, it is necessary to further configure the computer so that the system can work normally.

4.2 Installation and Configuration

This project used computer for Window 11, ARCore, AR Foundation, XR plug-in Development kits, which is equipped with Unity, Zapper platforms. And mobile phone for Android 13,

1) Install Unity Hub from www.unity.com, download the latest version of Unity 2022.3.19f1 (LTS) and install it. Figure 10. Shows installed 1 versions of Unity. LTS is Long Term Support which recommended to use and provide stable support for project. [19]

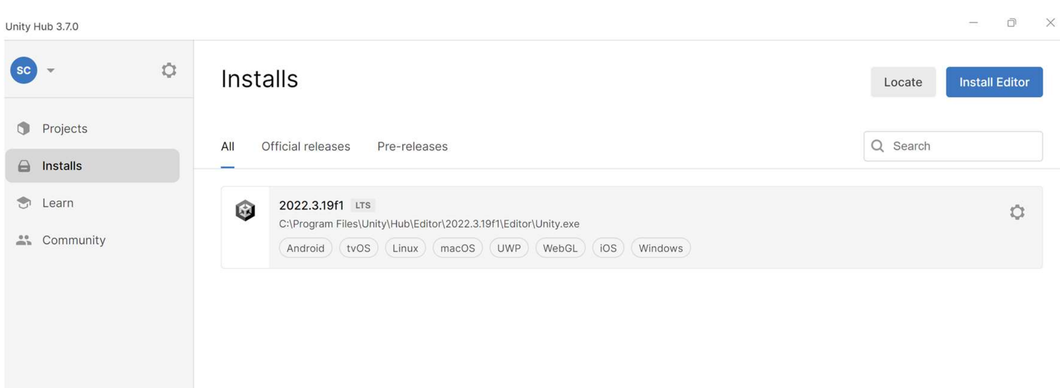

Figure 11. Installs view from Unity Hub

Turn on Unity: Project---New Project---Create a project with AR model, named MyProject(9).

Next to Toolbar: Window---Package Manager: (left corner) click‘+’, and Add package from git URL: https://github.com/zappar-xr/universal-ar-unity.git, Figure 12 shows packages in Project. Add package from git URL. Also, make sure installed the newest version for Universal AR.

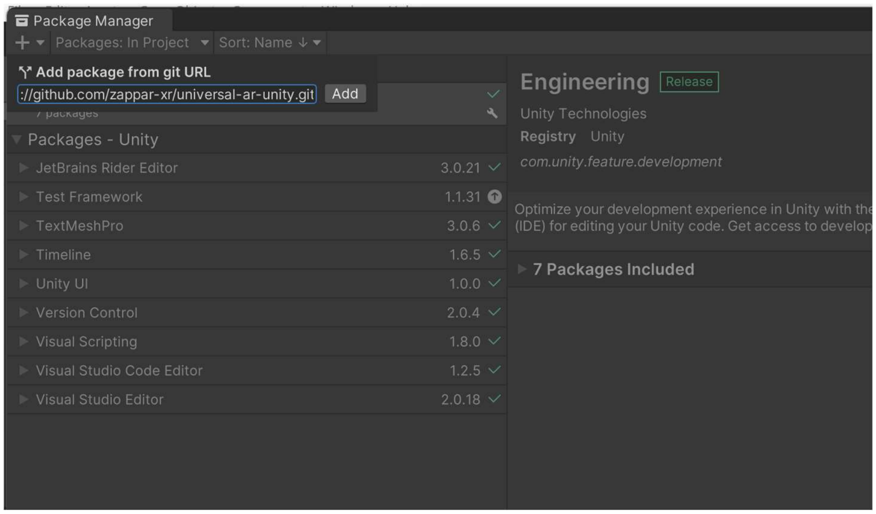

Figure 12. Add package from git URL.

Check the necessary files which are included: Window-Package Manager: to verify the packages had included: ARCore, AR Foundation, XR Plug-in, Uniersal AR (Zappar Universal SDK).

Check the necessary configuration are included: Figure 13 show some configurations in Window-Edit-Project Setting - Player. In this project choose Graphics APIs: OpenGLES3, and remove Vulkan if this is exist here.

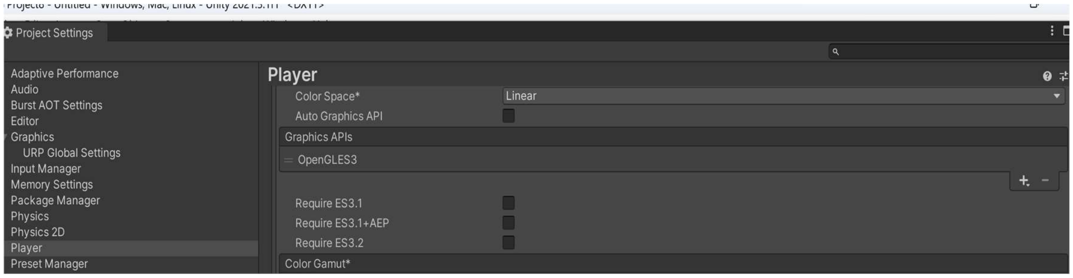

Figure 13. Configuration in Project Setting Graphics.

As Figure 14 shows for Identification-Minimum API level, choose Android 7.0 ‘Nougat’(API Level 24). For configuration-scripting backend choose IL2CPP.

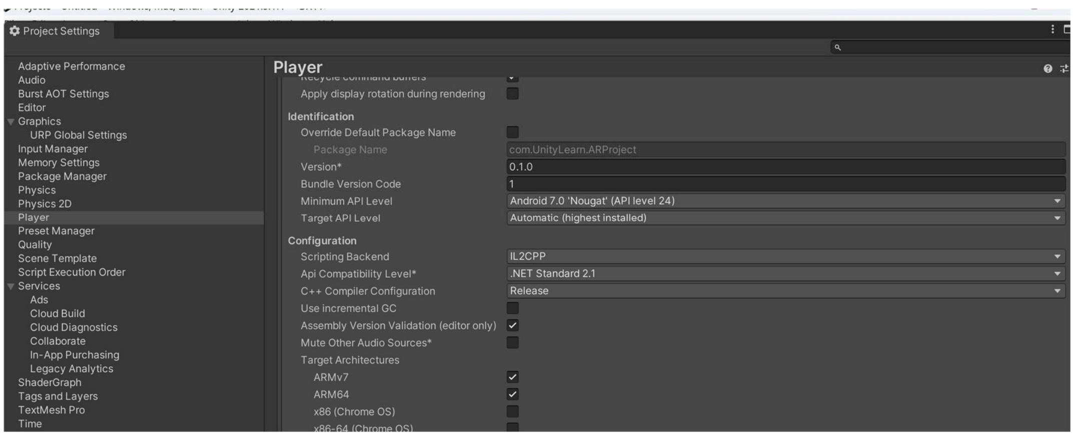

Figure 14. Configuration in Project Setting Identification.

4.3 Construction

When user opens Unity project, firstly there should create new scenes with a sample one and set up a new file name.

1. File---New scenes---save as: AR_LogoEarrings.
2. Delete Main camera,
3. Clicked Zappar on ToolBar:
   - Zappar camera, click to add a Zappar camera rear.

- Clicked Zappar Face Tracking to added a Zappar Multi Face Tracking Target. A subtitle Zappar Face Tracking Anchor 0, Zappar Full head model and Zappar Full head Depth the Mask as child components established.
- Clicked Zappar Face Tracking to added a Zappar Face Mesh. Drag it as subtitle under Zappar Face Tracking Anchor 0.
- Right clicked in Hierarchy, find 3D Object to choose Cube named RigdBody, as Child components under the Zappar Face Tracking Anchor 0.
- Right clicked in Hierarchy, find 3D Object to choose Cube named LeftEarring and RightEarring, as Child components under the Zappar Face Tracking Anchor 0.

4. From Assets (ToolBar) choose Import New Assets to import materials and Earrings 3D model(.fbx).
5. Configuration for all of objects in Inspector shows below.
    - Zappar Multi Face Tracking Targe: As a Figure 15 shows set Anchor List number is 1, Element0 is Zappar Face Tracking Anchor0.

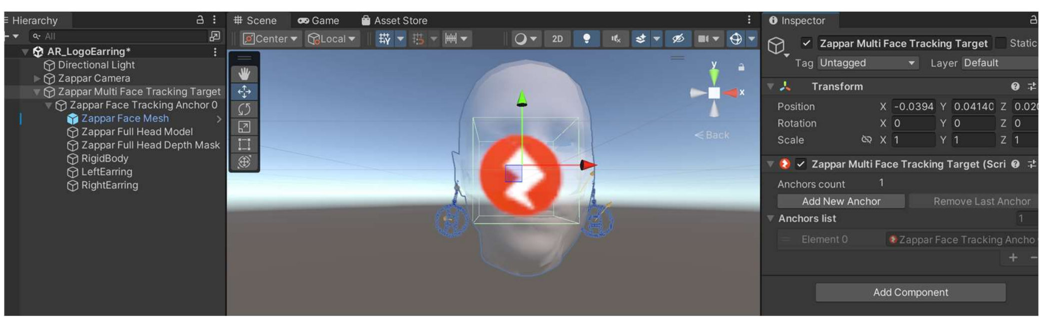

Figure 15. Configuration for Zappar Face Tracking Targe.

- Zappar Face Mesh: Script choose ZapparFaceMeshTarget, choose Use Default Face, Face Material import Transparent material, Face Tracking Anchor choose ZapparFace TrackingAnchor0.
- Zappar Full Head Mode: Script choose Zappar Full Head Model, Head Material import Transparent material.

- Zappar Full Head Depth Mask: Script choose Zappar Full Head Depth Model, Head Material import Depth Mask material.
- Figure 16 shows setting for Rigdbody. Set for LeftEarring: Import earrings .FBX file to 3D Model folder. Drage 3D file to Mesh filter and adjust earring's size and direction.

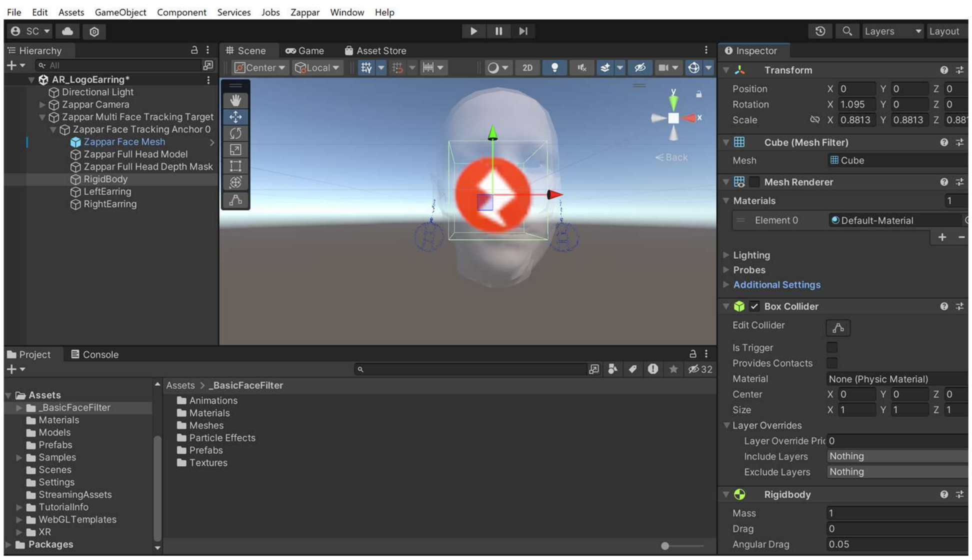

Figure 17. Configuration for RigdBody.

6. As Figure.17 shows a Scenes view and a Simulation view (Game view) of project during construction.

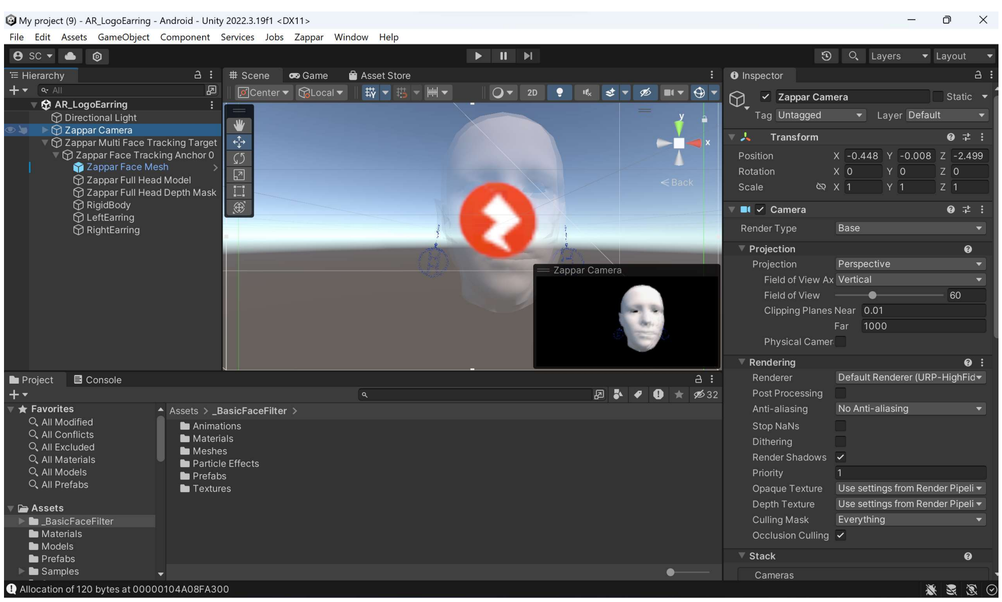

Figure 17. A Scenes from camera.

7. Set a Scripts for Zappar Multi Face Tracking Target Tracking.(Test it , sign script to Zappar Multi Face Tracking Target if needed)

```
using UnityEngine;
using UnityEngine.XR.ARFoundation;
using UnityEngine.XR.ARSubsystems;

public class FaceTrackingEarring : MonoBehaviour
{
    public ARFaceManager faceManager;
    public GameObject leftEarring;
    public GameObject rightEarring;
    private ARFace currentFace;

    void Start()
    {
        if (faceManager == null)
        {
            faceManager = FindObjectOfType<ARFaceManager>();
        }
    }

    void Update()
    {
        var faces = faceManager.trackables;
        foreach (var face in faces)
        {
            if (face.trackingState == TrackingState.Tracking)
            {
                if(currentFace != null)
                {
                    return;
                }
```

```
            currentFace = face;
            InstantiateEarrings();
            leftEarring.transform.position = currentFace.leftEar.position;
            rightEarring.transform.position = currentFace.rightEar.position;
        }
    }
}

void InstantiateEarrings()
{
    leftEarring = Instantiate(leftEarring, Vector3.zero, Quaternion.identity);
    rightEarring = Instantiate(rightEarring, Vector3.zero, Quaternion.identity);
}
}
```

8. Connected PC to a smartphone:

I. PC Part:

Figure 18 shows illustration of Build setting in computer part, selected Android and switch platform, and refresh the Run Device part to find right remote mobile phone.

- File--Build settings: Add Open Scenes (remove the older scene)—Choose Andiord —Switch platform.
- Save AR_LogoEarrings.akp to a folder.
- Refresh—and find a phone’s name, click it.

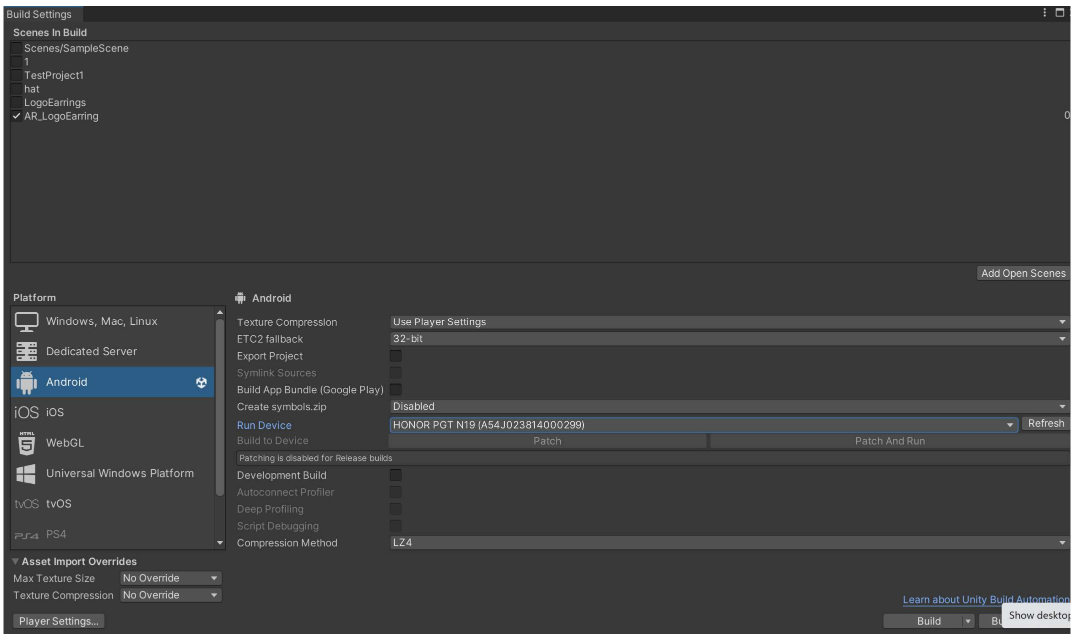

Figure 18. Configuration for Building Setting

II. Phone（This project use smartphone with Android version is 13.0）

- Download Unity Remote to Android phone from Google Store When project connected to the phone, a screen directly shows it(Shows in Figure 19).

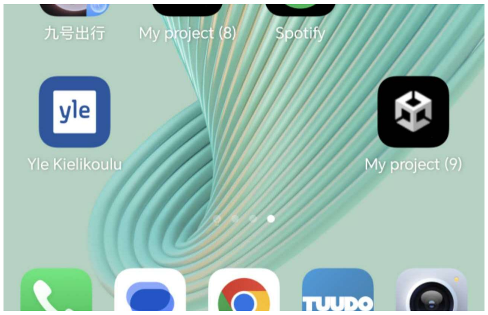

Figure 19. Unity Remote view from the smart phone

- Use USB cable connect PC to phone, enter Developer model (Phone：Setting---System—About phone or System--Version No., (click Version No., 7 times, then screen shows going to the Developer model).
- In the developer model:

  1）Turn on Developer Model,

  2) Turn on USB test, support ADB, which shows in Figure20 Developer Option (system will ask the permission to allow use it).

Figure 20. Developer Option

9. A running results automatically showed on the phone’s screen when system found right remote device as shown in the Figure 21. The project saved into phone even turned off the computer system.

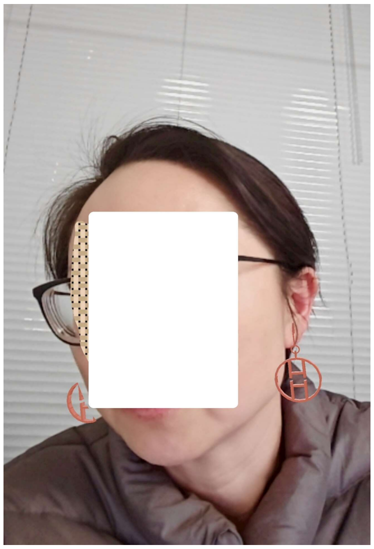

Figure21. Running results shows on the phone's screen.

4.4 Optional Plan

Here is another plan to use Zapworks Designer to finish this project. After registering and logging into Zapworks (which should go through from ZapStudio to Zapworks Studios), choose Zapworks Designer, create a model platform, import a 3D model, adjust it, and publish it. Figure 22 shows the Zapworks Designer Project setting page to choose a model that the customer prefers.

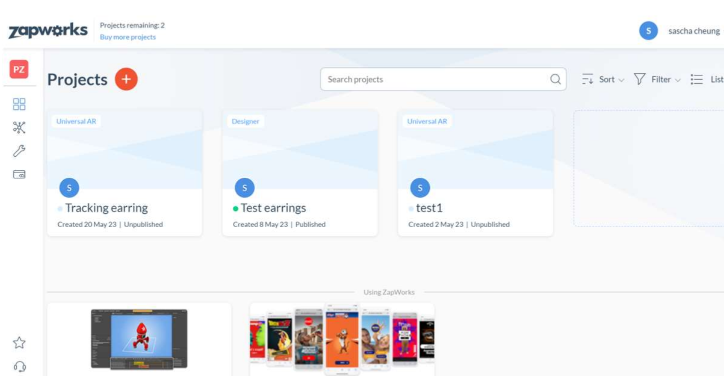

Figure 22. The Zapworks Designer Project Setting Page.

After selecting the model, photograph the object and adjust it as shown in Figure 23. At the same time, convert the QR code to scan and check the last image. This function also supports deep links to the face tracking project.

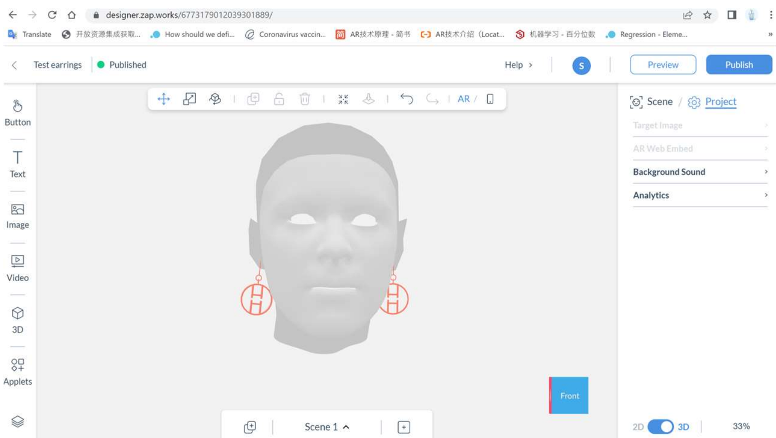

Figure 23. The Zapworks Designer modify page.

5 Results and Analysis

After project configuration and debugging, the final rendering effect on the mobile phone is shown in Figure 24. Two mobile phones were used in the project test on the mobile systems of Android 13. Both of them can display imaging in the end. Android 13 is used to connect to the PC for Unity-Zappar test. The testing QR Code image was scanned by the same device.

The platforms used in this project are Unity and Zapwork. Unity is a powerful 2D and 3D game engine, with different versions released every year or even every few months. The innovation, compatibility, and powerful rendering capabilities of Unity are excellent. The AR Visual Try-on used here is just a small part of the functions of Unity. Unity endows the scene with composition from different perspectives, making GameObject more vivid and detailed. For the cross-platform development of AR and XR, Unity has developed a huge function database for users.

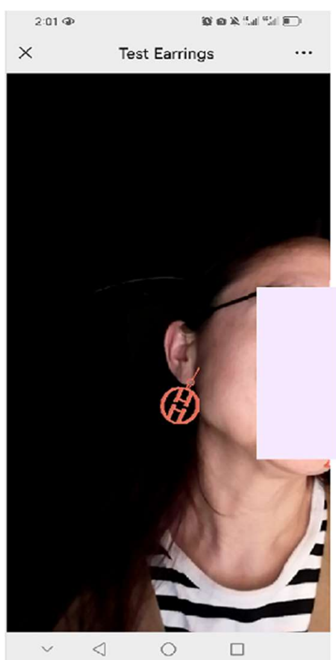

Figure 24. Visual Try-on.

The formidable capabilities of Unity can pose challenges for users. Proficiency in utilizing all of Unity's functions necessitates a sustained and comprehensive learning effort. This demands not only mastery of the application software but also a proficient understanding of programming. For individuals who are not professional game designers or experienced Unity users, the investment of time and energy required to effectively employ Unity in projects can be considerable.

For Zappar, its volume and functions are not as large as Unity, but its interface design is friendly and simple. At the same time, Zappar Unity can also improve the integrity of the entire project through coding. Zappar is a compatible platform that can be embedded into Unity. Its lens, scene, and character settings are far less complicated than Unity, but Zappar can quickly solve many problems. For example, it is suitable for jewellery designers to use the model directly. From building the model to releasing the finished APP, Zappar can quickly complete the project.

By this project, Zapwork can be prepared as an experimental model for initial moulds and pre-production releases. To create a model that conveys detail and accuracy, Unity is the better choice.

The 3D models and other jewellery materials used in the test were sourced from W&Z Design Studio. Creating different 3D models for numerous jewellery styles was a significant undertaking. The jewellery types included earrings, necklaces, bracelets, and rings. Face recognition technology in AR was exclusively used in this project, employing Unity's Default Face for tracking and distribution. Simultaneously, in conjunction with Zappar's Multi Face Tracking Target, an anchor point was added to the face recognized by the camera, and the 3D model of the earring was displayed on the earlobe after face recognition.

To achieve this, first define an empty game object as a subcomponent of the Zappar Multi Face Tracking Target. Subsequently, the Zappar Face Mesh, Full Head Model, Full Head Depth Model, and 3D models are added as child components of the empty game object. This project uses Unity 2022 version. In the scene, Directional lights were used and a Zappar Camera was added. Finally, in the testing part, an Android phone is used as the output display device. And please make sure that the physical camera on the computer has been given permission to use.

6 Summary and Conclusions

This project aimed to solve the problem how W&Z Design Studio can display jewellery and achieve diversified advertising, under the premise of increasing safe sales and saving costs. Furthermore, when offering customized services, AR was employed to create prefabricated models, allowing customers to visualize the effect and size after wearing. After the Covid-19 epidemic, improving the online shopping experience has become more urgent. As a member of the company, the successful implementation of this project has enhanced the customer's shopping experience and expands the display effect of jewellery. This project has increased economic benefits and brand value.

In this project, both joint platform and single platform testing and usage methods were employed. Various devices were used for connection testing in this project. After testing, jewellery was tried on in the store (LAN) and tested with three randomly selected customers. All tested mobile devices were Android phones. Further testing is needed to assess the security and stability of the network. This project primarily utilized Unity and Zappar, as well as a standalone Zappar platform.

The most significant finding in this project was the successful completion of an AR Visual Try-on using Unity and Zappar. Throughout the project, diverse software applications were employed across platforms, ultimately running on various hardware devices. It's notable that the comprehensiveness and power of the application directly correlated with the time and energy invested in its implementation. In scenarios requiring swift project completion, certain functions of the application might need to be dismissed.

Moreover, the research on applied technology and the meticulous evaluation of image integrity played a pivotal role. This research not only contributes to understanding how the applied technology functions but also aids in predicting and narrowing the gap between initial design sketches and their practical implementation.

Augmented Reality (AR) blends the real and virtual worlds, simplifying interactions and presenting significant opportunities for various industries. While AR can offer numerous benefits for jewellers, there are potential disadvantages to consider, including cost, technical complexity, user experience, accessibility, and maintenance.

Implementing AR displays can be expensive, particularly for smaller jewellery businesses with limited resources. Setting up and managing AR displays requires specialized skills, and jewellers may need to hire additional staff or outsource work. Although AR displays provide an immersive shopping experience, accurately conveying the weight of jewellery may be challenging. Compatibility issues with smartphones or tablets could limit the reach to certain customers. Additionally, ongoing maintenance and updates are necessary to ensure AR displays function properly, adding complexity and cost to their implementation.

When actually trying on jewellery, from a technical point of view, the high-tech display solves the problem of safe sales of precious jewellery in certain aspects. From the perspective of customers, it should increase sales participation and publish user experiences to the social circle at the same time. The starting point of wearable smart devices is to explore the way of interaction between people and technical solutions and provide everyone with exclusive and personalized services. The calculation method of equipment should also be implemented in the cloud service and on the client's device. Only in this way can the customer's personality be accurately defined and perceived, rather than relying on institutionalized data models. Only this unique and exclusive data design can discover the truly meaningful needs of customers. However, AR not only appears in books, but also in our lives.

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