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MASTER THESIS

TITLE: Graphic Digital Compass in Unity

MASTER DEGREE: Master in Science in Telecommunication Engineering & Management

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Abstract

This study is performed with two main goals in mind. The first goal is to understand the Augmented Reality technology and its mainly tracking and registration technology, the second one is find a way to improve the registration and tracking accuracy. The project is graphic digital compass designed for android devices based on these mainly technology. It can obtain the user's compass information to tell the orientation, get the GPS information which can locate user and demonstrate a map where the user is, using the GPS, accelerometer and compass sensors to improve the registration accuracy and we also set the markers calibrating orientation to make registration and tracking more precision.

We are using the Unity3D software which develop this project. This tool is cross platform game engine developed by Unity Technologies and used to develop video games for PC, consoles, mobile devices and websites and another really important tool is Vuforia, it is an Augmented Reality Software Development Kit (SDK) for mobile devices that enables the creation of Augmented Reality applications.

Key words: AR, registration, tracking, compass, GPS, unity3D, marker,Vuforia

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1. INTRODUCTION

1.1. Introduction of AR

1.1.1. What is AR

The term "augmented reality" was first proposed by Professor Tom Caudell in the 1990s while working in Boeing"s Computer Services' Adaptive Neural Systems Research and Development project in Seattle [5].

In 1997, the first author Ronald Azuma published a survey [6] (based on a 1995 SIGGRAPH course lecture) that defines AR application: (1) combines the real world with the virtual world, (2) is interactive and in real-time, (3) is registered in 3 dimensions. He summarized the developments up to that point. Since then, the field has grown rapidly.

The field of Augmented Reality(AR) has existed for almost twenty years, however the growth and progress in the past few years has been remarkable. Because of the new techniques support this fields now growing so fast. Nowadays It implements in many areas such like medical, manufacturing, navigation and so on.

Fig.1.1 HMD display for watching the visual tellurion.

But what is Augmented Reality[1]? The basic goal of an Augmented Reality is to enhance the user's perception and interaction with the real world through supplementing the virtual objects that appears to coexist in the same space as the real world. It is a real time direct or indirect view of a physical, real world environment whose elements are augmented or supplemented by computer-generated sensory information input such as sound, video, graphics or GPS data.

1.1.2. The Milgram definition

The Milgram defined a continuum of Real to Virtual environment[2], where Augmented Reality is one part of the general area of Mixed Reality. The differences is the surrounding of the Augmented Reality is real, while for the Virtual Environment the surrounding is not real.

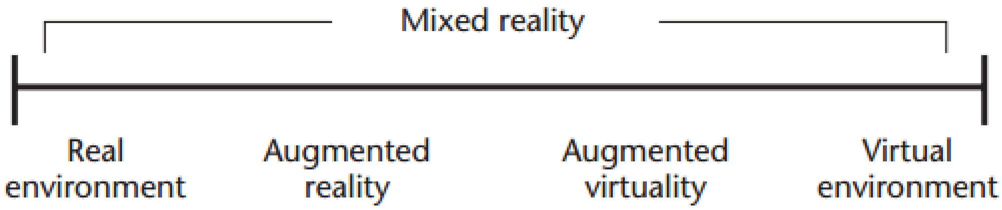


Fig.1.2 Milgram's Reality-Virtuality Continuum

In this study we will only focus on the Augmented Reality does not cover Augmented Virtuality or Virtual Environments. Using the virtual object in the real world to help people solve some problems.

1.1.3. Applications

The AR technology has changed a lot in our lives, the applications[23] are very broad, it has hundreds of possible applications, including education, medical industry design, games, entertainment and so on. With this technology people can be provided virtual information. An augmented reality system can immediately recognize what people see and retrieve and display data associated with that scene.

Publishing

With the combination of augmented reality technology, the traditional print publications will enter a new interactive multimedia era, imagine, headline is no longer boring text and pictures, a vivid three-dimensional image in the light and shadow, sounds play under the vivid display in front of us, we will be able to truly experience the fun of interactive reading.

Design

Even with the most accurate drawings, designers will also be limited from expressing the free ideas and it will impact delivering thoughts to the clients.

Augmented reality technology, just to make up for this shortcoming. Whether they are industrial design, architectural design, planning design, home design, fashion design, art design they all can be enhanced by this technology. Designers will be more fast creative and make it happened in the real scene by using the virtual objects, allowing users at design stage can have the directly view and experiences on the final product.

Marketing

Augmented reality technology can bring realistic effect of display, it is so great for advertising design, product promotion, it opened a new creative space. Many well-known international brands, including BMW, General Electric, Lego toys, and even the famous Hollywood studios, are using this technology to enhance the reality for their product promotion and commercial activities.

Science and education

Enhance the reality by bringing the virtual objects into the real world experience, science education will be upgraded to a new stage, a variety of astronomy, geography, biological knowledge is no longer a simple picture courseware, it can be real-time interactive 3D model now; dangerous Physical and chemical experiments can be safely operated at home using this technology.

In addition, researchers will be able to easily simulate real-world experiments with remote real-time collaboration using augmented reality technology to create new research results at low cost and efficiency.

Game and Entertainment

Undoubtedly, the AR technogoly has a great influence on the entertainment industry, AR and VR are the most closely integrated with the most extensive use in this area, it is more esay to put into use in this kind of industry.

However, entertainment, games and AR how will they combine ? The answer is it can be done in the office, bedroom, living room all the places can become a battlefield, playing guns, you can ride a plane; every scene captured with a cell phone can be used as a game stage. In the crowded streets, facing the monster appeared in the sky shooting, illusory and real combination makes it difficult to distinguish. In fact, we often see a lot of plots in the "Matrix" or other science fiction movies.

Medical

In the latest AR technology applications, doctors can accurately determine the location of surgery to reduce the risk of surgery, surgery can better improve the success rate!

Through this technology[15] allows doctors to see the patient's medical images and real patient overlay, the doctor can clearly see the places where patient needs operations. The first case of this system is spine surgery, which makes a screw easier, faster and safer to insert into the spine. The medical technology sounds incredible, but 10 years later, may become the norm.

Exhibition

Compared with the traditional display the mode of the physical information board, the augmented reality technology brings the rich information display capability in depth and the natural human-computer interaction experience, which brings a brand-new to the product conference, the exhibition and the product exhibition hall. At the same time, the exhibition hall controllable and easy to adjust the environment, in order to achieve the best augmented reality experiences

1.1.4. Motivation

Since the development of wearable devices, mobile phone and nowadays coming-of-age of mobile AR technology, we are beginning to see AR applications and videogames appearing in the Google and Apple app stores. Because of the special feature of AR, it will be really helpful in many areas, But the registration and tracking is a difficult problem because without the accurate registration, the illusion that the virtual objects exist in the real world is not accurate alignment. We have to try to find a approach to improve that.

1.2. Problem to be solve

The problem we have to solve in our project based on augmented reality is that the registration and tracking is not so accurate when the virtual objects locate in the real world, they lose the precision. We have to analyse this, if this kind of problem is important to our project.

Fig.1.3 Videogame Pokemon Go based on the mobile devices.

Like the videogame Pokemon Go this kind of AR applications don't need the high registration and tracking accuracy, because the virtual animals don't need a specific position, so it doesn't matter if they locate a little bit higher or lower in the real world. But to our project Graphic Digital Compass the answer is yes it is truly important to our project, because when the virtual object lose the precision in the real world, it will give the wrong direction, this is the last thing we want. This registration and tracking accuracy is really a key to the AR application like navigation application, manufacturing application, construction application and so on, for example in the navigation application if some pointer is not so accurate the driver will drive to the wrong direction. Then we have to fix this problem, we can use different ways to improve that.

Firstly we can change the hardware like the sensors of compass GPS and accelerometer, with the high precision sensors we can get a better results but the thing is we are using the mobile devices, this is a mobile AR application, so we couldn’t change the hardware. Secondly we still have to use this sensors which are not so accurate but we can think about some ways to improve the results, so here we use the markers, the idea is simple we know the directions of the marker and use the camera detect the marker and then calibrate the precision based on the information of the marker.

2. ENABLING TECHNOLOGIES

2.1. Registration and tracking

And the main technology of the Augmented Reality is the registration and tracking[16]. Registration and tracking technology is helping to quickly and directly locate the virtual scene into the real world exactly with the method of alignment, to achieve the perfect combination of virtual scenes. The process of locating virtual objects in the real world is called registration. This process requires the augmented real-time system to obtain real-world data from the current scene, including observer position, head angle, motion and so on, to determine how to reconstruct the coordinate system according to the observer's current field of view and display the virtual object to the correct location, this process is called tracking.

There are two types of tracking and registration: sensor- based and vision-based. In this project we used the sensor-based includes inertial based to obtain position and angle of the virtual object and magnetic-based to get the orientation and electromagnetic-based to get the location from the GPS. In the vision-based tracking it has two method :marker-based and feature-based method. In this project we used the vuforia it uses computer vision to recognize and track planar images.

Advantages:

With the Tracking and registration technology we can get many information such as pose position location and orientation. With these information we can build the virtual object more real more adapted to the real world. So this technologies are more suitable for the navigation applications for example the drivers need to look at the navigation screen to identify the directions only listen to the audio is not clear enough sometimes they will be confused at the complex streets or cross, besides it will distract the drivers' attention, it is dangerous! the solution is that why not just get the directions by seeing it in the real world. With the AR glasses we can do that, the driver can see the real road plus virtual reminder at the same times, it is more convenient. And for our project the idea is the same, we put this technology in boat navigation situation. The captial can get the informations combined with the real world. They can get the directions which are North South East West and the map. In the future work we may add some more practical information like the weather, the location of other boats around, dangerous information reminder and so on.

Disadvantages:

Some technology and method still have to improve because of the coverage accuracy interference and limitations. Sometimes depending the specific condition and we have to overcome inherent limitation to satisfy the use cases.
For example if we dealing with a big amount of virtual objects in the AR system we have to make sure that the operation rate is good enough to locate these

things perfectly, it requires the the fast operation of the CPU. Besides the accuracy of the sensor and interference avoidance are so important, in our project we have to use the information based on the compass,so if the compass sensor is not so accurate then we can get wrong information,and for GPS location is the same, it may locate the users in the other places. In order to avoid this situation we use the image tracking method to calibrate the directions, this can improve the results.

2.2. See-Through displays

For designing this project on mobile phone so we introduce the mobile devices run see through augmented reality (AR) applications, there are two different kind of displays: a video see-through and an optical see-through displays[18].

Fig.2.1 Video see-through HMD (left); optical see-through HMD (right)

2.2.1. Optical See-through Display.

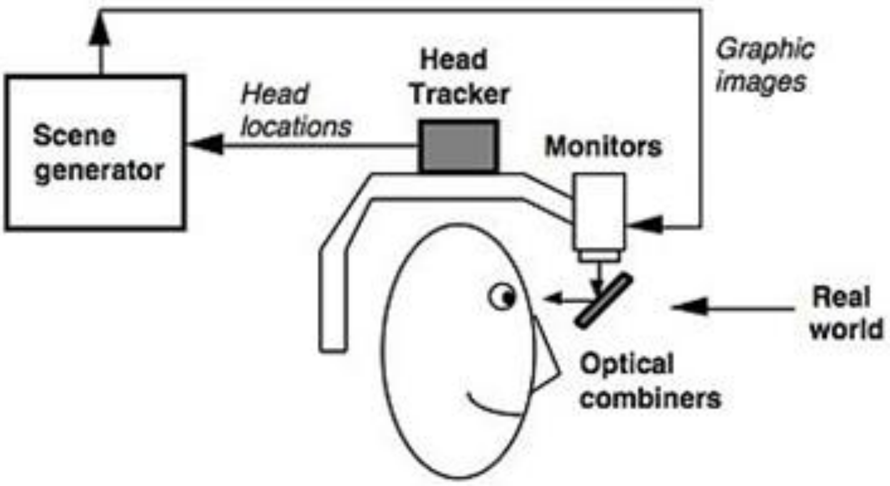
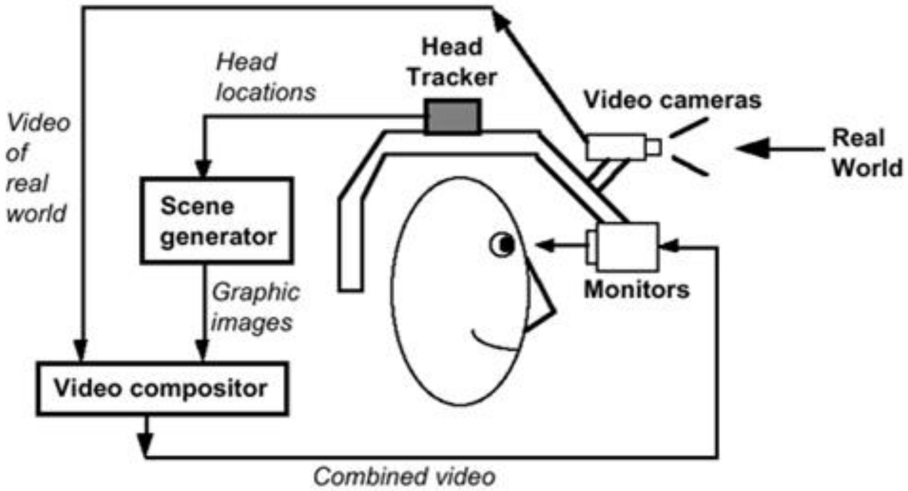


Fig.2.2 Optical see-through HMDs allow the observer to view the real world directly.

In optical see-through display[24], virtual contents are projected onto interface to optically mix with real scene. It requires the interface to be semi-transparent and semi-reflexive so that both real and virtual scenes can be seen. A interface head tracker is used to obtain users' positions and orientations for contents alignments. It enables users to watch real world with their natural sense of vision without scene distortion. The major problem is that it blocks the amount of light rays from real world and reduces lightness. Besides, it is difficult to distinguish virtual contents from real world when background environment is too bright.

2.2.2. Video See-through Display



Video see-through HMD conceptual diagram

Fig.2.3 The key strength of video see-through is that the combined real and virtual image is available as a single digital composite and, hence, various calibration techniques can be used to ensure a good overlay.

Video see-through display[24] has two work modalities. One is to use HMD devices to replace user eyes with head-mounted video cameras to capture real world scene. Captured video is blended with computer-generated contents and then sent to HMD screen for display. A head tracker is used to get users position and orientation. This mode is similar to optical see-through display and has been used in early MAR application.

2.3. Handheld devices

The other mode works with camera and screen in handheld devices. It uses the embedded cameras to capture live video and blend the video with virtual information before displaying it on the screen. This mode is predominant in applications with handheld devices. The former mode obtains better immersion experience at the cost of less mobility and portability. Comparing to optical see-through display, mixed contents are less affected by surrounding conditions in video see-through display, but it has problems of latency and limited video resolution.

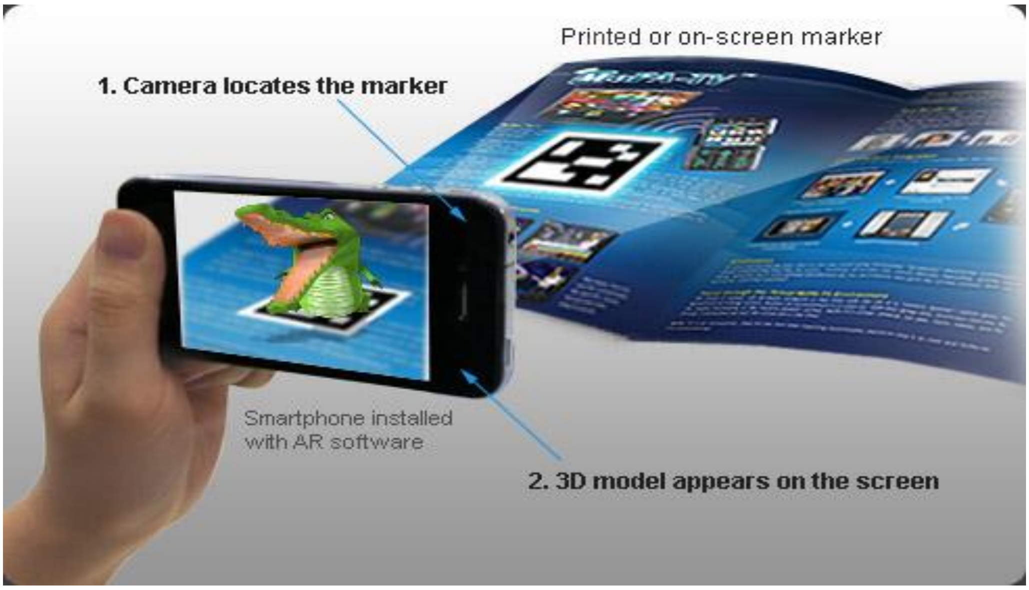


Fig.2.4 Mobile AR detected the marker showing the 3D model on the screen

2.4. Interaction technologies.

The interaction technologies[25] of AR are those technologies which can have some interactions with the AR system in order to give some input information. For example for those mobile devices which running the AR application we can use the touch screen technologies to give some orders and other AR project we also have speech recognition, gaze tracking and gesture recognition.

2.4.1. Touch screen

Touch screen is the natural interaction technology[19] when using a mobile device to run an AR app. there are many ways for users to control and interact with AR-assisted applications. Touch or tactile interfaces are now ubiquitous on smartphones and tablets. A user can tap on the screen at the place where an augmentation appears to see more details. Alternatively a user can manipulate the digital object with pinching and dragging motions on the screen.

2.4.2. Speech Recognition

The speech recognition system mainly have three parts, they are Speech Signal Preprocessing and Feature Extraction, acoustic model and pattern matching, language model and language processing. It can capture the user’s voice and convert it to a signal, and then the system will match them in the speech recognition library by using linguistic model, grammatical structure, semantics. Recognized commands are then executed by the system. This technology is very suitable for hands-free devices.

2.4.3. Gaze Tracking

Gaze tracking is also suitable for hands-free selection and interaction with an AR system. we can track a person's eye movements in order to understand the trajectory of observer's attention. This can help us find the user’s focus on a target, so the commands or interaction will appear depenging on this results and users will choose if they gonna use this information.

2.4.4. Gesture Recognition

Gesture recognition is a mathematical algorithm to identify the human gesture of a topic. Gesture recognition can come from movement of the various parts of the human body, but generally refers to the movement of the face and hands. The signals are easily detected by the sensors like accelerometer, gyroscope and so on. Then these signals will translated into commands, finally the AR software will execute the commands.

3. THE DEVELOPMENT TOOLS

In order to achieve our goals we choose Unity3D as a develop platform set the whole project, using vuforia develop kit to set the AR image marker and using the Visual Studio C# language to programming the scripts make every single element can work properly.

Fig.3.1 The three mainly development tools for android mobile devices

3.1. Unity3D

Unity3D is a cross-platform game development tool with a built-in IDE [4] developed by Unity Technologies[3] that allows players to easily create interactive content such as 3D video games, architectural visualization, and real-time 3D animation, and is a fully integrated professional game engine. Unity is similar to Director, Blender game engine, Virtools or Torque Game Builder and other interactive graphics development environment as the primary means of software. The editor runs on Windows and Mac OS X and distributes games to Windows, Mac, Wii, iPhone, WebGL (requires HTML5), Windows phone 8, and Android[7][9]. You can also use the Unity web player plug-in to publish web games, and support Mac and Windows web browsing. Its web page player is also supported by Mac widgets. We chose the unity3d to develop our project because it can handle all the rendering, transformations, the scene-graph and it also has others powerful aspect, the ability to code in C# make it easily extendable.

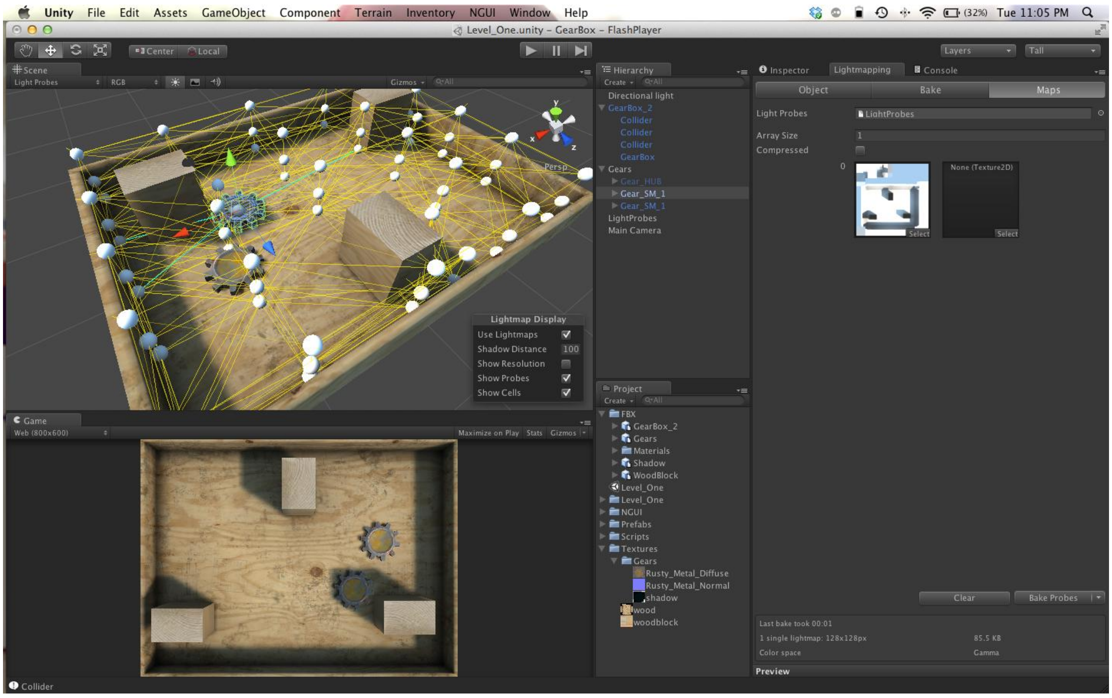


Fig.3.2 Unity3D editor

3.2. Vuforia

Vuforia Augmented Reality Software Development Kit (SDK)[10] is for QUALCOMM applications[11] that enhance real-world for mobile devices. It uses Computer Vision technology to recognize and track planar images (Image Targets) and simple 3D objects, such as boxes, in real-time. This image registration capability enables developers to position and orient virtual objects, such as 3D models and other media, in relation to real world images when these are viewed through the camera of a mobile device. The virtual object then tracks the position and orientation of the image in real-time so that the viewer's perspective on the object corresponds with their perspective on the Image Target, so that it appears that the virtual object is a part of the real world scene.

Vuforia Tracking Algorithm

The state of an image in an electronic device is a bunch of numbers. Feature points are those with a large difference between the surrounding digital values. Detection methods are generally: FAST, Harris, SIFT, SURF, MSER and so on. Vuforia tracks[26] scale-robust corners extracted with a modified version of the FAST (features from accelerated segment test) corner detector [14]. Below is an image showing a typical output from the FAST corner detector.

Fig.3.3 Original image and detected feature points

FAST feature point detection method because of the rapid detection, is well accepted by the researchers, specifically follow the following steps [13]:

First, finding the feature points, a pixel is selected from the image, denoted as P. If we want to determine whether it is a feature point, first the brightness value of point P is denoted by I. And then set an appropriate threshold t, used to control the selection of feature points. With P as the center of the circle and 3 pixels as the radius, there are 16 pixels on the boundary of the circle, as shown in the following figure:

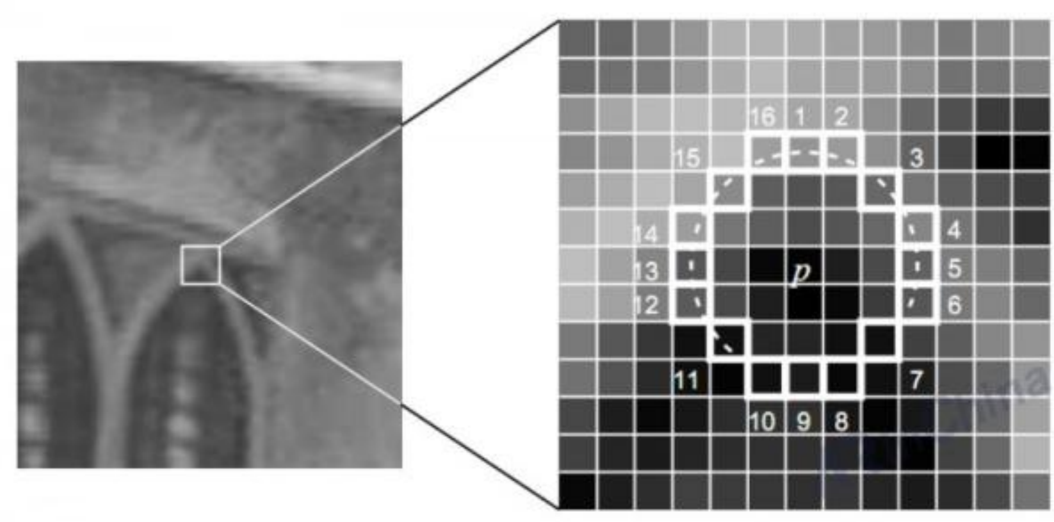


Fig.3.4 Finding feature points in the image

In short, the feature point is a larger contrast with the surrounding point, as shown below:

Fig.3.5 Simplified feature points in the image

Only know that the feature points are not detected, you must know whether the two images have the same feature points. How to determine whether the feature points are consistent, we need to use the feature point descriptor.

It is artificially controlled whether the two pictures are the same picture. We can set the match rate of 10% or more for the two images are the same image, you can also set the match rate of 90% or more. The specific criteria will depend on the application requirements.

At present, feature point matching technology is divided into two categories: one is to obtain two image feature points and feature point descriptor, according to a certain search strategy calculate these feature points and descriptors, and finally get the optimal value as the result. The other is to obtain the feature point information of the reference frame image and use it to find the best match on the current frame. The biggest advantage of this matching is that it only needs to extract the feature points of the reference frame, saving the half of the feature point extraction time.

Fig.3.6 Matching point detected in the reference image and the video feed

Before the tracking begins we have to detect the feature points of the image and store it in the database as a reference data. And then when the AR device detector capture the feature points analysed in real-time, comparing it to the reference date, once a sufficient number of matching points have been located, the homography [17](a projective transformation matrix) that maps the set of points in the reference image to their pairs in the video feed is estimated using error minimization methods.

$$\begin{pmatrix} x_1' \\ x_2' \\ x_3' \end{pmatrix} = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix}$$

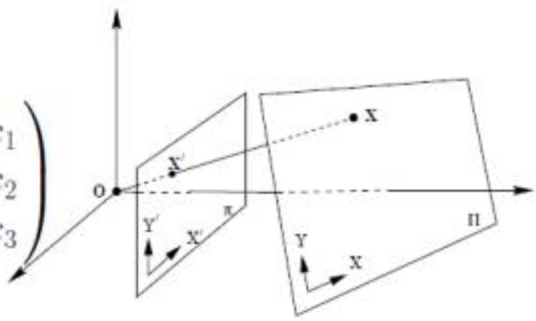


Fig.3.4 The homography H that maps point x to x', x'=Hx

From the homography the camera pose is estimated using an appropriate camera model, and the virtual graphics to be overlayed over the video feed can be given the appropriate angle and perspective.

4. DEVELOPING PROCESS

4.1. Solution 1: AR camera + GPS + Compass

At the very beginning, We have to build our digital compass in Unity. The solution 1 is using GPS, compass and accelerometer sensors to improve the registration and tracking accuracy.

4.1.1. Building the digital compass

We can get user’s location and demonstrate the map. so we have to use the camera of mobile device to get the real world, the output would be like showing the real world and virtual map together. Next our goal is tell the directions in a visualization way ,in order to identify the directions we set four different colourful balls which are virtual object representing the north south east and west. Here are some very basic steps showing in details.

We creat an empty GameObject renamed North, so do the others directions including South East and West which we would like to visualize in the map.

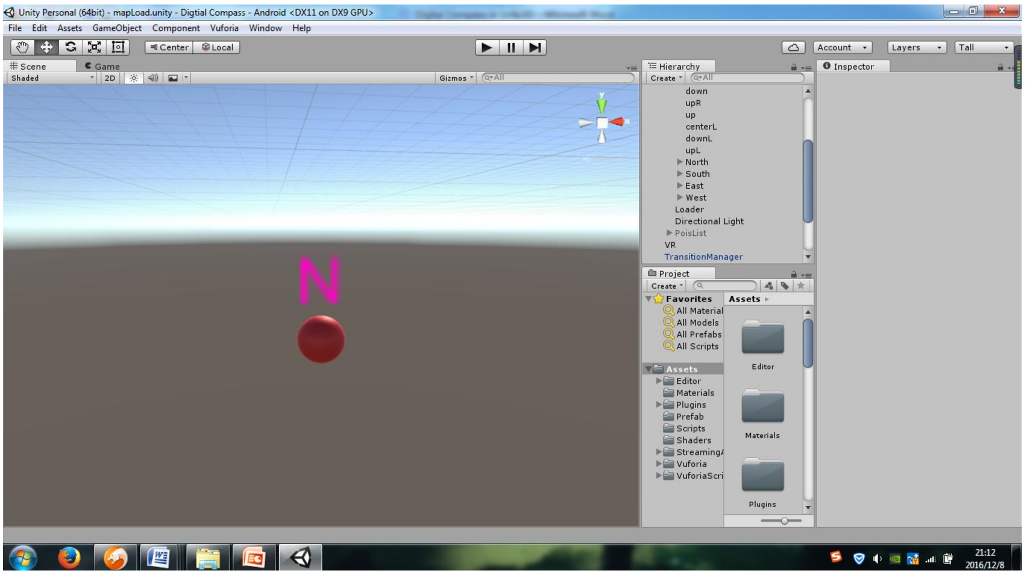


Fig.4.1 Red sphere and a text “N” representing the north

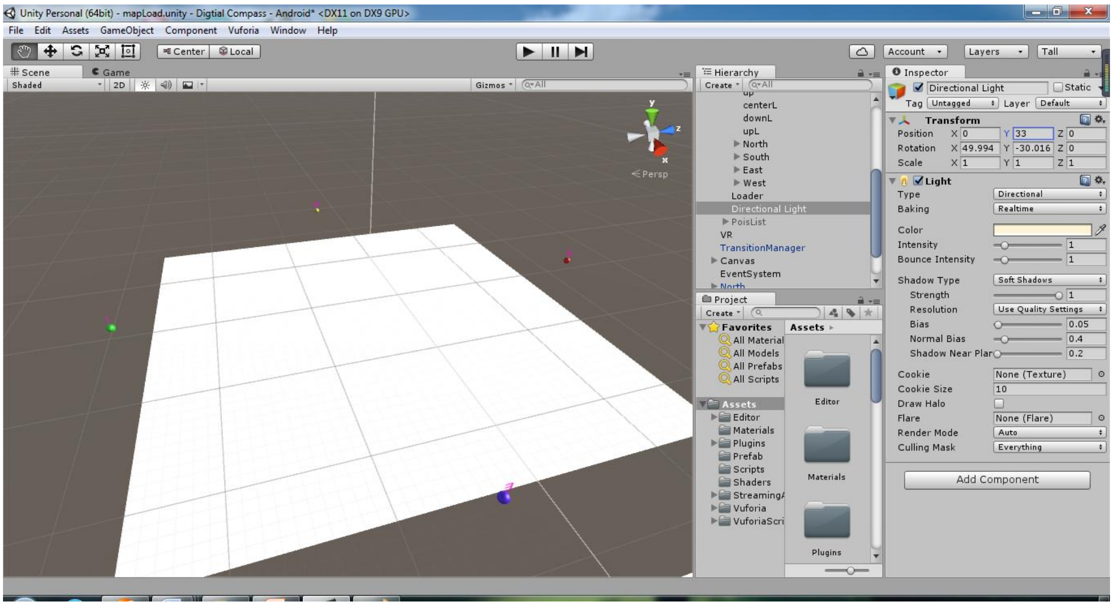


Fig.4.2 Virtual map and four different sphere representing the four directions

4.1.2. OpenStreetMap (OSM)

The application also requires the internet connection to download the map information. Here we are using the open street source getting the map.

OpenStreetMap (OSM)[20] is a collaborative project to create a free editable map of the world. (Wikipedia).

Fig.4.3 Open Street Map vs Google Map

For download the map goes to OpenStreetMap server http://(a,b,c).tile.openstreetmap.org/ Given a geolocated point, latitude and longitude, it is possible to obtain the tile where the point is located.

Load the map:

```
public void WorldToTilePos(float lon, float lat, int z)
   {
      tileX = (float)((lon + 180.0f) / 360.0f * (1 << z));
      tileY = (float)((1.0f -
 Mathf.Log(Mathf.Tan(lat * Mathf.PI / 180.0f) + 1.0f / Mathf.Cos(lat * Mathf.PI / 1
80.0f)) / Mathf.PI) / 2.0f * (1 << z));
   }
```

Download the map tile http://(a,b,c).tile.openstreetmap.org/zoom/tileX/tileY.png

Fig.4.4 Zoom = 0 Numer Tiles = 1 http://a.tile.openstreetmap.org/0/0/0.png

Fig.4.5 Zoom = 1 Number Tiles = 4 http://a.tile.openstreetmap.org/1/1/1.png

After finished all this we can test it in our mobile, As we can see from the screenshot of the user's camera. In the real world we have virtual object the four different colorful balls which represent the four directions: North South East and West and the map below that. We can use GPS information get user's location and set the map where user is.

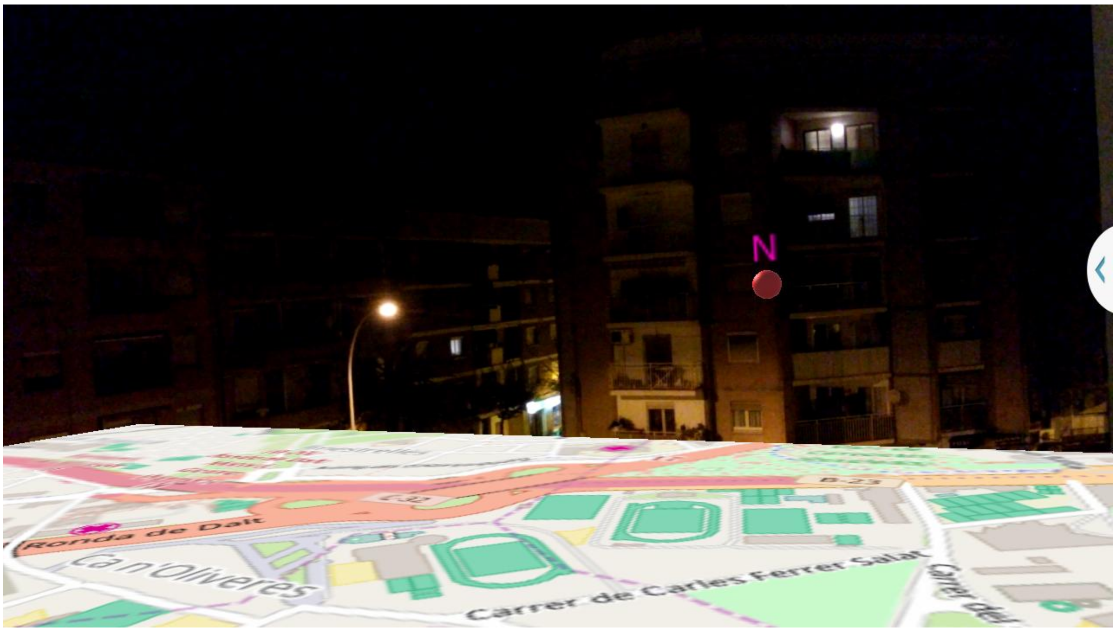


Fig.4.6 Virtual object north and map in the ARcamera

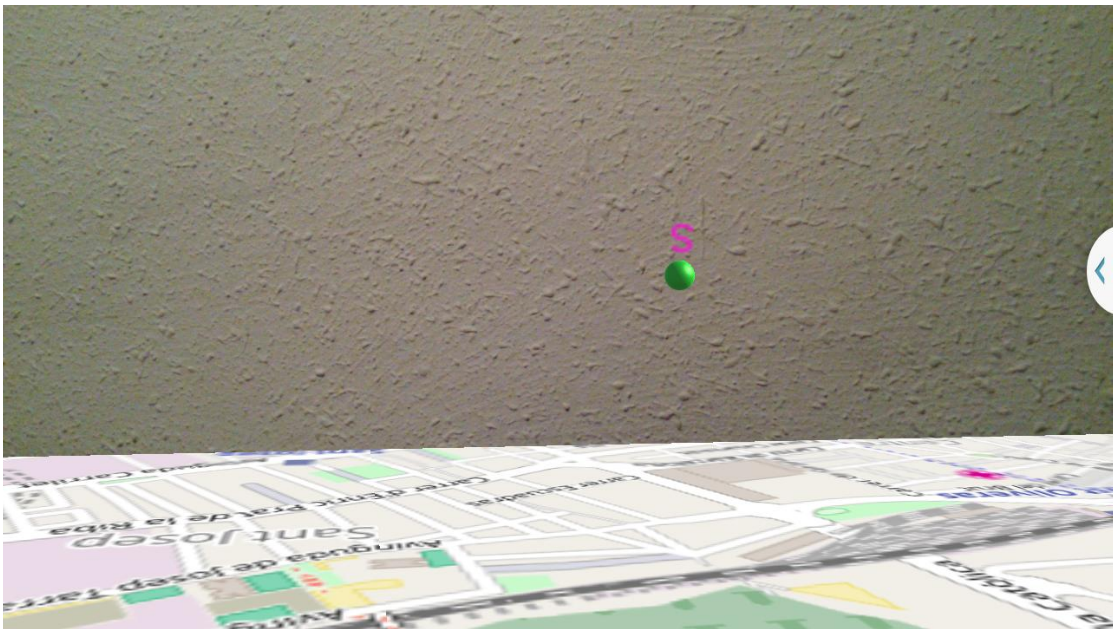


Fig.4.7 Virtual object south and map in the ARcamera

4.1.3. Adding the compass information

In this step our goal is adding the compass information to rotate the map, let the map place depending the real world situation which means the orientation of virtual map must be the same to our real world. According to this target we have to use the compass information of the mobile phone, according to the direction that we are heading right now and rotate the map based the compass information(the degree of north is 0 , east is 90 ,the south is 180 and west is 270) the virtual map have to rotate the angle α in order to match the real world.

Which the α is the compass degree we can get from the compass sensor from the mobile device.

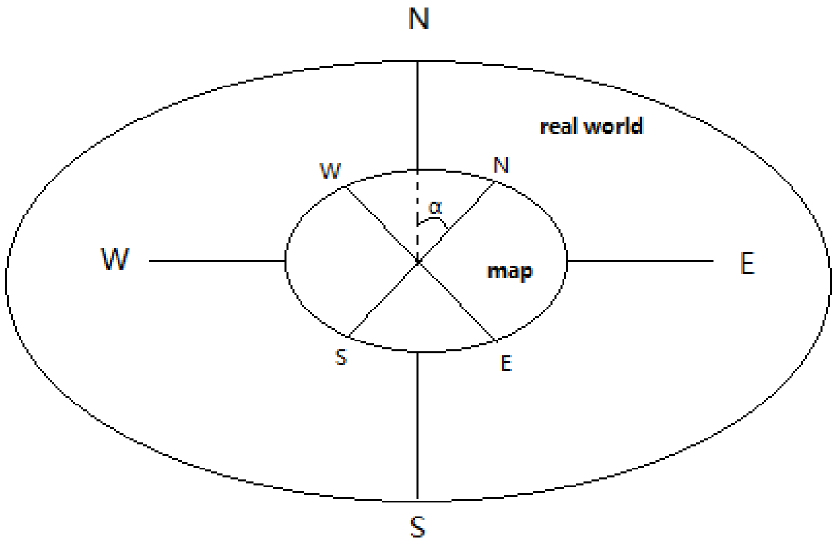


Fig.4.8 Rotate the map based on compass information

when the application load the map ,the map will adjust the direction to fit the real world situation. And we set a button which can get the compass information to test the direction if it is right. And add a text to show the compass degree which the user can read it and also a black square placed in the center of the screen to easily focus on.

First we have to enable the compass, and secondly rotate the map according to the compass and we have to put these part in the void start because when the system load the map, and the map will rotate,next is the code.

```
void Start() [21]
        {

        Input.compass.enabled = true;
        transform.localEulerAngles=newVector3(0,0,Input.compass.trueHeading);

        }
```

We can test it in the mobile phone to see if it works perfectly, yes it works very good. The map match the direction perfectly. But after the user turn around and test it for a period of time, the virtual object(map, directions) lose the precision. For example the red ball North is no longer the exactly direction North any more. It goes a little right. So we have to fix this problem.

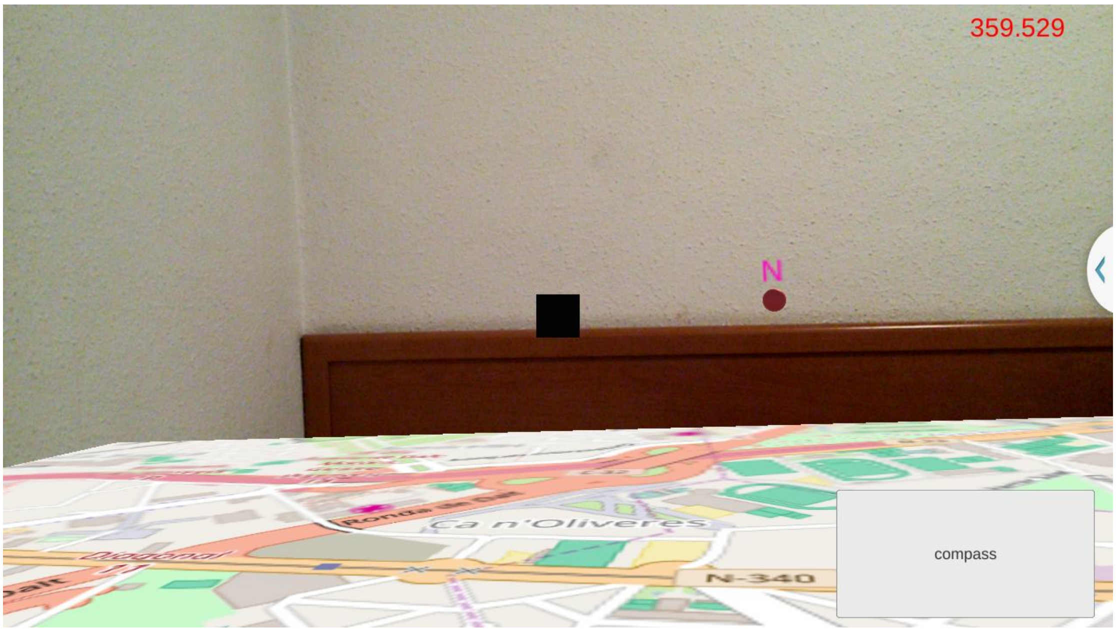


Fig.4.9 Virtual direction north matching the true real north

Fig.4.10 Virtual direction south matching the true real south

4.1.4. Calibration the compass

We also facing some other problems if you are around the some electronic device the compass information maybe is not correct so when the map use this incorrect information can cause the wrong rotation. and compass sensor in our mobile is not so accurate, it will lose the precision during the time so we can use this button to spin the map according to the exactly direction right now. The function is that we have to go away from these electronic devices and get the right information of the compass again and rotate the map again based on the right information of the compass.

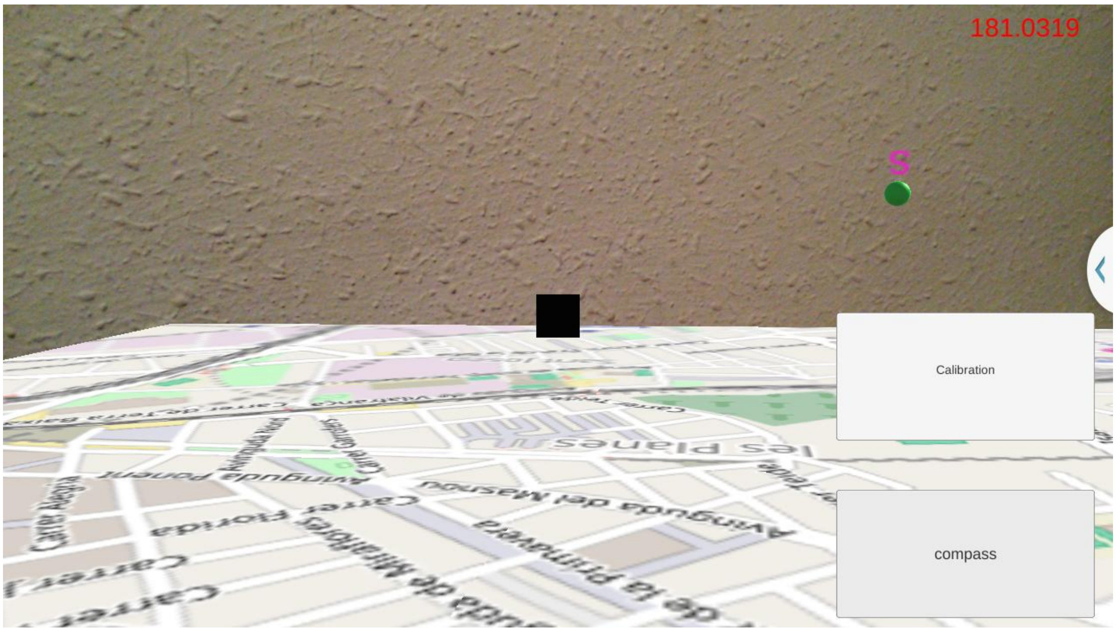


Fig.4.11 Using the compass information replace the map

After we set the map calibration function try to run it again in the mobile phone to see if it works correctly, but the result as you can see above. The precision is also not so good. What is the reason? The answer is the compass sensor responds so fast even you don't move a little. The solutions is that we just get the 20 samples of compass degree during the 2 seconds and then calculate the mean value and use this value to calibrate the map. Here you can see blow the resolution is much better.

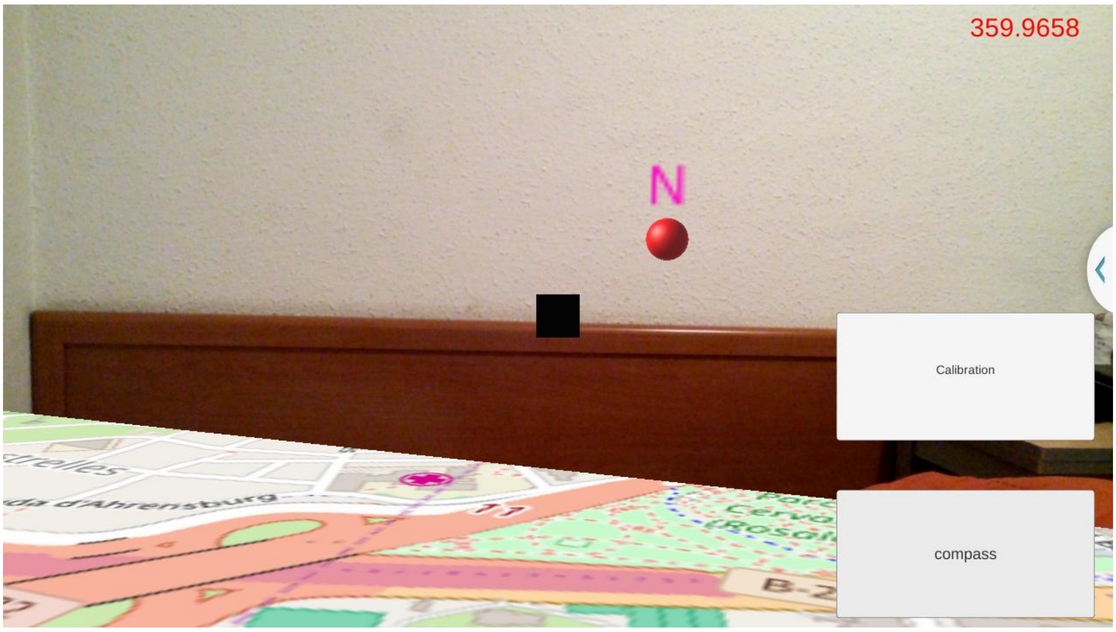


Fig.4.12 Using the mean value of compass replace the map

Now we test the result, at the first the precision is very good, orientation matchs perfectly but after the user turn around with the camera, the virtual object lose the precision, with the more movement of the camera the precision is worse. We test it three times with movement for one minutes the deflection results are: 26°, 45° and 37°.

4.2. Solution 2 AR camera + markers

However in the solution 1 the registration and tracking accuracy is still not so good because of the accelerometer, compass sensor of the mobile phone is not so accurate. As time moves on the virtual object lose the precision. After the user turn around with the mobile phone, the virtual object changed the position, we can use the compass information to see that differences. So how to solve this problem, we couldn't use more information from the sensor of the mobile phone. Here is another solution we have to using the real object in the real world to calibrate the virtual map and the directions. Here is the things: according to the some real objects which already exist on the some directions that we are sure. We can use this real object as a stander to calibrate the virtual object, in the first we only choose some images as the marker object. So the process would be when the camera detect the images the map will according to image recognition[8] to rotate the map properly.

4.2.1. Creat the markers

For the image recognition we have to use vuforia developer[22].

Enter to Develop Menu you have to have a account of vuforia developer if you don't you can just register one. After get into it. Create a new Database (type device) where you will add your trackable images (Target Manager). Add all targets you may use in your app. Download the data base as Unity Package. Here is four images that I used in my project which represent four directions.

Fig.4.13 Image targets for four directions

When you create an app in Unity3d use the license created in Licenses Manager and copy it into the unity3D ARcamera.

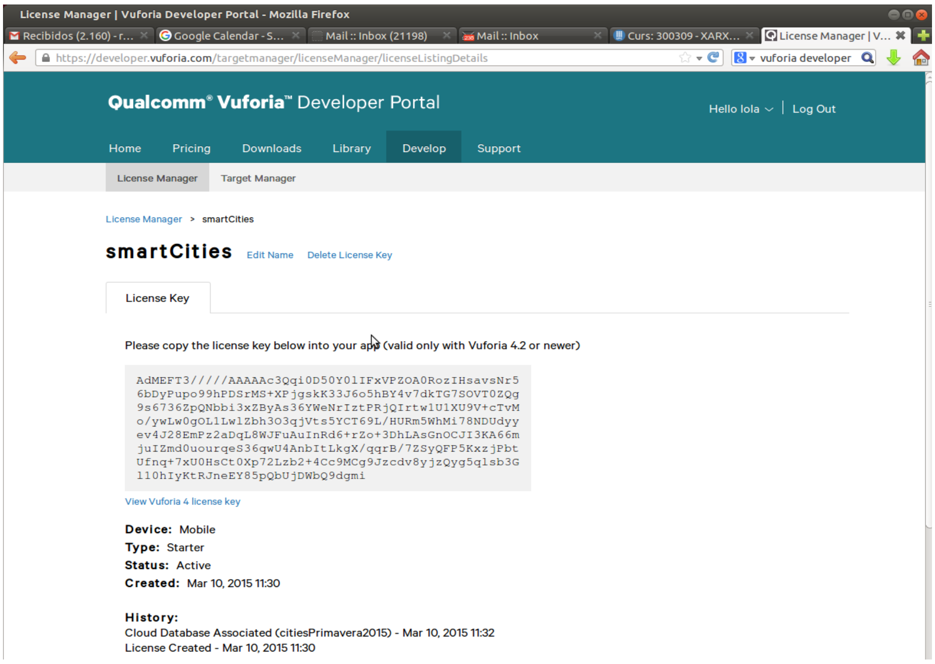


Fig.4.14 License created in Licenses Manager for AR camera

Import the data base VuforiaPackage as new Custom Package.In Assets you can find all directories imported. Open Qualcom Augmented Reality/Prefabs. Select ImageTarget and drag them to the scene.

Initialize these objects properly to use the images imported. Select ImageTarget object and assign to it one image. Select ARCamera and assign the license ID and Data Set

Create an 3D object and assign it to the ImageTarget.Resize the object as the imatge target size and locates it in the center of the Image Target.

Next the idea is when the camera detect the image “N” the map will move the north toward it. So the degree is 0. For the South West East are the same, we use the S image representing it, and W image is West, E image is the East but degree we have to change, they are 180 for the South, 90 for the East and 270 for the West.

We can test it to see if it gonna work:

Fig.4.15 The camera detect the tracker rotating the map point to north

Fig.4.16 The camera detect the tracker rotating the map point to south

4.2.2. Adjust the detect angle

Now we can rotate the map correctly according to the different image target. But there is another problem. The camera can detect the image target from the different position which it means the camera position determine the rotation of the map. What we want is when the camera face the image target vertically and then map rotate vertically point to the image target. So we have to set camera calculate the angle of the image target, when the angle is 90 degree then rotate the map, if it is not, don’t rotate the map. we can see that once the camera detect the image target we can find the transform of the image target include the position rotation and scale. So we can get the rotation information of the image target, because the rotation is a vector 3 value we have to determine the x, y and z axis.

We can move the image target to see how the rotation value changes and then we can know which axis determine the angle, after several experiment we just get the vertical value when the x axis is equal to 90 degree, y axis is equal to 0 degree and z axis is equal to 0 degree. The image target perpendicular to the camera. And we must allow some offset, so for the y axis we set between minus 5 and 5, for z axis is the same.

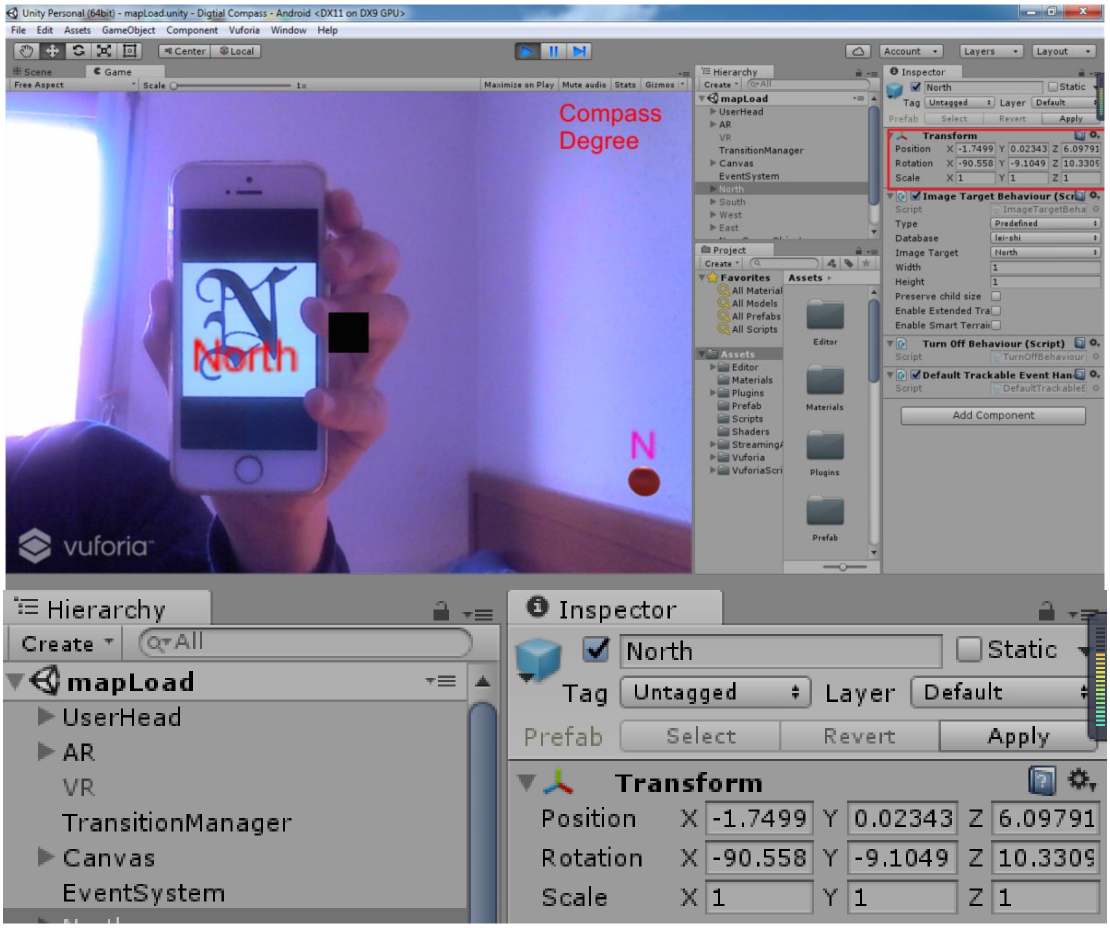


Fig.4.17 The transform information of the tracker north

After we set everything right we build it in our mobile phone to see if it work well, and we can see that if we take the mobile device at the one side of the image target, the camera couldn’t detect the image, when we move the camera slowly to the center of the image target, the camera could detect the image target and present the virtual object North and also rotate the map correctly. But we couldn’t see that transform of the image target on the mobile device so if we want to see the transform information we can just run this application in the unity editor using the camera of the computer, put the image target in front of the camera, when we mover the tracker, we can see the transform information changes as we move the tracker.

Comparing to use the mobile compass sensor to rotate the map, using the marker has a high precision, in the solution 1 we tested three times the error range was 26, 45 and 37 degree and now we use the same way to test solution 2, the error rate are within the 15 degree. The results are better. The reason is in the solution 2 we have the marker, the orientation of marker is fixed and accurate, everytime when the camera detect the marker it will calibrate the orientation depending on the markers, but in the solution 1 ,the mobile devices sensor are not so accurate so the orientation was worse.

4.3. Put this application into use

After use the image target to calibrate the directions now we can have a better accuracy, the registration has been improved. We can put this into use.

Fig.4.18 Using this application in the boat

In the real situation of a boat it doesn't have the four directions markers which represent the North South East and West, instead we have the very accurate compass sensor in the boat which can use this information as a marker, but it doesn't have a specific value because of the heading of the boat, so we have to rotate the map depending the information of the marker. The map rotation degree will be:

$$\text{Map rotation degree} = \text{marker degree} \quad \textbf{(4,1)}$$

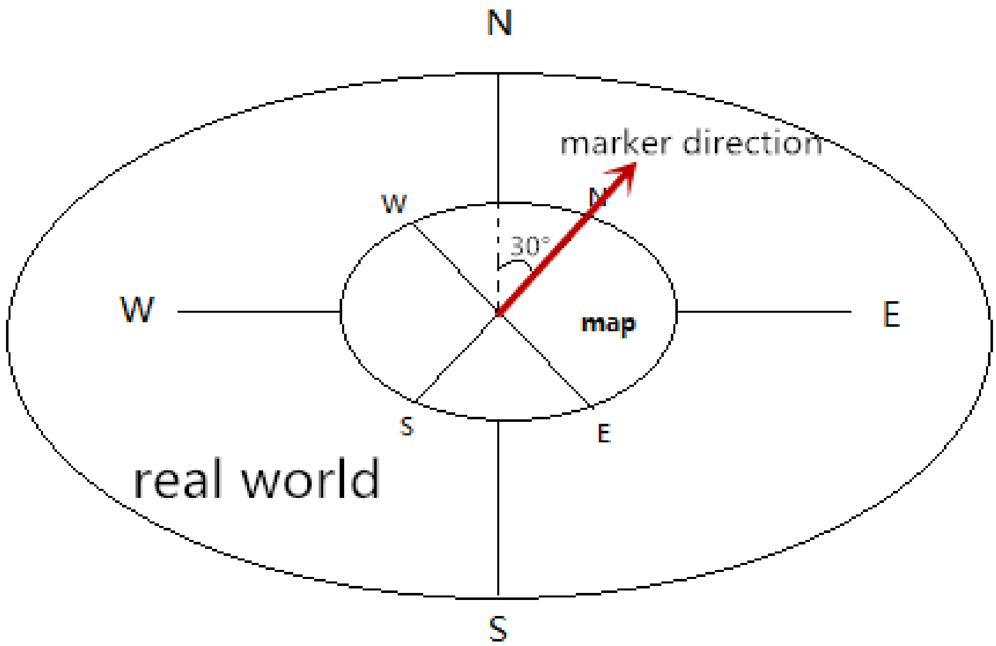


Fig.4.19 Rotate the map based on marker information

For example the the marker degree is 30, the virtual map has to anticlockwise rotate 30 degree which in the unity coordinate system is in the z axis the positive 30 degree.

ACRONYMS

AR	Augmented Reality
HMD	Head Mount Display
GPS	Global Positioning System
3D	Three Dimensions
HUD	Heads-Up Display
MRI	Magnetic Resonance Imaging
IDE	Integrated Development Environment
IOS	Iphone OS
C#	C Sharp programming language
SDK	Software Development Kit
FAST	Features from Accelerated Segment Test
POI	Point Of Interest
OSM	Open Street Map
ID	Identification
VR	Virtual Reality

CONCLUSIONS

After using several ways finally we can get a better result by improving registration and tracking accuracy. Now I will give a brief review and conclusion about the work what we have done before.

Review the project

In the first solution we are trying to use the mobile device sensors to improve the registration and tracking accuracy, we get the GPS information from the mobile device in order to locate the user, then download the map from the Open Street Map and demonstrate the map where user stays in the camera. The user can see the virtual map below and four different directions. And then we try to rotate the map to match the real world situation when we start this application, so we have to get the compass information from the mobile device, using this information rotate the map from the beginning. Then we calibrate the map because of some interference of electric devices and registration error, the theory is the same to get the compass degree again adjust the map. The solution 2 is using the image target to calibrate the directions, we used the Vuforia developer, set the image target and upload in our system, when the camera detect the image target, the map will rotate depending on the image target, then we have to choose the right detect angle avoiding the wrong rotation because the camera can detect the image target from different position, only the camera perpendicular to the image target is right angle, so we only detect this position. We are using the two ways to improve the registration and tracking, one is the sensors information, another is by markers.

Problems that occurred

During the developing process we test it in every step,mostly we can get the result what we want, however sometimes we have some errors, for example in the first solution for four different directions, at the first we choose four different points on the map represent north south west and east using the coordinate of the fours points but when the map rotate in order to match the real world, the four balls didn’t rotate. It didn’t match the real situation, so we decided to set four directions which are four coloful balls on the map not by choosing their coordinat, instead we set them as fix points on the map, so when the map rotate and so did the balls.

Another problem is that we want to make the map rotate when the system first loaded. I wrote a script that make the compass enabled and make the map rotate depending on the compass degree in the start frame, but it didn’t work at the first, the problem is that at the fitst we also want to get the GPS information this functions which conflicted with the map rotation. So i change the script of getting the GPS information, make map rotation also work at the first frame and the problem settled.

The finally one is that when we used the image target as a marker. The images which you unload in the vuforia developer they have to have more details that can be detected, after you have uploaded the images the system will give you a evaluation result which tell you the image details level, at least the image has to have three stars the full is five stars. At the first the image which i uploaded were too simple they didn't have too many detail points so the system is really hard to detect the image, after i change some more complex images the problem solved.

In generally it also depends on your mobile device because the AR application using a lot of information from the mobile device such like GPS informatin camera, internet connection and caculate abundante data from the accelerator of the mobile device in order to locate the virtual object in the real world when you change the position of your mobile. So becaust the test andriod device is not so good. The virtual object always change the postion as times move. The accurency is not so good we have to calibrate the system more often, this is also a big problem.

Future work

For the future work of digital compass in unity, from my point of viem is that if we want to put it into use, the first problem is to design the UI, make it more beautiful and some aspects we have to improve.

The virtual map has to match the real world perfectly, for example if i walk on the street i can see the real world and also the 3D virtual object jointed together like if i saw a building i also can get the virtual building model where stand on the same location of the real one, it like i am walking on the 3D map model. In order to achieve this we have to enhance the image recognition technology, no matter what device that we used for AR like the HMD or mobile device, the true thing is we have to have interaction with the real world, play the virtual object with the real object, so the camera must get real important true information from the enviroment, caculate these information in order to serve the user. For example for vuforia developer we can only choose the 2D pictures and some very simple 3D object as the tracker, but in our daily life they are all complex 3D objects, containing very large informations so i think for the future we have to combine the bigdata technologies and image recognition technologies together, maybe using the cloud computing , so when we use the AR technologies it can give us particular functions depending on the particular enviroment.

For other area

In the architectural field, architects can wear specific glasses which it can create virtual buildings and virtual buildings that have been built on a particular sheet of white paper, and it combine to other building which already exist. So they can manipulate the virtual image of the building like move, rotate, zoom in and out,change the floor height, floor shape and a series of operations. It can be observed from a whole view after the completion of the overall effect. And then use the compute building a series of data to be processed into a design drawing and print out the design through the printer. This can reduce the architect repeatedly modify the design of the trouble, save time.

People can also build a specific virtual computer by using AR glasses, the function of the virtual computrer is same to the real one. people can operate it by change the position of galsses, in front of the glasses presents a virtual computer monitor, by tapping the silicone keyboard, the virtual display input operation. The fingers wear a symbolic pendant, so that people can release a series of actions to achieve the function of the real mouse, by quickly clicking the mouse to achieve the function of double-click. Virtual computer through cloud computing, cloud services and other technologies can be the same to the real computer online, chat. Virtual computer is easy to carry, space savings, it also can avoid some bad situation such as unexpected failures: water and loss of data. Affect the progress of work to avoid unnecessary losses.

With the visual algorithm and hardware improvements, AR augmented reality will be fully into people's daily lives. For example, when cooking, augmented reality can help people find condiments. Teach people to cook ,show the steps to guide cooking each step which things are needed to put, how much needed, when to put. So that people can eat what they want to do, do not worry because AR will help, no necessary to only eat the fast food.

Another example is parents with children to go shopping, children can easily get lost. Ar reinforced reality can be achieved in the glasses on the virtual screen from time to time to locate the child, and mark the distance between the child and his parents. So when parents with children go shopping it will not be a problem any more because of AR techonogy it can easy to find. Since the virtual image is too small to be presented on the spectacle lens, there is no technique for imaging in the air without using any object. And the current technology is not very convenient in terms of virtual and real conversion. This product is temporarily not widely used.

Now science and technology is in the rapid development, it is possible in a few years scientists will be able to solve these problems. When scientists solve a transparent screen without the aid of anything in the air, augmented reality will have a leapfrog development. Many of the technologies which have problems with display technology will be solved.

Sustainability considerations

In generally for AR area it will have a strong impact[27] on society within many industries. Like advertisement, manufacture, navigation and so on. For our project for the future work it will trend to a navigation application, for the driver on the ground or some ships or boats. it will for everyday commuters and drivers, navigation devices will be built into the cars and mobile devices. This is already in the works, with some car manufacturers working to implement augmented reality windshields that will help drivers navigate without taking their eyes off the road.

With all of the positive impacts augmented reality will have, one must also consider the negative aspects as well. Just as malware has attacked mobile software, the same will happen with the AR mobile platform. There will always by cyber criminals that are looking to capitalize on new technology. AR heads-up displayed can offer criminals a huge advantage on ways to develop scams that will victimise the innocent users. This is why it will be essential for law enforcement to have an involvement and work with users and vendors to minimise any potential harms that could be unleashed and affect thousands.

And for other area which used the AR technologies one major field in which augmented reality will have a huge impact is the medical field. It is already being used for practical purposes and the technology will play an important role in the future of medicine. In fact, in 2013, a surgery was performed using Google Glass and VIPAAR, a virtual AR app. The capabilities of this technology will allow for surgeries to be simplified, offering a safe environment and experience to patients and reducing the chances of medical problems arising after surgery is performed. There are a variety of devices that can already be used in the medical field aside from Google Glass. There is an app called EyeDecide that will educate patients on eye health. Doctors can use a skin cancer app that will assess moles with real time vision and receive feedback. There are also glasses and devices that are being used to locate veins, allowing for blood work to be performed quickly and IVs inserted without ever worrying about missing a vein. The impacts that augmented reality can have is endless and the technology will affect every field. Not only will it be used by professionals and consumers, but it will also become a key tool for educational purposes in classrooms around the world.

Ethical considerations

AR is growing at a rapid pace and will continue to become more pervasive. It is a persuasive technology[28] that is already having direct impact on the lives of end users and, potentially, bystanders as well. Because of the interactive nature of this technology, it has the potential to engage and immerse the end user, all the while collecting information about them and their actions. AR is already being used to advise, inform, track, manipulate, entertain and persuade the end user while collecting and utilizing their data.

While this technology provides incredible opportunities for developers, businesses, marketers, and end users, it also raises significant ethical concerns and question. Some of the ethical concerns surrounding AR include how end users will be affected, manipulated, persuaded, or informed by the technology. Further, there are ethical concerns about how information about the end user is being collected and used by the application, and ultimately those who design it, pay for the design, and pay for the information. Issues of personal privacy and privacy protection abound. Further, due to the immersive and persuasive nature of AR applications, the actual physical safety of end users and those around them become an ethical concern. In our project the most important ethical consideration are the location issue, in order to locate the people and offer the geography service we have to get the user's GPS information, depending on this information maybe it also can leak something really important information like by analysis this information including how long the user have stayed in this area and at what time, how often and so on, it can cause the leakage of privacy.

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