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Final Thesis Dissertation
MSc Digital and Interaction Design
Supervisor: Prof. Margherita Pillan

How Augmented Reality redefines interaction design in mobile games



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Abstract

In recent years, Augmented Reality technology (AR), with the advancement and popularization of smartphones, has made AR available to public. Entertainment and games are two captivating proscenium of AR. AR and Mobile Game both use Smartphone as the main device. AR has changed the definition of ordinary virtual games. AR brings virtual content into the real world to giving mobile games a refreshing experience and more creative design opportunity.

This thesis will discuss How Augmented Reality redefines interaction design in mobile games— what makes AR unique to mobile games. The purpose is to help mobile game designers avoid problems by finding out the differences between AR interaction and general game interaction, and make use of AR's characteristics for game innovation. Since AR mobile games are interactive on the move and in real space, the situation is different from virtual games that interact on a 2D screen. Firstly, by summarizing the working principle of AR, we understand the technical characteristics of AR. Use these features to find design points that are different from regular game interactions. Then bring these characteristics into the comparison between AR and VR to find out the unique role AR plays in mobile game design. Use Storyboard, Experience Map and other tools to make Case Study and see how AR works in a specific business case. And verify the characteristics of AR and the compatibility between AR and mobile phones. In the end, I combined with the above AR mobile game characteristics and development direction to discusses the future development trend of AR based on natural interaction (NUI). Summarize the design principles to help game designer ensure that AR has a unique performance in mobile games.

Abstract: Negli ultimi anni, la tecnologia della Realtà Aumentata (AR), con il progresso e la divulgazione degli smartphone, ha reso l'AR disponibile al grande pubblico. Intrattenimento e giochi sono due accattivanti prosceni dell'AR. L'AR e i giochi per dispositivi mobili utilizzano entrambi lo smartphone come dispositivo principale. L'AR ha cambiato la definizione degli ordinari giochi virtuali, portando i contenuti virtuali nel mondo reale per offrire ai giochi per dispositivi mobili un'esperienza rinfrescante e un'opportunità di design più creativo.

Questa tesi discuterà come la Realtà Aumentata ridefinisce il design dell'interazione nei giochi per dispositivi mobili e cosa rende l'AR unico per gli stessi. Lo scopo è aiutare i progettisti di giochi mobili a evitare problemi scoprendo le differenze tra l'interazione AR e l'interazione generale di gioco, e utilizzare le caratteristiche dell'AR per portare innovazione nel mondo dei giochi. Poiché i giochi mobili AR sono interattivi, in movimento e situati in uno spazio reale, la situazione differisce dai giochi virtuali che interagiscono invece su uno schermo 2D. In primo luogo, riassumendo il principio di funzionamento dell'AR, ne comprendiamo le sue caratteristiche tecniche. Verranno usate queste funzionalità per trovare punti di progettazione diversi dalle normali interazioni di gioco. Quindi verranno portate queste caratteristiche nel confronto tra AR e VR per scoprire il ruolo unico che l'AR gioca nella progettazione di giochi per dispositivi mobili. Verranno usati Storyboard, Experience Map e altri strumenti per creare case study e vedere come funziona l'AR in un business case specifico. Verranno verificate le caratteristiche AR e la compatibilità tra AR e telefoni cellulari. Infine, ho combinato con le caratteristiche del gioco

mobile AR di cui sopra la direzione di sviluppo per discutere la futura tendenza di sviluppo dell'AR basato sull'interazione naturale (NUI). Verranno riassunti i principi di progettazione per aiutare il game designer a garantire che l'AR abbia prestazioni uniche nei giochi per dispositivi mobili.

Introduction

Motivation:

Augmented Reality (AR), as a novel form of visual expression of smartphone, began to enter the public eye in when Apple released AR Kit in 2017. But because the technology of AR was not stable at that time, AR seemed to disappear for a while after that. Around the recent launch of ARKit2, AR has frequently appeared in the entertainment space such as social software and mobile games. As a UI designer of mobile game, I am eager to apply this novel way of expression into the design of more mobile games. The main motivations are as follows:

- **First, the market demand:**

In recent years, the functions of smart phones have developed rapidly, and the hardware performance and software optimization of mobile phones have been greatly improved. Smartphones are also becoming extremely popular. In 2019, global smartphone shipments reached 1.373 billion units; In the first quarter of 2020, 276 million smartphones were shipped worldwide. In 2020, though it fell slightly, sales reached 1.34 billion units. (Digitimes Research 2020 Global Smartphone Shipments Report.)

Such an environment creates conditions for the game market to expand. Games 2020: \$174.9 billion in revenue, up 19.6% year over year. Among them, mobile game accounted for 49% (console 29%, PC 22%), an increase of 25.6%.

Such a surge in revenue has intensified the competition in the mobile game industry, and the number of new development projects for mobile game has soared. The demand for personalization has increased, and the demand for how to make mobile game more interesting and richer experience has become more urgent. Due to the gap in picture quality between mobile phone performance and computer performance, as well as the limitation of interaction, innovation requires new ways of interaction and expression.

Augmented Reality technology skillfully integrates virtual information with the real world. After simulating computer-generated text, image, three-dimensional model, music, video and other virtual information, it is applied to the real world. The two kinds of information complement each other, so as to realize "Augmented" to the real world. Because the AR graphics can be paired with the real world in countless ways, each game is meant to be as different to the player as possible. After Apple added AR game category in 2019, according to data released by Sensor Tower, an app market research company, AR game downloads reached 53% of all ARKit apps,

accounting for 62% of all AR app revenue, making it the content type with the largest proportion. It can be seen that people are very enthusiastic about the concept of AR.

- **Secondly, AR has high usability, which is convenient for designers and users to use and understand:**

As mentioned at the beginning, there are a lot of problems with AR technology in 2017. In recent years, AR performance has become mature. In addition to Apple, Google, Facebook and other major companies have successively invested in AR research and development. In previous years, AR was only available on iOS. AR system is unstable and has many bugs. AR causes phone body overheating, development cost and other problems. Nowadays, with the rapid improvement and popularization of the performance of smart phones, these problems have been gradually solved. AR went from being a mere gimmick to being able to make steady use of technology in games.

Now the release of Arkit2, ARCore update, the overall capability is greatly enhanced. Android system can also be fully equipped with AR system, AR optimization bugs are reduced, computing efficiency is improved, and mobile phone performance is enhanced to relieve heat problems. AMES Semiconductor, a provider of sensor solutions, has released the industry's first 3D DTOF solution for Android. It integrates AMS '3D optical sensor with ArcSoft imaging software to achieve more immersive augmented reality functions, which will further promote the popularity of AR. Compared with VR, AR requires simpler and lighter equipment. VR requires heavy VR headsets and lots of equipment. AR, on the other hand, is available with a smartphone that almost everyone has, portable and accessible.

- **Social Needs and Habit Changes—Online Life and Stay at Home**

Due to the rapid development of smart phones, people's living habits have changed a lot. People can solve basic problems of clothing, food, housing and transportation by using mobile phone Apps and online services. It brings convenience to people, but also brings physical and mental problems that people do not like to go out (Outdoors). However, on the one hand, AR can motivate and push people to explore the outdoors by combining location base technology like Pokemon Go, so as to make people Go outside. AR can also make the existing convenience of APP more vivid and concrete through the function of augmented reality. Especially after the global COVID-19 epidemic in 2020, the confined environment of home isolation can make the confined space vast and interesting. In this part, AR also provides great imagination space and design opportunities for designers. Now in 2021, when Apple had planned to release its AR glasses, there's a great opportunity for AR mobile gaming.

Goal:

The development of mobile game will have a positive impact on the development of mobile AR games, reduce the cost of users' understanding, and also bring some challenges.

The current development of AR also makes AR become a tool that is no longer limited to large companies or can only be used with abundant funds. Designers should understand the latest AR technology and development status, understand the optimization degree of AR and the bearing capacity of modern smart phones.

At present, the application of AR in interactive games is just the tip of the iceberg. By learning and discussing various knowledge and applications of AR, we can establish the connection and possibility of interactive application with games. This allows game interaction designers to understand the uniqueness of AR. Interfaces with real depth also require an understanding of the AR interface's unique points when designing the AR interface. The purpose of this paper is to show the current development and application of AR technology in the mobile game industry, analyze the advantages and disadvantages of cases study, and explore the potential of using AR technology and developing AR for interaction designers in their projects. In short:

Let game interaction designers understand AR to promote AR applications in mobile games.

Helps the UI/UX designers of AR Mobile games to provide ideas and avoid possible mistakes.

Help AR mobile game designers to provide more interesting interactive experience for players.

In the design of AR mobile game, the first thing to solve is how to reflect the value and differences of AR. This paper will focus on the differences of AR, the relationship between AR technology and game interaction design, in order to find the value of AR for mobile game. That is, How Augmented Reality redefines interaction design in mobile games.

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Chapter 1

Introduction to Augmented Reality

What is AR(Augmented Reality) and What is AR game. Definitions, functions, and application areas commonly used in the digital media industry. The difference between AR games and non-AR games, the types of AR games currently available.

1.1 What is AR(Augmented Reality)

1.1.1 Definition

Augmented Reality (AR) technology is developed from virtual reality(VR) technology and was first used in the military field. In recent years, due to the popularity of smart phones and the performance enhancement of smart phones, AR has set off a second wave of enthusiasm, and today's era is mainly related to the concept of interactive. With the application of AR in social life and entertainment industry, AR technology has gradually entered the daily life of the public. The most common AR is probably the various camera filters in various camera apps and social apps, or the markings on the track in sports shows, but these are not strictly AR technologies.

As early as 1990, the term augmented reality was officially born. Tom Caudell and David Mizell used the term augmented reality for the first time in the paper "Augmented reality: an application of heads-up display technology to manual manufacturing processes". (Huffington 2010)

Augmented reality (AR) is an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated perceptual information, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory and olfactory. (Schueffel & Patrick 2017)

After visualizing the virtual information with 3D and other technologies, AR superimposed the virtual information into the real world, so that the virtual information and the actual environment appeared on one screen. (Schueffel & Patrick 2017)

Currently, there are two common definitions of AR:

AR can be defined as a system that fulfills three basic features: (Ronald Azuma 1997)

1. A combination of real and virtual worlds
2. Real-time interaction
3. Accurate 3D registration of virtual and real objects.

(Wu,Hsin-Kai & Lee,Silvia Wen-Yu & Chang,Hsin-Yi & Liang, Jyh-Chong 2013)

Milgram's reality-virtuality Continuum was proposed by Paul Milgram and Fumio Kishino in 1994: They treat real and virtual environments as two ends of a continuous system, and the one in between is called "mixed reality". Among them, Augmented Reality is close to the real environment, while Augmented virtual environment is close to the virtual environment.(P. Milgram & A. F. Kishino 1994)



FIG 1 P. Milgram and A. F. Kishino, Taxonomy of Mixed Reality Visual Displays,1994

The overlaid sensory information in AR can be constructive (i.e. additive to the natural environment), or destructive (i.e. masking of the natural environment). In fact, the difference between these two definitions is not big. Both of them highlight a feature of AR, which is the **combination of virtual and real**. Both of these definitions are criteria that help us tell whether a technology is AR or not.

AR is used to improve a natural environment or situation and provide a perceptible rich experience. With advanced augmented reality technologies (for example, adding computer vision and integrating augmented reality cameras into smartphone apps and object recognition), information about the real world around the user will become interactive and digitally processed. Information about the environment and its objects is overlaid in the real world. This experience is seamlessly interwoven with the physical world such that it is perceived as an immersive aspect of the real environment.(Rosenberg & Louis 1992) In this way, augmented reality alters one's ongoing perception of a real-world environment, whereas virtual reality completely replaces the user's real-world environment with a simulated one.(Steuer 2018)

AR integrates virtual data into the real world through technical means, or blocks some scenes in the real world (Such as Google instant translation), so that the exquisite information of virtual and real can complement each other, enhance the visual experience and spatial perception of users, and strive to create immersive feelings.

1.1.2 Application field and development trend

While AR was originally used in the military, augmented reality applications have since spanned the commercial sector, from gaming and entertainment to medicine, education and commerce, and augmented reality has been explored in many applications.To help us understand AR by understanding its application in other fields. We can roughly see some features of AR: it is usually used on mobile devices; it has strong guidance and is often used in education and training of various industries; it is good at reproducing virtual scenes in reality; and it is commonly used for remote operation of unmanned automated machines(FIG 12):

① **architecture/decoration/urban construction and planning/archaeology**

This kind of application field is in the limited space of different sizes, using AR and 3D model technology to preset the internal layout of the space in advance, which is convenient for users to plan and view the layout at the minimum cost and with the minimum impact on the space(FIG 2).

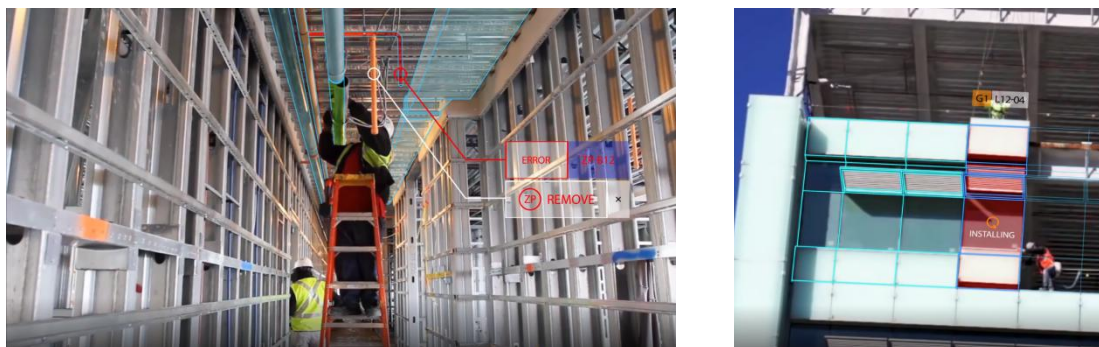


FIG 2 AR construction assistant (Onesight Shanghai official Web)

With continual improvements to GPS accuracy, businesses are able to use augmented reality to visualize georeferenced models of construction sites, underground structures(FIG 3), cables and pipes using mobile devices. (Churcher & Jason 2013) AR is applied to present new projects, to solve on-site construction challenges, and to enhance promotional materials. (Lee & Gun 2012)



FIG 3 Augmented Reality Apps For Architects: SmartReality (Hallie Busta 2015)

② Education/training/industrial manufacturing

The education and entertainment fields should be the areas where the "Augmented" features of Augmented Reality are most reflected. Pictures enhance words, teachers enhance books, and AR can enhance the interaction between learners and knowledge. AR has been used to complement a standard curriculum, making the contents to be learned more vivid and easy to understand.

As AR evolves, students can participate interactively and interact with knowledge more authentically. Instead of remaining passive recipients, students can become active learners, able to interact with their learning environment. Computer-generated simulations of historical events allow students to explore and learning details of each significant area of the event site. (Lubrecht & Anna 2012) AR real-time interactive features in the process of learning to let these complementary knowledge can be students interaction(FIG 4), in the actual training to the operation of the students in the form of superposition of the real-time guide to replace the drillmaster's verbal instructions and notebook, when training students more easily immersed in the process of training, more convenient and impressive. Chemistry AR apps allow students to visualize and interact with the spatial structure of a molecule using a marker object held in the hand. (Maier & Patrick & Tönnis & Marcus & Klinker & Gudron 2009)

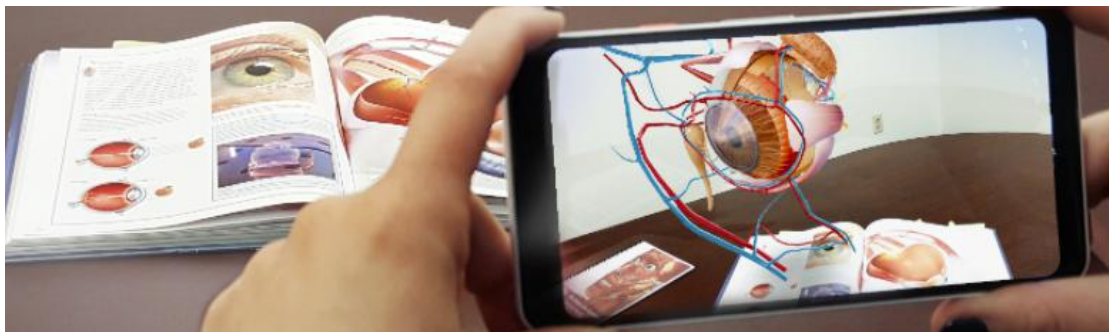


FIG 4 Human Anatomy Atlas app, "Use Cases of Augmented Reality in Education and Training"

(Victoria S.Copywriter 2019)

③ Media/commercial display/visual arts

These areas are the closest to games, because AR is a way of presenting Art, and AR is a way of presenting games. This kind of field makes good use of and gives full play to the expressive force of AR. Visual principles such as illusion are used to enhance the transmission combined with the appeal of reality. On the other hand, the interactive feature also gives full play to the advantages of 3D model. Users can view the 3D model of goods from multiple angles, and can even try on clothes, place furniture and other trial behaviors in any place with AR QR code. Users' interaction with promotional content is no longer a single one-way transmission. In 2017, Ikea announced the Ikea Place app(FIG 5). It contains a catalogue of over 2,000 products—nearly the company's full collection of sofas, armchairs, coffee tables, and storage units which one can place anywhere in a room with their phone.("IKEA's new app flaunts what you'll love most about AR" 2017)

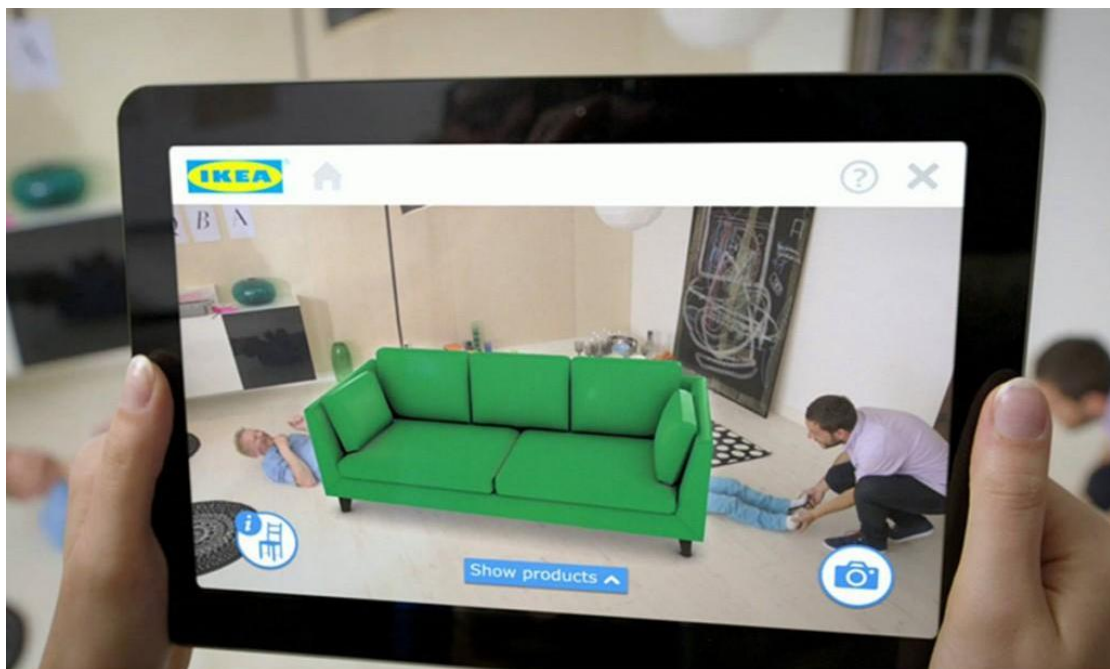


FIG 5 AR display furniture function of IKEA APP

Visual art brought by using AR immersive visual expression enhanced at the same time, also use AR interaction changes the traditional work effect on the viewer's single direction, even works between the viewer and the work of the relationship between the viewer and the interactions between the viewer and makes people the existence of a positive and as part of the works. The famous visual art team TeamLab's work "Universe of Water Particles in The Tank, Transcending Boundaries"(FIG 6) showing a waterfall from the sky to form a waterfall throughout the exhibition hall. Animation of water consists of continuous movement of countless water particles. The computer calculates the mutual effects between these water particles and the movement of these water particles depicts countless lines in space, forming a flat waterfall in the subjective space conceived by TeamLab. When the viewer stands in the work, the flow of the water flow will change the flow of the water flow, and become part of the art work. The viewer can appreciate this unique work formed by himself and others, allowing viewers to actively influence art works and other viewers. AR visual art is usually very avant-garde and experimental. Game designers could develop the art style of AR games by understanding the audience's feelings about AR visual

art. **AR visual art is the best reference for AR games.**



FIG6 Interactive Art Exhibition: "Universe of Water Particles in The Tank, Transcending Boundaries"TeamLab

④Medical / military

Medical and military also uses the advantages of Ar re-training staff and specific actual enhancements: Medical use AR remote collaborative medical treatment is more convenient, providing important information to doctors(FIG 7) or surgeons, without their sight from the patient. Recently, augmented reality has began seeing adoption in neurosurgery, a field that requires heavy amounts of imaging before procedures.(Tagaytayan, Raniel & Kelemen, Arpad & Sik-Lanyi, Cecilia 2018)



FIG 7 "AR Neurosurgical Fluorescent Receives FDA Clearance"(Kyle Melnick, 2018)

Military use AR remote operation weapons and drones greatly reduce personnel casualties and improving the hit rates of weapons, or use AR to overlay the details on the map or to show the building structure to guide tactics(FIG 8). As of 2010, Korean researchers are looking to implement mine-detecting robots into the military(FIG 9). The proposed design for such a robot

includes a mobile platform that is like a track which would be able to cover uneven distances including stairs. The robot's mine detection sensor would include a combination of metal detectors and ground-penetrating radar to locate mines or IEDs. This unique design would be immeasurably helpful in saving lives of Korean soldiers. (Kang & Seong Pal & Choi & Junho & Suh & Seung-Beum & Kang & Sungchul 2010)



FIG 8 AR military map to make tactic



FIG 9 Mine-detecting robot for Korean AR operation

⑤ Navigation and Tourism

Navigation and travel fit nicely with AR technology. After combining the 2D map with AR, the direction and depth can be changed. The superimposed information and AR guidance make the navigation more accurate and convenient, and reduce the information that the human brain needs to recognize and process during navigation. The rapid development of on-board AR navigation HUD in recent years is an obvious future trend (FIG 10). Aboard maritime vessels, AR can allow bridge watch-standers to continuously monitor important information such as a ship's heading and speed while moving throughout the bridge or performing other tasks. (Cheney Peters & Scott 2012) Similarly, AR also plays the role of navigation and introduction in tourism, which saves the labor cost of the tour guide and makes the tour more interesting (FIG 10).

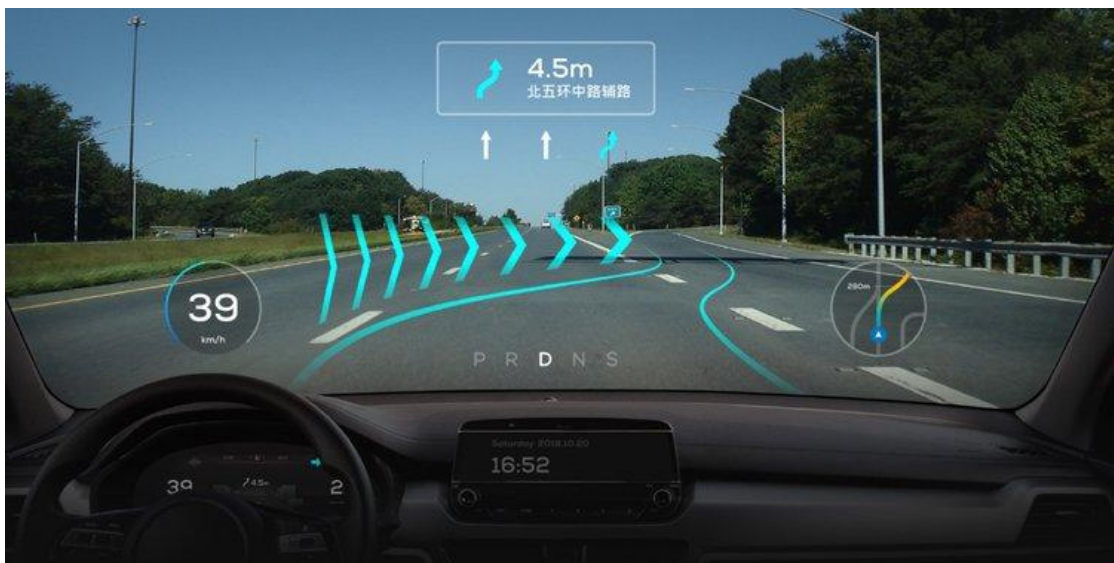


FIG 10 AR-Navigation & AR-HUD—Apollo High Speed Kilometer Autonomous Driving Solution (Baidu World 2018)



FIG 11 “How Augmented Reality (AR) is Changing the Travel & Tourism Industry” (Mrudul Shah 2019)

Location Base Service (LBS) in navigation technology is also one of the common combinations with AR.

©Virtual game

Virtual game itself can be regarded as a kind of Virtual reality. AR and VR originally have the same root. Both visual art and merchandising promote user initiative, which is what games are all about. AR technology is suitable for application in the field of games in all aspects, especially in mobile games where mobile phones can be used as AR devices. From the above fields, we can also see that the functional requirements of mobile games for AR are mainly rich vision, and the characteristic is that it tends to be immersed in realistic content(FIG 12). Next, I'll go into more detail on how AR can be used in games.

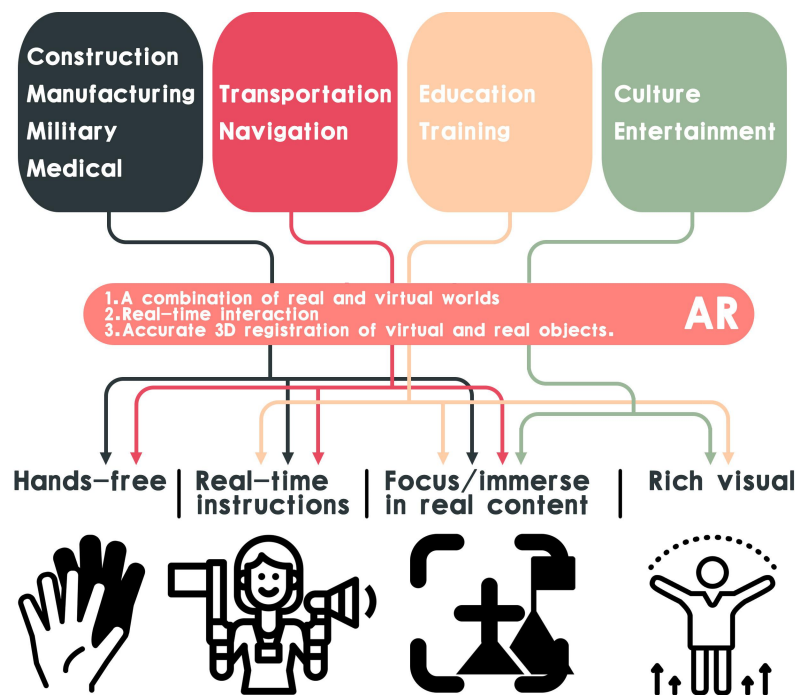


FIG 12 Functional performance of AR in various fields

1.2 What is "AR game"?

1.2.1 What kind of games can be called "AR games" and what is "AR mobile game"?

Although Apple added a AR app category to the App Store in 2017, there is no AR game category. There is no clear definition of what constitutes an "AR game" in the game industry. Therefore, this article only discusses mobile games that use AR technology in the core gameplay, and fulfills three basic AR features in the core gameplay. Here's an example: Pokémon Go satisfies Azuma's three AR criteria: the virtual Pokémon appears in the real world, the user can interact with them, and they appear fixed in space. (G. Stewart Von Itzstein 2017)

Mobile game is a video game that is typically played on a mobile phone. Historically, the term refers to all games that are played on any portable device, including from mobile phone (Feature phone or smartphone), tablet, PDA to handheld game console, portable media player or graphing calculator, with and without networkability. (Dal & Yong Jin 2017) The portability-"mobile" of a Mobile game is the key factor in determining whether it is "Mobile". Therefore, it is suitable for users to play in short and frequent "fragment time".

Therefore, mobile games that use AR technology and conform to the three characteristics of AR in the core gameplay can be called AR mobile games(FIG 13). This paper will discuss the interaction design of AR mobile game with smart phone as the main device.

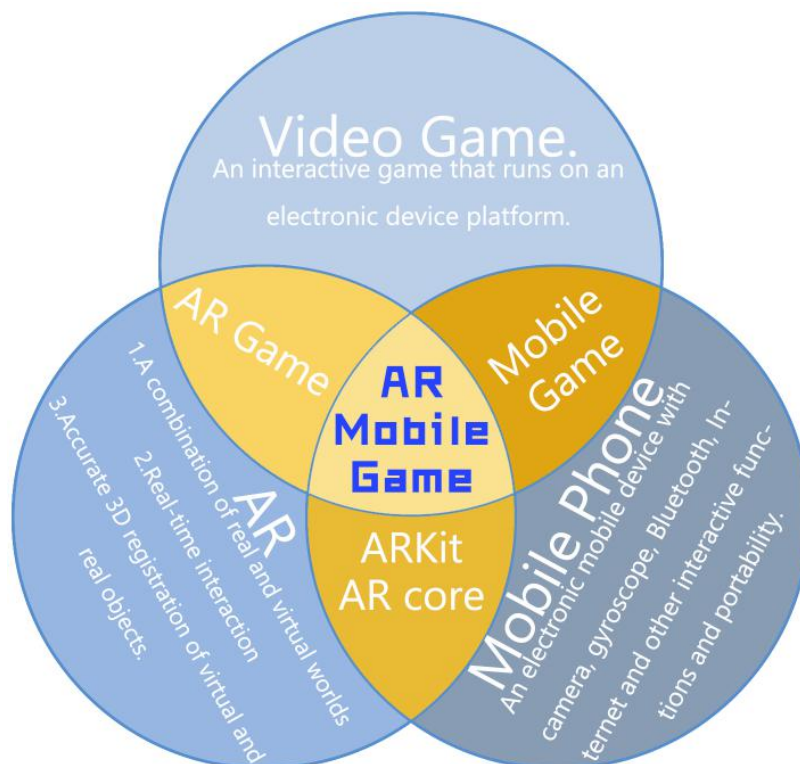



FIG 13 What is AR mobile game.

Chapter 2

Interaction pattern in AR mobile game.



Mobile game is also a kind of Mobile application, and AR is one of the display and interaction means of the application. Therefore, it is necessary to understand how to realize Augmented Reality in the application, including software and hardware technologies and how the AR system operates. Designers need to understand the uniqueness of AR and the technology available today to help us avoid mistakes and take advantage of its features to innovate.

(Since the publicity of Apple WWDC21 and the concept demo of the new AR Pokemon Go released by Microsoft and Niantic can see that AR glasses are a definite trend as AR game devices, this article will cover some knowledge of AR glasses, but not the main one. In this paper, the Interaction pattern of AR games is still discussed using smart phone as the main device.)

2.1 How AR works

Here's how AR works:

Key measure of AR systems is how realistically they integrate augmentations with the real world. The software must derive real world coordinates, independent of camera, and camera images. That process is called image registration, and uses different methods of computer vision, mostly related to video tracking. (Azuma & Ronald 2001) First by cameras and sensors for data sampling the real scene, and into the processor carries on the analysis and reconstruction, and then through the AR head show or smart camera on a mobile device, gyroscope, sensors and other accessories real-time update user space position change data in the real environment, so it is concluded that the relative position of virtual scene and real scene. Realize the alignment of the coordinate system and carry out the fusion calculation of the virtual scene and the real scene. Finally, the composite image is presented to the user. Users can collect and control signals through AR head display or interactive accessories on smart mobile devices, such as microphone, eye tracker, infrared sensor, camera, sensor and other devices, and carry out corresponding human-computer interaction and information update to realize interactive operation of augmented reality. Among them, 3D registration is the core of AR technology. 2D or 3D objects in the real scene are used as markers to match the virtual information with the real scene information, which means that the position, size and movement path of the virtual object must be perfectly matched with the real environment, so as to achieve the point of combining the virtual and the real. (Li Yanjing 2018)

Azuma's definition of AR as "a technology featuring virtual and real combination, real-time interaction, 3D registration (Recognition), and the use of additional pictures and text information to enhance the real world" can also be understood as the technology required for AR game production:

- ① To combine real content and virtual content, AR needs to have some display technologies that can be seen at the same time.
- ② To allow users to interact with virtual content, an input technology is needed.
- ③ In order to create the illusion that virtual content is fixed in the spatial tracking technology, it is necessary to use the spatial tracking technology to track and determine the user's viewpoint.

The production of AR games also revolves around these three requirements. The technical characteristics of AR also meet these three major technical needs.

2.2 AR Technical characteristics

From the working principle of AR, scholars have summarized three technical characteristics of AR:

- ① 3D registration (tracking registration technology)
 - ② Virtual Reality Fusion Display
 - ③ Real-time human-computer Interaction. (Chan QIU & Shien ZHOU & Zhenyu LIU & Qi GAO & Jianrong TAN 2019)
- As a designer, we need to have a deep understanding of these three technical features in order to do a good job in AR UI or UX design.

2.2.1 3D registration (Tracking registration technology)

The quality of the tracking registration technology directly determines the success of the augmented reality system. AR can obtain its position and shape and relationship with the real world through the computer, that is, how AR operates its position and the relationship with the real world. In order to realize the seamless superposition of virtual information and real scene, it requires the registration of virtual information and real environment in the three-dimensional space location. This includes the user's space location tracking and the virtual object's location in the real space. The position of the mobile device camera and the virtual information should be corresponding, which needs to be realized by tracking technology.

Tracking registered first test need to "enhance" tracking object, the object feature points and the contour of the feature points automatically generate 2D or 3D coordinate information.

Commonly used tracking registration methods are: based on tracker, based on machine visual tracking registration, based on wireless network mixed tracking registration technology. Smart Phone is registered primarily on Camera, which is Based on the registration of the tracker, generally there are 4 type: non-marking Ar, marked Ar, projected Ar, based on superimposed AR. The four arches will be described in detail later in this article.

2.2.2 Virtual reality fusion display

In the early stage, VR and AR were not clearly separated. However, after that, the virtual images on the screen of AR should be connected with the real world, which is the key that distinguishes AR from VR. That's what AR looks like, and that's what makes AR unique. Virtual Reality Fusion Display includes two parts: **display** and **Virtual object generation**. In order to get a more real-virtual combined system, the display part needs to shoot as clear as possible images of the external environment, so that the computer can effectively process and identify images, can be integrated with the virtual and real environment, and the images between the two can also be superimposed. Therefore, the use of colorful display and good performance of the camera is an important basis of its.

In addition in order to make the content of the virtual stack effectively in the real world, the virtual 3D models in addition to the art style of performance, to consider and display usage scenarios fit, effectively based on the algorithm procedure of the application, make the object display not abrupt, animation and operation nature as far as possible, the effect of virtual objects generated directly affect the player's experience, and even cause dizziness and vomiting. This feature of the technology also increase the power consumption of mobile devices or headsets, increasing the load of computing.

2.2.3 Real-time human-computer interaction

This feature is real-time feedback between people and the AR world. This feature tells us what AR can provide, reflects the value of AR products, and can also pry into the development trend of AR. The core of this technical feature revolves around the interactive experience and entertainment between people and AR products. Because human-computer interaction itself is an interdisciplinary technology, AR interactions are often combined with other technologies, such as gesture recognition, GPS and eye tracking. The interaction mode of AR can be roughly divided into two types:

The first is user interaction with specific devices, such as AR projectors (Project Starline, Google 2021), AR globes, and so on. This AR display and recognition is integrated into the specific product(FIG 14).

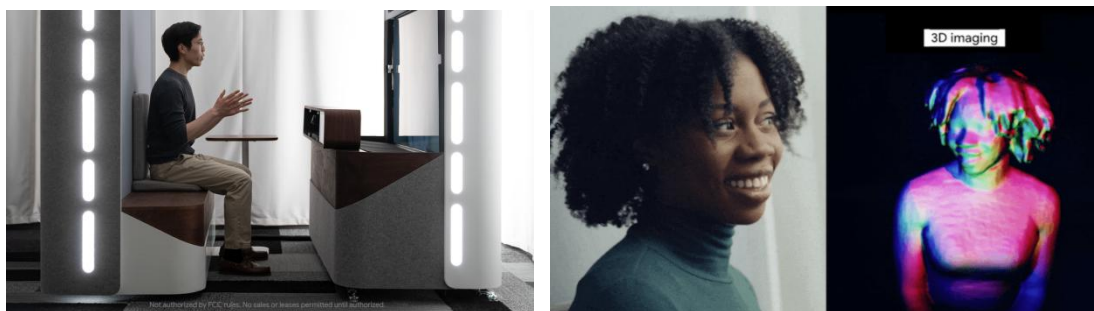


FIG14 Clay Bavor VP, Google "Project Starline: Feel like you're there, together",May 18, 2021

The second is to identify the specific postures or states of one or more things in the space, and these postures correspond to different commands. Users can change and use commands arbitrarily to interact, such as using different gestures to represent different commands. What's more common is that we interact with some kind of artificial or natural marker in the real world. For example, the ubiquitous QR code. The social AR mini-game, Facedance Challenge(FIG 15), Animoji for iPhone X(FIG 16), interacts by recognising natural faces. The form of this interaction also depends on the different categories of tracking methods in the first technical feature of 3D Registration.



FIG 15 Facedance Challenge,

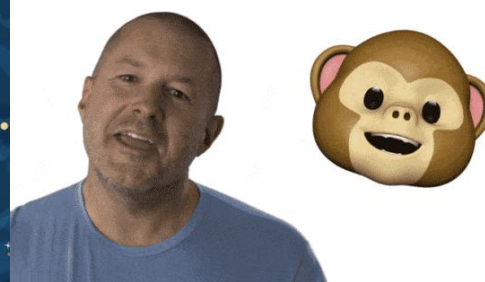


FIG 16 Animoji, iPhone X

The combination of these three technical characteristics is The greatest feature of AR: The combination of virtual and real. 3D registration is the foundation of augmented reality. Virtual Reality Fusion Display distinguishes AR from other Virtual reality concepts. Real-time human-computer interaction determines the specific role of AR(FIG 17).

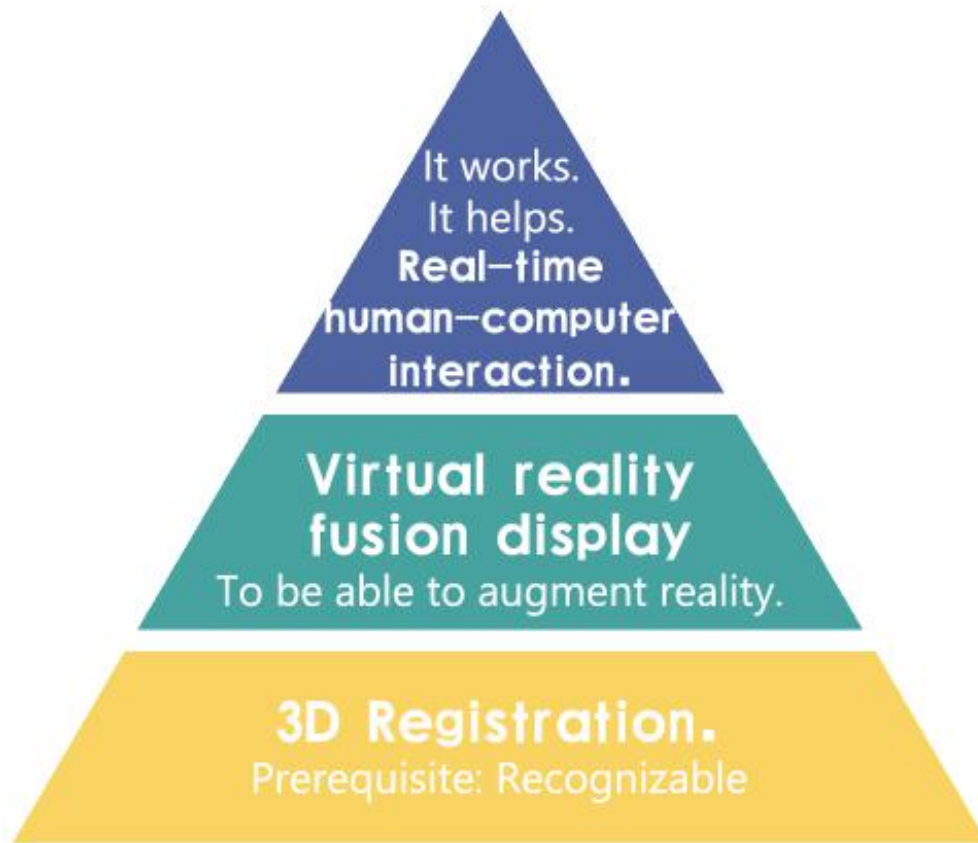


FIG17 "Hierarchical Theory of Needs" of AR Technology

2.3 The type of 3D registration, the type of AR games

After understanding the characteristics of various AR technologies, we start from the premise of 3D registration.

Unlike the way that AR technology itself is classified according to different AR display solutions, I think that AR games should be classified according to different AR tracking solutions. The classification of AR display scheme is mainly related to which device is used to implement AR technology. However, the devices of most AR games in the market are smart phones, so it is not appropriate to classify AR games by devices. Therefore, this paper also takes smart phone as the main device to discuss the design of AR mobile game.

Why do I think types of 3D registration are types of AR games?

AR tracking has a decisive impact on the core gameplay of a mobile game, because where and how it is tracked determines the context in which the game is played and how the Play interacts. For example, video games classify games by their core gameplay, such as RPG→ role-playing, ACT→ action game, FPS→ first-person shooter. In addition, with the development of the game industry, more and more games combine many kinds of gameplay. For example, role-playing games combined with action games become ARPGs, such as Dark Soul series. A game like Red Dead Redemption, which combines role-playing, sandbox and shooting, is hard to define. But none of these mixtures of gameplay will confuse the way AR is tracked, so I think that from the perspective of AR, AR games could be classified differently in terms of tracking: Unlabeled AR Game, Mark-based AR Game, Projection Based AR Game, Overlay Based AR Game(FIG 18).

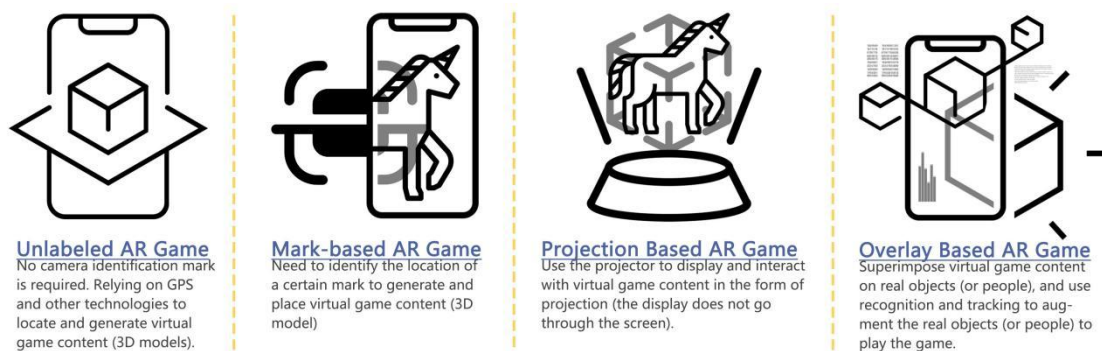


FIG18 AR games could be classified differently in terms of tracking



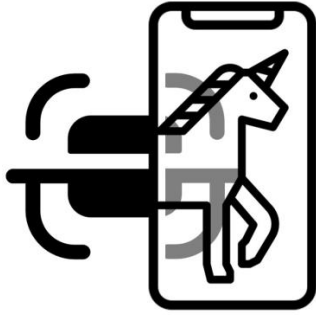
Unlabeled AR Game
No camera identification mark is required. Relying on GPS and other technologies to locate and generate virtual game content (3D models).

● **Unlabeled AR Game**

The famous Pokémon GO is one of these AR games(FIG 19). This kind of unlabeled AR is typically location-based (LBS) augmented reality, which uses GPS, gyroscopes and accelerometers to provide data based on the user's location. This data is then used to determine what AR content players find or acquire in a given area. With the popularity of smartphones, this type of AR typically generates maps and directions as well as information about nearby businesses. In the game, when players walk to a specific area with their mobile phone, they can get specific AR content. Applications include events and messages, navigation support. Even rely on other hardware, such as Mario Kart Live: Home Circuit relies on toy car cameras(FIG 19).



FIG 19 Unlabeled AR Game: Pokémon GO and Mario Kart Live:Home Circuit



- **Mark-based AR Game**

Nowadays, in most mobile games, AR functions are used to display roles or other models, and image recognition AR is usually used. Like Onmyoji's character demonstrations and dancing (FIG 20). Angry Birds: Isle of Pigs uses the recognition of a plane to build the scene (FIG 21). These are mark-based AR, requiring special visual objects and cameras to scan the markings, which can be QR codes or special markings, or simply flat surfaces, or anything that can be easily discerned. The AR device also calculates the position and orientation of the tag to locate the content. **This kind of AR recognition and tracking is less difficult and easier to implement.**

Mark-based AR Game

Need to identify the location of a certain mark to generate and place virtual game content (3D model)



FIG 20 "Onmyoji" character AR dancing



FIG 21 Angry Birds: Isle of Pigs



- **Projection Based AR Game**

Many interactive art exhibitions by the famous interactive art Team Lab use Projection Based AR. Projection-based AR uses video projectors to display images on a screen or on various physical surfaces, sometimes like holographic projections in science-fiction works of art. The basis of this type of AR is the use of real world objects to project virtual images. It is an interactive projection device. However, due to the differences in reflectivity, color and geometry, the projection quality of AR based on portable projection on heterogeneous and odd surfaces is limited to a certain extent. This AR relies on projectile devices, it has not been applied to AR

Projection Based AR Game

Use the projector to display and interact with virtual game content in the form of projection (the display does not go through the screen).

Mobile Game. However, there are also some ideas of low cost AR projection, such as small pyramid holographic projection with smart phone as projection device (FIG 22). Such projection AR can also be interactive, so I think projection AR has great potential in mobile games.



FIG 22 Small pyramid holographic projection with smart phone



Overlay Based AR Game

Superimpose virtual game content on real objects (or people), and use recognition and tracking to augment the real objects (or people) to play the game.

- **Overlay Based AR Game**

Similar to but different from mark-based AR. But this type of AR aims to enhance a realistic target object, rather than simply identify a location to generate a 3D virtual object. Overlay based AR overlays a graphic addition item onto the real object (or its exact copy of the image) on top of it, which is meant to provide an enhanced view of the real object. The ability of the technology to recognize objects plays a key role in overlay based AR implementations, because the inability to recognize objects makes it impossible to replace the original view with an enhanced view. Overlay Based AR games are not stable and have not been widely used in games. A similar example is

Nintendo's "Face Shoot(顔シューティング)" 3DS AR game(FIG 23), which uses a human Face to create a new image. If you can imagine the future, the form of an Overlay Based AR Game should be like a player wearing a virtual cloak in the real world.



FIG 23 "Face Shoot(顔シューティング)" Nintendo,2011

2.4 The type of AR displays

It is said before that AR is the means to realize display and interaction of mobile game. The mode of interaction, that is, the choice of input and output devices, usually depends on the type of AR display. For example, for handheld AR phones like Smartphone, the display is usually touch-enabled, so many handheld AR systems use touch input. After understanding the working principle of AR and the classification of AR game mechanism, we need to understand the current AR display scheme so as to know what interaction scheme options we can have and choose the most suitable display mode when making AR mobile game.

2.4.1 Display scheme of AR

In the previous section 2.3, we said that AR technology is classified according to AR display solutions. Let's take a look at the solutions:

- **Computer-based display**

The real world images taken by the camera are import into the computer, which is combined with the virtual scene produced by the computer graphics system and output to the digital screen display. The user sees the final enhanced scene on the screen. This scheme brings users a weak sense of immersion, but simple, low hardware requirements. Commonly used in live sports events, as shown in Figure(FIG 24), where Leo Messi and his teammates are computer-synthesized AR images. **This is a scene where the virtual content and the recorded video are synthesized in advance. It is not what the user sees through the camera screen, nor through optical equipment.**



FIG 24 Live sports events using Computer-based display AR, 2018 FIFA World Cup

- **Video-based display**

Video-based display augmented reality system adopts AR based on Video synthesis technology. Whether it's on a headset or on a phone, what we see on a display is a real-time composite of AR video(FIG 25). At present, AR of mobile terminal is basically displayed in this way, so it is our first choice when making AR mobile game. The scene that players see is not a scene where the virtual

content is combined with the recorded video in advance. Instead, the virtual content is superimposed on the real-time recorded video through the AR camera.



FIG 25 In Video-based display, AR cameras and cameras act as the user's eyes.

● **Optic-based display**

In the above video-based display scheme, the head-mounted devices are further divided into two categories according to the specific implementation principle, namely the Video see-through HMD based on Video synthesis technology and the penetrating optical see-through HMD based on optical principle. The two HMDs input information into the computer has two channels, one is the virtual information channel generated by the computer, the other is the real scene channel from the camera. In the realization scheme of optical see-through HMD, the camera is removed(FIG 26). The image of the real scene enters the human eye directly after a certain amount of light reduction processing, and the information of the virtual channel enters the human eye after projection reflection. The two are combined by optical method. That is, the virtual information and the real information are processed separately and then added together. The optical perspective augmented reality system has the advantages of simplicity, high resolution and no visual bias, but it also has the problems of high positioning accuracy, difficult delay matching, relatively narrow field of view and high price. (Lu Xin 2018) So it's not a good option for Mobile Game.

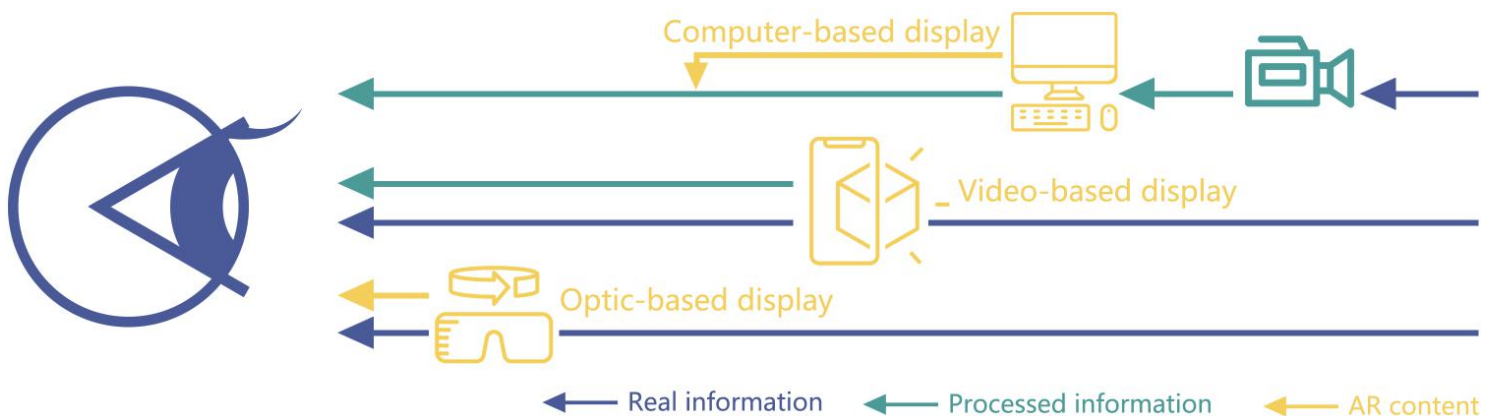


FIG 26 The differences between three display of AR

Summary:

From the user's point of view, the first two kinds of AR allow the user to observe the composite scene of the virtual and real superimposed by the camera." Now the AR application on smart phone that is more popular is this kind of application. The user watches the picture which is a composite picture of the real-time shot by the camera on the screen and the real-time superimposed virtual image. The Optic-based display is more forward-looking and the trend of future development. However, up to now, there are still many hardware problems in optical device technology that have not been solved, similar to VR headsets, such as fast power consumption and heavy battery.

However, major manufacturers are scrambling to develop optical AR. For example, Apple's unveiling preview for the second half of 2021 this year has a great hint of AR glasses, which is worth looking forward to. However, this paper still takes smart phone as the main research device, and the optical AR device will not be described in detail.

2.4.2 Augmented reality user interface

The display is the most important touchpoint for user interaction, and the display scheme directly determines the design of the user interface. The combination of virtual and real features of AR gives the interface of AR application a dimension of real space. Unlike the non-AR interface, in AR games the user has an intuitive sense of depth. This depth is different from the general sense of space that the screen UI uses to trick the eye with occlusion, projection, and virtual-real contrast. But the depth that can bring a sense of distance, is able to give users a direct sense of distance and near. Therefore, there are two concepts of depth in the interface display of AR:

- **Visual Depth:**

Visual Depth is almost everywhere, and all digital images that try to create a sense of Depth are Visual Depths. In the Video see-through scheme, although the virtual and real interface brings the user a sense of near and far, it is still only at the visual level(FIG 27), and the picture itself is just a composite Video, it's the world in the camera.

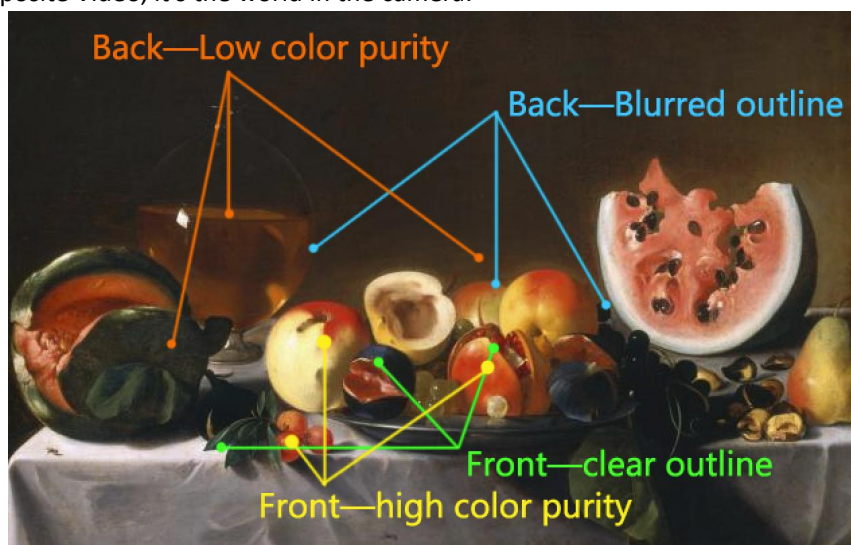


FIG 27 The front and back of the classic art space is created by blurring and clear, pure and gray.

- **True depth:**

In Optical see-through, the combination of virtual and real images brings the user a definite sense of distance between near and far. The world in front of the user is a new world of superimposed real and virtual images, instead of the world in the camera.

- **Influence of FOV(Field of View) on AR interface**

One effect of True Depth is that optical devices such as AR glasses generate different Field of View (FOV). FOV will affect the user interface design of AR glasses.

The user interface of AR glasses lacks the border separation of screen or video visually. In the OPTIC based display scheme, the image in the real world is displayed in the FOV range of human eyes, while the image display range in the virtual world is determined by the device's field of view Angle. However, under the currently available technology, the field Angle of the device is less than FOV of human eye (FIG 28). Taking AR glasses as the terminal, the vertical view Angle is taken as an example to illustrate the influence of the Angle on the interface seen by the user. Blue is the area where the virtual image can be displayed, yellow is the vertical height of the overall interface seen by the user, and AUI refers to the interface where the yellow area is located(FIG 28). Since FOV is an Angle range, the area of the red box and the gray box will be different at different depths, and the final rendering effect and proportion will also be different. In AR glasses, the difference between the FOV range of human eyes and the FOV of the device is particularly significant.(Lin Yingluo 2020)

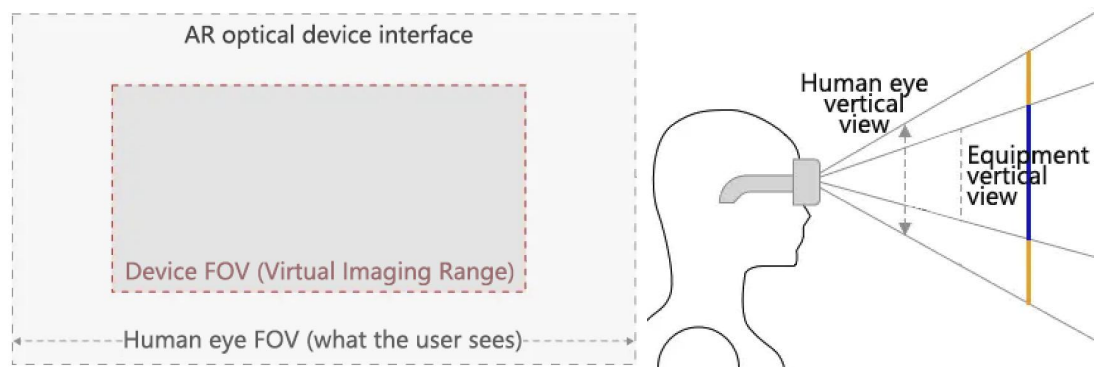


FIG 28 Human eye FOV (what the user sees)& Device FOV (Virtual Imaging Range)

Practical research shows that the human eye vertical distance from the point of view of the limit can reach 150 degrees (horizontal distance is about 230 degrees), the user can see interface theory should now than I painted yellow area is more long, but the sensitivity of the human eye identification information, far short of the ultimate value in the vertical direction about 40 degrees, 72 degrees horizontal area. The above diagram is just to illustrate that in general, the user's view of the interface will be larger than the visible area of the virtual image.(Lin Yingluo 2020)

The UI of AR should refer to the interface that the user sees with a combination of virtual and real information with visual or real depth information. Is a user interface that needs to process at

least one kind of deep information in conjunction with the real world. Therefore, in the optical display scheme of AR UI, users no longer have the feeling of screen, but a new world of superposition of real and virtual images.(Lin Yingluo 2020)

Because AR's UI is so special, Now some interaction designers engaged in AR also put forward the concept of AUI (Augmented Reality User Interface & Interaction) to distinguish it from ordinary UI. AUI requires a user interface that simultaneously processes at least one kind of depth information and combines it with the real world and meets two important points: the interface is depth-aware; Connect with the real world. Although AUI is just a touch point like traditional UI, with the concept of depth, what AUI designers end up designing is a new interactive environment.

It should be noted that although the True depth in the Video see-through scheme based AR mobile game interface is not obvious, **because the virtual content position of AR is corresponding to the real space, that is to say, the user moves in reality, Interactions like aiming will have a True depth.** Especially in mark-based AR games, the measurement of True depth has a great impact on the operation of players. If the distance between the estimation of True depth in AR and the on-screen virtual content is too large, the operation and feedback will be inaccurate, and a great sense of estrangement will be generated from the FOV gap. So the distance that the player interacts with in the game needs to be tried, measured and felt by the designers themselves.

2.5 Auxiliary interaction of smartphone

The interaction mode of AR is similar to that of VR devices, which advocates the natural interaction mode of human beings. Instead of learning tools such as keyboard and mouse, AR carries out human-computer interaction through special ways such as gestures and gaze, and complies with the concept of NUI (Nature User Interface& Interaction). Because AR puts Windows or modules that need to be operated into a spatial interface with deep realistic dimensions, this NUI interaction mode is also more suitable, convenient and three-dimensional.

2.5.1 Interactive assistance of mobile devices to AR

Mobile devices generally refer to smart phones and iPads, which are the most available and suitable for AR mobile devices. And because mobile devices have a very high popularity, it is very suitable for the promotion of mobile game. The first mobile AR game was Arcade Reality, released on the Palm mobile platform in 2007. In July 2016, Niantic released Pokémon Go on both Android and iOS, which may have been the first time AR technology entered the mainstream.

The development software and process of AR APP and AR game on mobile phones are relatively complete and the system is relatively stable. Mobile phone cameras, screens and computing speed, as important iterative and enhanced objects for mobile phone developers, will help AR's tracking and recognition become more accurate and the display effect becomes better . The development of mobile phones is in step with the development of hardware required by AR's

development. To some extent, it can be said that the progress of mobile devices is directly the progress of AR. Therefore, mobile devices are stable and friendly carrying devices for AR mobile games in the long term.

AR technology is mostly realized through smartphone applications, so the interaction mode of AR mobile game is mainly based on the interaction mode of smartphone itself:

- Touch:

Smartphone is the first touch to simulate the cursor, clicking, rotating, dragging, zooming and so on.

- Camera:

The camera moves or triggers special operations in AR space by pushing the camera, rotating the camera, shaking the camera, etc. But its main function is as an input device for AR recognition of reality information.

- Knuckle recognition:

Using different parts of the hand to tap or touch the screen area is different, to achieve different interaction with the touch cursor operation. Think of it as a simplified version of gesture control.

- Gyroscope:

gyroscope is a device used for measuring or maintaining orientation and angular velocity. It is a spinning wheel or disc in which the axis of rotation (Spin axis) is free to assume any orientation by itself. When rotating, the orientation of this axis is unaffected by tilting or rotation of the mounting, according to the conservation of angular momentum(Sándor Kabai 2018)Recognize the horizontal position of the player's phone, as well as the Angle. Many games use gyroscopes as a way for the player to aim and adjust the Angle of view more quickly than touching and dragging. You can also recognize the player's vibrations or walks to initiate special actions.

- Facial and body recognition:

Face image analysis technology is used to identify the movement of key points on the face. Facial recognition is currently used in filters on various social cameras. Further, players can use their facial or body recognition to change their expressions and body changes to interact with the filters (3D virtual objects) to achieve the game's mechanics.

- GPS:

Global Positioning System. At present, most AR mobile games combine location base technology. Using the GPS function of the mobile phone to synchronize the player's walking on the mobile phone to convert the player's displacement in the game. The best example of this is the popular Pokémon Go or the Walking Dead AR, where a player's walk in the real world is directly transformed into a movement in the mobile phone's AR space.

- Infrared sensor:

Mainly used for screen backlight automatic control. When making a phone call, the human ear is

close to the infrared sensor of the mobile phone, the sensor outputs the signal, the backlight is turned off, which saves unnecessary battery power loss and prolongs standby time. Can be used to identify the relative position of the phone and the human body.

- **Speech recognition:**

Speech Recognition requires microphones to allow machines (Smartphones) to convert Speech signals into corresponding text or commands through the process of recognition and understanding. The system analyzes the person's specific voice and uses it to fine-tune the recognition of that person's speech, resulting in increased accuracy. Systems that do not use training are called "speaker independent" systems. (Fifthgen.com 2013) The most popular MobileGame for Speech Control is "Don't Stop! The eighth note "(休むな！8分音符ちゃん), but only use the sound height to control the character's walk and jump.

AR Glasses et al. Is more convenient to use NUI's interaction, because both hands are idle, do not need to operate Smartphone:

- **Gesture control:**

The user wears a specific glove device to interact in the AR interaction scene seen. Or use the body-sensitive camera to identify the user's gesture for interaction.

- **Head tracking:**


It refers to the virtual content in the AR view of the AR field movement according to the viewing angle of the head.

- **Eye tracking:**

Eye tracking refers to the process of tracking eye movements or the absolute point of gaze (POG)-referring to the point the user's gaze is focused at in the visual scene (Fairclough 2014). With eye tracking, it is possible detect where users look at a point in time, how long they look at something, and the path their eyes follow (Bergstrom 2014).In order to achieve similar mouse cursor function, free user's hands.

Chapter 3

The difference between AR and VR.



To explore the specific points (values) of AR, it is very important to distinguish AR and VR. It is not to distinguish the pros and cons. On the one hand, VR and AR were one concept at the beginning, but later they chose different development directions between "virtual" and "real", and designers should promote their strengths and avoid weaknesses. They are like two sides of the same coin. They have great interconnection in technology and concept, and should be in the same ecology. But the design side must understand the differences between the two in order to avoid bad experiences and have a more accurate design direction. On the other hand, in the long run, AR and VR are mutually interactive and can learn from each other. The research and application of AR cannot be separated from the whole virtual reality mixed reality ecology.

3.1 What is VR

Virtual Reality (VR) is also known as the spiritual environment technology or artificial environment. The concept was put forward in the early 1980s, which specifically refers to the use of computers and the latest sensor technology to create a new human-computer interaction means. Virtual reality is the use of computer simulation to create a three-dimensional virtual world, providing users with the simulation of vision, hearing, touch and other senses, so that users can observe things in three-dimensional space in a timely and unlimited manner as if they were immersive. (Joe Bardi 2019)

Virtual reality technology combines computer graphics, computer simulation technology, sensor technology, display technology and other science and technology, it create a virtual information on the multi-dimensional information space environment, enable the immersive immersive, is perfect ability of interaction with the environment and help inspire ideas. Therefore, immersion, interaction and conception are the three basic characteristics of VR environment system. The core of virtual technology is modeling and simulation.

AR is complimentary to VR(FIG 29), technology that tries to fully immerse a person in a computer-generated environment. While AR uses virtual information to enhance a user's interaction in the real world, VR separates people from the real world entirely. (G. Stewart Von Itzstein 2017)

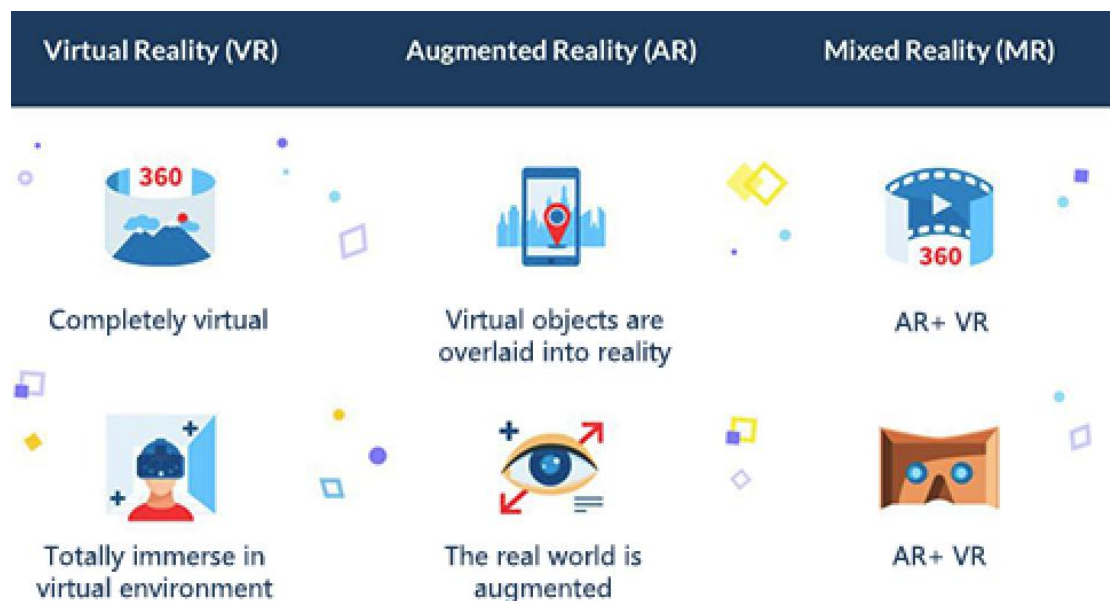


FIG 29 VR+AR=MR

In terms of hardware, VR technology can fully immerse the user in a virtual synthetic environment by using VR glasses, and cannot see the real environment. Using binocular vision, the virtual world is 3D in the glasses or VR headsets.

VR headsets: For example, Oculus, currently a company acquired by Facebook, can display virtual

scenes built by software such as Unity and immerse users in virtual worlds such as roller coasters, games, and movies.

VR goggles: The current solution is a headset phone frame that places a smartphone inside and displays it on a split screen to produce a VR-like effect, such as the Samsung Gear VR.

The near-eye display system of AR and VR is to form a distant virtual image from the pixels on the display through a series of optical imaging elements and project it to the human eye. The difference is that AR glasses need see-through, to see both the real outside world and virtual information, so the imaging system can't get in the way of the line of sight. This requires an additional optical combiner or set of optical combiners, which, in the form of "cascading", integrate the virtual information and the real scene(FIG 30), complementing and "enhancing" each other.(Li Kun 2019)

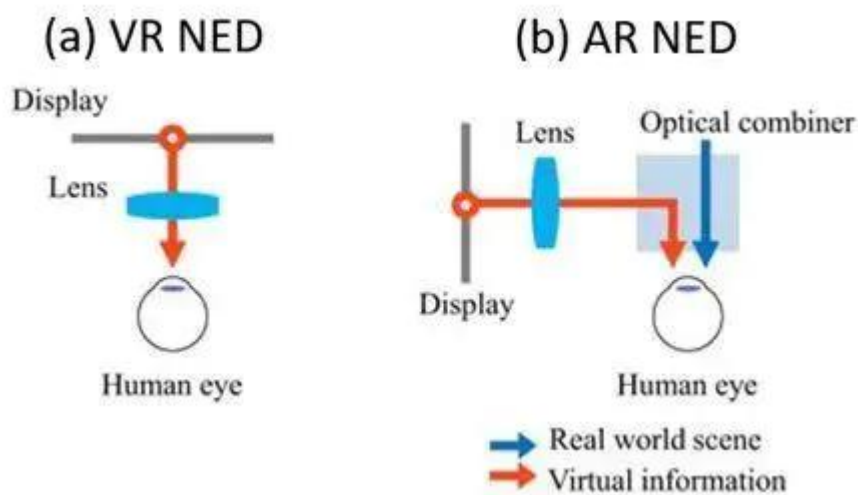


FIG 30 Differences between Near-Eye Display System of AR and VR(Li Kun 2019)

In terms of games, AR games use virtual digital content to enhance the player's vision of the real world. VR games, on the other hand, represent a completely immersive experience, reconstructing a virtual world. AR games are about putting virtual objects around you(FIG 31), VR games are about putting you in a virtual environment(FIG 32).



FIG 31 AR game "Minecraft Earth" Mojang



FIG 32 VR game "Summer Lesson" Namco Bandai

3.2 Equipment for AR and VR

The difference between AR and VR games is mainly reflected in the device differences. Before the comparison, let's first introduce a few headsets that are currently more mainstream in the VR game and AR game market in 2020:

3.2.1 VR Equipment

- HTC Vive Cosmos

The HTC Vive Cosmos has been recognized as the best VR gaming device of 2020(FIG 33), with a single eye resolution of 2880*1700, a Pixel-packed display with a screen refresh rate of 90Hz, a 110° wide field of view and leading position tracking technology. It can quickly calculate the location information of the device user. The weight is 555g. It goes on sale for \$699. Wireless battery life is 2.5h. (<https://www.vive.com/cn/>)

- Oculus Rift S

Oculus(FIG 34), which was bought by Facebook for \$2 billion, is one of the top makers of VR gear(FIG 34). Oculus's latest VR device, the Oculus Rift S, which was unveiled at GDC in March 2019, also got a lot of attention this year. The Rift S has an LCD screen instead of an OLED one, and has an improved resolution of 1280 x 1440, although the 80Hz refresh rate is lower than the previous model. But Oculus's tracking technology is so powerful that users can play without having to install cumbersome external tracking sensors. The weight is 470g. It will go on sale at \$399.

- PlayStation VR (Project Morpheus) :

The PSVR(FIG 35) has a 5.7-inch OLED display, a maximum refresh rate of 120Hz, a resolution of 1980X1080, and an FOV of 100°.The weight is 610g and the price is \$399. There is also a processing unit before the PSVR and PS4 are connected(FIG 34). It not support wireless transmission signal, must connect the cable to wear. It's quite a hassle to assemble. (<https://www.playstation.com/en-us/ps-vr/>)



FIG 33 | HTC Vive Cosmos



FIG 34 Oculus Rift S



FIG 35 PlayStation VR

3.2.2 AR Equipment

- Lenovo Mirage

Lenovo and Disney jointly launched an immersive AR gaming device based on the Star Wars series, which allows users to interact with digital content and holograms of Star Wars characters in the real world by driving and running the Star Wars: Jedi Challenge game app on a compatible smartphone(FIG 36). The weight is 470g. The price is \$200. The battery life is 5h. Since it is a game-specific device, it has been discontinued.

- HoloLens 2

The Microsoft HoloLens 2 (FIG 37) is a hybrid reality headset developed by Microsoft. The HoloLens 2 body is made of carbon fiber and is designed to be more comfortable with extra padding. Internally, it's powered by a Snapdragon 850 processor, has better hand tracking capabilities, and includes built-in eye movement tracking. The weight is 566g. The industrial version is only available at the moment, with a hefty price tag of \$4,950. The weight and price are both high because the glasses also feature an immersive VR experience and a battery that can run wirelessly. The battery life is 2h-3h.

- Viewer AR glasses

VieWer AR smart glasses(FIG 38), developed by Hangzhou Lli Information Technology Co., Ltd., is the only consumer AR all-in-one glasses in China and the lightest AR glasses in the world. The weight is only 68g, and its appearance is light and comfortable to wear. The optical utilization rate reaches 30%, and the display brightness reaches up to 4,500 nits, making it suitable for outdoor wear. The battery life is 8h. It goes on sale for \$300.



FIG 36 Lenovo Mirage



FIG 37 Microsoft HoloLens 2



FIG 38 Viewer AR glasses

3.3 Differences between AR game and VR game: Embrace virtual or explore reality

After reading these cases, we compared the performance of AR and VR in game experience from the following four aspects:

3.3.1 Portability: Stay in one place or keep moving

The expansion direction of VR is the virtual world, and the expansion direction of AR is the real world, and the strength of portability is just about this difference:

- **Weight and volume:**

First of all, we can see from the above examples that VR headsets are generally heavier than AR headsets due to more powerful visual hardware and more sensors. If you compare the weight with Smartphone, 110-130g is the weight of the current mainstream Smartphone, the weight gap is even bigger. It's also a lot bigger and bulkier.

The Lenovo Mirage AR includes a Lenovo Mirage Ar Glasses (1), a coordinate locator (1), USB charger (2), the sky is the game handle (1). There are 5 accessories(FIG 36).

HTC Vive requires an HTC Vive body (1), junction box (1), HDMI line (1), USB transfer USB (1), Lighthouse base station (2), Steam VR Wireless Action Controller (2) , Micro-USB transfer USB cable (Controller charging) (2), USB charging joint (2), 12V lighthouse base station power supply (2), 12V junction box / header power supply (1), Narrow Face head Wasket (1), Wide Face header (1), Lighthouse base station fixing frame (2), HTC headphones (1). There are 20 accessories. In this way, the installation process has also become more complicated, the higher the requirements of the play environment or the space. Because there are a large number of equipment lines, not only the length of the line limits the player's mobile range. In addition, because the VR helmet is in general, the player can't see the surrounding real environment, and the complicated line is more prone to stumble or the status of the player. (FIG 39).

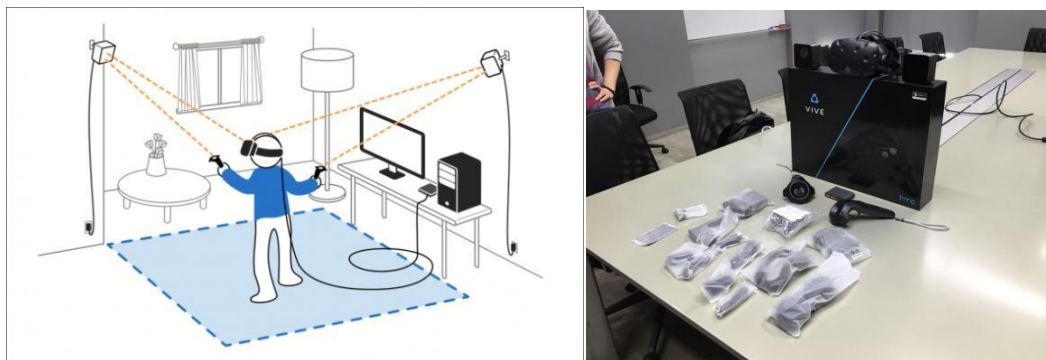


FIG 39 HTC VIVE, VR devices have a wide range of components.

- **Power Consumption:**

As can be seen from the above example, the wireless battery of the head wear device of Ar and VR is basically about 2-3 hours, and many VR headset devices do not support wireless because wireless transmission is difficult to transmit the VR game. Hundreds of images and signals required. Therefore, the consumption of electricity is faster. Smartphone and Ar Glasses can use mobile charger to end due to lower power supply requirements.

In this article 1.2.1, it is said that the portability is a key factor in which a game is Mobile Game is conducive to players to use the debris time to play. Obviously, the current technically cumbersome VR devices do not have experience in providing higher portability, and the AR equipment is relatively suitable for the design and development of Mobile GAME.

Whereas VR allows people to stay within a fixed range of play, the value of portable AR should be to encourage players to play on the move.

3.3.2 Immersion: Visual immersion or playability immersion

The quality of a virtual game is usually measured by two criteria: visuals and playability (gameplay). Both of these attributes are driven by the reader, and both contribute to immersion.

1. Visual immersion

The range of the human eye in a fixed Angle of view is usually about 120 degrees, which is also the best range we have when watching a movie in the theater. If you go beyond that, the eye will drift off the screen and lose the 3D effect of the screen (Martin S. Banks & Jenny C. A. Read & Robert S. Allison & Simon J. Watt 2012). Compared with the traditional 3D screen, the difference lies in the fact that VR has a 720-degree omnidirectional 3D immersion, that is, no matter from all angles to observe the internal scene in VR, there will be a 3D effect, so that you can observe the whole picture, which is the so-called "immersion" of virtual scene.

Both AR and VR devices can create a certain level of immersion. With fully closed isolation experience, rubber or sponge products in the contact part with the face make the face closely fit with the device to form a closed visual space, VR can create a stronger sense of visual immersion. Visual immersion is an important indicator to measure the quality of a VR device. The stronger the immersion is, the more users will believe that the virtual scene they are in is real. Theoretically speaking, when full immersion is achieved, users will not be able to distinguish between the virtual world and the real world.

In addition, VR's computing mainframe is computer and console, computing power is far more than that of mobile phones. VR headsets also have better resolution and frame counts than AR glasses. Therefore, the quality of the screen and 3D model of VR game can be more realistic, which is suitable for realistic games with high rendering difficulty and large computation. Comparatively speaking, Smartphone and Smartphone-based AR glasses that process game content have much less computing power. In addition, AR shows that the open camera shooting to the real world leads to less closed experience like VR.

2. Playability immersion

AR integrates virtual data into the real world through technical means, or blocks some scenes in the real world, so that the exquisite information of virtual and real can complement each other, enhance the visual experience and spatial perception of users, and strive to create immersive feelings. Therefore, the immersion of AR does not rely on realistic images, but on the integration of the virtual into the real world, creating rich and interesting gameplay. It's fun driven, arousing players' curiosity, and keeping them engaged with interesting levels and interactions. According to Shigeru Miyamoto, a famous game producer, Nintendo's games focus more on fun and are indispensable.

On the contrary, the open experience of AR game is different from that of VR. The technical characteristics of the combination of virtuality and reality encourage people to pay attention to the content of reality, find the fun of reality, and use AR technology to strengthen and create the

fun in reality. Just like the sand pile, building blocks and jigsaw puzzle we played with when we were young kids, this kind of happiness is the unknown and curiosity to the world. But when we grow up, the joy of the game becomes the catharsis and conquest of the world. Negative emotions and pressure are mixed in. Maybe the simple pleasure of catharsis is increased, but the fun is reduced.

AR games, on the other hand, can bring players back to the original state of curiosity and have a strong sense of fun. AR plays to the social nature of people, because people like social media platforms. AR encourages players to go out and socialize, which is also one of the means to gain fun. The popularity of Snapchat's AR social mini-game is enough to prove this. Even the simplest game mechanics can be fun to show off in AR. For example, the game of Tetris made into AR, because it has become the dimension of the real space, the fun and difficulty of the game will surge and increase the playability of the game. Complex real environment creates endless combination of virtual model and real environment, which will greatly enhance the fun of players.

The visual immersion of VR has become an obstacle to the early development of VR. First of all, due to the limitation of closed experience, activities and venues, the field that can make use of VR is mainly confined to the entertainment industry, so there are great limitations in the development of economy and technology. Every time players want to start the game, the preparation work is complicated, and they can't quickly socialize with the people around them. For example, when they answer the phone or send messages on social software, they don't put on or take off the VR headset frequently, which hinders people's communication. These can greatly affect the experience of the game.

3.3.3 The market status of AR games and VR games

As can be seen from the above VR and AR game equipment examples, the hardware of VR equipment requires high cost and high price. AR devices are relatively cheap, the application is simple and flexible, and the ease of use and popularity of Smartphone make AR user base large.

VR has a small user base, poor mobility, and isolated immersion, so it is mainly focused on entertainment purposes. Entertainment is likely to account for two-thirds of the industry's revenue, with hardware accounting for about a quarter. The size and fragmentation of the current user base limit its development. AR will reach more people than VR because it is a seamless addition to People's Daily lives. Some analysts also believe that AR will become "part of a more everyday mobile application." At the same time, the popularity and low cost of mobile AR also help enterprises to adopt AR technology, and enterprise AR can grow steadily. (Zan Yingying 2019)

Digi-Capital is an AR/VR/MR (XR) intelligence-reports, analytics platform, strategy consulting firm. AR/VR revenue statistics from Digi-Capital in 2018 shows that AR dominates (FIG 40). While AR games account for more than two-thirds of app store revenue (with other categories accounting for less than a few percentage points), by contrast, games will take a long-term share of the VR

app store revenue market. VR technology seems to be more of a subset of the video game market, where it has been heavily marketed to the user base of gamers.

AR/VR Platform Revenue

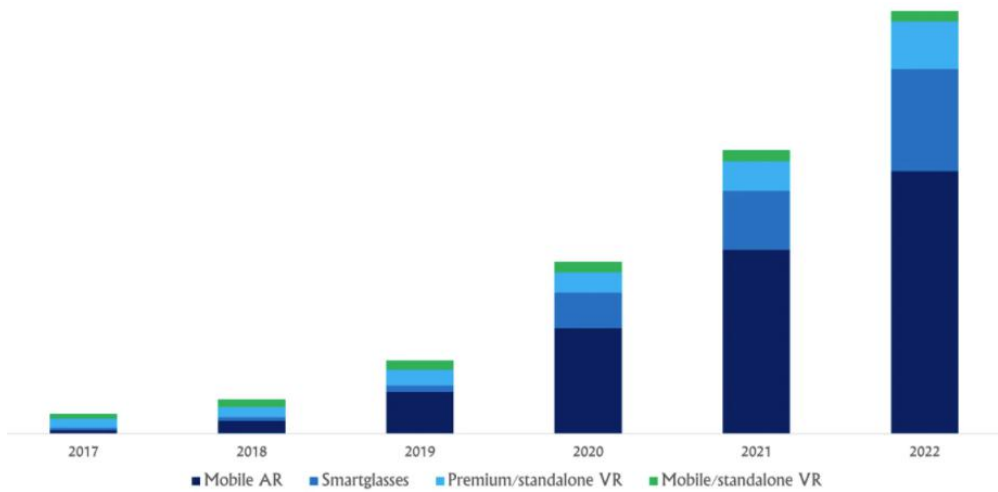
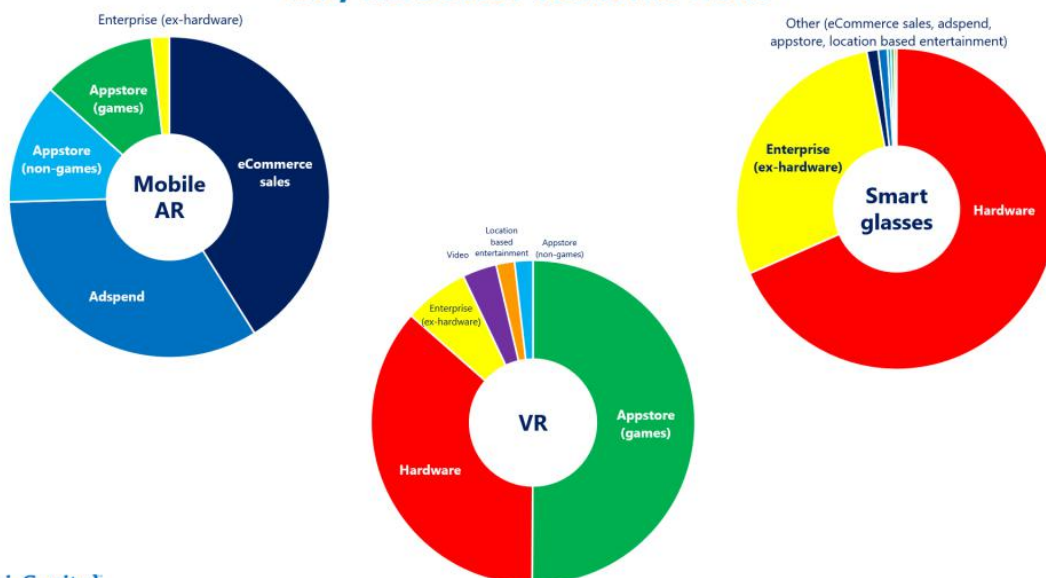


FIG 40 Digi-Capital AR/VR Platform revenue 2019

Digi-Capital released a report in 2019 showing that the number of users of AR (mobile AR and AR glasses) is expected to reach 2.5 billion by 2023, and the market size will reach \$70 billion to \$75 billion. VR (VR box, VR all-in-one machine, PC VR) will have 30 million users and a market size of 10-15 billion US dollars. Tim Merel, a Silicon Valley AR/VR consultant and managing director of Digi-Capital, said in the article that mobile AR will grow to be the most popular application scenario in AR/VR, with more than 850 million devices supporting mobile AR at the end of last year and more than 2.5 billion devices expected by 2023(FIG 41). This refers to devices that are compatible/support ARKit, ARCore, Spark AR, Snapchat, Web AR, not the number of smartphones.(Tim Merel 2019)

AR/VR Sector Revenue 2023



Digi-Capital

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FIG 41 Digi-Capital AR/VR Analytics Platform and Augmented/Virtual Reality Report

Summary:

By comparing AR and VR, it is obvious that AR technology is more suitable for developing mobile game. Due to the different development directions of AR and VR, AR game designers should avoid the shortcomings of AR and Smartphone: 3D animation rendering computing capability is poor, and visual immersion is poor. Clarify the technical characteristics of AR virtual-real combination. Take advantage of AR's high flexibility, strong playability, large user base, low cost and social advantages.

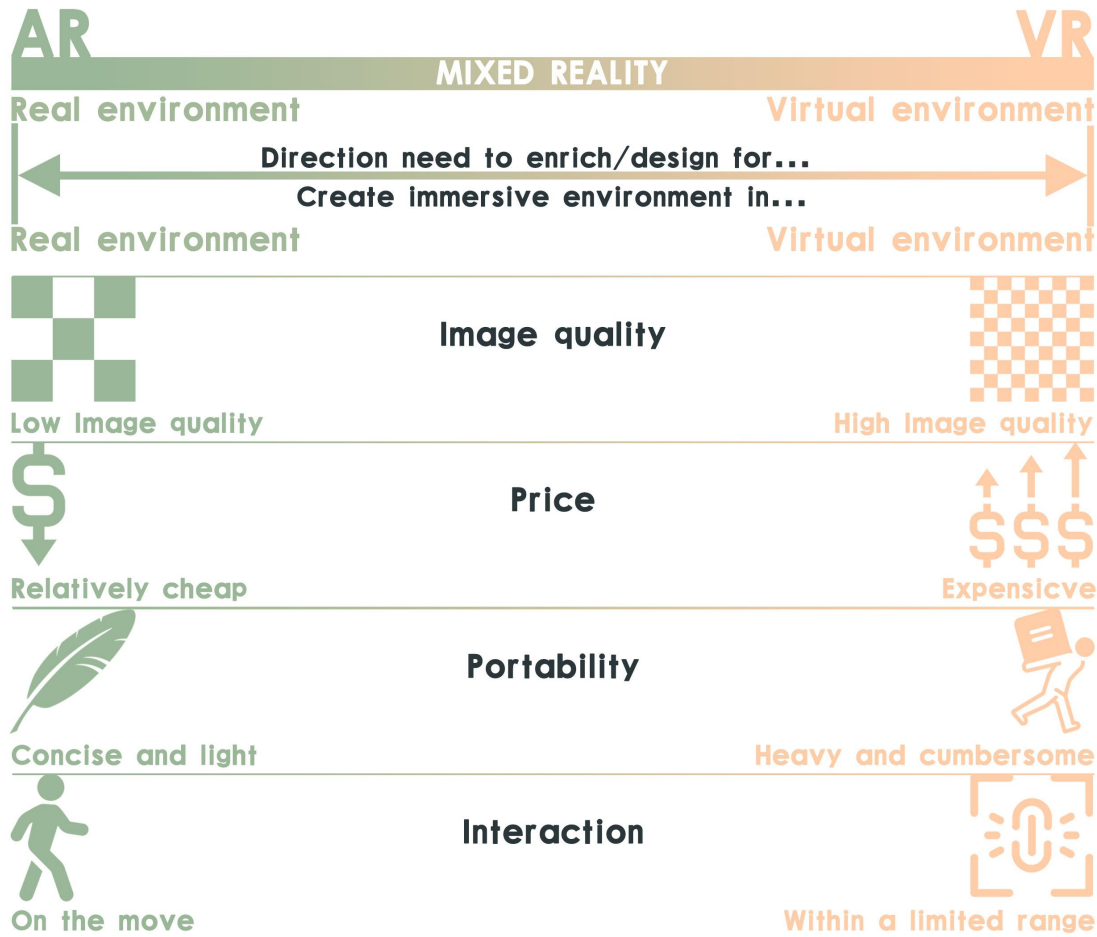


FIG 42 Summary of AR and VR comparison

Through comparison (FIG 42), we know that the design of AR games should be designed with real content (scenes, objects) as the center, and interactive design should be considered with mobility as the characteristic. Avoid shortcomings in image quality.

As Climax Studio CEO Simon Gardner puts it, "The biggest challenge for VR is the price of the device and the number of users, which limits its profit potential. High-end hardware also leads people to expect more of a game, which drives up development costs even further, and low user numbers are bad for monetization. Another lesson we've learned from VR is to make sure you take advantage of the strengths of AR and design your game around that."

Chapter 4

The application of AR in mobile games AR , Cases study.



Design activity: In this chapter, I use storyboard, experience map and system map as the main method to analyze the case, supplemented by some analysis of the game interface design. I determined that my research user group is mainly the young people of the largest group of games (18 to 30 years old).

Storyboard is drawn based on these three surveys: the gaming experiences shared by the majority of players on the Internet and in game forums. I interviewed some classmates and friends who played the game. And my personal experience of the whole process of the game.

Experience map uses an ethnographic method to pay attention to the comments on the game: first I watched game videos recorded by several game anchors and players in my target age group. Observe their reaction and experience during the game. Then I collected the evaluation of the game in the google play store and the evaluation of the game forum. Finally, I summarized the general game process based on the above information, and then classified these experience evaluations and emotional points into the process.

The system map is based on the company's introduction on the game's official website, game advertisements, and online analysis articles on game operations.

The purpose is to Find out and learn how AR is applied to mobile games. Explore how AR makes mobile games novel from these popular AR mobile games. Verify the characteristics of the AR mobile game summarized above.

4.1 Longevity classic, Pokemon Go

Even now, most people's first reaction to AR Mobile Game is to recall Pokemon Go, which was released five years ago. Pokémon Go is an Augmented Reality Pet Battle RPG mobile game, jointly developed by Nintendo, The Pokémon Company and Niantic Labs (Nintendo is responsible for game development and distribution; The Pokémon Company is responsible for content support and The design of The game's story; Niantic is responsible for technical support and AR technology for the game.). The game was released on 7 July 2016 on Android and iOS in Australia and New Zealand. Being the fastest mobile app ever to achieve more than \$1 Billion USD in revenue, Pokémon Go shows the huge potential that combining location-based gaming, AR and a well-known brand can have. Even today, Pokémon Go remains popular.

Next, this paper analyzes how AR is used in Pokemon Go.

4.1.1 Game play & storyboard

Smartphones allow players to discover, explore, capture, nurture, fight, and swap Pokemon in the real world. I make a storyboard of Pokémon Go flow to get a sense of how it works, based on my own play experience, and shared stories with players on the Internet. (FIG 43).

From this story (FIG 43), we can see that the gameplay of Pokémon Go is basically the same as the previous Pokémon series, in order to capture, train and fight other Pokémon. But with the support of AR and LBS (Location Base Service) for the same gameplay, the relationship between the game and the real environment is greatly strengthened. AR takes Pokémon's game mechanics and virtual content and puts it into the real world. LBS conversion and simulation of player movement, the game map is cartoonized according to the player's position, the route and landmarks in the game (the place where the game props can be supplied), are consistent with the real world. As the player moves in the real world, the map surrounding the mobile game changes (FIG 43 ③). When the player encounters a Pokémon on the street, the AR function is turned on, and the player can see the Pokémon as if they were in the real world in front of them through the phone screen, and then can capture and interact with the Pokémon (FIG 43 ④).

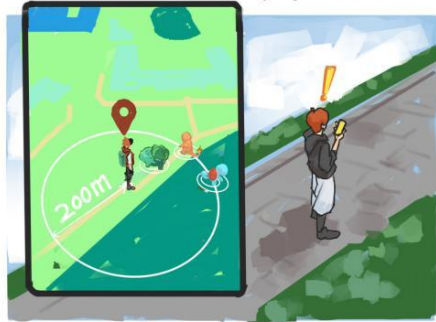
In this way, the dual integration of reality and virtuality with AR+LBS greatly enhances the sense of fun and immersion, as if the players felt that Pokemon really appeared in our neighborhood. The core flow of the game is to move through the real map, collect Pokémon along the way, and then enhance and upgrade them to get to the top Pokémon that the player loves. Players and teammates' Pokémon fight against enemy, then occupying DOJO for camps, gaining belonging and sense of accomplice (FIG 43 ⑧).

In addition, although most mobile games have social interaction, LBS and AR make Pokémon Go players have to walk on the street, which greatly improves the chance of face-to-face social interaction (FIG 43 ⑦). The game also has a Pokémon exchange mechanism, prompting many non-social players to try social with others for the Pokémon they want. This is the opposite of virtual social in traditional games. At the same time, the player group that likes to stay at home increases the opportunity to exercise.

① Players learn about Pokemon Go through social networking or advertising.



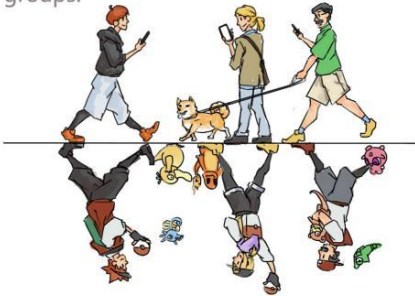
③ The map of the game is based on Google Maps, which locates the player through LBS and displays the Pokemon within 200 meters of the player.



⑤ Setting a Pokemon as the player's Buddy increases the Pokemon's EXP as the number of steps increases. To help it upgrade.



⑦ Players will meet other Pokemon Go players during the game, creating face-to-face social opportunities for players. Players can also choose their own faction and join large groups.



② Download the App and create a character -Pokemon Trainer. Then Go out and play.

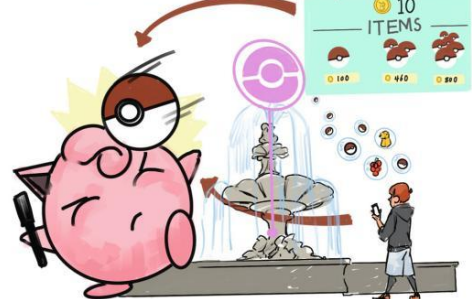


④ In an encounter with Pokemon, the player uses AR and a camera to discover Pokemon 3D model in the real world and try to capture it.



⑥ Players can also capture new Pokemon to gain candy that increases the Pokemon's EXP. Players get Pokemon balls at a supply station (usually a landmark).

You can also buy them in shop—SHOP



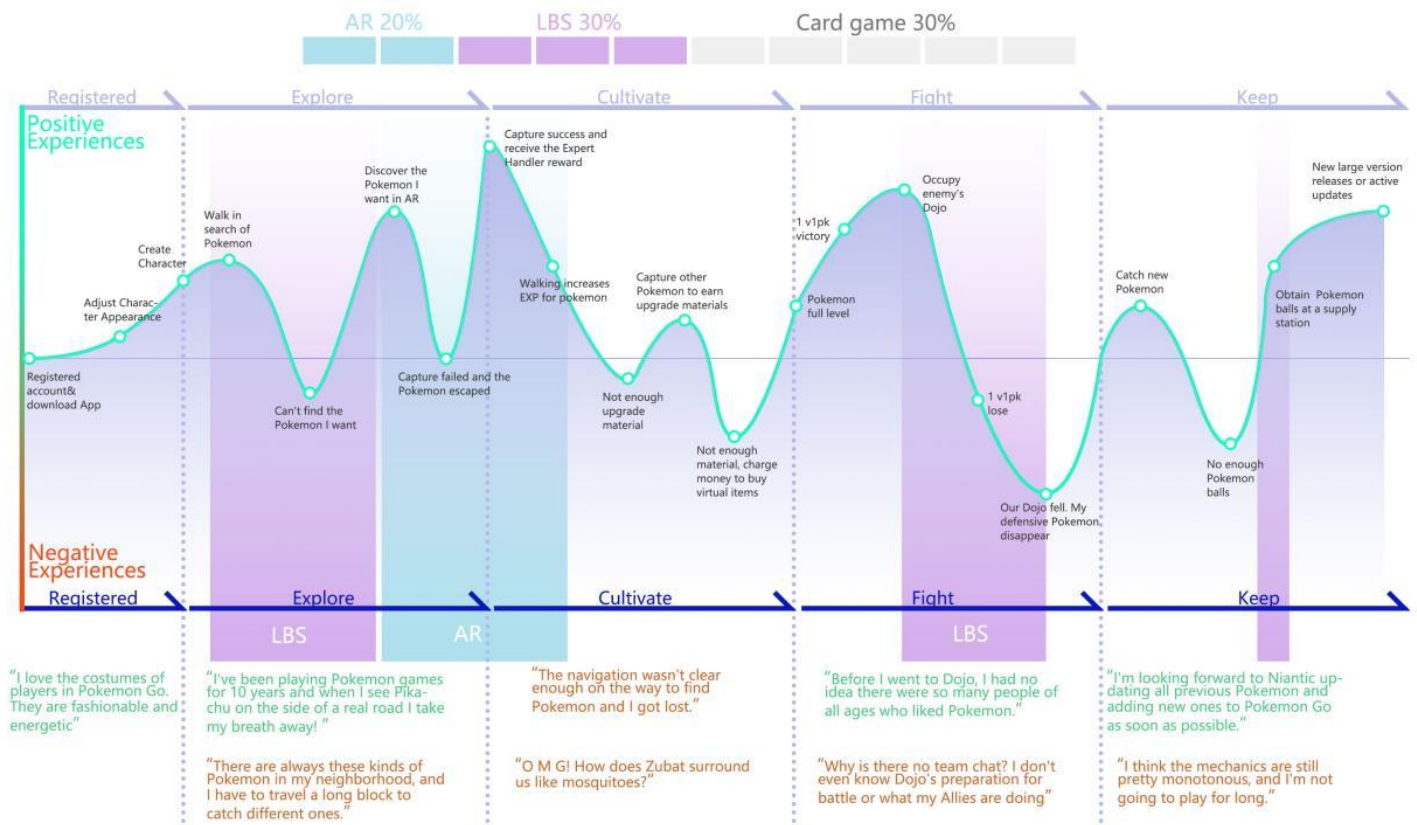
⑧ There is an arena "Dojo" in each block, and players from different camps attack, occupy and defend these Dojos. Players can also train Pokemon in Dojo of their own camp.



FIG 43 Pokémon Go storyboard

4.1.2 Game composition & Experience map

The core of Pokémon Go is made up of three elements: LBS + AR + Pokémon card collection. According to the flow distribution of the whole game experience, the weight of the three elements is about 50% for Pokémon card, 30% for LBS, and 20% for AR(FIG 44).



According to the user evaluation and feedback of the pokémon App in google play, I made an experience map(FIG 44). It can be seen that, Exploration, AR+LBS, and social interaction are the three most interesting aspects of games.

1.Exploration: From the experience map(FIG 44), it can be seen that the exploration of the unknown Pokémon, the exploration of the unknown form (evolution) of Pokémon, and the challenge and cooperation of other players are the two parts of the greatest fun of the game. Pokémon is the theme of the whole game. **The rhythm of the game is relaxed, and the mobile phone's portability and immediacy are fully utilized. The camera and GPS module are used to improve the freshness of the game process.** The player's **outdoor activities**, and the role of elf trainer tightly tied together; The constant introduction of new sprites and the social network of the Sprite world will keep players playing the game for a long time.

2.AR+LBS: Looking at the whole experience map(FIG 44), AR experience content accounts for 20%. AR technology only appears in capture and battle scenes, and the effect is to replace the background with the dynamic content of the camera. The design is relatively thin, but such novel

gimmicks are more used to attract players to download and experience. About 30% of LBS is a game that can't be played without walking. LBS gameplay drives the player out of the house, triggering a social field by capturing the faction building Dojo or inviting the player to the landmark to find supplies. It leads to the use of AR to show off, exchange Pokémon, fight and cooperate, forming a social network in the Pokémon world.

3.Social: Generally speaking, social interaction in games starts with showing off, builds acquaintances in battle, cooperates at a peak level of intimacy, and finally, when the game is exhausted, the relationship declines(FIG 44).

The social aspect of a game usually starts with an avatar(FIG 45). The first is the player character dress, there are 10 variable content, so that each player to a very low degree of compatibility, Pokémon Go is very emphasized for each player to create a different personality role, which provides the immersion basis for the sense of belonging of all kinds of honor and shame in the later social, "I am such a fashion trainer". Players can also compete to display their avatars in Dojo for more people to see. Each occupied Dojo can hold between 1 and 10 Pokémon, making Dojo like Pokémon display cabinet for each player. Players standing in Dojo with Pokémon not only receive admiring stances from visitors, but also gain real experience points by being challenged. In the game, the player's medal wall is used to show the player status, allowing other players to see their level and preferences. These are all ways to show off.

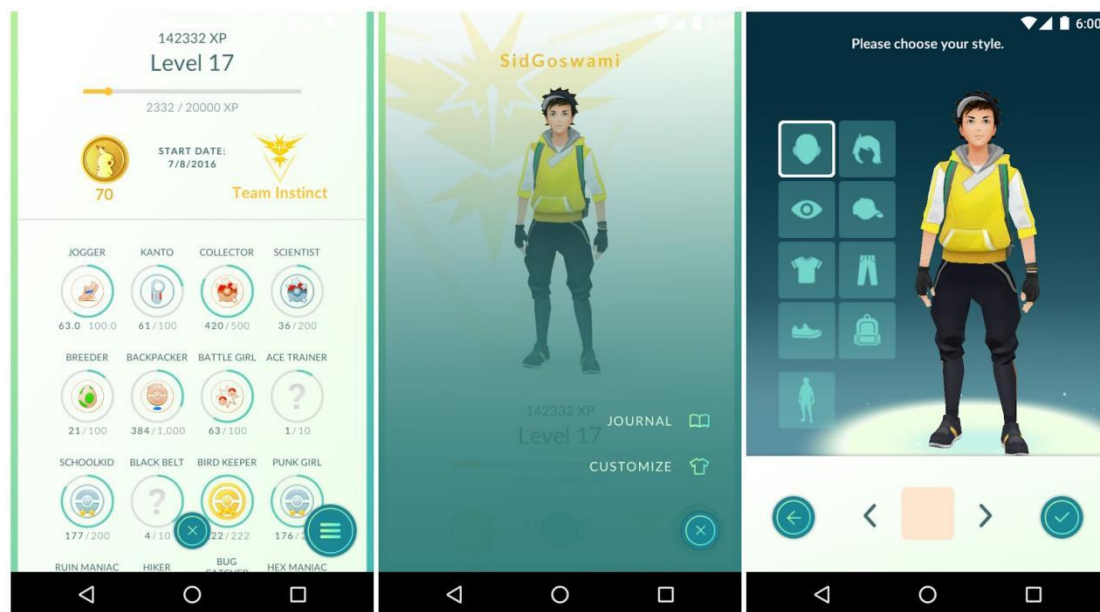


FIG 45 Pokémon Go Player Avatars -- Personalization.-Pokémon Go interface.

In terms of AR, when capturing Pokémon, the default function is to take a picture with one button. When rare Pokémon is difficult to capture in the later stage, the printed picture with the player's name can prove that they have met before. The combination of AR and reality also allows players to take a lot of interesting photos of Pokémon combined with reality when interacting with them, which can be shared on social media.

4.1.3 Data sharing with strong IP (Intellectual Property), System map

Pokémon Go's developer, Niantic Labs, is a spin-off from Google, whose founders pioneered products such as Google Earth. Niantic's history with Google Map makes Pokémon Go closely related to LBS data. Since 2017, Pokémon Go has been using free VGI (volunteered Geographic Information) LBS data due to the policy of not using Google Map in certain regions. For example, VGI (OSM) data was used only in South Korea, and this was due to the country's security regulations prohibiting the provisioning of commercial GIS data to non-Korean companies including Google. (Brian Alan Johnson 2019)

Interestingly, Pokémon GO in turn encourages people to contribute LBS data to VGI (volunteered Geographic Information) through OSM (OpenStreetMap). The number of daily contributors and daily edits both increased by more than 17 times following the launch of Pokémon GO in South Korea. Most individuals contributing to OSM because of Pokémon GO reportedly did so to improve the in-game map appearance and in-game mechanics; and individuals motivated to contribute to OSM because of Pokémon GO tended to create/edit OSM "park" and "water body" features more than other OSM contributors. (Brian Alan Johnson 2019) I simplified a system map based on the company relationship of Pokémon Go, peripheral cooperation, and data exchange around LBS (FIG 46). **From the point of view of System map (FIG 46) LBS Data Flow, this is a win-win situation between games and public data sharing.**

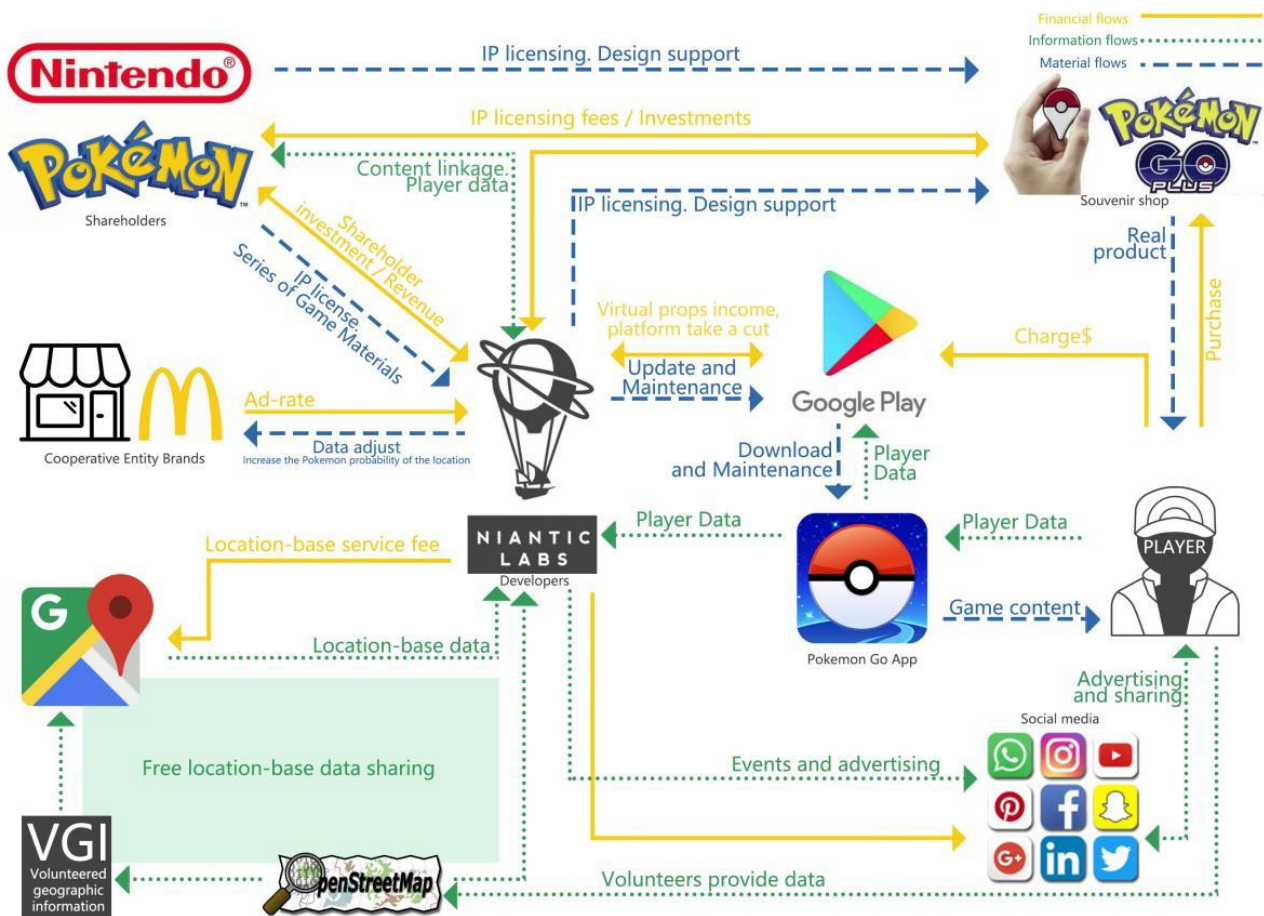


FIG 46 Pokémon Go system map

There's a strange financial flow between a developer's AD business and a merchant's partner's, where Niantic gets its Ad Fee by modifying game data near the merchant's partner(FIG 46). This is LBS product placement: **Pokémon GO can be used to attract players to a business to achieve the effect of advertising**, which I think is a unique product placement in the game industry, and one that only MobileGame can achieve.

In the game, players can get in-game items, such as Pokémon balls, super balls, blood potions, etc. by approaching the Pokémon supply station(FIG 47). These station ICONS have pictures of real world locations. Pokémon GO can be used to lure players to a supply station near a partner store, or to increase the number of rare Pokémon near the partner store, or by changing the occurrence rate near the partner store.

In addition, Pokémon GO has launched its own physical wearable device. The device, called Pokémon GO, connects to any mobile phone with Pokémon GO installed via Bluetooth(FIG 48). Both the player's phone and Pokemon Go Plus will vibrate when a Pokemon is nearby. Of course, various smart wristbands and Apple Watch can also do this simple interaction, but this complementary design of game interaction using wearable devices other than AR glasses is also one of the ideas of AR Mobile Game interaction design.

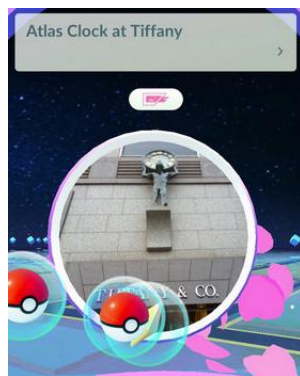


FIG47 Pokémon supply station



FIG 48 Pokémon GO Plus

The combination of AR+LBS has been around for years with Niantic Labs' previous game Ingress and various Map apps, and it's not a new model. The success of Pokémon GO is based on the same IP in the Pokémon series. Through the attraction of AR, the construction of LBS social network and user engagement, the final goal is to connect the world of Pokémon with the real world. What really moves players is the charm of Pokémon IP itself. From the System Map(FIG 46), we can see that many financial flows are IP licensing fees. Because the IP of Pokémon series is very well known in the world, its series of works have successfully entered dozens of countries around the world, and become a world-famous cartoon and Japanese animation character. Sales of related products amounted to more than billions of dollars.(Bailey, Kat 2018)

4.1.4 Interface interaction

The Pokémon GO game itself requires players to operate on the move, and the interaction

scenario is harsh. But the game's interpage structure, internal framework, and distribution of elements have been cleverly designed.

1. Shortcut menu

Point-aggregation navigation: In any case, click the function navigation key of the core hot zone to open the point-aggregation navigation interface(FIG 49). The distance between each button is very large to avoid accidental hits. The color purity of the mask is very high, and it is difficult to distinguish the interface from the background color when it is mixed in the sunlight.

Pokémon sorting: After the accumulation of a certain number of Pokémon, it is very important to select appropriate Pokémon for exchange and combat. The sorted list is based on the frequency of use, and the combat power (for combat), name (for exchange) and other dimensions are arranged according to the order from near to far from the hot are(FIG 50), which is fast and convenient.



FIG 49 Pokémon GO Point-aggregation navigation



FIG 50 Pokémon sorting

2. Map positioning:

In a routine hunt, the game's real-life radar players can search for Pokémon within 200 meters. In the lower right corner of the screen, the Pokémon category is directly displayed by scrolling bar. Click to search. The functions and information are integrated and displayed(FIG 51). **The content is the entry.** This AD placement is very clever, many businesses further attract players by purchasing petal rain that can attract Pokémons(FIG 52).

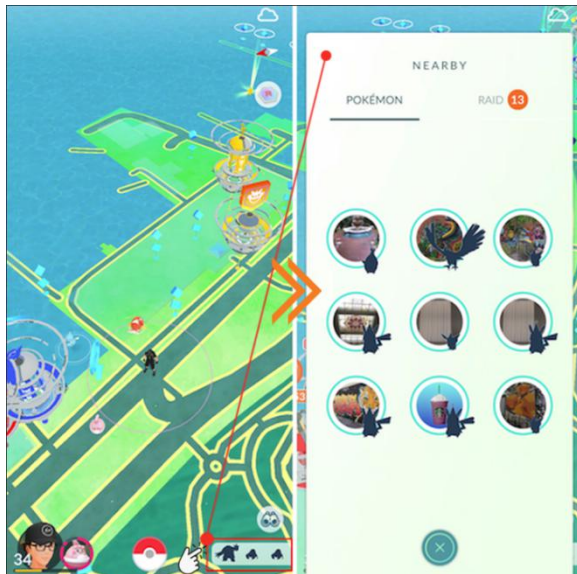


FIG 51 Pokémon GO Map positioning

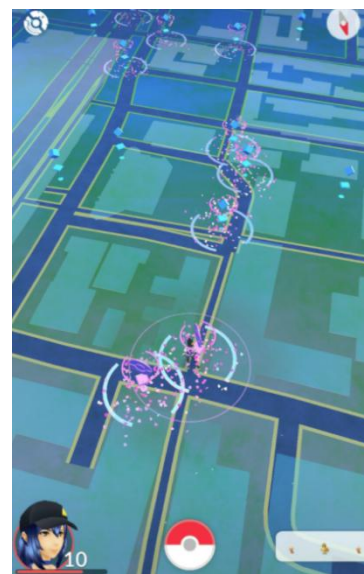


FIG 52 Petal rain

3. The AR capture:

The black edge and white arrows on the screen edge of the capture screen indicate the Pokémon's direction during capture in the AR interface. Because of the extra black edge on the arrow, it can be seen even into sunlight. Need quick use of the camera button and high use of the backpack button in the lower right corner of the hot area(FIG 53).

In the capture process, the Pokémon ball is thrown, the picture is clean, no other elements, and the learning cost is low. Before the capture, the CP (combat power, the higher the more difficult to catch) of Pokemon will be displayed, and the halo on its head will change from green to red, which also indicates the difficulty of capture. You will be prompted to use items while grasping, and the aura will continue to zoom in and out of the cycle(FIG 54), the younger you hit, the higher EXP you will get. After success, use three sub-interface prompts: Confirmation of capture → Bonus → What was captured.

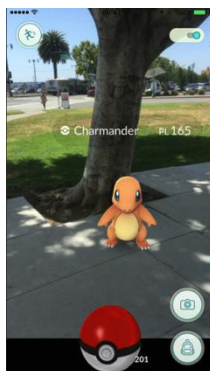


FIG53 AR capture interface



FIG 54 Capture guidance

Messages of the same type in Pokémon GO are strictly positioned. As long as the status is presented, they are all vertically arranged in the upper right corner and slowly disappear(FIG 55).



FIG 55 Pokémon GO interface category division

In order to avoid accidental hits, disposable props will appear in the center of the screen to present the pending state before use. The shadow and mask will be separated from the background(FIG 56). Click to use directly. Functional controls are all concentrated in the lower right corner of the hot zone. The combination of these types of items makes Pokémon GO's interface interaction highly appreciated.

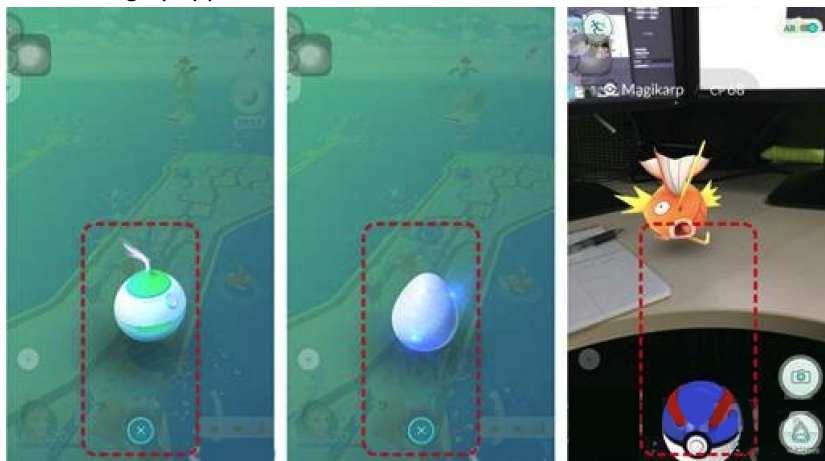


FIG 56 Pokémon GO interaction with consumable items

To sum up, there are three main reasons for the popularity of Pokémon GO.

The first is that this AR game does not require additional equipment. After downloading the Android or Apple version, Pokémon are found and captured on the phone's screen, and the phone's camera can see the Pokémon in the real world. If you play the game with HoloLens, you'll see Pokémon in the real world. In the past, VR/AR games required peripherals such as special glasses or headsets to project images. Pokémon GO, which can be played on a mobile phone alone, is popular because of its **easy entry**.

Secondly, it has completely changed the history of game players staying at home playing games. When the game tells you that your nearest Pikachu is two kilometers away, you have to follow the instructions in your phone to have a chance of catching it. Gamers flock to the streets to socialize, exercise and have fun. But it was so wonderful to encounter a Pokémon in the real world, which used to only exist in the virtual world, that Internet users shared various images of

Pokémon appearing on computer screens, in NBA practice courts, and even in hospital beds while someone's wife was giving birth.

Third, powerful IP+ powerful real scene + powerful background technology. As the IP source of Pokémon GO, Pokémon games have been released for more than 20 years, with a total of 240 million copies sold and thousands of types of Pokémon in 12 categories. It has a strong fan and brand effect in the countries where it has been released, and has been deeply rooted in the hearts of players in the European, American and Japanese markets. Pokémon Go's success was built on the developer's previous game, Ingress. In 2005, when people were able to get a bird 's-eye view of their homes from the air for the first time, the Google server briefly crashed as a result of so many attempts. Since then, the tech team has developed the LBS AR game Ingress, which has attracted 15 million fans and accumulated vast amounts of geo-location data for Niantic to use in Pokémon Go, such as all the Pokémon supply stations and Dojo, Its location, name, and image are all taken from previous Ingress players' uploads and applications. **Data sharing makes the game feel more like it's being perfected by the developer and the player.**

4.2 Terse and forceful—Angry Birds AR: Isle of Pigs

Because there didn't seem to be a lot of interaction with AR in Pokémon GO before. Next, we chose an AR mobile game that was almost full of AR interaction to do a case study, which was Angry Birds AR: Isle of Pigs, focusing on the mobile game dominated by AR interaction.

Although not as famous or as old as Pokemon's IP, Angry Birds is also a popular mobile game and has its own animated and commercial films. Even on March 18, 2016, former United Nations Secretary-General Ban Ki-moon appointed the red birds in the game as honorary ambassadors for green. Angry Birds, one of the first games to be released on smartphones in 2009, has been around for 10 years. Time magazine described Angry Birds as the world's first truly mainstream mobile success. (Virginia Heffernan 2010) Angry Birds AR: Isle of Pigs is a physical catapult AR mobile game. Based on the Angry Birds series, it adds AR gameplay. Players can discover the Pigs' towers in reality through virtual interaction and use the slingshot to find the right Angle in the real depth of space at 360°. Shoot the pigs and the towers.

4.2.1 Game is interactive & Storyboard

The game mechanism is very simple, is to use the slingshot to launch the bird, destroy the pig buildings, eliminate all the pigs. But the game's physics engine is very good. When birds bouncing and colliding, the buildings collapsing with debris, have an impact on the game scene, which requires careful calculation. After the combination of AR, the original 2D environment becomes 3D, the direction of object movement becomes more, so the game changes more. But at the same time the player can move around the level 360 degrees to find weak spots and hidden objects. I drew the storyboard based on my game experience and the stories shared by the players to illustrate how the game works(FIG 57).



① Players were attracted by the popularity of Angry Birds and the novelty of AR and downloaded the game.



② After opening the game, the game first needs to identify a plane as a 3D-built beacon. The player will select the nearest coffee table and identify the plane of the table.



③ After successful identification, the game will build a 3D model of the enemy's tower on the table. Birds and slingshots appear near the player's screen.



④ Players can circle the table 360° to find the right Angle to knock down enemy towers. Player can also rotate the tower model on the screen if the Player is not easy to move around.



⑤ Pull the slingshot, feel the distance, and knock down the tower.



⑥ If the player is outdoors, you can also build a tower with a human height to make the game experience more immersive.

FIG 57 Story board of Angry Birds AR: Isle of Pigs

From the storyboard(FIG 57), we can see the two biggest features of this mobile game after adding AR. **One is that the game has real spatial depth. The second is that the player "moves".**

First of all, no matter the game menu, battle scenes, or set items and so on. In the game, the AR form of the interface is done thoroughly(FIG 58), with the real environment, making the whole game three-dimensional, which is a world of difference from the previous 2D plane, the first time to use it will be amazing. This not only gives the player a very high level of immersion, but also enriches the gameplay. In the previous 2D images, the interior of the building could be seen at a glance. In the AR version, the building becomes three-dimensional, the firing Angle becomes 360°, and the player can even go around the back to attack. The structure of the building became more complex, so many of the mechanisms were placed inside the building, and sometimes the player had to break the outer layer to see the hidden TNT inside(FIG 57-④, ⑤).

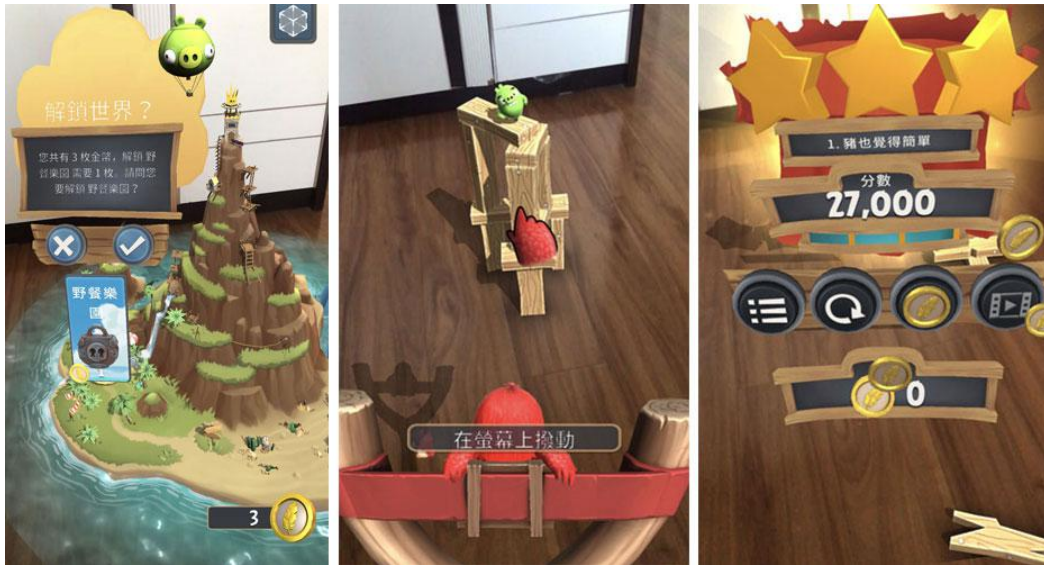


FIG 58 Angry Birds AR: Isle of Pigs

And thanks to the introduction of AR cameras, the game's scenes have real depth, allowing the player to change the size of the buildings depending on the distance they can identify and the size of the space around them (FIG 59). That means gameplay can be tiny, such as playing on a cushion, or life-size if you're playing the game outside, according to a Rovio spokesperson. Imagine the novelty of being able to feel and push a tower of pigs as tall as you are on your phone's tiny screen (FIG 59).

Also, full-angle buildings require the player to view from all angles, so the player has to move himself to find the angles (FIG 57-④). This is completely the opposite of the traditional virtual game that encourages players to sit down and play, creating a more fresh and interesting experience. In addition, players look for angles by moving their mobile phones and themselves, pull the slingshot phone to give sound and vibration feedback and other interactive actions, which are all compatible and advocated by AR and natural interactive ways, so that players can be more absorbed in the game.



FIG 59 Angry Birds AR: Isle of Pigs "The AR game scene is as high as the player"—Google play Ads

4.2.2 Game design & Experience map

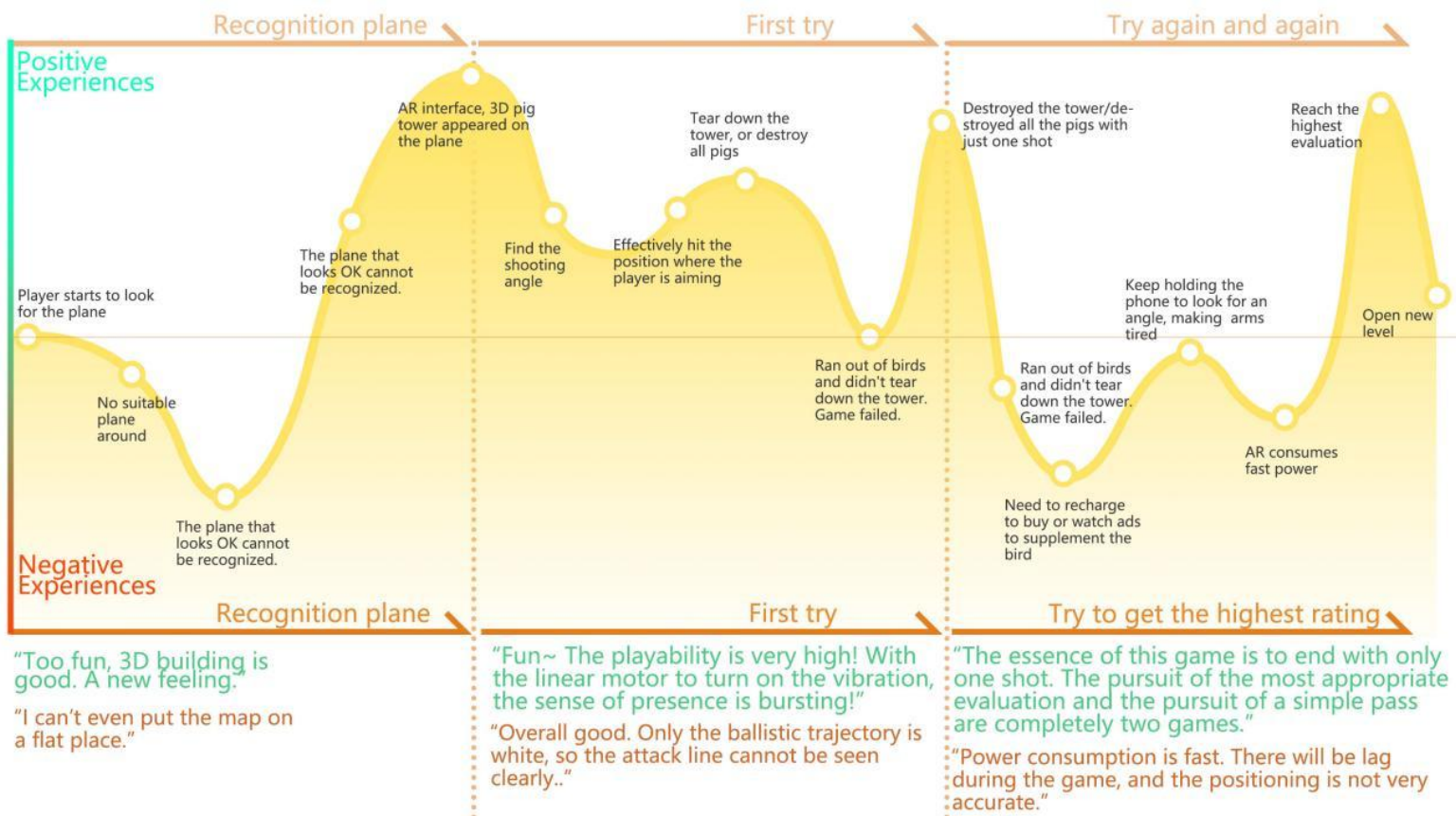


FIG 60 Angry Birds AR: Isle of Pigs experience map

Judging from the reviews of the game on Google Play (FIG 60), the most exciting moment for players was when the Pig Tower was built in reality via AR. This, like other AR mobile games, is the biggest explosion that attracts players to start playing. But it's the right level design that gets people talking about it and sticking with it.

"From our point of view, it was such a great fit," said Tommy Palm, CEO of Resolution Games. "Angry Birds was one of the first real big hits on touchscreen, it was super accessible and a lot of people understood what to do and had fun playing the game." (Amelia Heathman, 2018) As Tommy said, the game has a simple yet complex catapult attack and trajectory estimation and a rich variety of level design. The plot is simple and requires no learning, with each level taking less than a minute. Because of this, it's popular with people who just want to wait for meetings, rides, meetings to take a break, **to fill in the fragments of time without learning, quickly to start.** Interesting graphics and the ability to relieve the stress of the job during the explosion of the pig's head allowed it to win over the non-gaming audience (people who never bought games and gaming equipment), and the audience size grew from there. While there are only 40 levels to pass at the moment, **players can replay them from different angles by AR in reality, so it's hard to get bored.** This is also one of the advantages of AR. The combination with reality will make the game more varied, but within a controllable scope.

My assessment of the game is that it is terse and forceful. Terse and forceful game design is a good fit for AR games. On the one hand, the combination with the reality, **the real environment itself has a lot of complicated factors, if the virtual 3D part is also very complicated, it will make the game scene become chaotic**, improve the difficulty of players to effectively interact, a presumptuous guest usurps the host's role.

On the other hand, because the content of the game is concise, there are fewer problems in the game, because the AR game needs to use the AR camera, which has a high power consumption on the CPU of the phone. Too much game content and complex 3D content can make the game mechanics difficult to work steadily. According to the experience map, the biggest problem is that AR has a certain pressure on the CPU computing capacity of ordinary mobile phones, resulting in very high power consumption.

Overall, Angry Birds AR: Isle of Pigs is a fairly complete AR game. There are no outstanding problems, from the comments, the identification of optimization needs to be more stable, interface optimization needs to be more clear, are the needs of continued optimization (FIG 58). Finally, from the perspective of experience map, I personally believe that more interesting interactions and content can be provided when identifying planes at the beginning, which will make the curve of game experience smoother and more complete. In addition, there are no social advantages of AR that have not been exploited. Imagine how much fun it would be to shoot pigs and pull down towers with friends while they were looking for angles in real space.

Chapter 5

Research outcomes and reflection.



Distill and summarize. Research outcomes and reflexion.

5.1 How will AR be used in Mobile Game in the future

AR is still a new technology in rapid development, with new concepts and trends emerging every year. Given these trends, what can help design AR mobile games to be better in the future? In this thesis, the characteristics, advantages and disadvantages of AR are analyzed from the aspects of AR technology, interaction, equipment and application. Look for design trends that align with AR characteristics, and measure this knowledge against AR's strengths and weaknesses. Summarize the concepts that have helped AR Mobile design in recent years.

5.1.1 NUI (Nature User Interface) Trend. Influence and connection between AR technology and Game Interaction

Think back to when we were little or when our grandparents were little and what were the "games"? It may be playing in the mud, catching dragonflies, or playing hide-and-seek with other friends, all of which come entirely from nature, and the interaction is also natural. Then "games" became building blocks, poker or chess, abstracting certain phenomena of nature into rules and using artificial tools such as cards, pieces, and chessboards. Now, the first thing that comes to mind when we think of games is video games made up of virtual 3D content(FIG 61). From the comparison between VR and AR in Chapter 3, it can be seen that AR's enhancement and immersion direction is reality. In the case study of Chapter 4, AR mobile game encourages players to go out of their homes to play games. AR makes the concept of "game" return to nature. From the history of game development: the pursuit of more realistic virtual immersion in virtual games and the status quo of staying at home, AR mobile game seems to be a way of reverse thinking, but it is also the most profound feature of AR's redefinition of mobile game(FIG 61).



FIG 61 The trend of game interaction and environment change

When we look for the relationship between AR and interaction, NUI is one of the answers.

In the past, human beings have separated tools from nature to serve human beings. Today, with the continuous development of machines, human beings are exploring how to return the interaction of machines to nature. This gives birth to the Nature User Interface or Interaction (NUI) trend. Not just what people see when they communicate with machines, but all the things they can feel when they communicate with machines. Touch, eye contact, voice, gestures, etc., are all the means of communication studied in natural interaction(FIG 62). Not only voice,

gestures, eye movements, etc., these are all natural forms of expression when people communicate. The recent advances on User-Centered Design (UCD) applied to Natural User Interfaces (NUIs) intend to make use of human innate features, such as speech, gestures and vision to interact with technology in the way humans would with one another. User-centered design (UCD) is a key part of any current system design process. The idea behind UCD is that endusers needs, wants and limitations are accounted for in the design process foreseeing how users are likely to use a product testing their behavior in real world tests. This design ideology is the cornerstone of NUI development. (RAS Fernández 2016)



FIG 62 NUI trend

The interaction requirements of AR conform to this design trend, and AR also provides a bridge for various natural interactions. As in the game example mentioned earlier in this article, the addition of AR technology has moved the interface from a two-dimensional to a three-dimensional space, but it has not yet become a standard, like the "mouse + keyboard" in the PC era and the "multi-touch" in the smartphone era. The NUI concept gives designers the right direction to look for such a standard. Users need more natural interaction, and AR mobile games need more natural interaction.

On the one hand, natural interaction advocates the use of gesture recognition, movement recognition, facial recognition, eye tracking and even facial expression interaction. NUI also greatly matches the needs of AR mobile games for interaction on the move. **On the other hand, it's more important to make the game's content and mechanics lean toward these natural interactions.** For example, in early May 2018, Snapchat launched an AR face game featuring face play and multiplayer interaction. And Facebook's little AR game, Face Dance. In these two games, players input the correct expression with the front camera of the phone, and then compare it with the player's expression by 1: N, which is easy for players to understand and does not have too much burden in terms of technology. Videos of gameplay are also good social networking material, and therefore suitable for use in social apps. Smartphone's built-in gyroscope, vibration and other interactive features also allow users to use body movements to adjust the phone's Angle to replace or supplement simple touch. And **these NUI interaction modes can also make it easy for users to think about how these interactions should be implemented, which is more close to the natural reaction of human instinct.** This is all part of the "Industrial Revolution 4.0" trend.

NUI & GUI: Although there is the concept of NUI, in the product, NUI and GUI are still an inseparable combination and must cooperate with each other. In AR mobile game design, "I" in

NUI, interface&interaction.NU-Interface generally requires designers to pay attention to the interface of the AR device is an interface with real depth. As mentioned in 2.4.2 of this article, the interface design of AR game cannot consider depth, space and distance like traditional GUI interface.

In terms of NU-Interaction, NUI should cooperate with GUI. With current technology, NUI is more convenient in input, and it is more difficult to output complex information feedback. At this time, a GUI is needed to convey complex information. In general, a GUI provides some functions to help operators in certain tasks that are difficult to be supported by a NUI. For example(FIG 63), they correspond to tasks when the operator requires detailed information such as vehicle set up or mission monitoring at software level (during software maintenance). (RAS Fernández 2016)

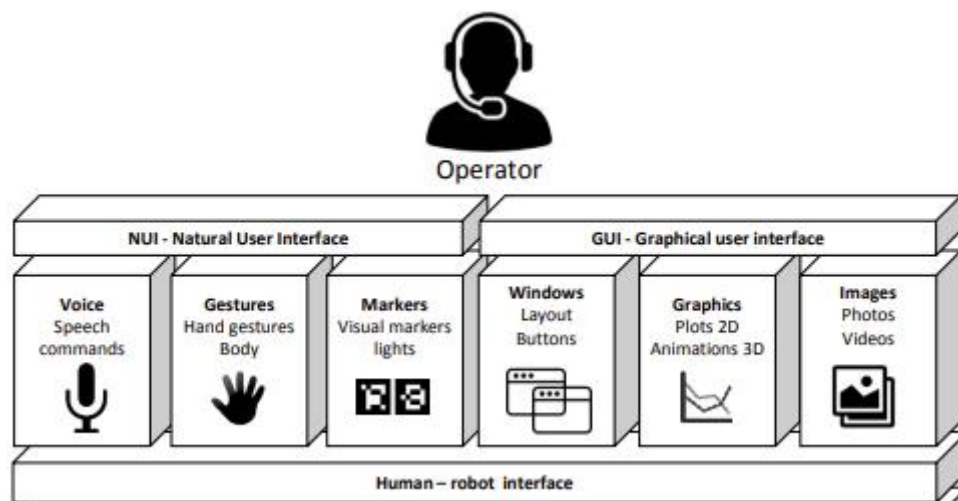


FIG 63 The NUI and GUI collaboration framework in the NUI interaction mode(an unmanned aerial vehicle system). — Ramon A. Suarez Fernandez and others"Natural User Interfaces for Human-Drone Multi-Modal Interaction", 2016

In the final design of Politecnico di Milano's course, my teammates and I tried to create an interactive billboard(FIG 64) using voice recognition and gesture recognition.



FIG 64 Concept of Interactive billboard"Mr. Milan"

The user inputs his own operations through gestures and voice, and the GUI of the billboard screen feeds back a large amount of customized advertising information to the user (FIG65).



FIG 65 Prototype of Interactive billboard"Mr. Milan"

When people see or hear this billboard, they can interact with gestures or voice, naturally they will be curious and want to try it. Because gestures and sounds are natural interaction methods, users can quickly understand and learn to interact with this advertising board(FIG 66). This NUI interaction mode allows users to passively accept advertisements and turn them into active interactions, seeking information. I personally think that the user is in the process of interacting with the active and passive exchange, which is also one of the charms of NUI.



FIG 66 Storyboard of Interactive billboard"Mr. Milan"

Of course, the last thing to note is that AR games should be designed to follow the NUI trend while also being easy to interact with. AR UI has two meanings: Augmented User Interface & Augmented User Interaction, designers should use virtual images to design a new environment combined with the actual environment, the purpose is to cooperate smoothly with people and

machines, so as to improve the original work efficiency or get more interesting operation experience. The vividness of AR and the simplicity of NUI greatly reduce the cost of understanding user interaction.

5.1.2 AR+ filter + social, popular one-two punch

Social is one of the properties to consider all in all game design. Social integration can help the game increase the number of players, but also one of the drivers that make players causing user viscosity. All game companies are undoubtedly to broaden their group groups, especially social platform investment game projects, and they use their platform user base and platform propaganda advantage to promote their own games. AR novel expressions and concepts are a suitable stage. Multi-social app comes with a lot of interesting filters is using AR technology, then further, AR Mobile Game is also suitable for mounting these platforms.

For example, Instagram has launched many new game filters using AR. People may not be very interested in AR games, but this form of game filters can shoot interesting videos and attract more people to learn about AR. Snapchat introduced AR games on the social platform back in 2016, but Instagram has a much larger user base and can help Facebook explore the gaming space, as well as promote AR games to more potential users. In the Instagram version of Fruit Ninja, players earn points by "slicing" various fruits with their faces, not their fingers. Once the score reaches a certain point, players can post the process to their friends on Instagram, similar to videos that show users turning into a dog or Disney character through a filter. This process attracted more players to try out the AR game.

Dr Stephan Lukosch, Associate Professor of Applied Game Simulation at the University of Canterbury in New Zealand, said: "I think the Instagram game filters are very interesting because they are bringing AR to the public and opening up the possibility of AR applications, which in the long run will lead to more people being exposed to and learning about AR technology." Jesse Schell, a distinguished professor of game design at Carnegie Mellon University, calls the combination of AR games and Instagram "a great fit." He also thinks: "When you talk about a game that people don't want to play, this feeling is very strange. But if you can make a video in the process of playing games, it is very interesting. In order to let people really want to go Experience Ar, from the industry has already spent a long time to think about various ways. "

However, social intent is just a beginning, not directly playing a complete AR game directly on the APP of the social platform, which may cause a burden on the app itself, increasing the difficulty of compatibility. However, you can carry a streamlined version of Ar Mobile Game on a social app, or Demo, bring traffic to the game body, increase the number of downloads of the game body.

At the same time, social features and systems within Ar Mobile Game also need to be carefully designed. The AR game is created into a social platform to enhance the sociality of Ar Mobile Game. When Pokemon GO first launched in the US, New Zealand and Australia, players around the world went crazy. 70% of players who download Pokemon Go continue to play the game the

next day. That's more than double the industry average, and it's closely related to how well a game makes money. In addition, people spend an average of 33 minutes a day on Pokemon Go, compared to 22 minutes on Facebook, 18 minutes on Snapchat, and 17 minutes on Twitter, making Pokemon Go arguably the most popular social gaming platform at the time. (Luke Lancaster 2016) Pokemon Go has formed such a social platform. From the previous case study, it can be seen that players have carefully considered the requirements of social interaction in terms of their virtual images' clothing, movement mode and interaction mode.

5.1.3 Location Based Service

Whether it is a widely raised Pokémon GO, or Harry Potter: Wizards Unite, The Walking Dead: Our World, MINECRAFT EARTH, etc. Most of these flexible AR Mobile Games are used in the Location Base Service technology. The frequent occurrence of the combination of AR+LBS in AR Mobile confirms the good fit between AR and LBS. On the one hand, LBS gives full play to the "mobile" characteristics of mobile game, and builds the game mechanism on the basis of the mobile amount of players. For example, Pokemon Go was explored and discovered in the previous article. The Walking Dead: Our World and Minecraft Earth require The player to go out and find "survival supplies". On the other hand, LBS is based on the player's location and environment in the real world, which encourages the player to go out and gives AR a better chance to enhance the real environment. The three AR Mobile mentioned above all use AR to enhance street scenery and render the game world into the real world to bring players a sense of immersion.

LBS is also a trigger to realize the trend of NUI, prompting players to go out and do more natural game interactions, and promoting a healthier game environment and movement instead of staying at home, which is also a reverse design driver for the development of virtual games. The player only has the opportunity to interact in natural ways in the context of movement and real space. Although LBS does not belong to AR technology according to the definition of AR technology in the first chapter, it enables players to walk in the real world as the game map, complemented by AR technology's enhancement of reality. The identification with a character and the immersion of players in the fictional world was increased using physical objects and deploying a strong connection between the fictional world and the urban setting in which the game took place. In this sense, we noticed that the interaction with physical objects and with the real environment added a sense of physicality and realism to the digital experience usually provided by mobile games.(Davide Spallazzo & Ilaria Mariani 2018)

In marketing, LBS is convenient to locate merchants who purchase game advertising services in reality. For example, in Pokemon Go in Chapter 4, changing the type and number of Pokemon at a certain location. It can draw players directly to a certain location, which can lead to a very immediate advertising effect. Effectively increased the revenue of the game company. At the same time, LBS also facilitates people's data contribution to OSM(OpenStreetMap), enriches the data of VGI (volunteered Geographic Information), facilitates the use of geographic information by the society, and contributes to the society while playing games. Both public and private benefits.

5.1.4 Wearables auxiliary

With the popularity of smart phone, its product ecological chain is also gradually improved and popularized. One such module is wearables, such as smart wristbands and the Apple Watch. This kind of product is characterized by the interactive functions of mobile phones, such as vibration, sound, infrared sensor and gyroscope.

According to IDC, 17.6 million smartwatches were shipped globally in the third quarter of 2019, up 48% year on year. In the third quarter of 2019, 19.2 million smart bracelets were shipped globally, up 48.6 percent year on year. In 2019, the global shipments of smart bracelets and smartwatches accounted for 22.7% and 20.9% of the global shipments of wearable devices, respectively.

Global smartwatch shipments are estimated to be around 62.63 million units in 2019, up 43% year on year, according to Trend Force data. Global smartwatch shipments will grow 28.6 percent year-on-year to about 80.55 million units in 2020. Worldwide shipments of smartwatches are expected to reach 113 million units in 2022. The CAGR(Compound Annual Growth Rate) will reach 35% from 2016 to 2022. This means that smartwatches have become widely recognized as one of the next growth areas in the consumer electronics sector after smartphones.

With such a large user base and the interactive function of mobile phones, it is just like the control handle of AR Mobile Game which requires the interactive mode of motion-sensing operation. Because there are vibration, sound, infrared sensor and gyroscope and other functions, just like Joy-Con of Nintendo Switch, position and Angle determination can be realized and feedback of sound and vibration can be provided, which increases the interactive convenience and game experience of AR mobile Game. Therefore, we should not only make good use of the interactive functions of Smartphone, but also find ways to improve the interactive efficiency of the game with the assistance of wearables.

5.1.5 Thoughts on wither technology - make good use of smartphone interactive function

GBA (Game Boy) creator Yokoi Gunpei's design philosophy of "thinking about withered technology" means that "in product development, researchers always want to use the most advanced technology to make the best product. But I think that trying to develop profitable products using the most advanced technology is not a plus but a minus for the product. It's easier to take a technology that's already mature, or even close to obsolete, and think horizontally, and apply it to a completely different field, and it's easier to create a best-selling product." I think the philosophy of using mature smartphone to make AR mobile games is the same.

When designing Game & Watch, Sharp and Casio were engaged in a fierce price war in order to compete for the market of electronic computers, which led to the surplus of production equipment of semiconductor and liquid crystal display in Japan. Yokoi Gunpei is the use of cheap

but mature computer technology in the development of portable games, not only to reduce production costs, but also to ensure the stability of the product.

In the latest Switch console, one of the controllers features the same three-axis gyroscope as a regular phone, plus a 320-resolution infrared camera that senses shape, motion and distance. These are all well-established components that are in intense competition. With these simple sensors, multiplayer games as varied as "Mario Party" can be made. Smartphone almost has these components, so we should make good use of the interactive function of Smartphone itself to design the interaction of AR game. When making AR games, many designers are eager for the latest AR features, but unstable technology can lead to difficult projects or poor experience. So it is better to quote Yokoi Gunpei's idea and make good use of the interactive functions of mature Smartphone.

5.1.6 The Psychology of Immersion - Generating Fun - "Flow" :

In Chapter 3, AR Vs AR, we mentioned that the disadvantage of AR was that it could not achieve a particularly realistic virtual effect. VR is visually driven immersion, AR is playability driven immersion. So, when the game can playability, we have to mention the Csikszentmihalyi's Flow theory, similar to athlete's "zone" - a state of high concentrated attention. Now Game Design's most commonly used theory is to surround how to generate this "flow"(FIG 67):

In psychology, Csikszentmihalyi's Flow (1990, 1998) is a general way of describing involvement as a deep level of concentration and attachment. Flow is the feeling of being intensely engaged in an activity for its own sake. During flow, the passing of time seems to disappear due to a deep focus in the activity. As we will see below, this is an experience that players often seek when playing, and a game's ability to create flow is often seen as a sign of its quality. In games, the sense of flow can be associated with different aspects of the game, depending on what aspect the player finds most attractive for his or her experience. For some, then, flow may be created by exploring and navigating an environment, while for others, flow is initiated by following the development of a plot. (Stein C. Llanos 2011)



← FIG67 Flow

AR Game Designer can focus mainly in this design that produces Flow's loops. AR game actually performing game interactions in the real world, and people who are directly playing games are also themselves in the game. Unlike traditional visual games, the "person" of the game is the role in the game. Need a lot of episode, scene rendering to make players produce their own Proteus Effect. Proteus Effect: The Proteus effect describes a phenomenon in which the behavior of an individual,

within virtual worlds, is changed by the characteristics of their avatar. (Nick Yee 2007) It can be said that the Proteus Effect of the AR Game player needs very little, so the focus is not visually created. AR is also avoided from the disadvantages of the 3D scenes of Too true and complex.

5.2 Design Principles

5.2.1 Feedback must be effective

This is the core of interaction, and the deterministic feedback is more important than anything. One of the technical features mentioned before AR is that Real-time human-computer interaction, not timely and unauthorized interaction feedback is often fatal for AR's experience. In addition to the feedback from the AR, there is environment feedback. The most important thing is the 3D recognition feedback of the Mark-Based AR Game.

- **Feedback for 3D registration (recognition) :**

Even if we see the successful examples Pokémon GO and Angry Birds AR, we still see a lot of poor evaluation about 3D registration feedback on the game on the Google Play platform. 3D registration (Recognition) technical characteristics are the foundation of AR technology. **In AR game, 3D registration (recognition) is the first important step at the very beginning of the game. Because all subsequent interface interactions are based on identifying the object and adding virtual content to the real object. Only after successful identification can subsequent operations become closed loops. The interaction between man and machine can be smooth only when the perception of external environment is well done.** 3D registration is not good, AR games even can not start. As an interaction designer, try to be sure of this.

- **Environmental feedback:**

Since the AR scene is in a real space, some small feedback to the real scene or the player can also enrich the game experience. For example, in Angry Birds AR, Birds on the ground give the player a thumbs-up if the player hit a building. Pokemon Go's AR mode, in which the Pokemon don't interact with the player at all, is less vivid.

MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) has developed technology that allows viewers to "touch" and directly manipulate objects in videos, which feel like objects they can be seen and touched in the real world. The MIT group also created a case study in conjunction with Pokemon Go(FIG 68) to explore the potential uses of the technology(FIG 46). Although not used in the game, the video shows that AR interaction is much more vivid due to the rich and effective feedback.(Lisa Harvey 2016)

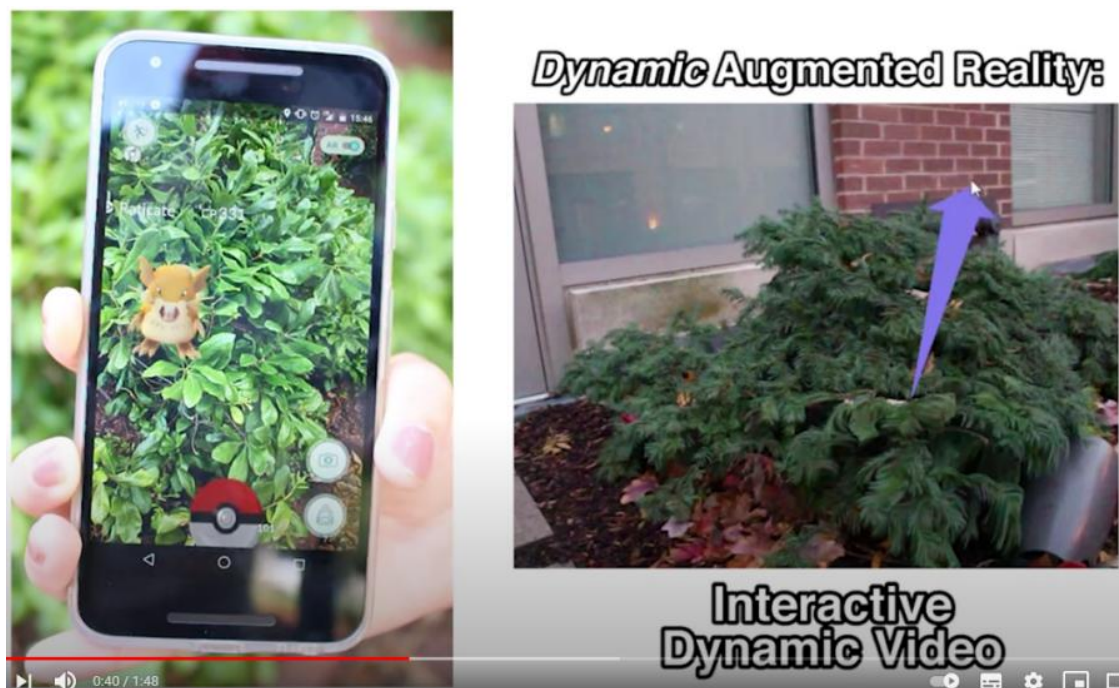


FIG 68 "Pokemon GO and Interactive Dynamic Video"<https://www.youtube.com/watch?v=9f1fCCb3hVg>

5.2.2 Keep the Operating and game mechanics simple and clear

"My advice to other developers is to make sure your game is 'augmented reality' and not just a traditional mobile game played on an AR plane. Take advantage of the fact that the player can actually move around in an AR game scene, and take advantage of the AR capabilities of the device to minimize the amount of unnecessary control." -- Simon Gardner, CEO, Climax Studio.

- **Simple interaction:**

The way AR itself requires certain learning costs, so try to ensure that the operation is simple to reduce learning costs. AR has the advantages of NUI operation. Try to think about using the interactive function of Smartphone itself, which allows players to move and change their posture and other natural interactions, to replace or supplement the single touch operation. Get the players out of their seats and into real action.

- **Shortcuts:**

Since AR mobile games are likely to be played in a moving or demanding situation to complete some actions, they need to be quick and easy to operate. **On the one hand, it reduces the risk of accidents and gives the player the ability to pay attention to their surroundings. On the other hand, it alleviates the fatigue of players.** The fatigue level of play determines whether such interaction mode can be used for a long time and frequently. Interaction that requires too much physical and mental energy must not be the mainstream interaction. Traditional games are played sitting down for a long time. But moving around in AR games, or holding up your phone for too long, can make players tired and weary if it's not appropriate or too long. So the interaction needs to be carefully considered. The shortcuts of Pokemon Go in Chapter 4 are a

good example. The hierarchy is simple and orderly, which is convenient and fast.

- **Game mechanics:**

Simple game mechanics are AR games that fit the NUI trend. Starting from a simple game mechanism, it should be simple, understandable and logical. After adding AR, the increase of dimensions and the influence of the real environment will increase the difficulty and fun of the game, and players will enjoy nearly endless combinations of changes. At the same time, because the game mechanics are simple, there are not too many bugs that will make the game experience worse. The simple difficulty of the game and the fact that the game should not be played for too long also mitigates the problem of fast AR power consumption.

If the game mechanics are complex, adding a dimension of reality through AR will create confusion and make the game difficult to play.

In addition, the simple operation and game mechanism is also in line with the advantages of mobile game for fragmented time. The fourth chapter, Angry Birds AR is a great example of this. The low cost to learn and easy to understand game mechanics allow players to get up and running quickly.

5.3 Design thought

5.3.1 At the present stage, the position of AR is mainly auxiliary

If you're developing a game, the game planner says, the story needs and the content needs are huge, then don't use AR as the whole way of playing, let AR as the auxiliary.

The current technical level of AR decides that it is mainly a form of expression, which mainly plays the role of icing on the cake in mobile game. The first is that AR speeds up smartphone battery consumption. Secondly, complex and realistic models and virtual scenes will be difficult to achieve in AR. AR just as a bridge's form determines who and what can travel across it, the form an AR experience takes substantially determines the set of possible interactions with and within the mixed reality. The interactions built into and around a mixed reality set the stage for a complete user experience and thereby determine much of its potential value. The criticisms of current AR experiences show they offer little value beyond their material's immediate novelty. (Joe Lamantia 2009)

In larger games, such as Pokemon GO and My Dino, AR is reduced and used only in capture and combat environments. Onmyoji and other mobile games only add AR as a way and gimmick to show the game role model. In this way, the advantages and disadvantages can be exploited, and the new attraction of AR as a novel concept can be used to ignite player attention and promote social promotion.

Another common idea is Pokemon Go, Harry Potter:Wizards Unite, The Walking Dead: Our World, Minecraft Earth, Angry Birds AR. Yes, they are well-known IPs, and AR AIDS can amplify the value

of these Intellectual Properties. Even the mechanics of capturing and cultivating Pokemon, which have been in Pokemon games for generations, are completely new when combined with AR.

5.3.2 Think carefully about social interaction needs

As stated in article 5.1.2, **AR is most powerful when matched with other technologies. Users naturally want to share their AR experience, because it's the only technology that puts 3D content into the real world.** As mentioned above, Snapchat and Instagram both use AR mobile game as a way to enhance social communication, and social communication and AR are highly compatible. One of the major advantages of Mobile game is its strong sociability based on Mobile social network. On the one hand, social communication helps to promote the game and expand the player group. On the other hand, social interaction is an important driver for players to keep playing.

In Pokemon Go, because there is no team chat, players on the same team don't know how to do Dojo combat and how to cooperate with their teammates. If you make this part more social, add team chat, and add a mentoring mechanism, it will make the combat experience much smoother. If the designer could add a multiplayer team-up to catch Pokemon, it would encourage more people to make catching Pokemon an outdoor activity for a long time, which would increase player engagement. Angry Birds AR, on the other hand, has almost no social interaction at all. If there were a partnership model, I think a lot of people would be playing Angry Birds AR at parties.

As an interaction designer, under the condition that the design principles mentioned in 5.2 are met, social interaction channels in AR game should be opened, such as voice chat with team members, fast signal, etc. Provide convenience for players to socialize and promote social interaction between players.

5.3.3 Game interaction design in the real dimension

In traditional games, the player sits in front of a computer or PS4 and plays the game, almost regardless of the environment. Game content is often measured in terms of the dimensions of the game engine.

However, the design of AR games is not to design in a new and completely virtual environment like VR or traditional games, but to strengthen and upgrade the real environment. AR mobile game is a game that players play on the move. It is a real dimension and requires space. There are also indoor and outdoor different use of the difference between the scene. The technical features of AR also give AR game interface real depth. All these require AR game designers to combine the knowledge of AR imaging theory in Chapter 2 and Chapter 3 and design games with the concept of space when designing games.

The first is the sense of distance, because AR is an interface with real depth, so the game's virtual content operates on the scale of real dimensions. Then the motion effect of the 3D object should conform to the motion law in the real space to avoid the sensation of vertigo. The game's interaction and flow should be designed to leave the right space for the player. Then there are

the specific user scenarios for the indoor and outdoor environments. Lighting and weather factors should be taken into account, such as avoiding confusion in the skylight when designing the interface UI.

The depth and distance of these Spaces need to be measured and felt by the designers themselves. When The designers of "The Legend of Zelda: Breath of The Wild" designed The map for The game, The entire production team took The Kyoto City map as The model and measured how it felt to run around. For example, they went to a temple and used the time they spent walking around it to assess the size of the "temple" in the game and the difficulty of the puzzle (The player's time spent). The "sense of density" of the game, on the other hand, relies on the daily experience of "how often I see a convenience store" or "how often I run into a post box" while walking down the street.

5.3.4 Reservation of non-AR operation play mode

In Pokémon Go, the player captures Pokémon and the battle can switch the AR scene, and become the full virtual scene with the game. If you don't want to move, you can find the right shot angle by rotating the tower through the rotation button below. These design points are not unnecessary, because there are a lot of situations that are not suitable for AR. For example, the lighting is extremely dark, the environment is extremely crowded, or the disabled player can't move easily. This little design improves the adaptability of the game to different usage scenarios, giving the game more chances to survive.

A new case to consider is the conversion between indoor and outdoor. Due to the COVID-19 epidemic last year and this year (2020-2021), everyone is staying at home and can't get around. LBS games such as Pokemon Go and Minecraft Earth, which are used to getting out and walking, have been badly affected. In particular, Minecraft Earth, which was launched less than a year ago, has been devastated. Microsoft has decided to stop operating Minecraft Earth in June 2021, due to the fact that it has been hit by an epidemic since its launch and the game's revenue is insufficient to support its operation. Therefore, future AR games should consider this situation, and the exchange mechanism between the outdoor game mechanic and the indoor game mechanic, whether it is to reduce the scale of the map, reduce the amount of rewards collected, or increase the difficulty. This provides an experience for people who are quarantined at home to expand their limited space, while at the same time maintaining revenue from the game to survive.

5.3.5 Safety design

This thesis previously described Pokemon Go's AR+LBS game mechanics and its popularity. However, because of its large player base, AR+ LBS encourages players to look at their mobile phones while walking, resulting in many security accidents. One Reddit user claimed to have broken his foot while playing the game: "Less than 30 minutes into the game last night I slipped and fell into a ditch. I broke the fifth metatarsal bone in my foot and it will take six to eight weeks to heal. I told the doctor I hurt it while walking my dog... Watch the road, lads!"

And one of the core parts of Pokemon Go is the Pok Spot where players can collect Pokemon and

the items they need to catch them. But sometimes a Pok spot is not a Pok spot. Or the Pok spot is private property. For example, designer Boon Sheridan lives in what used to be a church, but is now his home. His house was flagged as a Pok spot, resulting in a number of break-ins. In virtual games and mobile games, because players do not move in reality, they only need to consider the safety issues of 3D vertigo and inducing epilepsy as well as game content. In addition, privacy security is also very important. AR Mobile Game often collects players' private information during the game, such as activity location and facial recognition data. This is even a threat to player property, as facial recognition payments and verification are common now. The protection of this information is also an important part of AR Mobile Game Design.

5.4 Summary

These are the key points of interactive design in AR mobile game(FIG 69). We hope to help game interaction designers make stable and creative mobile games at the current level of AR technology.

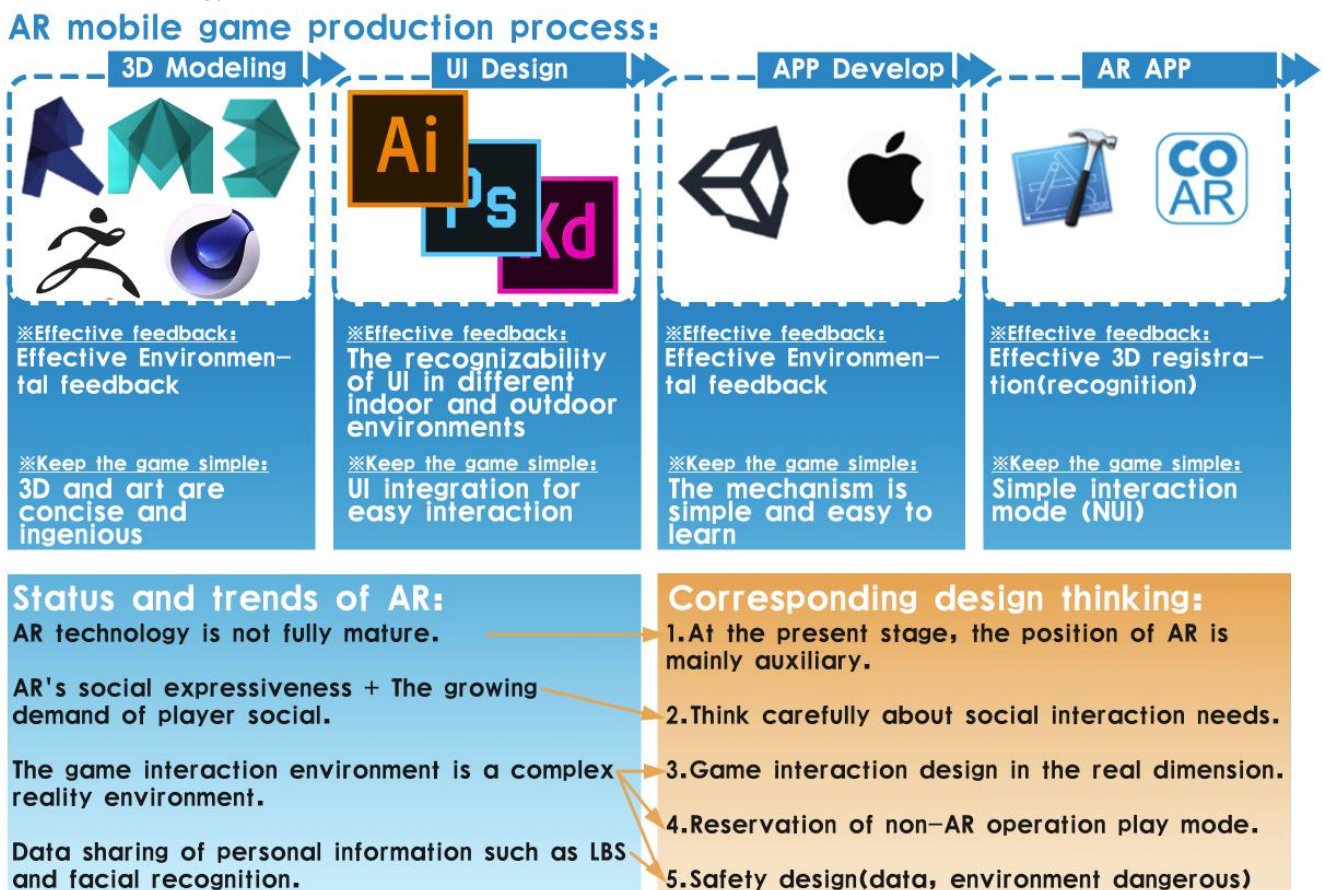


FIG 69 The key points of interactive design in AR mobile game

AR is a very characteristic technology for game design. By organizing this thesis, I learned the basic principles and methods of how AR is applied to smartphones, and analyzed case studies for verification. First, AR is a form of game expression, and then it is an interactive tool. As a game designer, only after learning the principles of AR can truly understand the characteristics of the combination of virtual and real AR. Make full use of the combination of virtual and real to give full play to the advantages of AR and avoid shortcomings in power consumption and errors in

interface design of real depth. Learned how to carry AR into a mobile game. Only by learning the performance of smartphones and the situation of AR wearable devices can we choose the appropriate interaction methods (eye tracking, gesture recognition, gyroscope, etc.). Learn other technologies that work well with AR (LBS, social media, etc.) to improve and enrich our AR game design.

So, How Augmented Reality redefines interaction design in mobile games? In summary, all the characteristics of AR are the combination of virtual and reality (that is biased towards reality immersion), and it makes it possible for mobile games to combine more technologies and interactive methods. This provides our game designers with creative ideas that gradually break away from the virtual overhead imagination, focus on the integration with the real environment, and make the players move as much as possible to interact with the game in a natural way.

The first thing to solve for AR Mobile Game is how to reflect the value and differences of AR. In this thesis, the technical characteristics and interactive characteristics of AR in game design, and the differences between VR and AR are discussed. In my opinion, AR, through the combination of the virtual and the real, makes games have an inflection point in the pursuit of a more realistic virtual history, allowing players to refocus on the possibility of interacting with reality. AR Mobile Game once again takes the real environment as the main body of the game, 3D enhancement as the way to introduce the interaction from the plane to the 3D, so that the game process is not limited by virtual space, and the interaction of the game tends to the game way when we are kids.

Virtual games allow people play with imagination in virtual world. Mobile games allow people to play with imagination in a virtual world anytime and anywhere. AR mobile game is to let people play with imagination in the real world anytime and anywhere.

In the short term, AR mini-games will gradually increase, especially when technology companies such as Apple and Google release technology, with gamified scenes as the premise of display, it will definitely inspire more game manufacturers and game developers to try AR game creation, and low cost AR mini-games will be a good starting point. Therefore, I think it's fair to say that if we look at the content of AR games in the App Store and Google Play stores in the long run, there will be phenomenal AR games like Pokemon Go.

For the next development of AR mobile game, I think the answer is NUI trend and socialization. In this article, the characteristics of AR, market data, technical environment, the needs of mobile game user groups, and the trend of Industrial Revolution 4.0 have all pointed out the development direction of NUI for the interaction of AR mobile game. Games are not just fun, they are also a proving ground, an acceptable way to interact. So the achievement of AR's application in games will also be extended to other fields. Other areas of technology can also be used in GAME. How easy to understand and learn these natural interactions? How high can the recognition accuracy and efficiency of these NUI technologies be? Can it meet the application of a richer environment? These can all be explored with games as experiments. I am optimistic and full of expectations for the future development of AR Mobile Game.

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