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**Joining Together – An Outdoor Running
Support System based on Augmented
Reality**

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Abstract

In this research, we proposed an outdoor running support system based on augmented reality, which allows running users to see running information directly in time and supports inside user to watch a running event lively. With a see-through AR glass, we displayed all the running information such as speed, duration, distance on the screen of the glass. By wearing the Gear VR Head-mounted Display, we allow your friends inside to watch a running event lively, which we use AR glass camera to capture the sight view of outdoor running user. Through this system, we aim at creating join-together feeling to uses who are in different place and display running information directly in order not to interrupt user when running.

Keywords: Augmented Reality; Running Support; Gear VR; Joining Together; VR Glasses; Outdoor Running;

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Chapter 1

Introduction

1.1 Background

Nowadays, with increasingly focus on health care, more and more people choose to use smart watch, smart phone software for running. There are some famously used applications such as MapMyFitness [1], GuDong [2] which are used to monitor running data and share with friends. However, for runners, they have to check these running data in time while running, which we consider is an interrupt for runners. In that case, we proposed a way displaying running data directly to runners without interrupt. After Google AR Glasses [3] appeared, they are also some applications which are used to watch live sports. With this inspiration, we want to integrate Augmented Reality with outdoor running system to support runners with a convenient way to inform the running information. Thus, we implemented Joining Together - An Outdoor Running Support System based on Augmented Reality, which we used Epson AR glasses [4] to display running data and Gear VR Head-Mounted Display [5] to share running event lively.

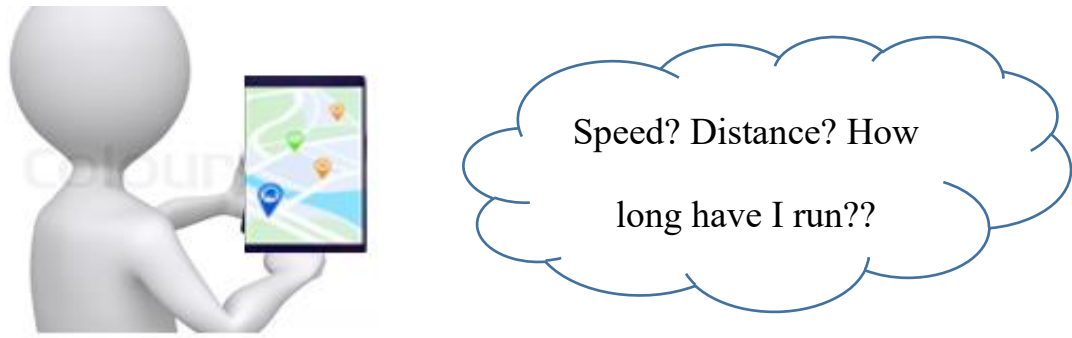


Figure 1.1 Running system on smart devices

1.2 Augmented Reality

1.2.1 Overview

Augmented reality (AR) is a technology which can calculate positions and angles of camera images in real time, which is a live direct or indirect view of a physical, real-world environment whose elements are "augmented" by computer-generated or extracted real-world sensory input such as sound, video, graphics, haptics or GPS data. [6] Augmented reality is related to a more general concept called computer-mediated reality, in which a view of reality is modified (possibly even diminished rather than augmented) by a computer. Augmented reality enhances one's current perception of reality, different from virtual reality, which replaces the real world with a simulated one [7,8]. Augmented reality is always used in the purpose of enhancing the experienced environments or situations, with offering enriched experiences. In the original, the immersive augmented reality experiences were used in entertainment and game businesses, however, now in nowadays, there are other business industries are also getting interested about AR's possibilities for example in knowledge sharing, educating,

managing the information flood and organizing distant meetings. There are lots of potential in gathering and sharing tacit knowledge in Augmented Reality [9]. The techniques of augmentation are rather typically performed in real time and in semantic context with environmental elements.

The advanced AR technology (e.g. adding computer vision and object recognition) made the information about the surrounding real world of the user becomes interactive. Information about the environment and its objects is overlaid on the real world, which enables people feel immersive feelings and also this information can be virtual [10,11,12,13,14,15] or real, e.g. seeing other real sensed or measured information such as electromagnetic radio waves overlaid in exact alignment with where they actually are in space[16,17]. Augmented reality brings out the components of the digital world into a person's perceived real world, like an AR Helmet for construction workers which display information about the construction sites. The first functional AR systems were invented in the early 1990s, which provided immersive mixed reality experiences for users, starting with the Virtual Fixtures system developed at the U.S. Air Force's Armstrong Labs in 1992 [18,19,20]. Currently, Augmented Reality is used everywhere in our daily life in the field of education, where content may be accessed by scanning or viewing an image with a mobile device, which is changing the way of traditional lives [21].

1.2.2 Technology

The technology of Augmented reality is very closely related to software, application level and hardware. Related to the software, the important point about the system of Augmented reality is how to integrate the augmented elements or objects with the real world, how to interactive and control the augmented objects in real world. In terms of hardware, there refers the augmented reality platform combinations of

processors, displays, some sensors and the input devices, such as some AR glasses, AR or VR Head-Mounted Display. While about the application, it ranges from initial use of military and extends to our daily lives.

Hardware components for augmented reality are such, processor, display, sensors and input devices. Modern mobile computing devices like smartphones and tablet computers contain these elements which often include a camera and MEMS sensors such as accelerometer, GPS, and solid state compass, which making them suitable AR platforms [22]. There are Various technologies that are used in Augmented Reality rendering including optical projection systems, monitors, hand held devices, and display systems worn on the human body, which is a new way.

Recently, A head-mounted display (HMD) is popularly used in augmented reality. HMD is a display device paired to the forehead such as a harness or helmet. HMDs place images of both the physical world and virtual objects over the user's field of view. Modern HMDs often employ sensors for six degrees of freedom monitoring that allow the system to align virtual information to the physical world and adjust accordingly with the user's head movements [23,24,25]. HMDs can provide VR users mobile and collaborative experiences [26]. Specific providers, such as uSens and Gestigon, are even including gesture controls for full virtual immersion [27,28].

Usually AR displays can be rendered on devices resembling eyeglasses. Versions include eyewear that employs cameras to intercept the real world view and re-display its augmented view through the eye pieces [29] and devices in which the AR imagery is projected through or reflected off the surfaces of the eyewear lens pieces.

A head-up display, which known as a HUD, is a transparent display that presents data without requiring users to look away from their usual viewpoints. A precursor technology to augmented reality, heads-up displays were first developed for pilots in the 1950s, projecting simple flight data into their line of sight thereby enabling them to keep their "heads up" and not look down at the instruments. Near eye augmented reality devices can be used as portable head-up displays as they can show data, information,

and images while the user views the real world. Many definitions of augmented reality only define it as overlaying the information [30,31]. This is basically what a head-up display does; however, practically speaking, augmented reality is expected to include registration and tracking between the superimposed perceptions, sensations, information, data, and images and some portion of the real world [32].

CrowdOptic, an existing app for smartphones, applies algorithms and triangulation techniques to photo metadata including GPS position, compass heading, and a time stamp to arrive at a relative significance value for photo objects [33]. CrowdOptic technology can be used by Google Glass users to learn where to look at a given point in time [34].

A number of smartglasses have been launched for augmented reality. Due to encumbered control, smartglasses are primarily designed for micro-interaction like reading a text message but still far from the well-rounded applications for augmented reality [35]. In January 2015, Microsoft introduced HoloLens, which is an independent smartglasses unit. Brian Blau, Research Director of Consumer Technology and Markets at Gartner, said that "Out of all the head-mounted displays that I've tried in the past couple of decades, the HoloLens was the best in its class." [36]. First impressions and opinions have been generally that HoloLens is a superior device to the Google Glass, and manages to do several things "right" in which Glass failed [37,38].

The key measure of AR systems is how realistically they integrate augmentations with the real world. The software must derive real world coordinates, independent from the camera, from camera images. Many computer vision methods of augmented reality are inherited from visual odometry. Usually there are two parts. The first stage is to detect interest points, fiducial markers or optical flow in the camera images. The second stage is a real world coordinate system from the data obtained in the first stage. Some methods assume objects with known geometry are present in the scene. Currently there are some SDKs to enable rapid development of Augmented Reality Applications, such as Vuforia, ARToolKit, Catchoom CraftAR, Mobinett, Wikitude, and ARLab.

1.3 Research motivation

As we all know, in recent years there is an increasingly focus on health care that more and more people start to run outside using smart watch, smart phone, bracelet and even smart AR glasses. However, none of them is perfect or convenient for runners to check running information and get running date smoothly without interrupt and can share a live running event to friends or families while running. It is always seen that runners touch smart phone or watch smart devices to check the speed, duration. In this case, our motivation is to find a solution and implement a system that can solve this problem.

1.4 Organization of this paper

This paper is organized as follows:

Chapter 1 introduces the background of outdoor running system and augmented reality technology used in this research.

Chapter 2 introduces research goal which kind of problems we want to solve and approach that how we implement the target.

Chapter 3 introduces the design of our target system, outdoor running system based on augmented reality. The whole structure of our system and the functions of the system.

Chapter 4 introduces the implementation of all the functions in software, devices that used in our research and how we implement every function and what development environment we used.

Chapter 5 introduces some related works about this research.

Chapter 6 gives the conclusion and some future works.

Chapter 2

Goal and Approach

2.1 Target Problem

The target problem we are aiming at solving is to help local runners run more convenient without interrupt and motivated, also help runners in separated location get a feeling of joining together and share running event to friends in separated place lively. There are some researches that used augmented reality technique and head-mounted display to share viewpoint and increase the interests when running [38,39,40]. These researchers have proved that using augmented reality technology in running system made benefits for runners which enhanced and maintained the motivation of runner. We find that currently, there are many outdoor running systems, such as Apple Watch, smart phone. However, on one hand, none of these can make a smooth running without checking running information interruptedly. On the other hand, none of these systems can give a real joining together feeling or enable people to watch a live running event. Thus, we are targeting to propose this research to solve these problems.

2.2 Research Goal

In this study, we aim at proposing an outdoor running system which is based on augmented reality. It is constructed for two main functions: one is for outside runner itself checking running information directly and another is for outside runner sharing the sight view to insider user. First, the outside runner run outside wearing the AR see-through glass. While running all the running information (speed, distance, duration, calories) will be displayed on the screen of see-through glass. At the start point, all the initial data is zero, with the running event continuing the displayed data will change in time, through which runner can clearly know the running. Secondly, we aim to share the sightseeing of outdoor runner to indoor user. The indoor user wears a head-mounted display to watch the video of a outside running event lively. For example, people in different place cannot run together, then in order to make them feel running together, we propose to share the running information or running event lively, through which they can support each other and get the feeling of joining together. Thus, even in a physically separated place in the world, we aim to create an environment which can support runners to feel running together.

2.3 Research Approach

The consists of our system's setup are as bellow: the AR see-through glasses (Figure 2.1) through which we use to displace running information directly to outside user. With the AR see-through glasses, which is different from traditional device used for running such as smart watch, smart phone and bracelet, we enable runner to check the information directly without interrupting running. Meanwhile, through displaying augmented reality objects, we inspire the motivation of runner and make runner feel accomplished strongly how much distance he or she has run.

For the insider user watching a running event lively, currently we still use the normal camera of EPSON AR see-through glass to catch the sightseeing of outside running. Then the capture of video will be transferred to insider user, while the inside user joint this running by wearing a Gear VR head-mounted display.

The EPSON AR see-through glass and SAMSUNG Gear VR with Galaxy S6 insert inside Gear VR are used in our system. We calculate the running data through the GPS of the see-through AR glass which is an Android system. We aim at sharing the long distance running event like marathon, thus short distance running can be measured but not high accuracy. With the long distance running like 10 KMs(or more that it), we can provide a high accuracy because of the calculation, which calculates not only the straight line but also circle line.

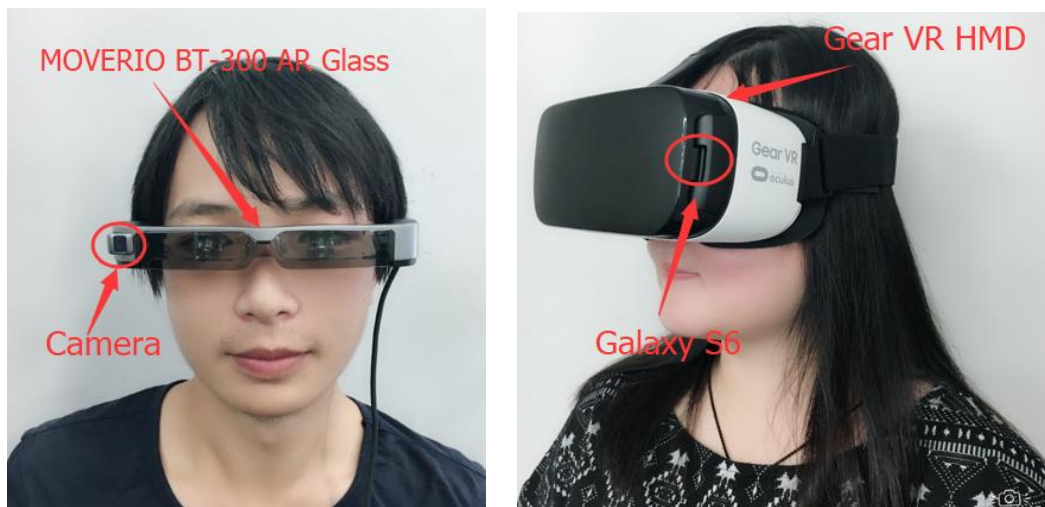


Figure 2.1 The wearable devices of EPSON AR see-through Glass MOVERIO BT-300 for outside runner to check running information directly and to capture sightseeing for sharing to insider user. The SAMSUNG Gear VR Head-Mounted Display with Galaxy S6 inserted inside for insider user to watch running event lively.

2.4 Novelty and Potency

Our system consists see-through AR HMD glass and Gear VR HMD. In this system we use the augmented reality technique to show augmented reality objects to enhance motivation of running. We consider the novelty and potency as follows:

1. Displaying running information directly to users without interrupting running by wearing a smart AR glass is a new way to enable runner to enjoy running. Using augmented reality technique to show some AR objects will encourage and strengthen user's interests in running

2. Using Gear VR HMD can allow the long-distance families to support or watch a running event lively and feeling running together with runner.

Chapter 3

System Design

3.1 Target System Structure

The proposed system is designed for outdoor running. There are two main functions in this research. One part is displaying running information directly to user. Another part is watching running event lively interface. Through the Target System Structure, we can see the first part of watching a live running event, we use Gear VR HDM to enable inside user to watch the running. We use AR glasses to capture the running video and then deliver to Gear VR. As for the second part, we use Epson AR glasses BT-300, through GPS we get the Longitude and Latitude, then once the user moves, the location will be changed, we monitor the Location-changed event in Unity to calculate the distance.

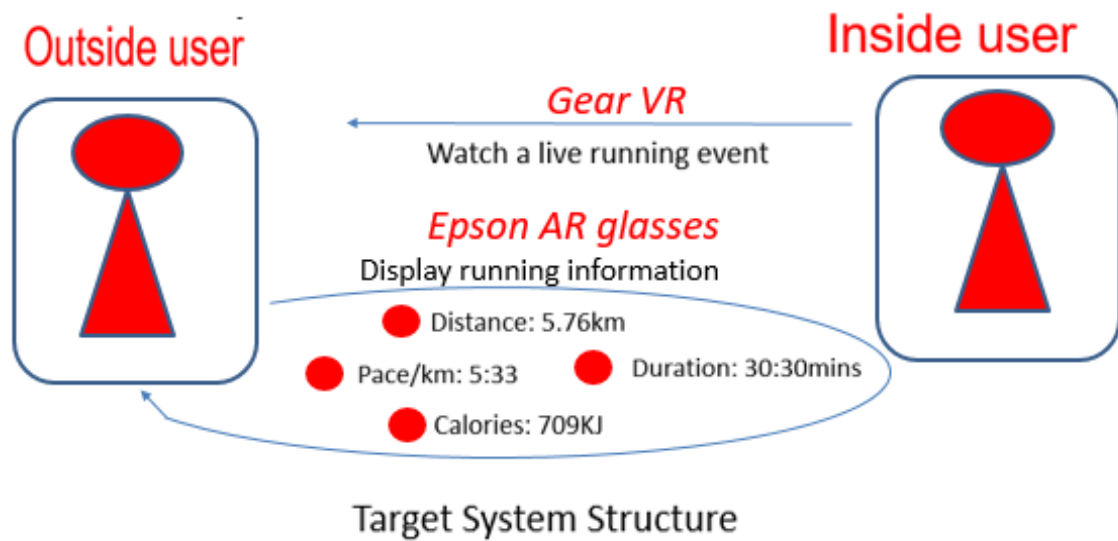


Figure 3.1 target system structure

3.2 Join-Together Feeling

In this study, we come up with the idea Join-Together Feeling is that when running the view of the runner is shared to the user who watches the running inside in a separated place. Although there are still uncertain aspects which limit the sharing views, our research currently focuses on the support of experiencing running for both inside user and outside runner lively, even for some disable people who cannot run or for separated friends who cannot run together by just wearing the HMD devices and see-through AR glass. Moreover, currently we are not aiming at supporting interaction between insider user and outside runner except for encouraging runner by insider user that giving some hints like “good”.

Sharing a running event to your friends where he or she is in a physical separated place and cannot join or support your running event is another main function in this system. The example shown follow is the inside user wearing a Gear VR Head-Mounted Display while the outside runner wearing MOVERIO AR see-through glass through which the outside runner shares the sightseeing when running and the inside user can enjoy the same view of outside runner, feeling together and like himself also running outside.



Figure 3.2 The outside runner(a) run outsider then share the view to the insider user(b) of his view sight lively then, both of them can enjoy the same scenery of (c).

3.3 Usage Scenario Diagram

The usage scenario diagram of the outside runner and inside user is shown as Figure 3.3. The outside runner wears the Android system smart AR see-through glass, through which he or she can check running information that displayed directly on the screen of glass and can also see the AR objects. For example, when the runner accomplishes running the goal 5KMs, we can show the AR object water as a reward. If the runner achieves a half-marathon as a goal, we can reward an AR medal like real marathon. When the runner runs in the real environment towards a school or a famous traveling place, we can display the symbol AR object as explanations which can inform the runner where he or she locates at that moment. While for the inside user, he or she watches the running event lively through Oculus HMD.

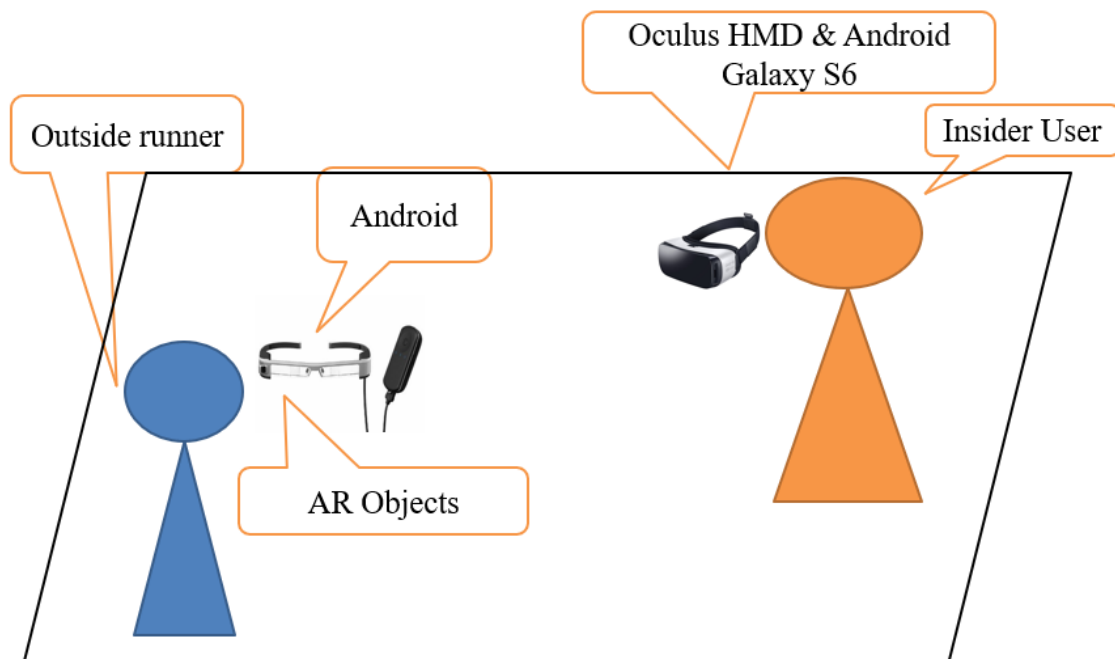


Figure 3.3 Usage Scenario Diagram

3.4 Through GPS Get and Display Running Data

The proposed system is designed for outdoor running. There are two main functions in this research. One part is displaying running information directly to user. Another part is watching running event lively interface. Through the Target System Structure, we can see the first part of watching a live running event, we use Gear VR HDM to enable inside user to watch the running. We use AR glasses to capture the running video and then deliver to Gear VR. As for the second part, we use Epson AR glasses BT-300, through GPS we get the Longitude and Latitude, then once the user moves, the location will be changed, we monitor the Location-changed event in Unity to calculate the distance.

3.4.1 GPS and How it works

As we know, The Global Positioning System (GPS) is a satellite-based navigation system made up of at least 24 satellites. GPS works in any weather conditions, anywhere in the world, 24 hours a day, with no subscription fees or setup charges. The U.S. Department of Defense (USDOD) originally put the satellites into orbit for military use, but they were made available for civilian use in the 1980s [41].

GPS satellites circle the Earth twice a day in a precise orbit. Each satellite transmits a unique signal and orbital parameters that allow GPS devices to decode and compute the precise location of the satellite. GPS receivers use this information and trilateration to calculate a user's exact location. Essentially, the GPS receiver measures the distance to each satellite by the amount of time it takes to receive a transmitted signal. With distance measurements from a few more satellites, the receiver can determine a user's position and display it electronically to measure your running route, map a golf course, find a way home or adventure anywhere[41].

To calculate your 2-D position (latitude and longitude) and track movement, a GPS

receiver must be locked on to the signal of at least 3 satellites. With 4 or more satellites in view, the receiver can determine your 3-D position (latitude, longitude and altitude). Generally, a GPS receiver will track 8 or more satellites, but that depends on the time of day and where you are on the earth. Some devices can do all of that from your wrist. Once your position has been determined, the GPS unit can calculate other information, such as:

- Speed
- Bearing
- Track
- Trip distance
- Distance to destination

Today's GPS receivers are extremely accurate, thanks to their parallel multi-channel design. Our receivers are quick to lock onto satellites when first turned on. They maintain a tracking lock in dense tree-cover or in urban settings with tall buildings. Certain atmospheric factors and other error sources can affect the accuracy of GPS receivers. Garmin GPS receivers are typically accurate to within 10 meters. Accuracy is even better on the water.

Some Garmin GPS receiver accuracy is improved with WAAS (Wide Area Augmentation System). This capability can improve accuracy to better than 3 meters, by providing corrections to the atmosphere. No additional equipment or fees are required to take advantage of WAAS satellites. Users can also get better accuracy with Differential GPS (DGPS), which corrects GPS distances to within an average of 1 to 3 meters. The U.S. Coast Guard operates the most common DGPS correction service, consisting of a network of towers that receive GPS signals and transmit a corrected signal by beacon transmitters. In order to get the corrected signal, users must have a differential beacon receiver and beacon antenna in addition to their GPS.

In this system, we keep the status of location of the user on, in order to get the

position. There are two kinds of way to get location in Android system. One is the new way of getting location using Google Play Service which is bind to Google Service and are not yet applied in this kind of EPSON MOVERIO BT-300 AR glass. Thus, we choose to use the old APIs of Android SDK, which we enable the access of location by registering the ACCESS_FINE_LOCATION, ACCESS_COARSE_LOCATION and INTERNET permission.

3.4.2 Method of Calculating

In this system, we calculate the distance by getting the Latitude and Longitude of the location of network-based GPS. Then the original location (let us define as latitude1 and longitude1) will be remembered and once the user moves, the location-changed event will be activated. The second location (latitude 2 and logitude2) will be registered. Based on the follow formulas, finally we calculate the Distance:

$$\text{lat3} = \text{latitude2} - \text{latitude1};$$

$$\text{long3} = \text{longitude2} - \text{longitude1};$$

$$\text{dist1} = (\text{lat3} * \text{lat3}) + (\text{long3} * \text{long3});$$

$$\text{Distance} = \text{Mathf.Sqrt}(\text{dist1});$$

Thus, even runner runs a circle or not straight course, we can still accumulate the distance in a high accuracy. Calculating the speed is simple. We just divide with running duration. There are many ways to calculate the calories burned while running. Usually, the market Applications requires user to input the personal information such as weight, height. Thus, first we will have the runner to input the weight and it will be saved. We use the formula shown follow:

$$\text{Kcal} = \text{Weight(kg)} * \text{duration(hours)} * \text{K}$$

$$\text{K} = 30/\text{speed}$$

3.4.3 Display Running Data

In our system, displaying running data directly on the screen of AR glass is the main function. At the beginning of running, runner can see the original data that is initial zero. Meanwhile, because of the see-through glass which will choose specially for running, runner can also of course see the naturally real world without dangerous.

Figure 3.4.2 shows at the beginning of a running start:



Figure 3.4.2 The originally initial data and the naturally real world

Then after running for a time, the data will be changed despite of the distance and location. Runner can see clearly on the screen of the see-through glass.



Figure 3.4.3 Check the changed running data

Even run a circle course, the running data still can be calculated accurately based on our calculating method. The bellow picture shows a runner run a circle run-course around which is measured about 1.5kms. By checking the data shown on the screen, we can see almost the same distance with the official measured distance.



Figure 3.4.4 Run a circle(1.5kms) course, check the accurate distance

Chapter 4

Implementation

4.1 System Hardware Overview

Our system's hardware is divided in two parts: the outside runner and the inside user. Figure 4.1 bellow shows the overview of the system hardware and the information structure.

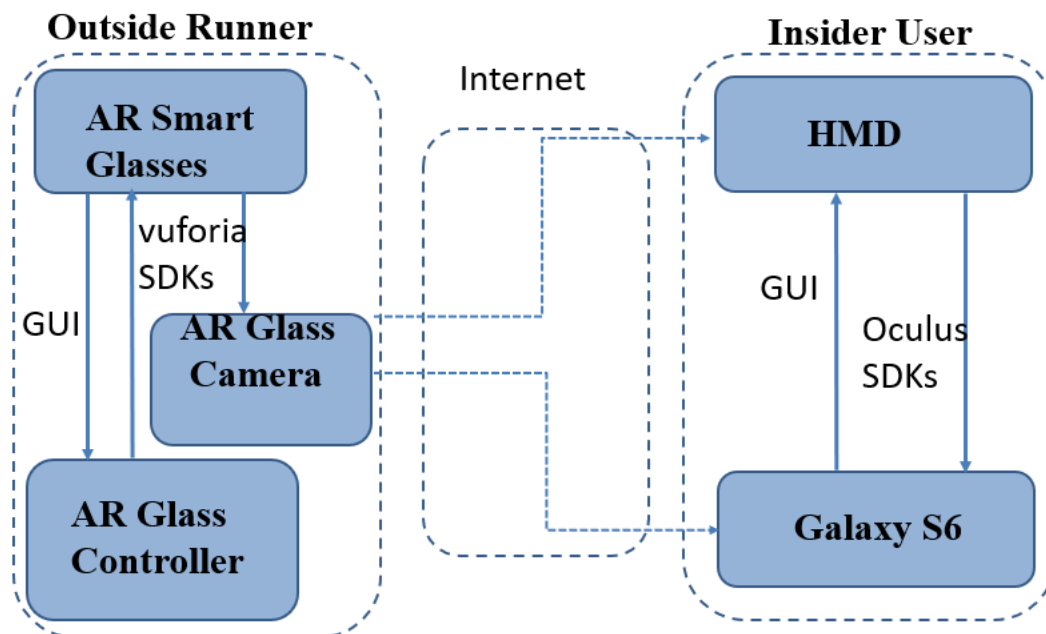


Figure 4.1 System Hardware Overview

4.1.1 Outdoor Runner Hardware

In our system, the outdoor runner wears see-through AR glass, the EPSON see-through augmented reality smart glasses MOVERIO BT-300 and Gear VR Head-Mounted-Display of Oculus Rift are used.

Compared to the original MOVERIO from five years ago, the new BT-300 pair is 72% lighter. The two lenses have been upgraded from using LCD displays to silicon-based OLED (Si-OLED) display technology. As a result, the picture quality is now HD (1,280 x 720). The BT-300's Intel Atom processor, battery and controls are contained within a separate handheld box. It's powered by Android 5.1 Lollipop and there are Android-based buttons on the control box. The Figure 4.2 bellow shows the EPSON AR glasses. The camera is used to capture live video and two eyes displays are used to display the running information.



Figure 4.2 EPSON AR see-through glasses

4.1.2 Indoor User Hardware

A head-mounted display (or helmet-mounted display, for aviation applications), both abbreviated HMD, is a display device, worn on the head or as part of a helmet, that has a small display optic in front of one (monocular HMD) or each eye (binocular HMD). A HMD has many uses including in gaming, aviation, engineering, and medicine. There is also an optical head-mounted display (OHMD), which is a wearable display that can reflect projected images and allows a user to see through it. A typical HMD has one or two small displays, with lenses and semi-transparent mirrors embedded in eyeglasses (also termed data glasses), a visor, or a helmet. The display units are miniaturised and may include cathode ray tubes (CRT), liquid crystal displays (LCDs), liquid crystal on silicon (LCos), or organic light-emitting diodes (OLED). Some vendors employ multiple micro-displays to increase total resolution and field of view. HMDs differ in whether they can display only computer-generated imagery (CGI), or only live imagery from the physical world, or combination. Most HMDs can display only a computer-generated image, sometimes referred to as virtual image. Some HMDs can allow a CGI to be superimposed on real-world view. This is sometimes referred to as augmented reality or mixed reality. Combining real-world view with CGI can be done by projecting the CGI through a partially reflective mirror and viewing the real world directly. This method is often called optical see-through. Combining real-world view with CGI can also be done electronically by accepting video from a camera and mixing it electronically with CGI. This method is often called video see-through [45]. Currently, there are many applications used for HMD in sports, medicine and research, training and simulation, engineering or gaming and video, especially for supporting of 3D video.

In our study, the indoor user wears Oculus Rift Gear VR Head-Mounted-Display with Samsung Galaxy S6 inserted inside. This HMD uses a pair of lens that provide 101° field of view, 62mm(fixed)x10mm with interpupillary distance and eye relief.

There are home key, back key and touchpad which are used to control or interact with your system. The screen of an application also can be full of the screen or just two big eyes-screen.



Figure 4.3 oculus rift Gear VR Head-Mounted-Display

4.1.3 Setup of Indoor User and Outdoor Runner

The Figure 4.3 shows the setup of Indoor user and Outdoor runner. The outdoor runner wears see-through AR glass and capture the running live video. Then the video will be transmitted to server, through which the indoor user can watch in time by wearing the Gear VR HMD.

Outdoor Runner



Running Live Stream
GUI

Indoor User



Figure 4.4 Watching live running event in door through wearing Gear VR

4.2 Development Environment

Our system is implemented in Unity5.6 of 1.1 with the Microsoft Visual Studio editor and the language we used is C#. Both the AR see-through glass and Oculus Rift Gear VR Head-Mounted-Display (with Samsung Galaxy S6 inserted inside) are the Android system, thus we build the development environment by installing android SDK (the Minimum API level should be Android 4.1 Jelly Bean level 16 because of using Augmented Reality) in Unity. For the Augmented Reality, we used Vuforia SDK for Unity (vuforia-unity-6-2-10). There are different kind of SDKs for augmented reality, such as Vuforia, Kudan, ARkit, SmartAR and so on. Considering the capability of android SDK, AR SDK and Oculus VR SDKs for Gear VR, finally we selected the good capability of vuforia-unity-6-2-10 as AR SDK. In order to use vuforia SDK, the App License Key is required, which we need to register and generate the key from vuforia website. The details will be discussed in next part. For Oculus Rift, All Unity versions 5.1 and later ship with a bundled version of the Oculus OVRPlugin that provides built-in support for Rift, Oculus Go, and Samsung Gear VR support. Oculus support is enabled by checking Virtual Reality Supported in the Other Settings > Configuration tab of Player Settings.

4.2.1 Vuforia-Augmented Reality Development Environment

First, download the latest vuforia SDK for Unity from Vuforia webpage and then create your own develop-lisence key like **Figure 4.5** and **4.6** below:

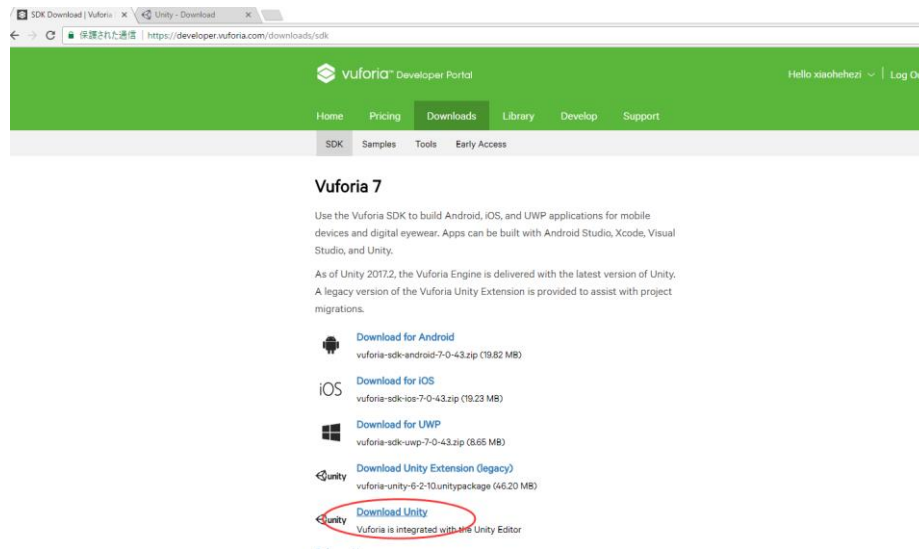


Figure 4.5 Get vuforia SDK for Unity

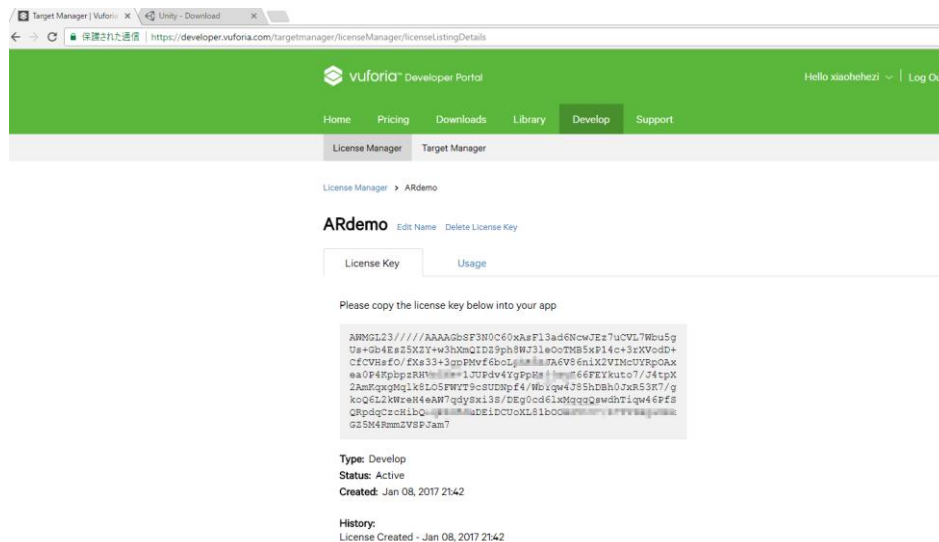


Figure 4.6 Create develop License key

Then in Unity, add your AR Camera and configure the development-license key for system in Inspector VuforiaConfiguration App-license-key, the details of configuration like Eyewear Type, Render Texture Layer can also be changed. **Figures** bellow show the configuration.

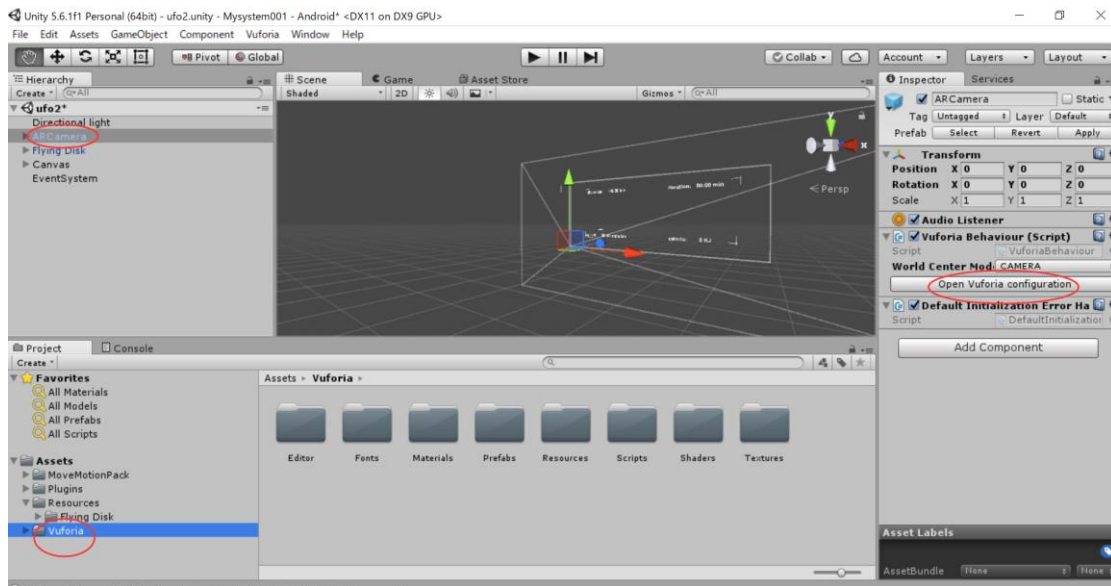


Figure 4.7 The configuration of AR Camera used with vuforia

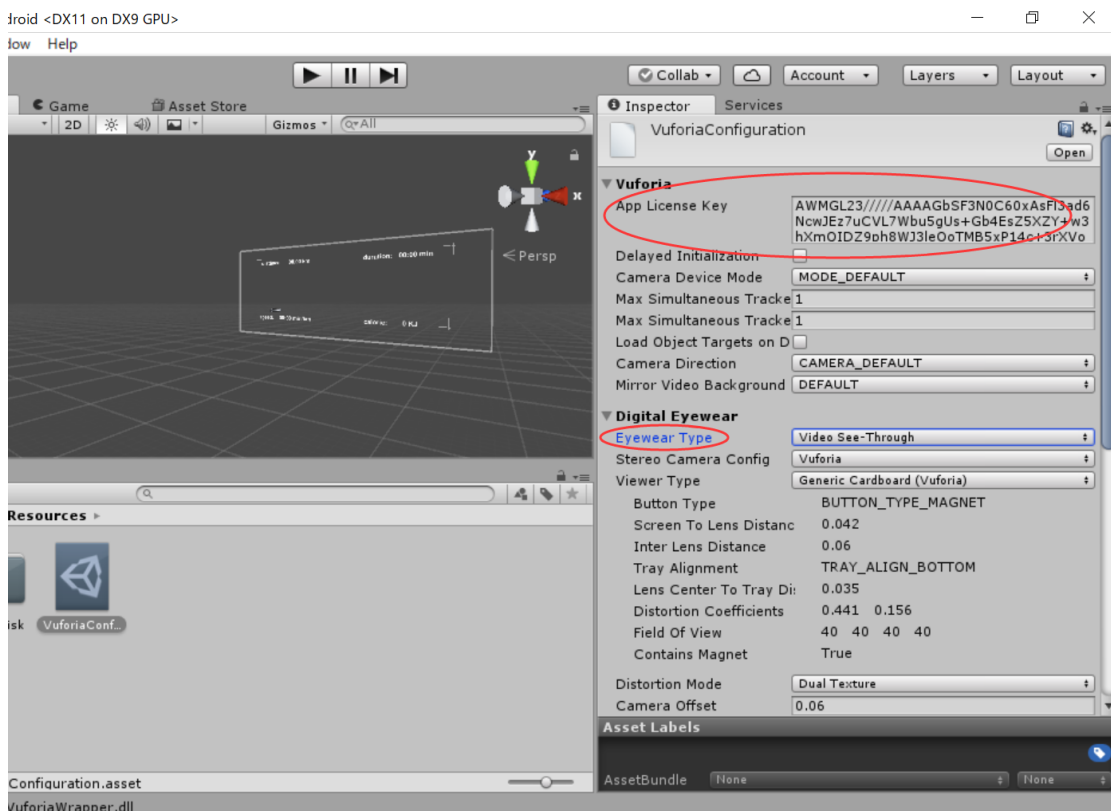


Figure 4.8 The configuration of vuforia app license key

Chapter 4 Implementation

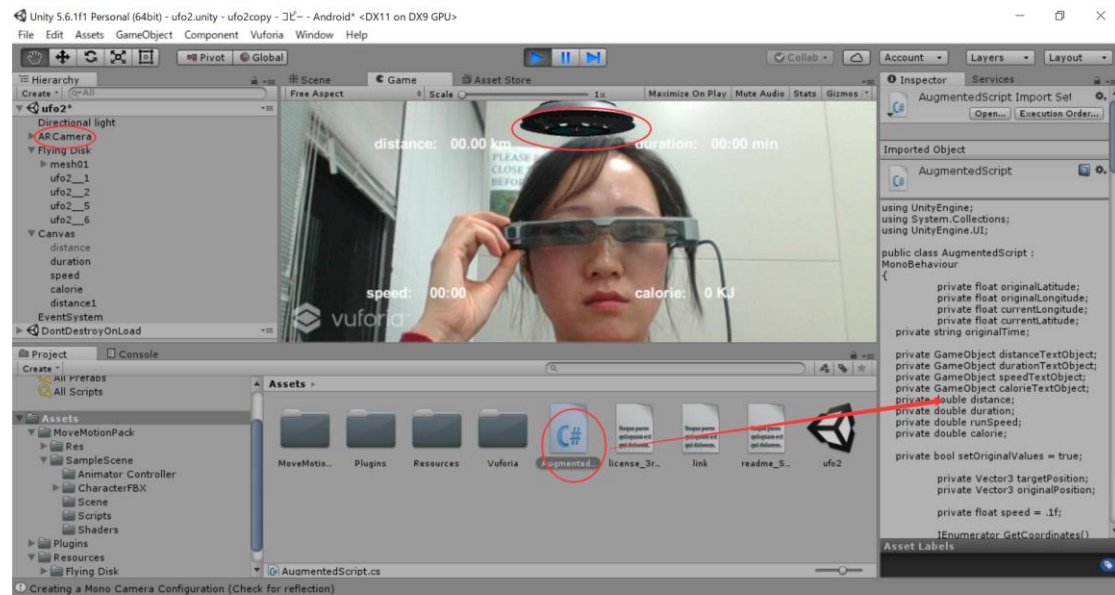


Figure 4.9 The sample of vuforia AR object in AR Camera

4.2.2 Android Development Environment in Unity

Figure 4.10 below shows the Android configuration of our system in Unity.

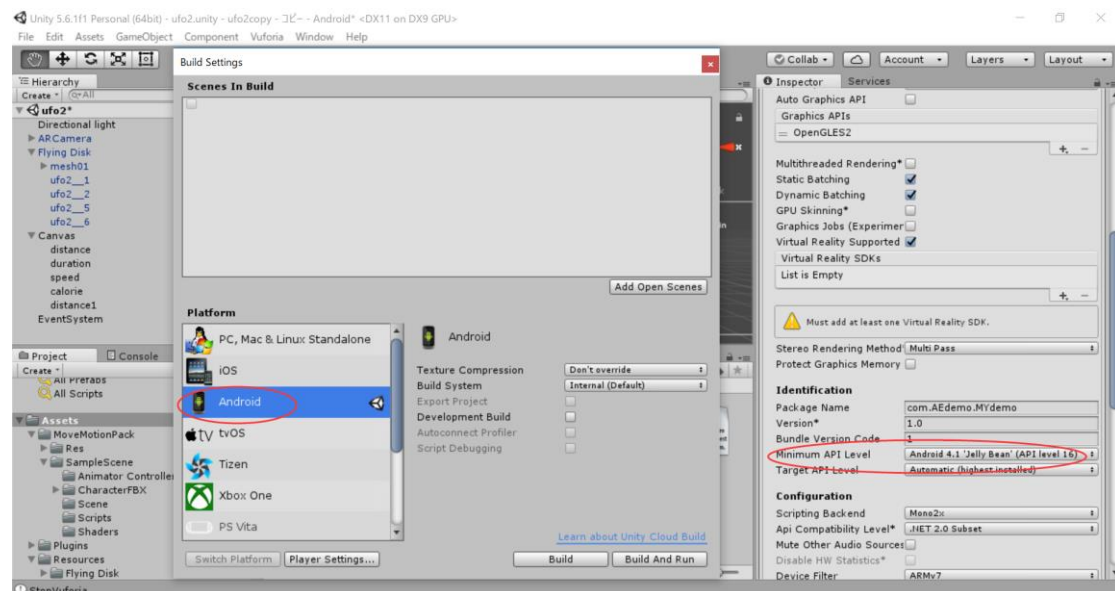
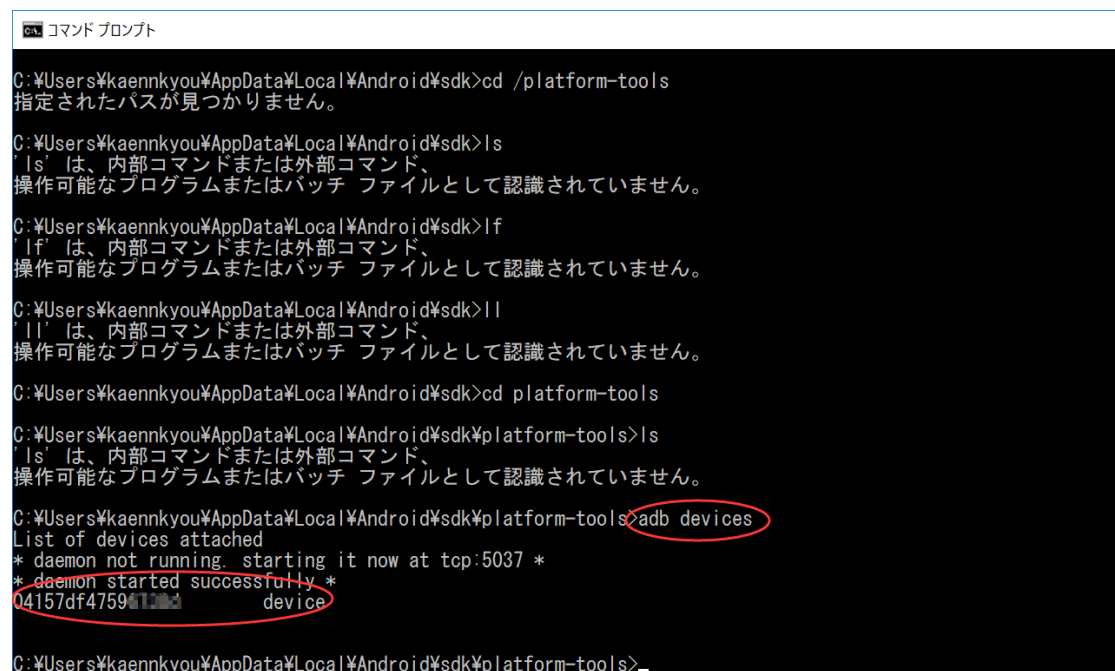


Figure 4.10 the Android SDK setting in Unity

4.2.3 Oculus Rift Gear VR Development Environment in Unity

For Oculus Rift Gear VR environment, we need to generate a oculussig signature file and put it in Unity Project under the path Project/Assets/Plugins/Android/assets/. The first step is to access Android SDK path under the adb, then in command use order “adb devices” to find the android device id as **Figure 4.11** shown below. Then access the formal website to get signature file by inputting device id and download the signature file as **Figure 4.12**. Finally, put the signature file under the path of Unity Project (as **Figure 4.13** shows) where Android file exists because of the system of Gear VR Galaxy is Android system, then when start the project the oculussig signature file will be loaded automatically. It will remind user to insert the Galaxy S6 device to Gear VR. The sightseeing of the outdoor runner view can be seen from Gear VR as **Figure 4.14**.



```

C:\Users\kaennkyou\AppData\Local\Android\sdk>cd /platform-tools
指定されたパスが見つかりません。

C:\Users\kaennkyou\AppData\Local\Android\sdk>ls
'ls' は、内部コマンドまたは外部コマンド、
操作可能なプログラムまたはバッチ ファイルとして認識されていません。

C:\Users\kaennkyou\AppData\Local\Android\sdk>if
'if' は、内部コマンドまたは外部コマンド、
操作可能なプログラムまたはバッチ ファイルとして認識されていません。

C:\Users\kaennkyou\AppData\Local\Android\sdk>ll
'll' は、内部コマンドまたは外部コマンド、
操作可能なプログラムまたはバッチ ファイルとして認識されていません。

C:\Users\kaennkyou\AppData\Local\Android\sdk>cd platform-tools
C:\Users\kaennkyou\AppData\Local\Android\sdk\platform-tools>ls
'ls' は、内部コマンドまたは外部コマンド、
操作可能なプログラムまたはバッチ ファイルとして認識されていません。

C:\Users\kaennkyou\AppData\Local\Android\sdk\platform-tools>adb devices
List of devices attached
* daemon not running. starting it now at tcp:5037 *
* daemon started successfully *
04157df4759 device

C:\Users\kaennkyou\AppData\Local\Android\sdk\platform-tools>

```

Figure 4.11 Get android device id for signature file

Chapter 4 Implementation

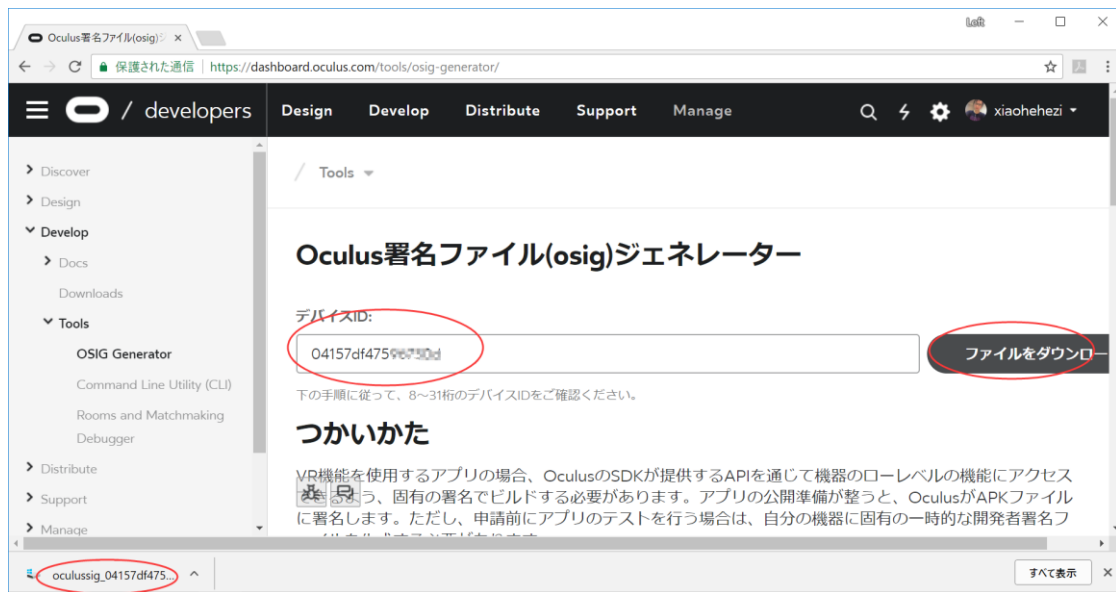


Figure 4.12 Generate signature file and download file

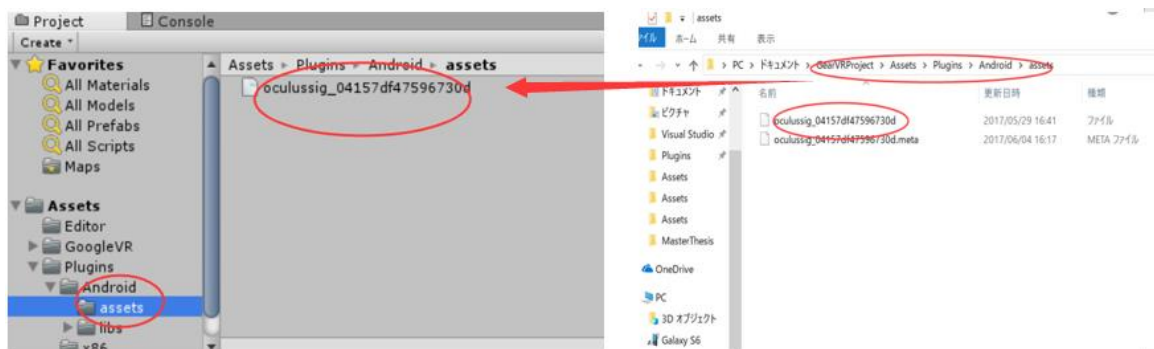
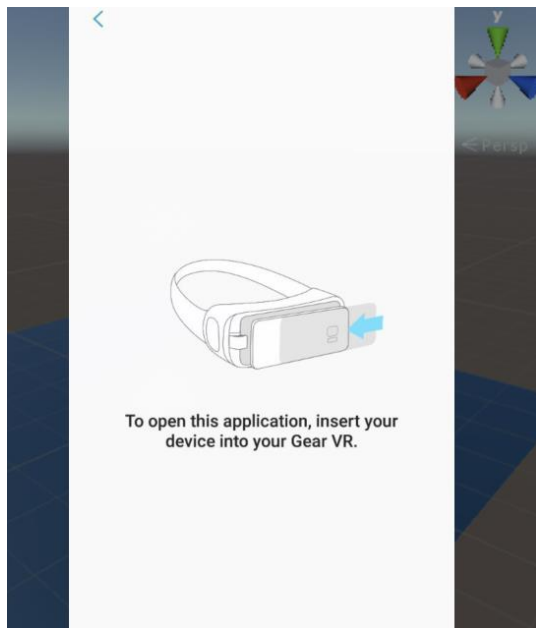


Figure 4.13 Put the signature file under path of Unity
Project/Assets/Plugins/Android/assets



(a) Start the system



(b) Insert device to Gear VR



(c) Indoor user watch the sightseeing of Outdoor runner

Figure 4.14 Install and start the Gear VR project to watch Outdoor runner sightseeing

4.3 Display Running Information Function

For the initialization, first the weight of the runner will be saved in order to calculate the consumed calories in running. After inputting the weight, we initialize the original running data as zero as figures 4.3.1 and 4.3.2 shown below:

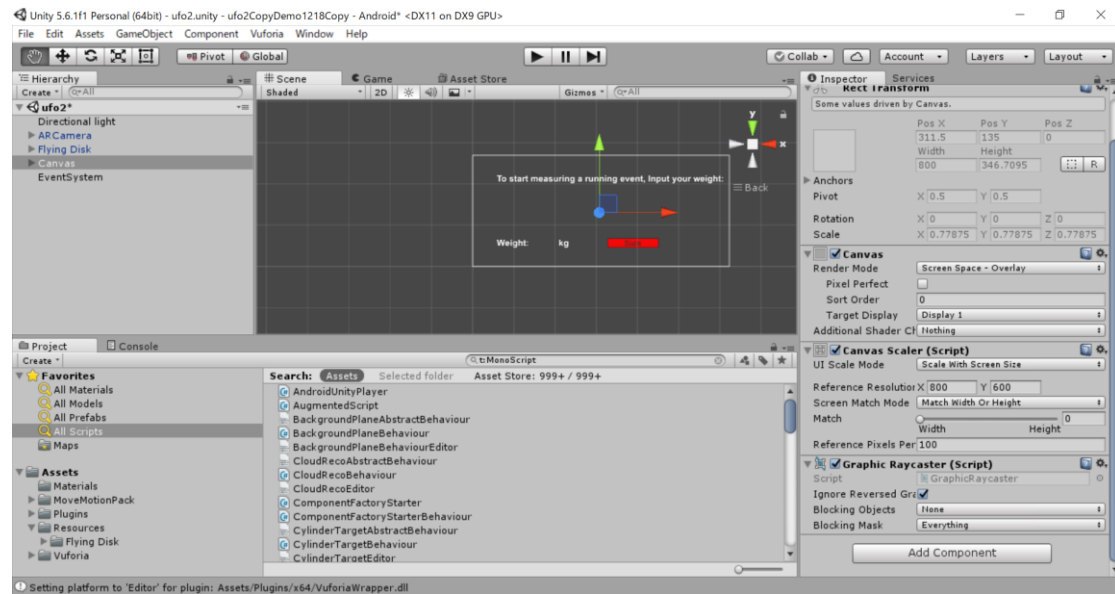


Figure 4.3.1 Initialization of runner weight

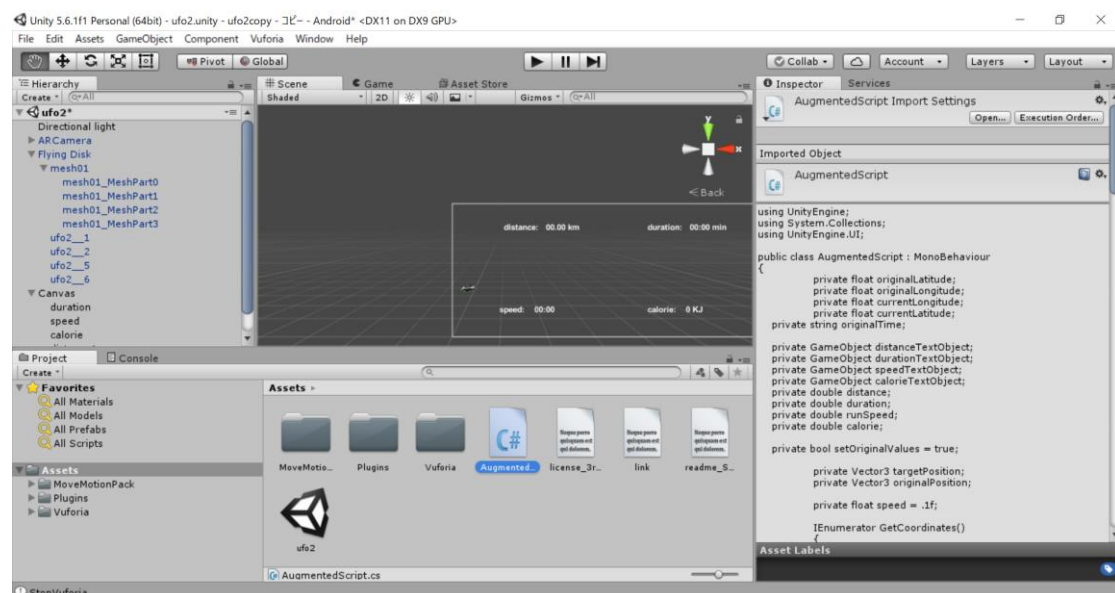


Figure 4.3.2 Initialization of the original running data



Figure 4.3.3 At the start of running all the running data is zero displayed on the screen of AR see-through glass

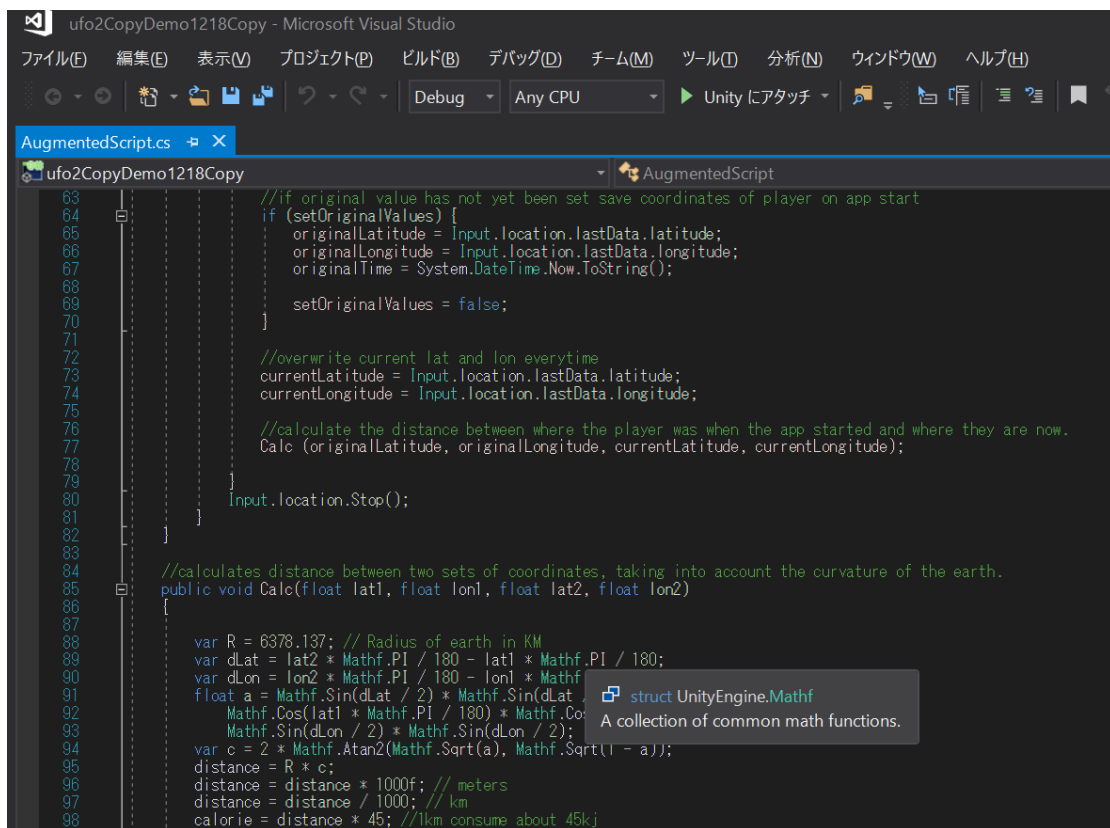


Figure 4.3.4 The method used to calculate the distance through GPS

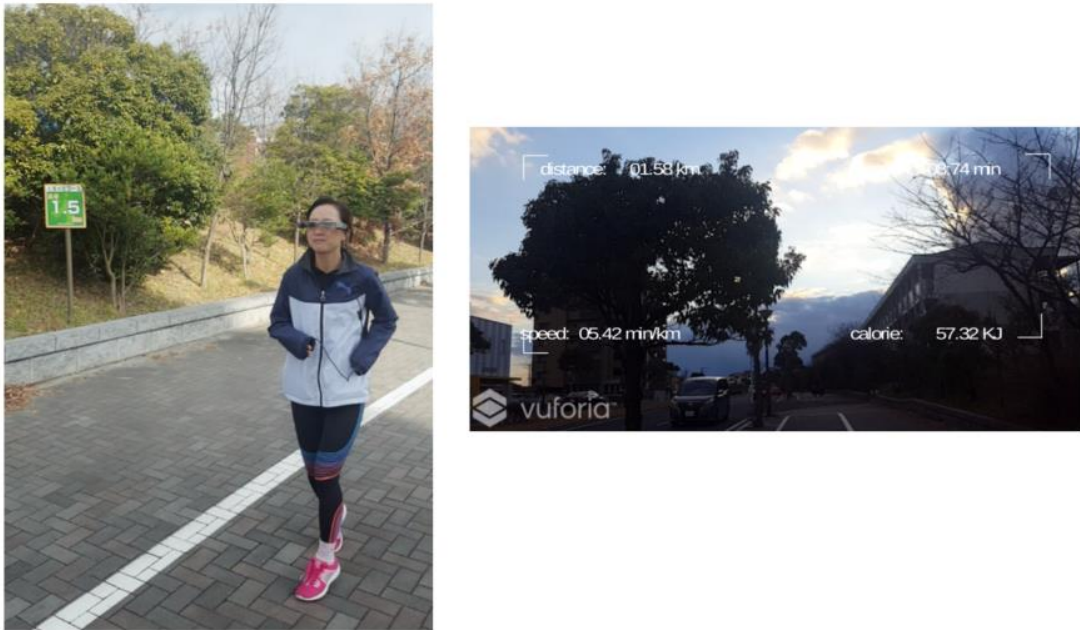
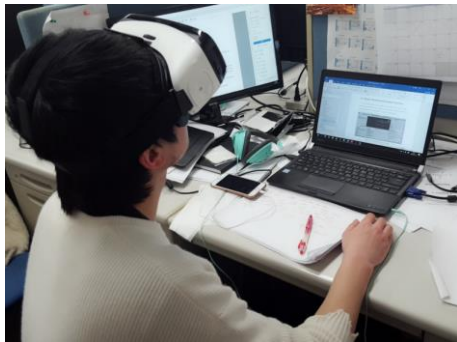


Figure 4.3.5 The distance showed on the screen of AR glass after 1.5km running

4.4 Watch Running Event Function

For the watching running event lively function, the outdoor runner will wear the AR see-through glasses when running through the camera of the AR glass sightseeing scenery will be captured and uploaded to server. Then inside user wearing Gear VR will be able to watch the same view of sightseeing scenery as **Figure.4.4.1** below:



(a) Inside user wears Gear VR



(b) Outside runner wears AR glass



(c) Join together



(d) See the same sightseeing in Gear VR

Figure 4.4.1 The inside user wearing Gear VR watch the same view sightseeing of the outsider runner

4.5 Show AR Objects Function

The figures below show the AR objects. **Figure 4.5.1** is when runner runs about 1.58km the AR robot will be seen from AR see-through glass, which can give a feeling of companion. **Figure 4.5.2** shows when runner runs about 3.55 km, A flying disk will be seen that can entertain the running. The flying disk also moves as a set speed, so the runner will also get encouraged. **Figure 4.5.3** is another kind of robot AR object when the speed is low, the AR robot will also run slowly to impress runner current running is slow.



Figure 4.5.1 When runner runs about 1.58km the AR robot will be seen



Figure 4.5.2 A flying disk will be seen that can entertain the running



Figure 4.5.3 When the speed is low, the AR robot will also run slowly

Chapter 5 Related Work

Related Work

5.1 Research about Out Together Feeling System

C.Chang [42] proposed WithYou– A Communication System to Provide Out Together Feeling. The presented system is a video-based remote communication system that provides Together Feeling and panoramic view, through which the Outdoor User can share the out view to the Indoor User and while the Indoor User can control the direction of Outdoor User. While in our case, we enable user to watch the running event lively without supporting to control the outside runner.

5.2 Research about Remote Sightseeing System

Cai [43] proposed A Remote Pair Sightseeing System Supporting Free Viewpoint and Gestural Communication, which the Outdoor user shares his or her Free Viewpoint of 360 Panoramic and the Indoor user can interact with the Outdoor user using gesture, then both of them can get the Trip together feeling.

5.3 Research about Supporting Jogging System

Seito Tomoya [44] proposed Proposal, Implementation and evaluation of a system to support jogging continuation. The author implemented a system that allows users to enjoy jogging while maintaining motivation through a mobile phone. The multi-users running information (for example distance, photo) is displayed directly in a mobile phone screen. However, runner has to hold on a mobile phone all the way, which is a burden for runner. Different with this proposal, we used a see-through AR glass to show the information directly, which runner can see easily and convenient without interruption.

Chapter 6

Conclusion and Future Work

6.1 Conclusion

In this study, we proposed out system Joining-Together an outdoor running support system based on Augmented Reality for outdoor runner sharing a lively running event to the indoor user. Moreover, our system enables runner to check the running information in time through seeing the wearing AR BT-300 glass without interrupt the running event. Except the two of main function, we also maintain the motivation of runner by showing AR project as rewards to encourage runner to achieve the running goal.

In the proposed system, we assume our user is runner that aims at running marathon or long distance running, willing to share his or her lively running event to friends or families who are in a physical separated place. Although currently our system still is limited in some aspects of sharing lively running event, we think positive about the future work in which we can enrich the interactions between the outdoor runner and indoor user, which will make the running event more meaningful.

6.2 Future Work

In the future work, there are some improvements still left in this system. For example, about the sharing running event part, we can enhance the sharing with interaction between indoor user and outside runners. Additionally, multi-users can be invited to enjoy or support the running event lively. Different with the traditional way, multi-users can also be organized in a running event and through wearing AR see-through glass share their running information, make competition wherever they are in a physical separated place.

Acknowledgement

On the completion of this thesis, I should like to express my deepest gratitude to all those whose kindness and advices have made this work possible.

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