Combining AR Markers with Various Kinds of Markers to Enhance User Interactions

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Abstract

Nowadays, the augmented reality technology is gradually appearing into people's view. The numerous augmented reality applications have been used in the people’s daily life of different kinds and disseminated all over the world. Marker-based AR system is one of the most popular AR systems and many kinds of AR markers are used. They all use visual marker-based systems for motion tracking and pose estimation but always independent and no connection. Users cannot do some interaction or control the AR contents by combing multiple markers as they desire. The user experience is not enough in multiple markers field.

In this research, we proposed an augmented reality system which can create new interactions between users and markers by combining multiple markers, hidden markers and auxiliary markers. The system will detect multiple markers at the same time and process them in a certain order with 2-dimension layout in one camera view. The system also can detect a kind of controller marker called hidden marker, which can support users put their finger on the button area to input commands. And the auxiliary markers always perform as a token or key to get specific or decrypted information. This kind of marker can help user to protect some unpublic AR contents in some cases. In this research, we also give some applications based our new system.

Keywords: Augmented reality, Multiple marker, Hidden marker, Auxiliary marker

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Chapter 1

Introduction

1.1 Introduction

Augmented Reality (AR) brings digital information and virtual objects into the physical space [1]. Nowadays, numerous augmented reality applications have been used in the people's daily life of different kinds and disseminated all over the world. There are three types of augmented reality: marker-based, marker-less and location-based. The marker-based AR is the best-known type which uses cameras and visual cues.

Recently, with the development of marker-based AR system [3], a large number of visual markers appear. And just only using single AR marker sometimes cannot meet needs of users.

In this study, we survey the visual markers in current marker-based AR system and compare their advantage and disadvantage. Then propose the framework of new marker-based AR system which can combine multiple markers and using some other additional markers to make the traditional marker-based AR system more attractive and effective.

1.2 Organization of the thesis

The rest of the thesis is organized as follows: Chapter 2 introduces the background of the thesis, survey of the current visual markers and also related work. Chapter 3 will tell the research goal and the approach. Chapter 4 is the system design part, where the design concept and ideas will be introduced, and the mechanism and algorithm design will also be told. Chapter 5 will be the system implementation part where the detailed environment and implementation will be talked. Chapter 6 will be the conclusion and future work part, where we will conclude the previous content and talk about future possibilities.

Chapter2

Background and related work

2.1 Augmented Realty

2.1.1 Definition

Augmented reality (AR) is an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated perceptual information [1].

AR can be defined as a system that fulfills three basic features:

1. a combination of real and virtual worlds
2. real-time interaction
3. accurate 3D registration of virtual and real objects [2].

AR also known as Mixed Reality, aims to combine virtual and real scene together to achieve that virtual ones are belong to the real world. Being characteristic of integration of virtual and real scene, many applications of Augmented Reality are emerging, such as in field of education, medical treatment and entertainment [3].

There are three types of augmented reality: marker-based which uses cameras and visual cues, marker-less which uses positional data, location-based which uses GPS information. In this research, we focus on the marker-based AR system and try to enhance it.

2.1.2 Marker-based Augmented Reality System

Marker-based AR uses a camera and a visual marker to determine the center, orientation and range of its coordinate system by computing the pose matrix [3]. Image recognition is an imperative component of augmented reality systems. By use of identifying visual markers already registered within the system, virtual contents can be generated above of the real-world.

2.2 Visual Markers

The 3D virtual contents need to be registered in AR system for rendering. This registration implies that the geometry of the virtual camera where the augmentation takes place is known with respect to the real world. Visual markers are widely used in the existing AR systems. For example, ARToolKit [4], CyliCon [5], ArLoc [6], and CyberCode [7] all use visual marker-based systems for motion tracking and pose estimation. The performance of such AR systems depends highly on the performance of marker detection, decoding and pose estimation. Currently, there are more than a few existing marker tracking systems. Depending on the application, there are different tracking and pose estimation requirements. For instance, 3D graphic objects often need to be superimposed in good alignment with the real world. This requires the tracker to provide very accurate pose estimation. While in the case that only text information is displayed, the registration requirement is not as strict. In simple office applications a few markers may be enough. In large industrial applications hundreds or thousands of uniquely coded markers may become necessary. It is desirable to enable the AR application developer to determine which marker system is the most suitable for a given AR application [8].

Even though there is effort made to explore marker-less or feature based tracking and 3D reconstruction, AR applications are expected to continue to use visual markers for the foreseeable future. In the AR applications, the square shaped visual markers are the most commonly used ones. The reason is probably that a square shape provides at least 4 co-planar corresponding points so that the camera calibration can be carried out with a single marker in the scene. On the contrary, a circular marker can only provide one-point correspondence, it means the center, unless the circle itself is used. If the center is used, at least 3 circular markers with known 3D positions must be captured in the same image for pose estimation. In this paper we focus using different markers due to their features in one system and try to build a "bridge" to connect them for better performance and new user interactions. We also will introduce some kinds of markers in this chapter at first.

Image Target marker

Vuforia [9] is an augmented reality software development kit (SDK) for mobile devices that enables the creation of augmented reality applications. It uses computer vision technology to recognize and track planar images and 3D objects 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 objects when they are viewed through the camera of a mobile device [10].

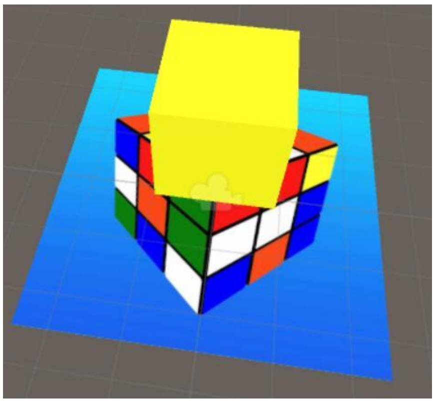


Figure 1 Image target marker shows the AR content by Vuforia.

In Libowen's work [11], he also using image target marker to archive his two method: Encryption and permission of the secure AR (Augmented Reality). After the system detect the encrypted 3D virtual content, an interface will pop-up to let the user input his password. Each input will be recorded by the system database. System will match the user’s input with the correct password which is recorded in the database.

AR toolkit marker [4]

ARToolKit is a software library for building Augmented Reality (AR) applications. These are applications that involve the overlay of virtual imagery on the real world. The ARToolKit video tracking libraries calculate the real camera position and orientation relative to physical markers in real time. This enables the easy development of a wide range of Augmented Reality applications.

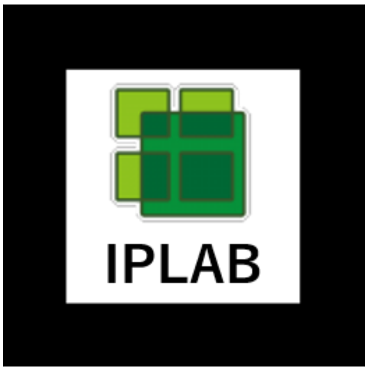


Figure 2 The visual marker of AR toolkit.

CyliCon [5]

CyliCon is a software package for 3D reconstruction of industrial pipelines. This software enables users to work with hundreds of images. It uses geometric features, such as occluding edges and vanishing points, and image processing methods, such as multi-resolution edge refinement, in order to provide semiautomatic user-friendly software. The software has been successfully tested on hundreds of indoor and outdoor industrial images. For maximum accuracy the images are taken with professional cameras resulting in high-resolution images of 3000x2000 pixels. CyliCon lets the user interact conveniently with low-resolution images, while the computation is performed using high-resolution images. A multi-resolution edge refinement algorithm uses the user’s rough input and gradient images at different resolutions to detect edge lines computed from high resolution images.

ArLoc [6]

A real-time system for industrial augmented reality (IAR) applications. This system runs on a mobile computer equipped with a USB camera. One objective of this system is to provide precise localization of the camera (and the user) in a large industrial environment. The real-time localization result can be used to identify the object of interest and for example create hyper-links to the industrial maintenance database.

The camera attached to the computer captures a marker, it displays the image on left side and displays the location of the camera on the floor map as a red dot on the right side. Given a user defined path, the software also shows the path and displays arrow to lead the user to his/her destination.

Barcode

A barcode (also spelled bar code) is a method of representing data in a visual, machine-readable form [12]. Initially, barcodes represented data by varying the widths and spacings of parallel lines. These barcodes, now commonly referred to as linear or one-dimensional (1D), can be scanned by special optical scanners, called barcode readers.

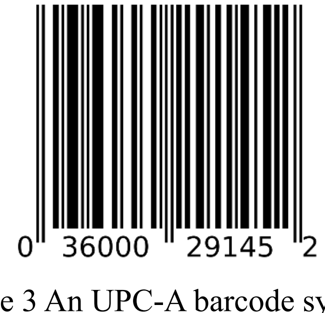


Figure 3 An UPC-A barcode symbol.

QR Code

QR code (abbreviated from Quick Response code) is the trademark for a type of matrix barcode (or two-dimensional barcode) first designed in 1994 for the automotive industry in Japan [13]. QR codes are used in some augmented reality systems to determine the positions of objects in 3-dimensional space. QR Codes are also being used to deliver Augmented Reality experiences. By scanning a QR Code, smartphone users can capture everyday objects in 3D and place them in their surroundings via their camera. IKEA's Place App, Puma's NYC flagship store and Lego toys have used QR Codes to deliver AR resulting in a better consumer experience.

Figure 4 QR code for the URL of the IPLAB home page.

CyberCode [7]

CyberCode is a visual tagging system based on a 2D barcode technology. Designed to be read by low-cost CMOS or CCD cameras common in mobile devices, it can also be used to determine the 3D position of the tagged object as well as its ID number. A CyberCode tag is a 2D barcode symbology designed to be read from many angles. A computer with attached camera can locate the tag and decode the data within the 2D barcode. Visual fiduciary markers surrounding the barcode allow the computer to quickly locate the tag within the field of view of the camera. Additionally, the design of the CyberCode tag allows the computer to track position and orientation in three dimensions. These features allow the tags to be used for augmented reality applications. CyberCode tags affixed to real-world objects would allow the user to view the world through the camera and have the computer overlay additional information over the display. The information encoded in the barcode identifies the object, and because of the tag's design, the computer can detect the orientation of the object relative to the viewer. The main limitation of CyberCode is its extremely limited capacity. Holding only 24 data bits plus 7 error correction bits (or 48+14 in a double-sized variant), the number of objects it can identify is limited.

The Yuji Ayatsuka and Jun Rekimoto based on the Cybercode propose an extension of it, named Active CyberCode [14], which has a variable part for direct manipulations by fingers or other objects. A user can control a character or information invoked by a 2D code by "pushing" printed buttons. The variable part is recognized as an extended part of a code so that it costs almost the same as a normal CyberCode and is robust.

Chapter3

Research Goal and Approach

3.1 Problem

Augmented reality is becoming more and more popular in many fields. And the AR markers are widely used in the existing AR marker-based systems. They all use visual marker-based systems for motion tracking and pose estimation. But these kinds of system still have some problems:

1. When users scan the AR marker by their camera, mostly static AR contents are shown.
2. Even if there is a dynamic AR content, people also cannot control it directly as they desire.

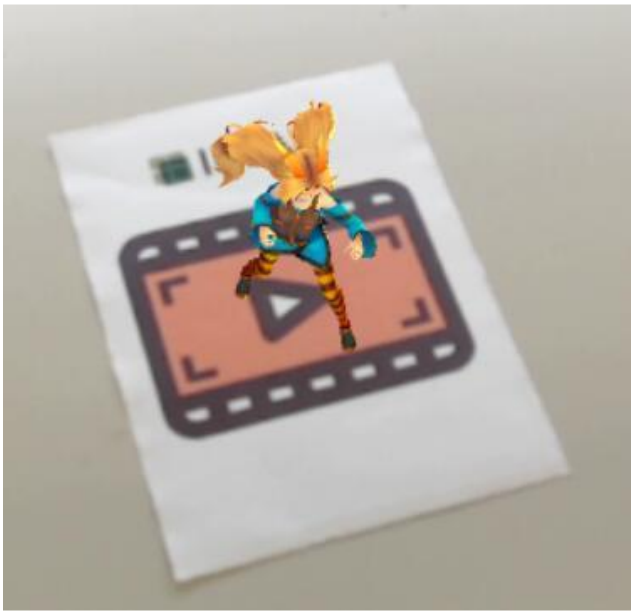


Figure 5 Independent AR contents above the maker.

Usually marker-based AR system just shows separate and independent AR virtual contents above the marker. It means there are no connection and relationship between multiple markers.

For multiple markers, current AR system have a lot of limitation. Users cannot do some interaction or control the AR contents by combing multiple markers as they desire. The user experience is not enough in this field.

3.2 Goal

This research tries to make the current AR system's interaction with the user part more explicit and visible. We propose a controllable AR system that allows users can use multiple visual markers and have direct manipulation with the AR contents. And according to the different situation of the observers, system will display different customized 3D-virtual content. Finally, we propose the method to encrypt and unlock the AR information which is not public to everyone.

3.3 Approach

We have proposed a marker-based AR (Augmented Reality) system. Differ from the traditional AR system, the new system using multiple markers, hidden markers and auxiliary markers combining with AR marker to achieve our goals.

Chapter4

System Design

4.1 Multiple Markers Recognition

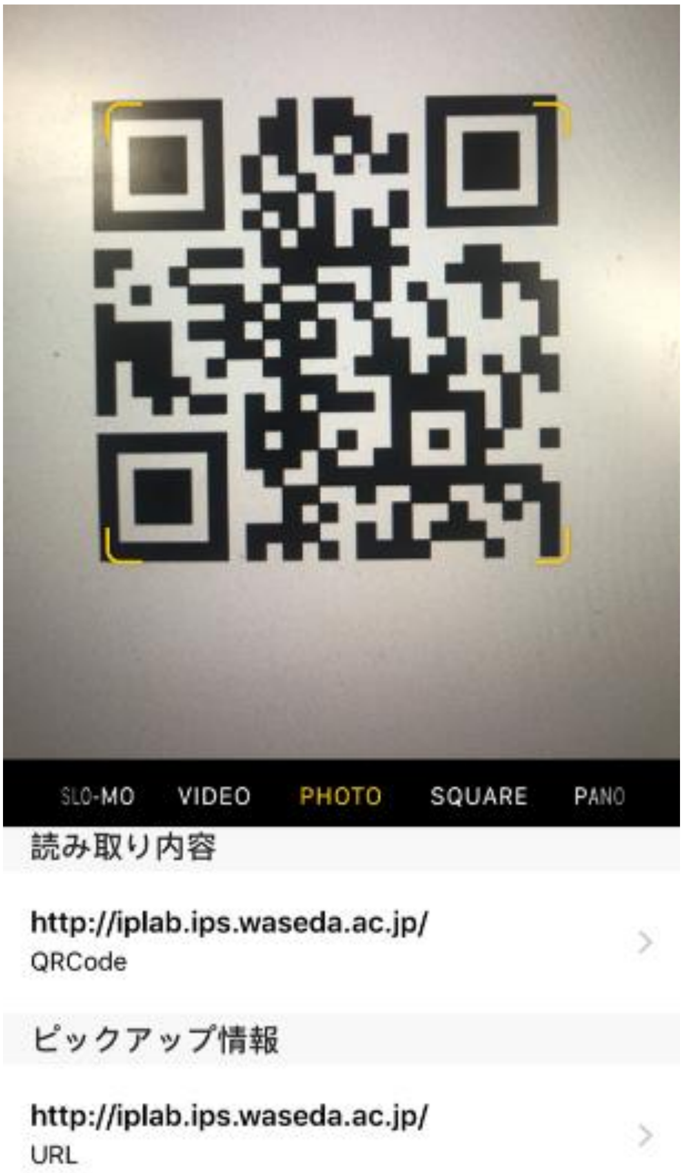
AR markers are widely used in the existing AR systems. However, in current implementation. Each marker needs the specific scanner to detect their information. In our research, we will be trying to combine multiple kinds of markers and recognize them in one system at the same time instead of use one kind of markers.

4.1.1 Framework

Multiple Markers

We try to use multiple markers in our research: QR code, ATK marker and Image target marker.

QR code: QR code (abbreviated from Quick Response code) is the trademark for a type of matrix barcode (or two-dimensional barcode) first designed in 1995 for the automotive industry in Japan. A QR code uses four standardized encoding modes (numeric, alphanumeric, byte/binary, and kanji) to store data efficiently; extensions may also be used. The Quick Response system became popular due to its fast readability and greater storage capacity compared to standard UPC barcodes. A QR code consists of black squares arranged in a square grid on a white background, which can be read by an imaging device such as a camera and processed using Reed–Solomon error correction until the image can be appropriately interpreted. The required data is then extracted from patterns that are present in both horizontal and vertical components of the image.



読み取り内容

http://iplab.ips.waseda.ac.jp/
QRCode

ピックアップ情報

http://iplab.ips.waseda.ac.jp/
URL

Figure 6 Scanning QR code by smartphone.

ATK Marker: ATK (ARToolKit) is an open-source computer tracking library for creation of strong augmented reality applications that overlay virtual imagery on the real world. In order to create strong augmented reality, it uses video tracking capabilities that calculate the real camera position and orientation relative to square physical markers in real time. Once the real camera position is known a virtual camera can be positioned at the same point and 3D computer graphics models drawn exactly overlaid on the real marker. The marker used is simpler than image target marker but Fast enough for real time AR applications.

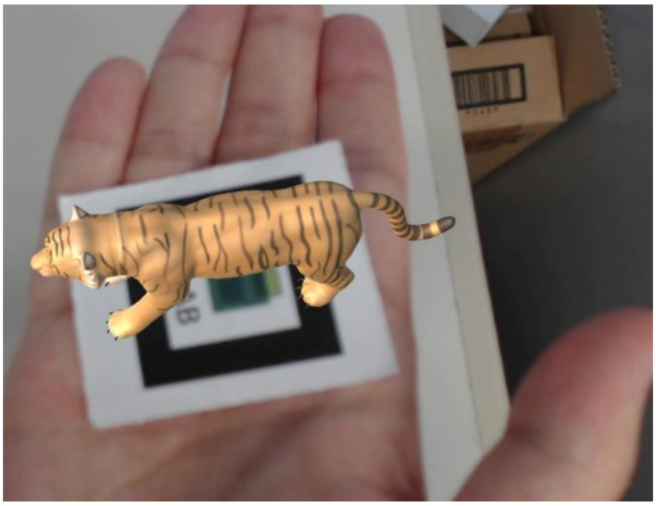


Figure 7 ATK marker showing AR contents.

Image target markers: Image Target marker represent images that Vuforia Engine can detect and track. The Engine detects and tracks the features that are naturally found in the image itself by comparing these natural features against a known target resource database.

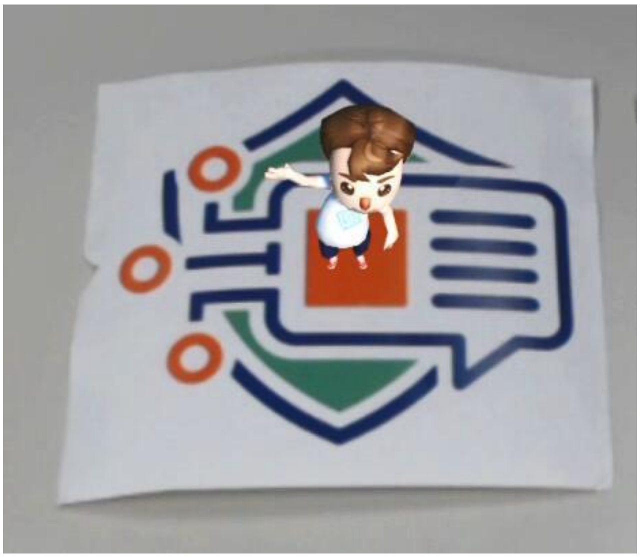
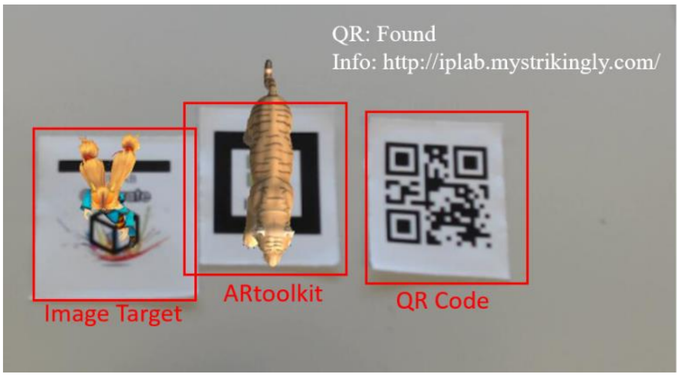
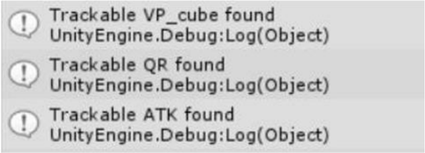


Figure 8 Image target marker showing AR contents.

Multiple Detection

In our research, the camera in the system can recognize the image target marker, ATK marker and QR code at the same time. We integrated these three kinds of markers recognition in one scanner. And the information get from different markers will interact with each other.





```
Trackable VP_cube found
UnityEngine.Debug:Log(Object)
Trackable QR found
UnityEngine.Debug:Log(Object)
Trackable ATK found
UnityEngine.Debug:Log(Object)
```

Figure 9 Multiple recognition.

Position Measure

After detected multiple markers, system also can measure the markers position. The 2-dimensions coordinate axis will be built in the camera view. And the axis origin will start from the center of camera view. All the marker in these camera view can be measured the position information. This information will be used for next step.

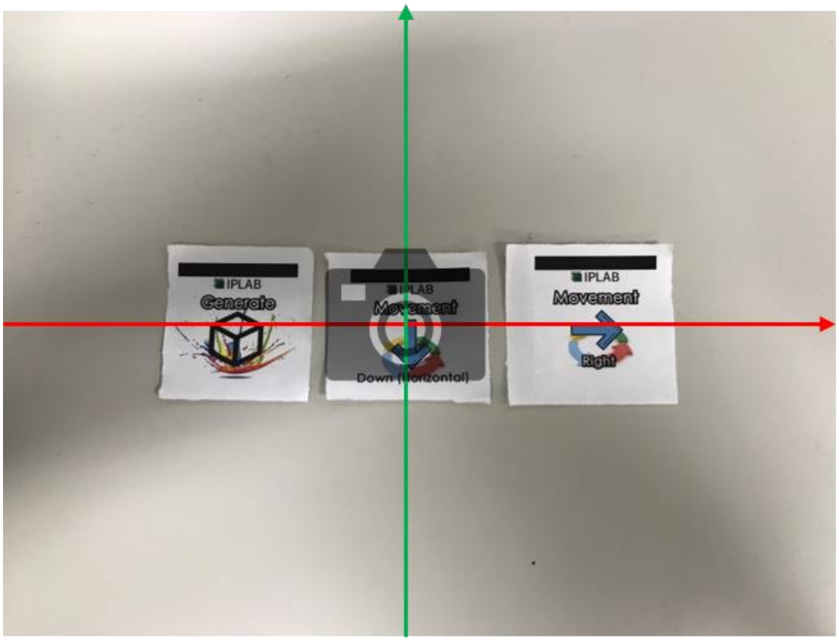
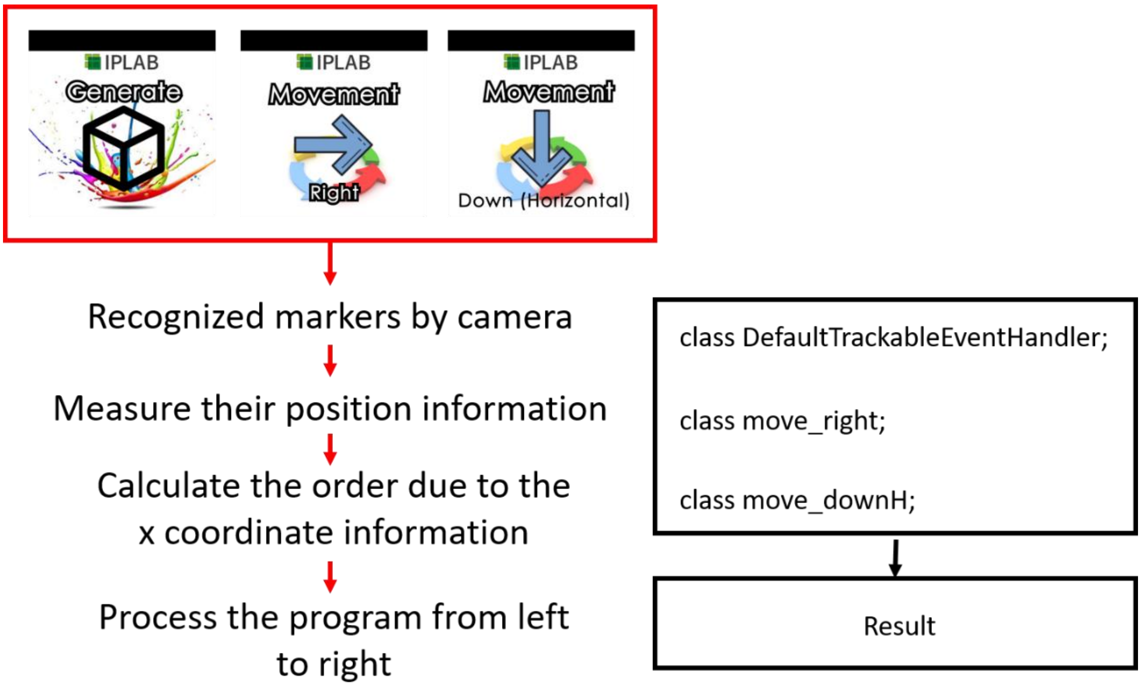


Figure 10 Measuring the marker’s position.

4.1.2 Example of Application: Multiple markers combination

Processing order

Our system will detect all the markers in the camera and generate the commands classes. And then try to measure them in the one world coordinates. According to the x axis information to confirm processing order at first. If there are some markers placed below the main order lines, system will add them after the same x axis information marker. After all the classed lining up, system will process them at last.



Recognized markers by camera

Measure their position information

Calculate the order due to the x coordinate information

Process the program from left to right

```
class DefaultTrackableEventHandler;

class move_right;

class move_downH;
```

Result

Figure 11 Making programs by lining up command cards.

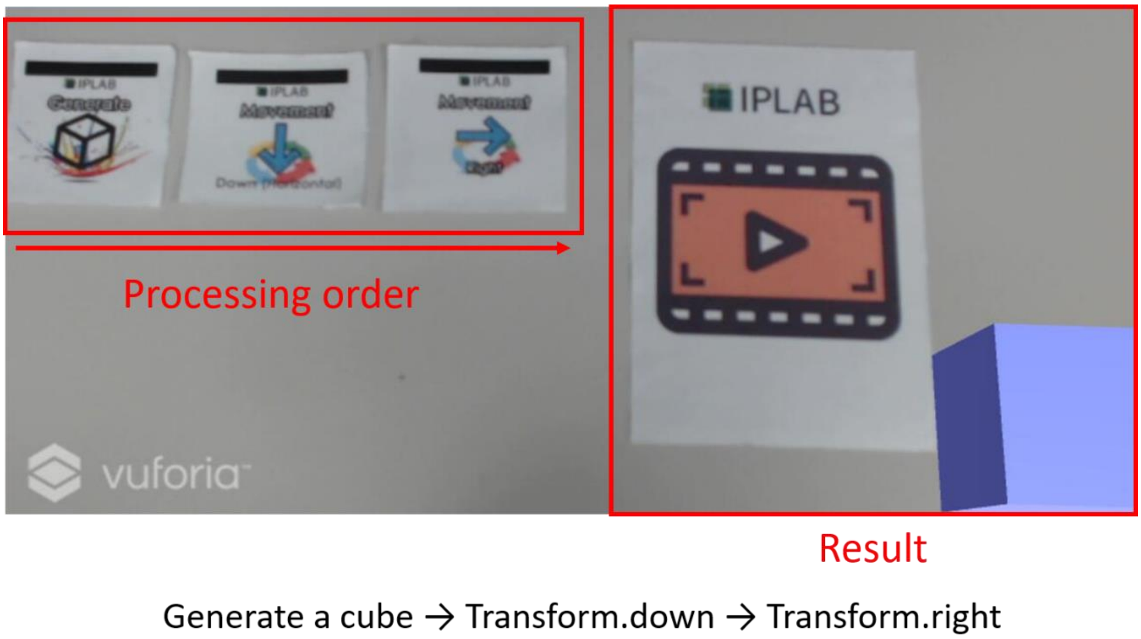


Figure 12 The result will be shown by AR.

Different usage for multiple markers

Therefore, we used three kinds of markers in one system, due to the attribution of different kind of markers, they will contain a variety of commands. We are using QR code to storage the URL and simple texture for model. User can use them to download the 3D virtual contents. And the ATK marker contains some command looks like movement and action to control the 3D virtual contents. The image target marker because we can use natural feature points to make users have some intuitive interactions (put finger on button area to input commands), we can use them to debug the program that user build. Also, the result will be shown as AR and generate by image target marker.

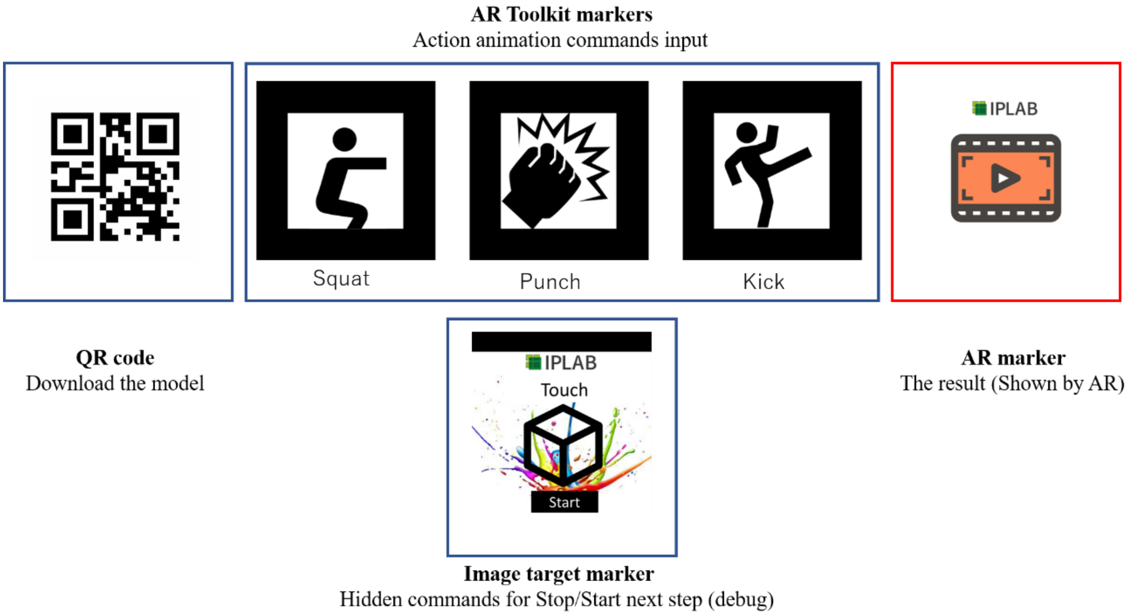


Figure 13 Different usage of markers.

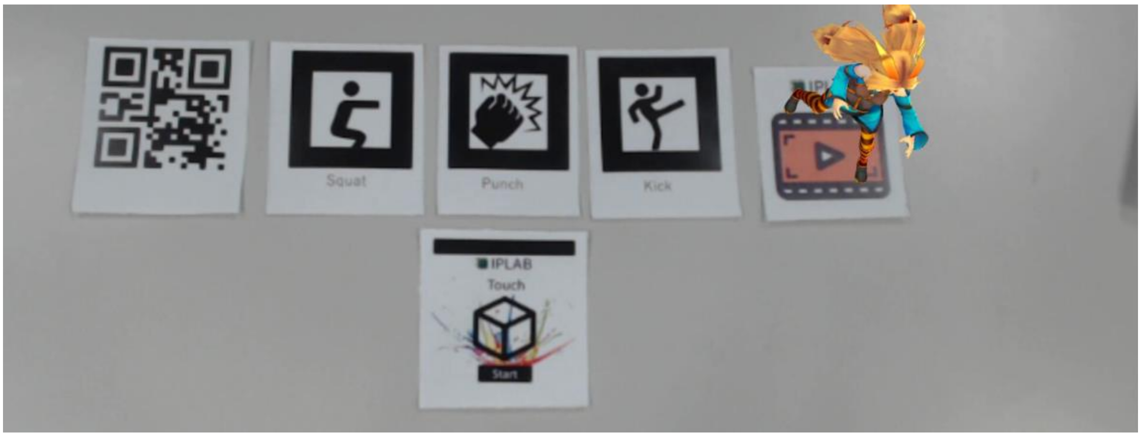


Figure 14 Output result by AR.

In this example, we can see the system download the model by recognize the QR code at first. And due to the ATK markers place order and information start to do some battle actions. Because the hidden marker based on image target marker placed below the punch marker. After the model do the punch action, system will wait for user’s touch. If user press the button area which defined in the hidden marker. The model will start to do the next action: kick. All the result will be shown by AR.

4.2 Hidden markers recognition

Based on the augmented reality technology, we can use the natural feature points which are recognized by system to define some button area.

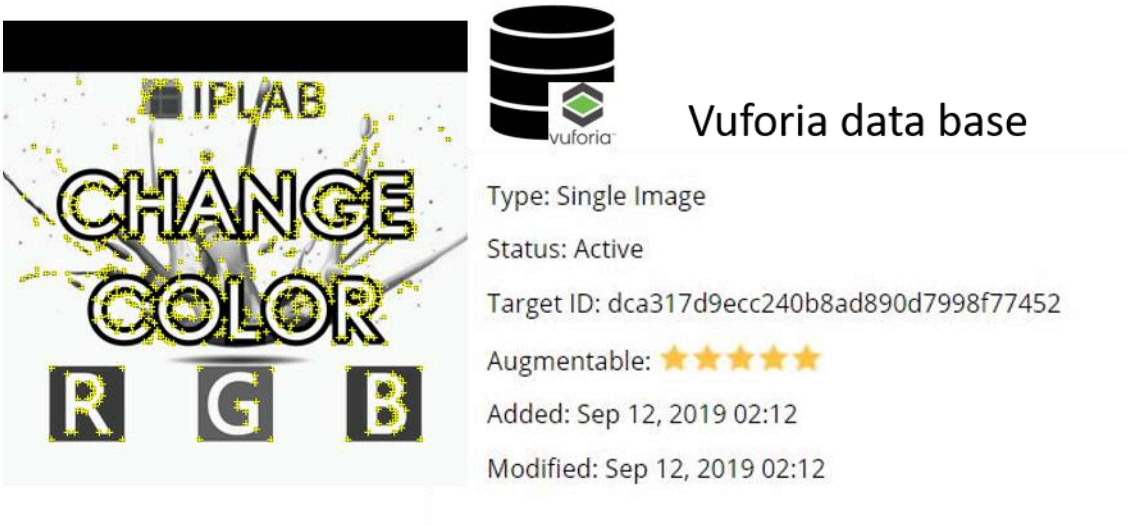
When user’s finger hides the feature points in one button area we defined. The system will recognize which button has been pressed. So, we also can say this kind of auxiliary marker as Hidden Marker.

4.2.1 Framework

Target star rating

Image target markers are detected based on natural features that are extracted from the target image and then compared at run time with features in the live camera image. The star rating of a target ranges between 1 and 5 stars; although targets with low rating (1 or 2 stars) can usually detect and track well. For best results, we should aim for targets with 4 or 5 stars. To create a trackable that is accurately detected, we should use images that are:

Attribute	Example
Rich in detail	Street-scene, group of people, collages and mixtures of items, or sport scenes
Good contrast	Has both bright and dark regions, is well lit, and not dull in brightness or color
No repetitive patterns	Grassy field, the front of a modern house with identical windows, and other regular grids and patterns



Vuforia data base

Type: Single Image

Status: Active

Target ID: dca317d9ecc240b8ad890d7998f77452

Augmentable: ★★★★★

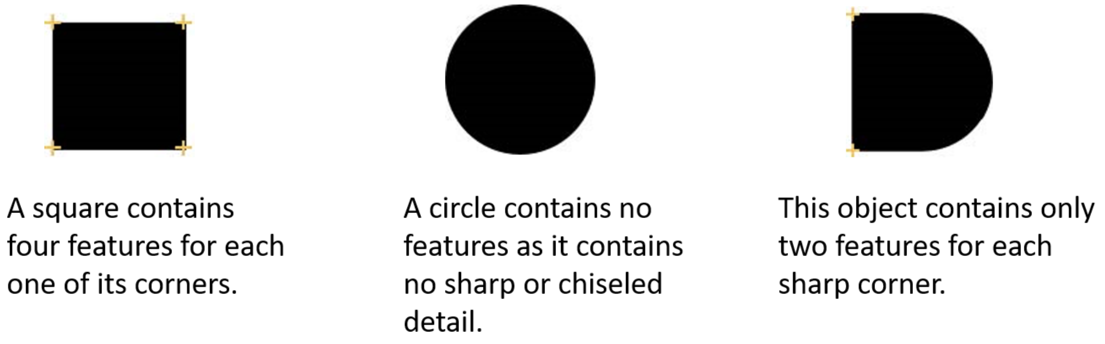
Added: Sep 12, 2019 02:12

Modified: Sep 12, 2019 02:12

Figure 15 Star rating of markers in Vuforia database

Features

A feature is a sharp, spiked, chiseled detail in the image, such as the ones present in textured objects. The image analyzer represents features as small yellow crosses. Increase the number of these details in your image and verify that the details create a non-repeating pattern.



A square contains four features for each one of its corners.

A circle contains no features as it contains no sharp or chiseled detail.

This object contains only two features for each sharp corner.

Figure 16 Features recognition.

Button defines

Hidden button provides a useful mechanism for making marker interactive. The size and placement of hidden buttons must be considered when designing them. There are several factors that will affect the responsiveness and usability of hidden buttons.

1. The length and width of the button.
2. The area of the marker that it covers.
3. The placement of the button in relation to the both the border of the image, and other buttons on the marker.

Button events are triggered when a significant proportion of the features underlying the area of the button are concealed from the camera. This can occur when the user covers the button or otherwise blocks it in the camera view. For this reason, the button should be sized appropriately for the source of the action it is intended to respond to.

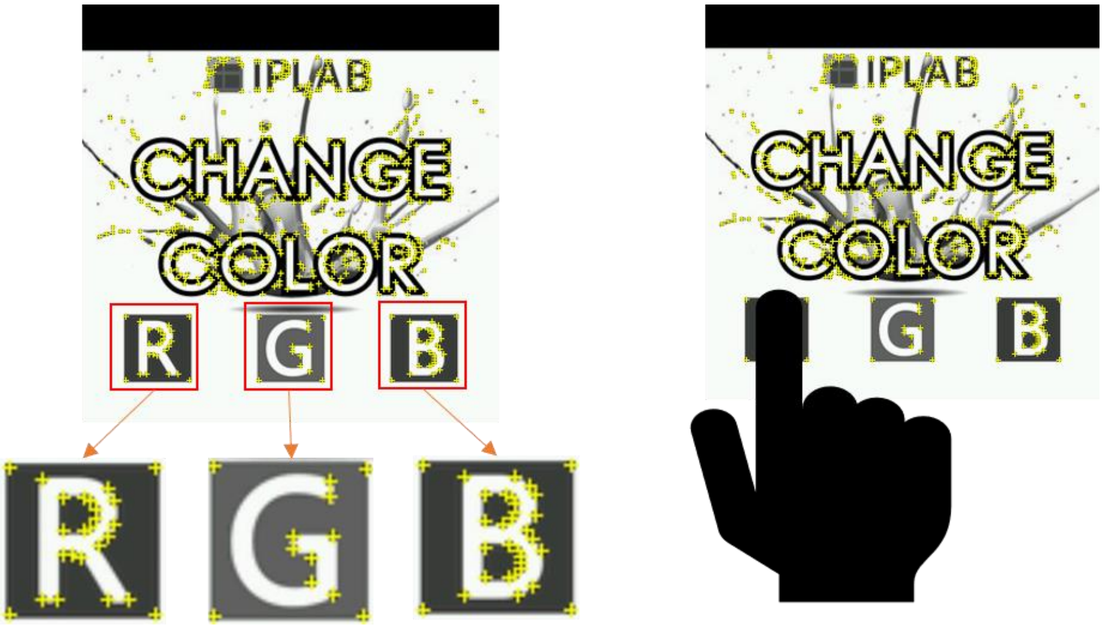


Figure 17 Hidden marker’s button area.

Evaluate sensitivity

We also need to evaluate the sensitivity of buttons. Buttons with a HIGH sensitivity will triggered more easily than those with a LOW sensitivity. The button's sensitivity reflects the proportion of the button area that must be covered, and the coverage time. We need to test the responsiveness of each of buttons in a real-world setting to verify that they perform as expected.

4.2.2 Example of Application: AR Calculator

The AR calculator is consisting of two kinds of visual markers. One is AR marker for show the result by AR. The another one is auxiliary markers for user can input the numbers and operation.

System Output

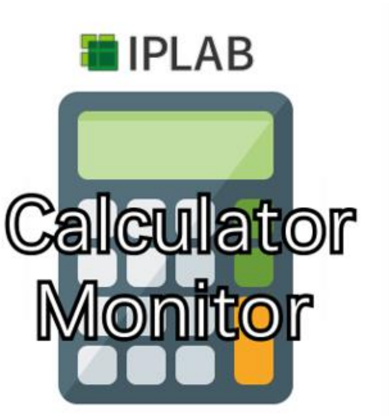


Figure 18 Monitor marker.

The AR marker part can show the 3D virtual contents which perform like the traditional AR system. In this case, the marker will show a 3D virtual calculator. This 3D model will output information to the user: show the number the user input or the calculated result. Just perform as the monitor part in traditional physical calculator. So, we also can call this kind of marker as monitor marker.

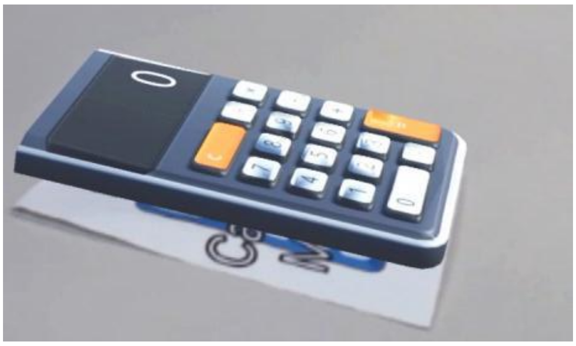
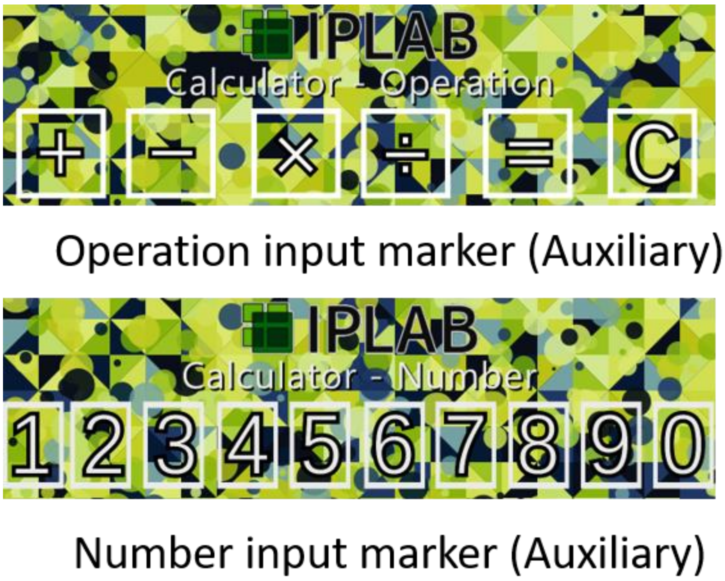


Figure 19 Calculator 3D model.

User Input



Operation input marker (Auxiliary)

Number input marker (Auxiliary)

Figure 20 Hidden marker.

For the user input, we also design the input markers. This kind of auxiliary markers cannot generate the 3D virtual AR contents but can help user to make some interaction with the AR contents which is generated by AR marker in the same camera view. Because the user needs to use their finger to hide the specific button area to input the information, we also can call this kind of markers as hidden marker.

Combining markers

As the result, user can combine these three markers and scan them by one camera. Then they will get a 3D virtual calculator by AR and put the finger on the button area defined in hidden marker to input some numbers and operations to calculate. Result will be shown by AR. The interaction between the user and AR calculator is very intuitive and understandable. Every user who have no guidance also can realize how to use this AR calculator in very short time.

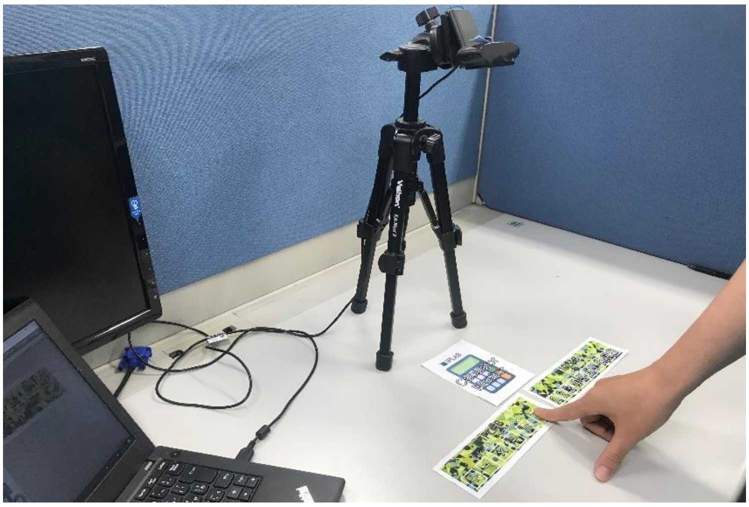


Figure 21 Combine three markers.

Enhance the Algorithm of hidden marker

About the hidden marker's algorithm. We try to enhance the hidden logic. As 5.3 input commands part shows, we just using 1-dimension buttons layout for input the information. Because if the user's hand hides multiple area, system will recognize the multiple button has been pressed and have a lot of wrong inputs. But in our AR calculator's case, 1-dimension buttons layout for numbers input is not natural. In daily life, people always input numbers by 3X3 2-dimensions buttons layout. So, we enhanced our number input marker.

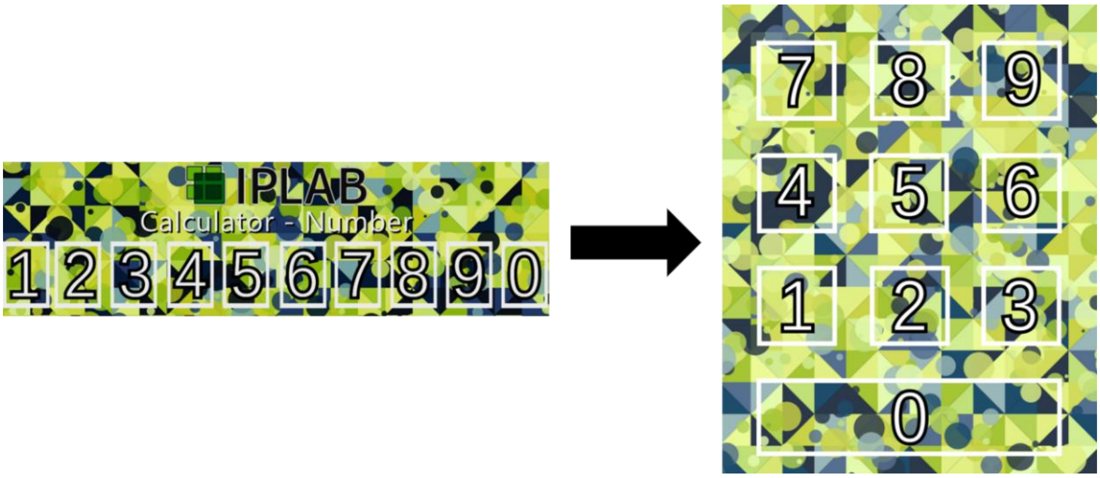


Figure 22 Re-design the number input marker.

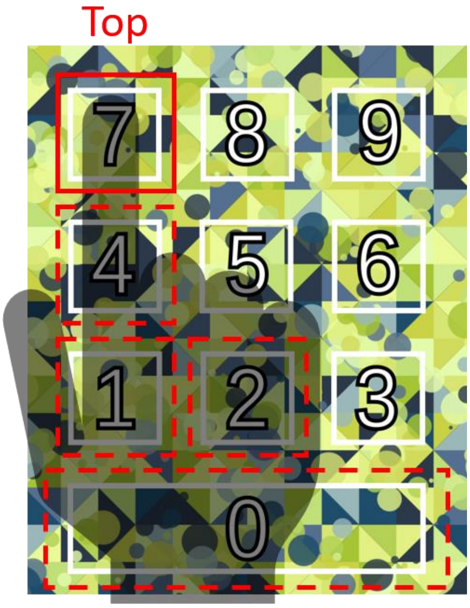


Figure 23 Recognize the top button area user pressed marker.

As figure shows the new number input markers using this kind of 2-dimensions buttons layout. For the user input we add some new logic for it. When the system detects the button area has been hidden, the system will not generate the input commands at once. System will start to wait for 1 second give the time to user's hand slide over the marker and fix his gesture. After the user's gesture is fixed, the system will try to recognize the multiple button areas hidden by user's hand and calculate which is the top button area and generate the top button area's command.

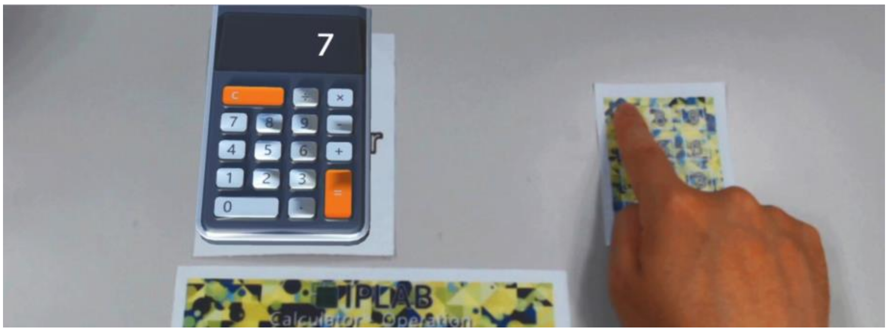


Figure 24 Input number by 2-dimensions buttons layout marker.

As the result, our AR calculator can use this kind of algorithm to provide more natural number input layout for the user without 1-dimension buttons layout.

4.2.3 Example of Application: AR Piano

We have introduced a kind of input method by users put their fingers on the auxiliary marker's button area to input commands. To enhance the hidden markers algorithm for recognition, user can use 3X3 2-dimensions buttons layout to input numbers in the AR calculator application we have mentioned before.

In this part we use this method to make the new application named AR piano. This application support user can have the multiple touch to input the multiple commands at the same time.

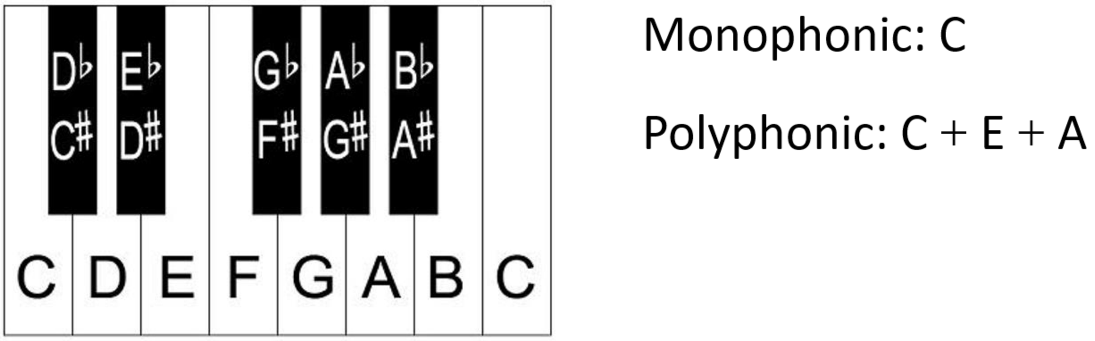


Figure 25 AR piano marker and phonic.

Multiple Touch

As the formal piano in the real-world. If user touch one key, the piano will generate single tune at one time, we call it monophonic. And if user touch several keys at the same time, the piano will generate several tunes at same time and combine them as a new voice, we call it polyphonic. In this research we make the AR piano by our AR system, and can generate polyphonic by multiple touch.

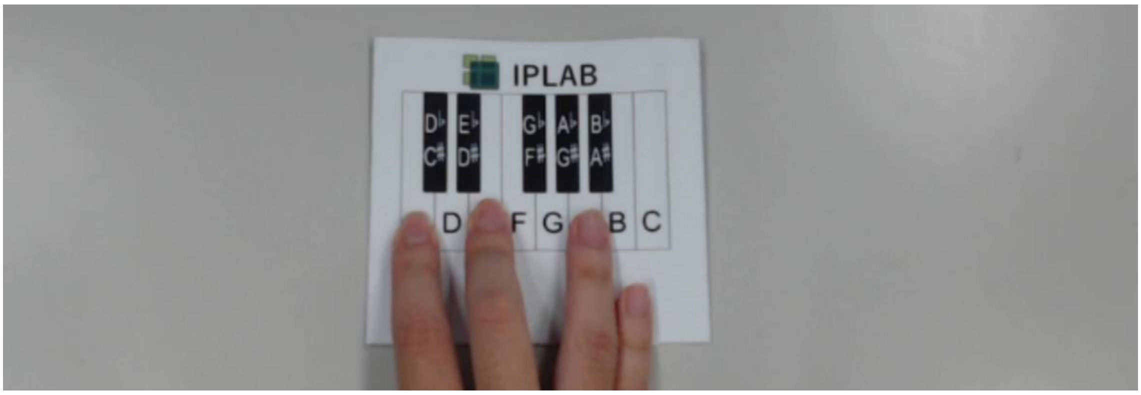


Figure 26 Multiple touch.

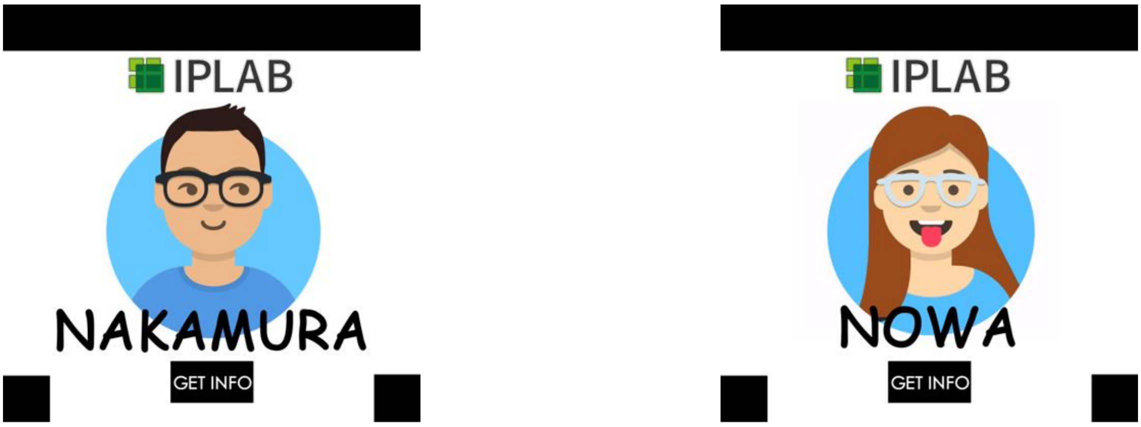
As the figure shows, user touch the C, E and A keys at the same time, the system will generate the C＋E＋A piano tune voice together and make a polyphonic voice.

Because of we use the 2-dimensions buttons layout ‘s algorithm for recognition in this application, touch the black key to play some tunes and multiple black key touch to play polyphonic are also available.

4.3 Auxiliary Marker

4.3.1 Personalization

The identity of the user is an important condition for the customized AR display. The system to display different 3D virtual content for users with different identities is one of the cores of customized Augmented Reality. In our system, we use a kind of auxiliary marker connect to the database which is store the user information. And when the user put the auxiliary marker with the AR marker, the user information data will be checked by system and show the customized contents to the user.



Name: Nakamura Tarou
Class: M1 Spring
Language: Japanese

Name: Nowa James
Class: M2 Fall
Language: English

Figure 27 Two kinds of personal auxiliary marker and information.

In this research we have set an AR marker in the lab. The fictitious student A and student B will receive different information on the 3D-virtual Call-board activated by this AR marker. Because that when they want to get information from this AR marker, they need to put their own auxiliary marker which contains their personal information with the AR marker together.

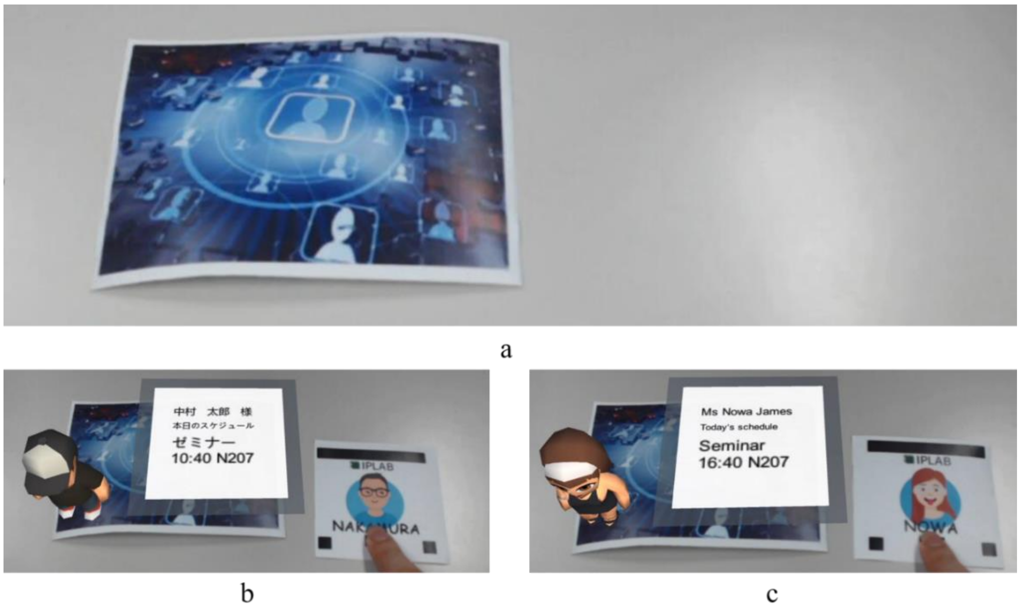


Figure 28 Get customized information from the AR marker.

When there is no auxiliary marker, the AR marker will not show anything, like figure 28 (a) shows. And after the student put his own auxiliary marker with it, the AR content will be shown. We can see:

> **Nakamura**: He will see his today's schedule by Japanese according to his class and prefer language. He also can see his 3D virtual avatar by AR, like figure 28 (b) shows.
>
> **Nowa James**: She will see her today's schedule by English according to her class and prefer language. She also can see her 3D virtual avatar by AR, like figure 28 (c) shows.

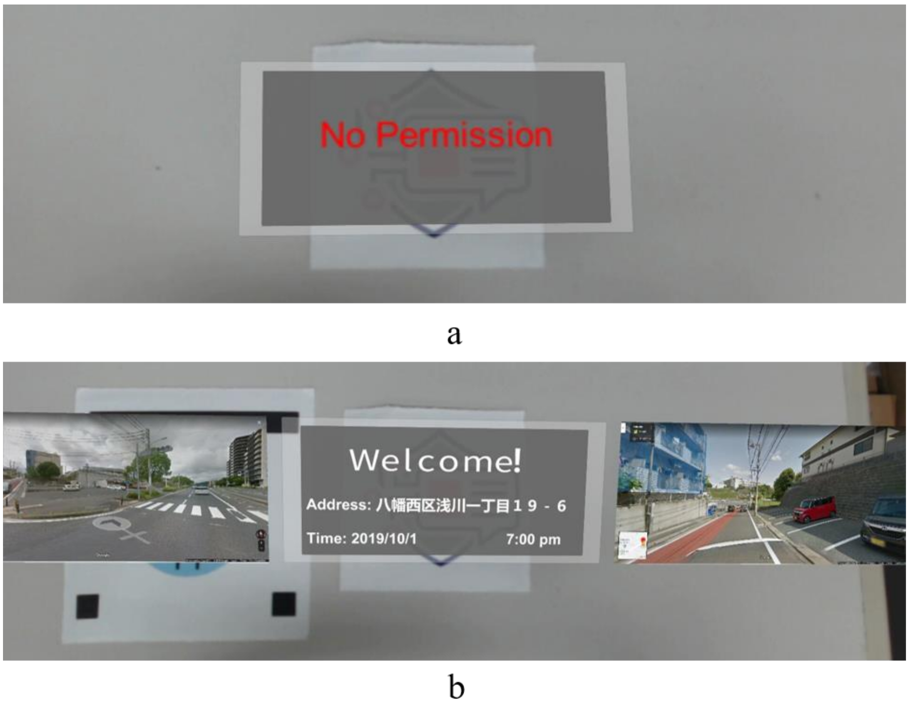
As the result, our system supports two difference nationality and class students in one lab can get their different schedule from one AR marker just by putting their auxiliary marker with the AR marker without any ID or password input.

4.3.2 Encryption/Decryption

Sometime the providers of 3D virtual content do not want all the users to see the hidden information. In the other hand, give other people your personal account and password is very dangerous. In our research, the user can use the auxiliary card which can perform as a key to unlock some encrypted AR contents. The key is only for decrypting and does not contain any personal information. We designed two simple usage scenarios to show how encryption/decryption part is working in this system.

Usage Scenario A – AR mail

In the usage scenario of this research, there are two users: user A and user B. User A prepare a mail which contains AR contents to user B for inviting user B and his family to user A's house. Because of the address information, user A does not want other people can see the contents, so he encrypted the AR mail then post it and pass the auxiliary key marker to user B by another way.



a

b

Figure 29 Encrypted AR mail.

User B received mail and key by two different ways. If he just using the camera scan the mail marker without auxiliary key marker, he only can see the text “No permission”, like figure 5.11 (a). And if he put the auxiliary key marker with the mail marker, the 3D virtual contents containing 3D avatars, address information, map and photo will be shown, like figure 5.11 (b). And if he wants to let his family know this, just need to pass the mail and auxiliary key marker. He does not need to share his account and password.

Usage Scenario B – AR announcement

In Libowen’s research, the 3D virtual Call-Board at Sakura House shows the permission check function of the system. In the pre-set, user A is not a resident of Sakura House, so he has no permission to make the hidden 3D-virtual Call-Board display. Instead, the system will give her a "No Permission!" message. In the other hand, the fictitious user B is the resident of the Sakura House in the pre-set. So, he can see the notification from the system about the dealing with old furniture.

The usage scenario of our research, the principal of Koharu house always need to tell some announcement from door to door in the past. Looks like the disaster prevention and early warning. We try to use our system and set permission for Koharu’s residents. And the user who is not the resident of Koharu house cannot acquire the information on the AR announcement marker. The principal just needs to share the key marker to the residents, anytime, anywhere and let them gain the access to the content which he has set up before.

Chapter5

System Implementation

5.1 Develop Environment

We established the system and built the 3D module on Unity and use the C sharp as the development language. We use Vuforia-Unity SDK (As of 2017.2, Unity integrates the Vuforia Engine), AR Toolkit SDK to detect the AR-marker and QR code scanner to detect the QR code in camera view. Finally, we integrated them in one system and add 3D virtual content in the user's view.

Figure 30 Unity3D, Vuforia, AR Toolkit.

5.2 System Hardware

We have used the WEB camera (Velbon EX-Mini S & HD Pro Webcam C920) for detect the markers. A PC with the windows 10 operation system provides a platform for the system to process the program. Our system also can be installed in other platform looks like smartphone and AR glasses.

Figure 31 PC.

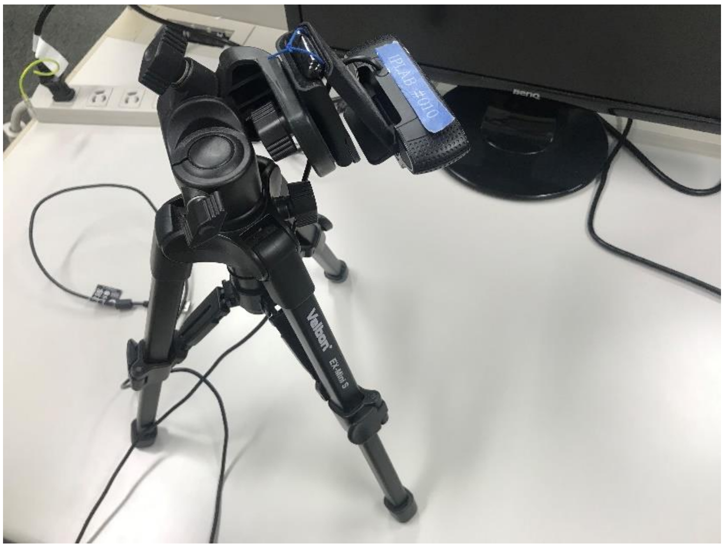


Figure 32 Web camera.

5.3 Project Scene

Once the project is created, Unity structures it into scenes. Every scene is like a game level and is loaded when required. Each unique Scene file is a unique level. In each Scene, we can place our environments, obstacles, and decorations, essentially designing and building our application in pieces.

Application menu is considered a scene too and its function is to manage the application different scenes. Scenes that use device's camera as AR camera launch the capture process, define the tracker and execute its renderization. AR Cameras are the eyes of the application. Everything the player will see is through AR camera. Users can position, rotate, and parent camera just like any other Game Object.

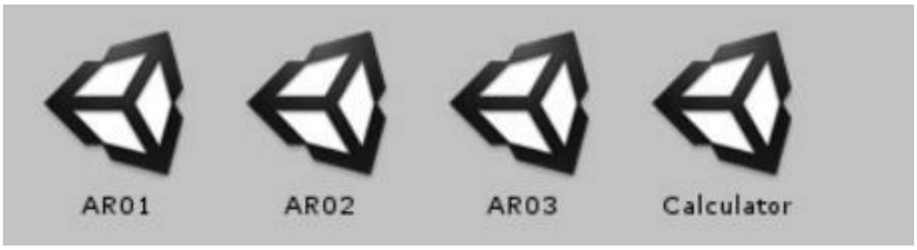


Figure 33 Different scenes.

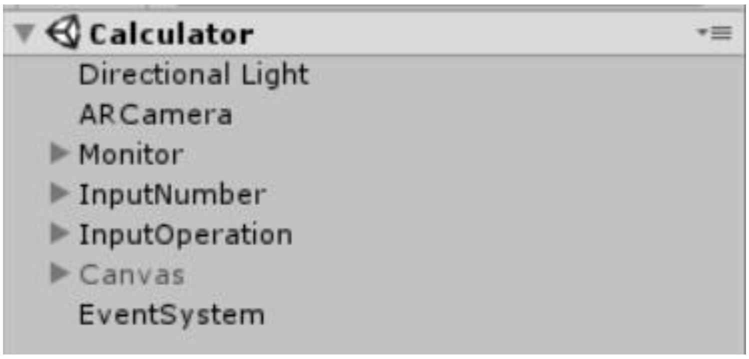


Figure 34 Elements in the scene.

5.4 3D Virtual Content Modeling

Our system will display these 3D virtual contents to the users. So, we need to create those fictitious 3D virtual content in advance. We use 3Dmax and Unity 3D to accomplish this part of work.

5.4.1 Modeling in 3DMAX

We build the AR Calculator’s 3D virtual model in 3DMAX. We need to define the calculator’s outline at first. For the realistic, we consult the traditional Calculator’s shape and size in the real-world. And after that, we add the button and screen on the model. The button layout is also like the traditional calculator’s design and combine with the digital calculator button area and color.

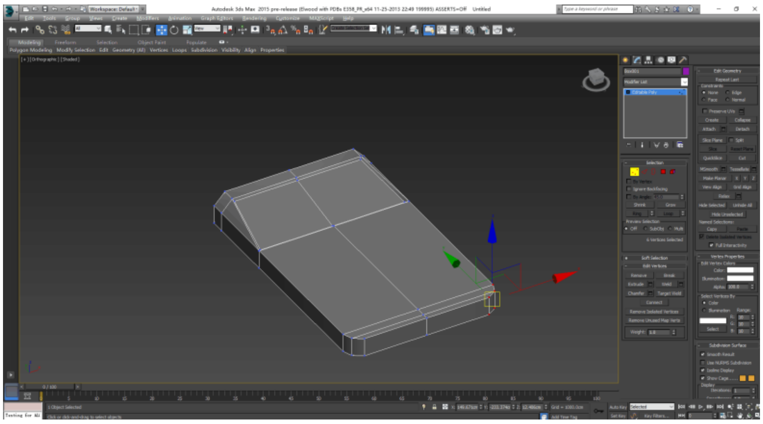


Figure 35 Building the outline.

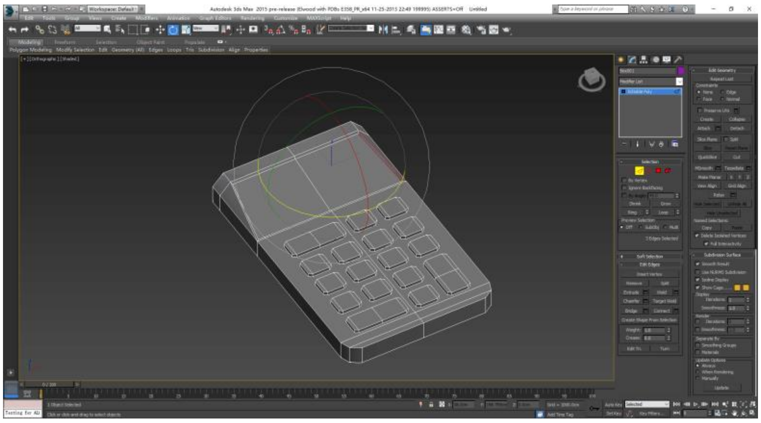
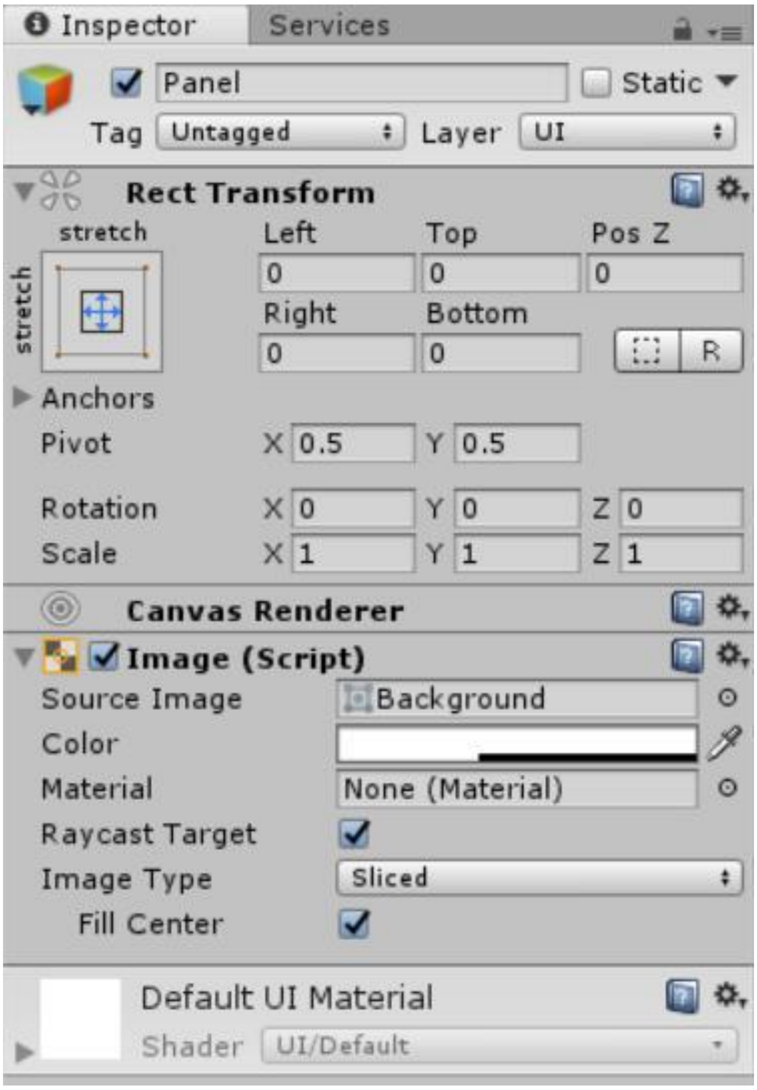


Figure 36 Adding buttons.

5.4.2 Modeling in Unity3D

In the personalization and Encryption/Decryption parts, we have created several 3D virtual panel in the scene. The system will display these kinds of 2D panel to the user when they put their auxiliary markers with the AR marker together.

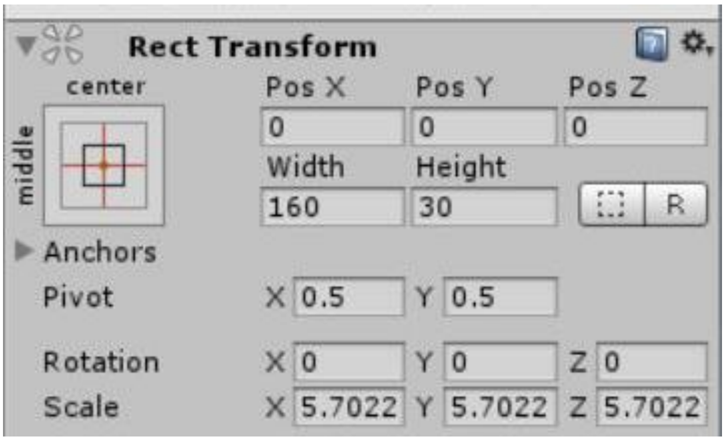
We designed the 3D virtual panel like the call board in the real-world. And not only the text information, we also can add some pictures in the layout. The size of panel needs to be reset for fitting our markers.



☑ Panel □ Static
Tag: Untagged
Layer: UI
Left: 0
Top: 0
Pos Z: 0
Right: 0
Bottom: 0
Pivot: X 0.5 Y 0.5
Rotation: X 0 Y 0 Z 0
Scale: X 1 Y 1 Z 1
Source Image: Background
Material: None (Material)
Raycast Target: ☑
Image Type: Sliced
Fill Center: ☑
Shader: UI/Default

Figure 37 The panel of UI.

After we created the panel, we also need to add the text script on it. The size is fit to the mother panel and we can design the font size, color and other attributions by text script.



Rect Transform

center / middle

Pos X 0 | Pos Y 0 | Pos Z 0

Width 160 | Height 30

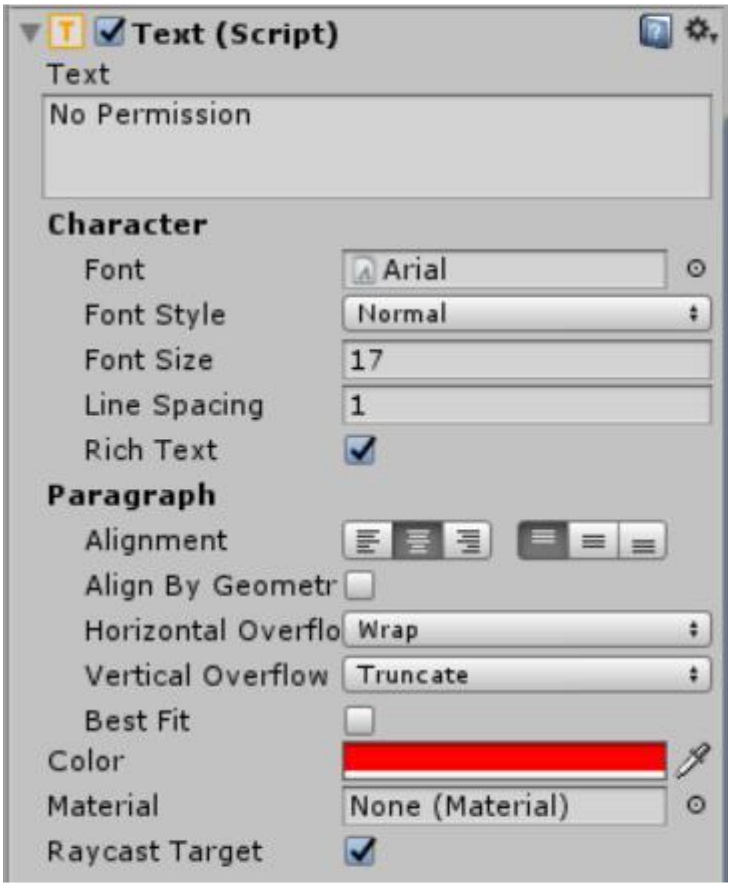
Anchors

Pivot X 0.5 Y 0.5

Rotation X 0 Y 0 Z 0

Scale X 5.7022 Y 5.7022 Z 5.7022

Figure 38 Rect transform.



☑ Text (Script)

Text: No Permission

Character

Font: Arial

Font Style: Normal

Font Size: 17

Line Spacing: 1

Rich Text: ☑

Paragraph

Alignment

Align By Geometr: □

Horizontal Overflo: Wrap

Vertical Overflow: Truncate

Best Fit: □

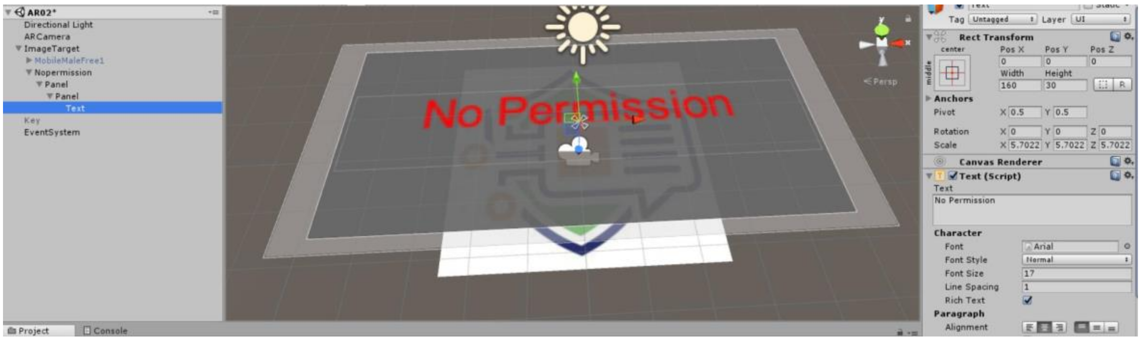
Color: 🟥

Material: None (Material)

Raycast Target: ☑

Figure 39 Text edit panel.

As figure shows, in the Encryption/Decryption part. If the user used the correct key auxiliary card with the AR mail, he can see the address information and two pictures about the street for the user can easily find the building where is the inviter lives in.



```
▼ AR02*
    Directional Light
    ARCamera
  ▼ ImageTarget
    ▶ MobileMaleFree1
    ▼ Nopermission
      ▼ Panel
        ▼ Panel
            Text
    Key
    EventSystem
```

Tag Untagged Layer UI

Rect Transform: center / middle; Pos X 0, Pos Y 0, Pos Z 0; Width 160, Height 30

Anchors

Pivot X 0.5 Y 0.5

Rotation X 0 Y 0 Z 0

Scale X 5.7022 Y 5.7022 Z 5.7022

Canvas Renderer

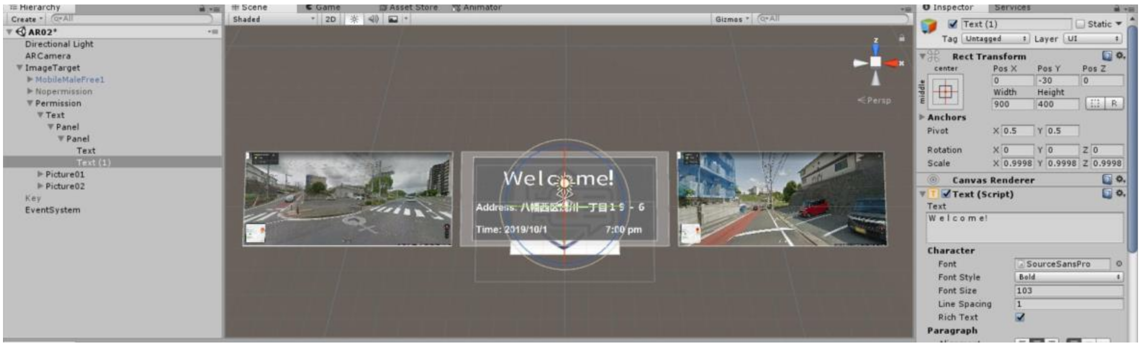
☑ Text (Script)

Text: No Permission

Character
Font: Arial
Font Style: Normal
Font Size: 17
Line Spacing: 1
Rich Text: ☑

Paragraph
Alignment

Figure 40 No Permission UI.



```
▼ AR02*
    Directional Light
    ARCamera
  ▼ ImageTarget
    ▶ MobileMaleFree1
    ▶ Nopermission
    ▼ Permission
      ▼ Text
        ▼ Panel
          ▼ Panel
              Text
              Text (1)
      ▶ Picture01
      ▶ Picture02
    Key
    EventSystem
```

☑ Text (1) □ Static

Tag Untagged Layer UI

Rect Transform: center / middle; Pos X 0, Pos Y -30, Pos Z 0; Width 900, Height 400

Anchors

Pivot X 0.5 Y 0.5

Rotation X 0 Y 0 Z 0

Scale X 0.9998 Y 0.9998 Z 0.9998

Canvas Renderer

☑ Text (Script)

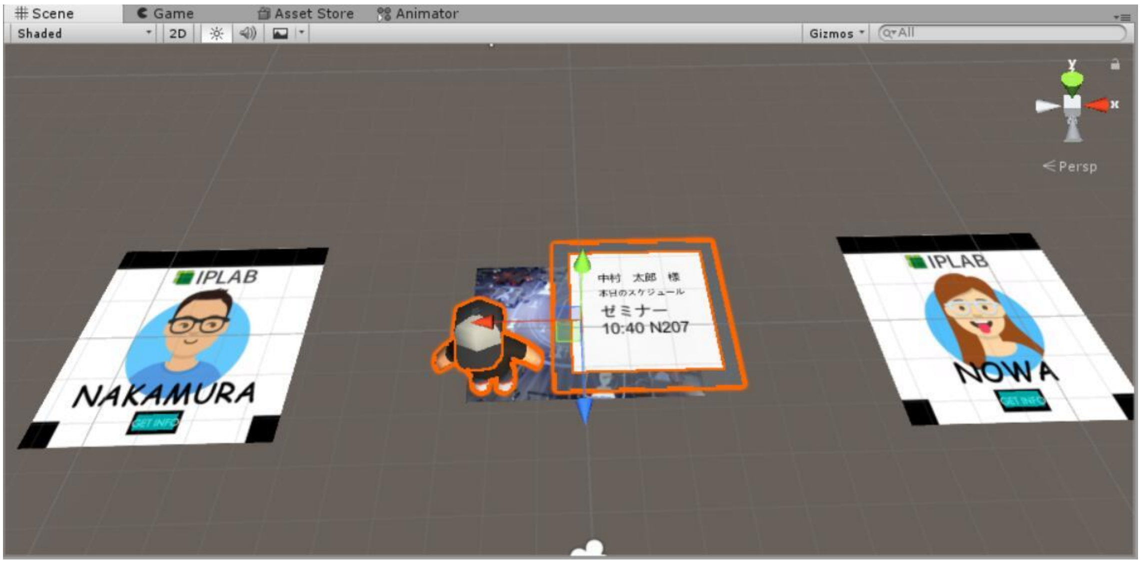
Text: W e l c o m e!

Character
Font: SourceSansPro
Font Style: Bold
Font Size: 103
Line Spacing: 1
Rich Text: ☑

Paragraph

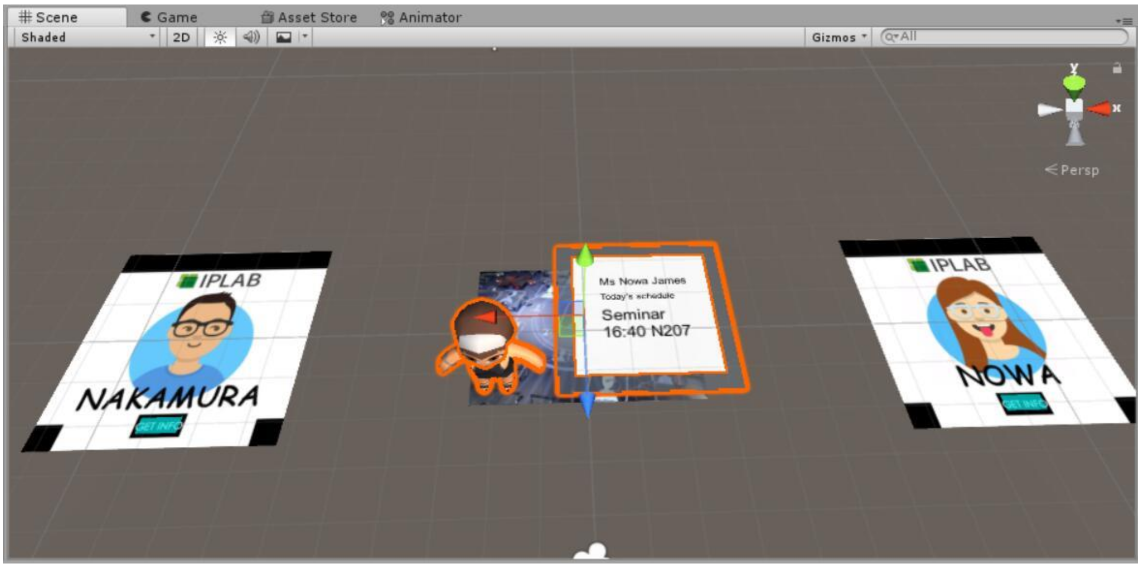
Figure 41 The AR invitation card in detail.

As figure shows, in the personalization part. If the user used his/her id auxiliary card with the AR marker, he can see his/her schedule and 3D avatar.



中村　太郎　様
本日のスケジュール
ゼミナー
10:40 N207

Figure 42 The AR personalization card for Nakamura.



Ms Nowa James
Today's schedule
Seminar
16:40 N207

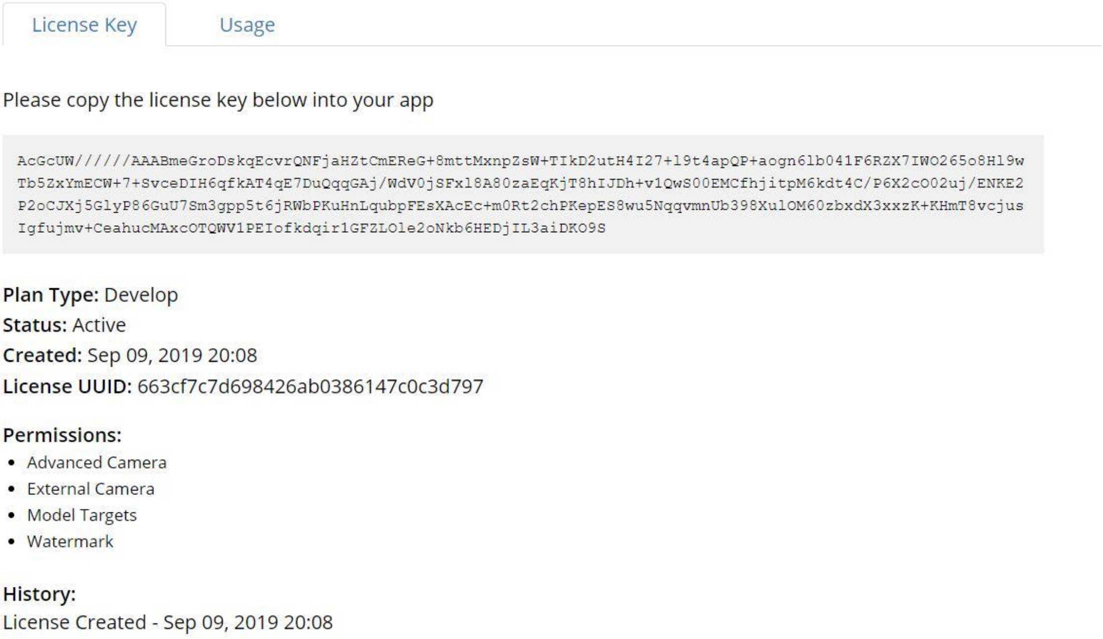
Figure 43 The AR personalization card for Nowa.

5.5 Multiple recognition

5.5.1 Vuforia

Based on Vuforia service, our system can recognize the image target marker with natural feature points. For using this engine, we need to get the free license from their homepage (https://developer.vuforia.com/legal/license).

After we get the license, we can upload our marker to the database and get the analysis data. For best results, we should aim for uploaded image target markers with 4 or 5 stars. And If the target is not focused well in the camera view, the camera image result can be blurry, and the target details can be hard to detect. Consequently, detection and tracking performance can be negatively affected. We need to make use of the appropriate Camera Focus Mode to ensure the best camera focus conditions.



Please copy the license key below into your app

```
AcGcUW//////AAABmeGroDskqEcvrQNFjaHZtCmEReG+8mttMxnpZsW+TIkD2utH4I27+l9t4apQP+aogn6lb041F6RZX7IWO265o8Hl9w
Tb5ZxYmECW+7+SvceDIH6qfkAT4qE7DuQqqGAj/WdV0jSFxl8A80zaEqKjT8hIJDh+v1QwS00EMCfhjitpM6kdt4C/P6X2cO02uj/ENKE2
P2oCJXj5GlyP86GuU7Sm3gpp5t6jRWbPKuHnLqubpFEsXAcEc+m0Rt2chPKepES8wu5NqqvmnUb398XulOM60zbxdX3xxzK+KHmT8vcjus
Igfujmv+CeahucMAxcOTQWV1PEIofkdqir1GFZLOle2oNkb6HEDjIL3aiDKO9S
```

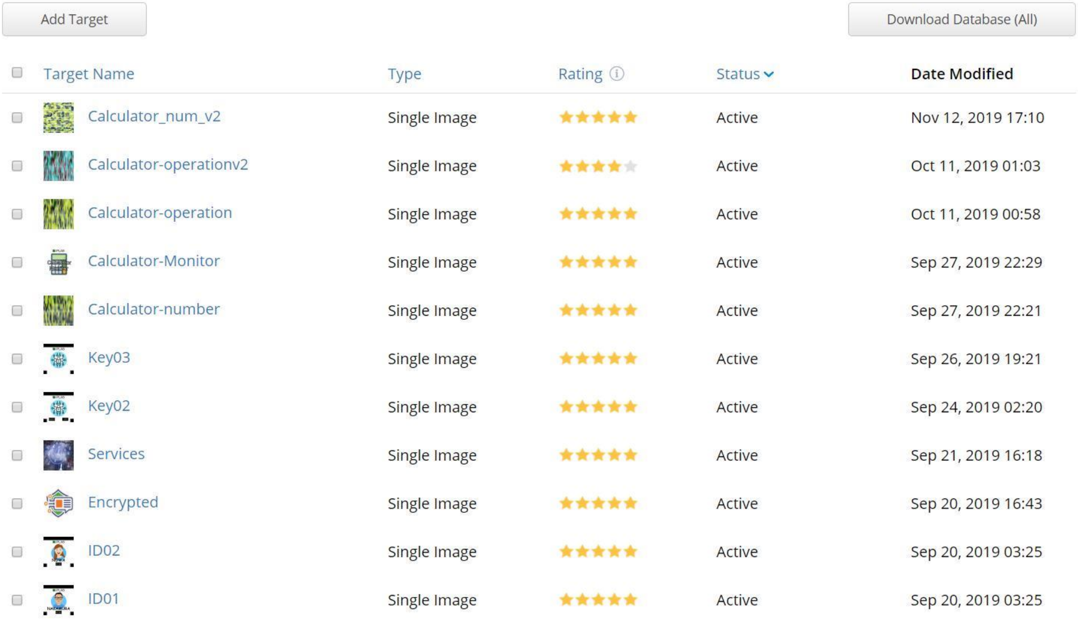
Plan Type: Develop
Status: Active
Created: Sep 09, 2019 20:08
License UUID: 663cf7c7d698426ab0386147c0c3d797

Permissions:

- Advanced Camera
- External Camera
- Model Targets
- Watermark

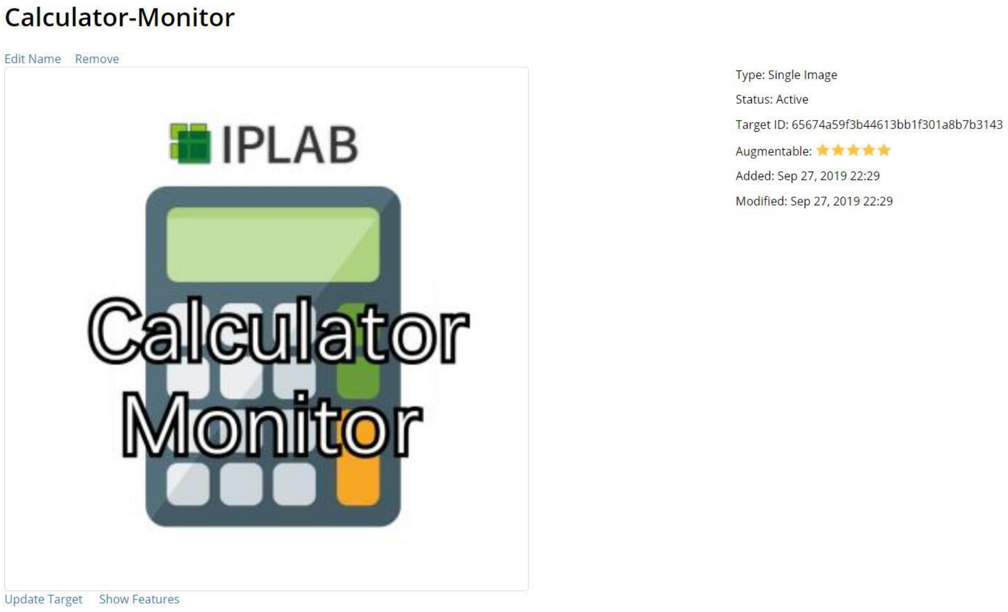
History:
License Created - Sep 09, 2019 20:08

Figure 44 Getting the license key from Vuforia.



□	Target Name	Type	Rating ⓘ	Status	Date Modified
□	Calculator_num_v2	Single Image	★★★★★	Active	Nov 12, 2019 17:10
□	Calculator-operationv2	Single Image	★★★★☆	Active	Oct 11, 2019 01:03
□	Calculator-operation	Single Image	★★★★★	Active	Oct 11, 2019 00:58
□	Calculator-Monitor	Single Image	★★★★★	Active	Sep 27, 2019 22:29
□	Calculator-number	Single Image	★★★★★	Active	Sep 27, 2019 22:21
□	Key03	Single Image	★★★★★	Active	Sep 26, 2019 19:21
□	Key02	Single Image	★★★★★	Active	Sep 24, 2019 02:20
□	Services	Single Image	★★★★★	Active	Sep 21, 2019 16:18
□	Encrypted	Single Image	★★★★★	Active	Sep 20, 2019 16:43
□	ID02	Single Image	★★★★★	Active	Sep 20, 2019 03:25
□	ID01	Single Image	★★★★★	Active	Sep 20, 2019 03:25

Figure 45 The image target markers database.



Calculator-Monitor

Type: Single Image

Status: Active

Target ID: 65674a59f3b44613bb1f301a8b7b3143

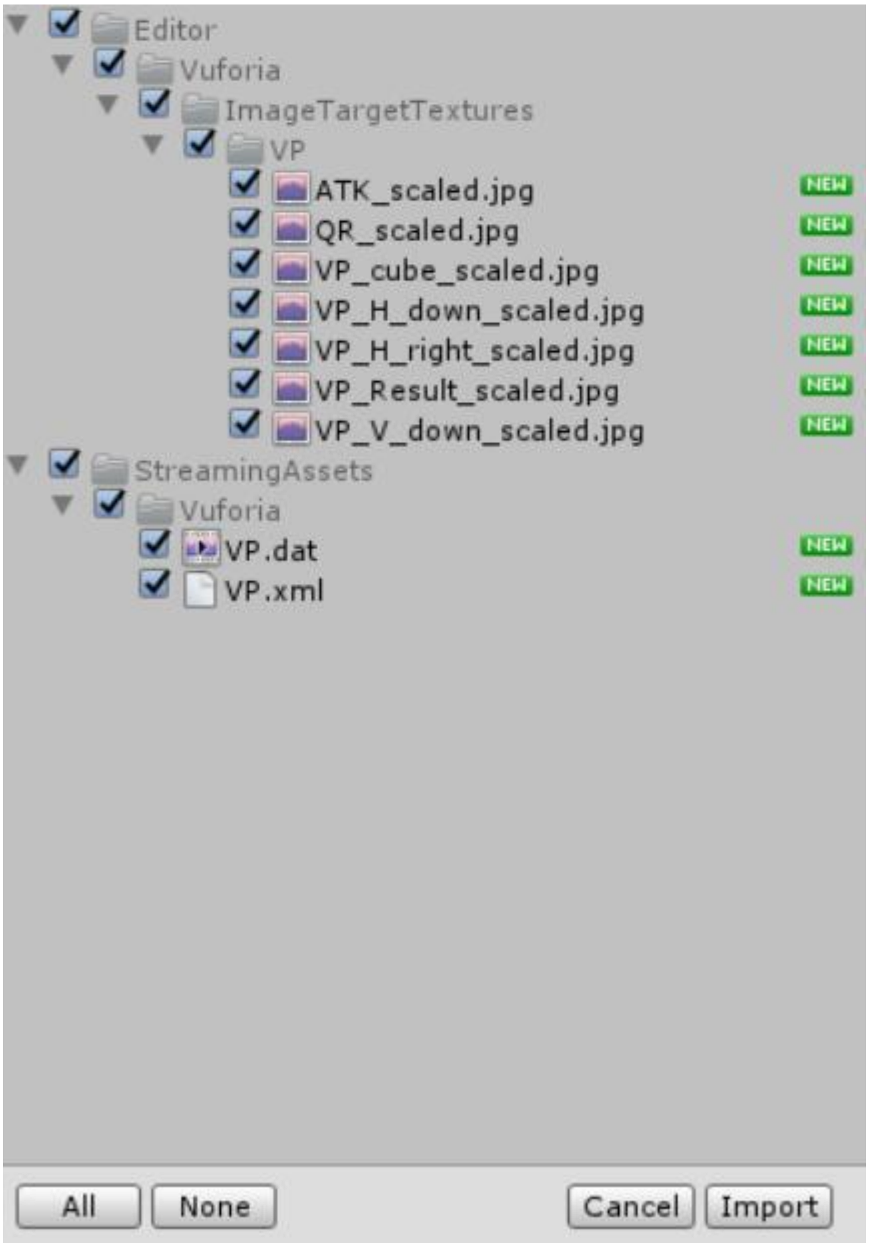
Augmentable: ★★★★★

Added: Sep 27, 2019 22:29

Modified: Sep 27, 2019 22:29

Figure 46 Image target marker ‘s information in detail.

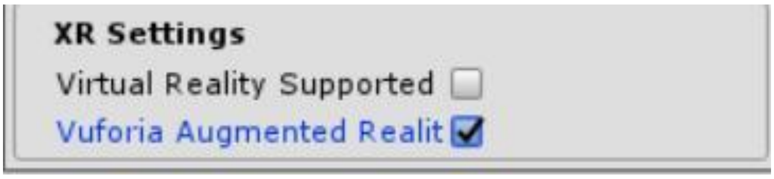
We can download the Vuforia database from target manager page and import it into our unity project. Then we can track the image target marker and generate AR virtual contents above it in our system.



```
▼ ☑ Editor
    ▼ ☑ Vuforia
        ▼ ☑ ImageTargetTextures
            ▼ ☑ VP
                ☑ ATK_scaled.jpg          NEW
                ☑ QR_scaled.jpg           NEW
                ☑ VP_cube_scaled.jpg      NEW
                ☑ VP_H_down_scaled.jpg    NEW
                ☑ VP_H_right_scaled.jpg   NEW
                ☑ VP_Result_scaled.jpg    NEW
                ☑ VP_V_down_scaled.jpg    NEW
▼ ☑ StreamingAssets
    ▼ ☑ Vuforia
        ☑ VP.dat                          NEW
        ☑ VP.xml                          NEW
```

Figure 47 Import the database.

After downloaded the database and import it, we need to active the Vuforia Augmented Reality in unity's player setting panel.



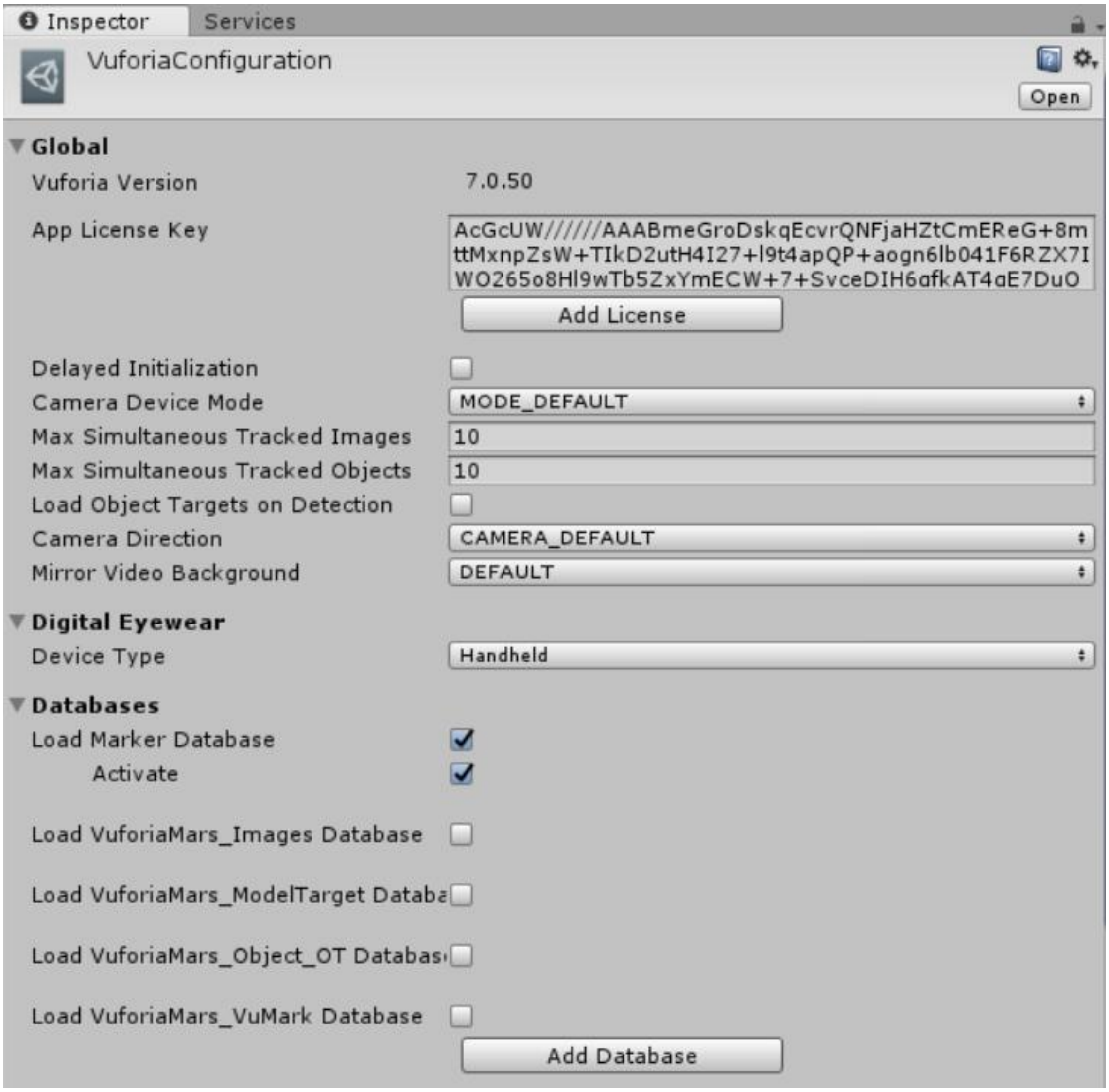
XR Settings

Virtual Reality Supported ☐

Vuforia Augmented Realit ☑

Figure 48 Active the Vuforia.

Then open the inspector of Vuforia add our license key and set the number of max simultaneous targets. We also need to check the box of “Load Marker Database” and “Active” to make the system works.



VuforiaConfiguration

Global

Vuforia Version	7.0.50
App License Key	AcGcUW//////AAABmeGroDskqEcvrQNFjaHZtCmEReG+8mttMxnpZsW+TIkD2utH4I27+l9t4apQP+aogn6lb041F6RZX7IWO265o8Hl9wTb5ZxYmECW+7+SvceDIH6afkAT4aE7DuO
Delayed Initialization	□
Camera Device Mode	MODE_DEFAULT
Max Simultaneous Tracked Images	10
Max Simultaneous Tracked Objects	10
Load Object Targets on Detection	□
Camera Direction	CAMERA_DEFAULT
Mirror Video Background	DEFAULT

Digital Eyewear

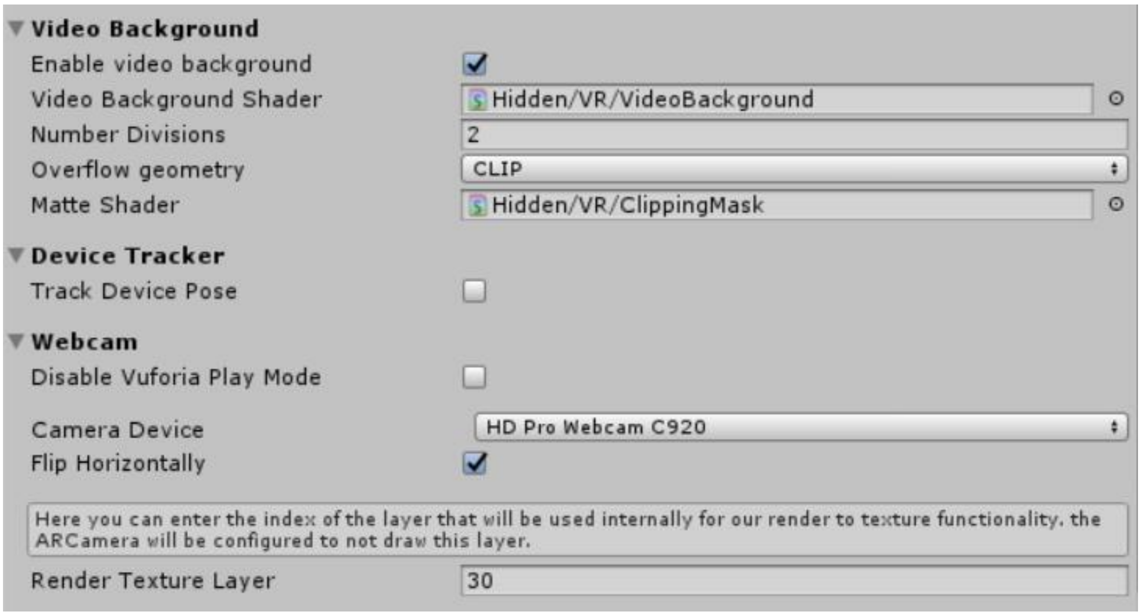
Device Type	Handheld

Databases

Load Marker Database	☑
Activate	☑
Load VuforiaMars_Images Database	□
Load VuforiaMars_ModelTarget Databa	□
Load VuforiaMars_Object_OT Databas	□
Load VuforiaMars_VuMark Database	□

Figure 49 Input the license key.

Because we use web camera HD Pro Webcam C920 in our research, the camera device in Vuforia setting need to be changed from integrated camera.



Video Background
Enable video background ☑
Video Background Shader Hidden/VR/VideoBackground
Number Divisions 2
Overflow geometry CLIP
Matte Shader Hidden/VR/ClippingMask

Device Tracker
Track Device Pose □

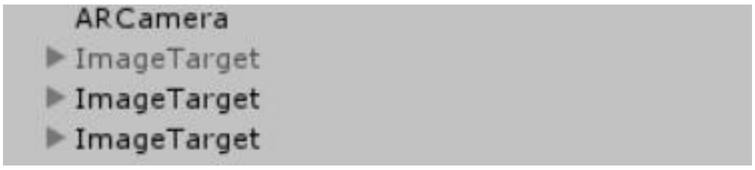
Webcam
Disable Vuforia Play Mode □
Camera Device HD Pro Webcam C920
Flip Horizontally ☑

Here you can enter the index of the layer that will be used internally for our render to texture functionality. the ARCamera will be configured to not draw this layer.

Render Texture Layer 30

Figure 50 Change the camera.

After all the preparations have been down, we need to build an AR camera in the scene and create an image target by Vuforia engine.



ARCamera
▶ ImageTarget
▶ ImageTarget
▶ ImageTarget

Figure 51 Add image target marker.

The AR content we want to show above the image target marker need to be registered below the image target.

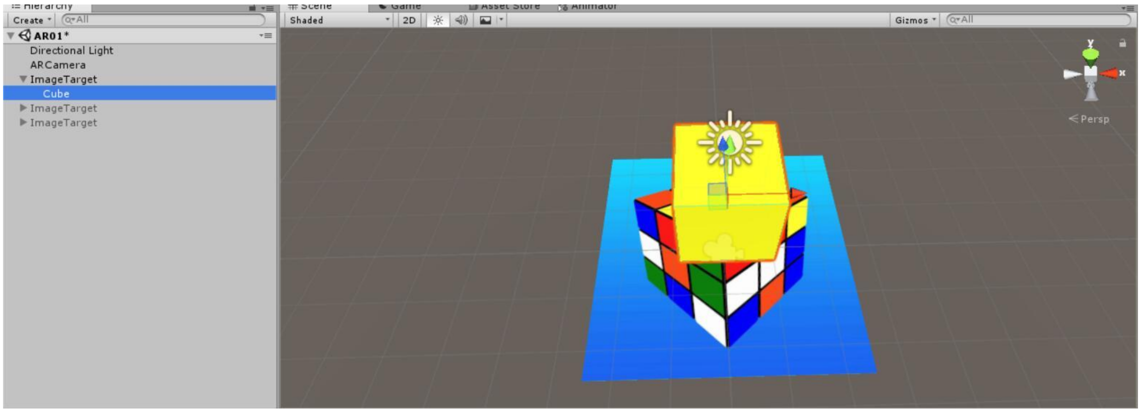


Figure 52 Register the AR content above the marker.

Then we can use our web camera to scan the image target marker and see the AR content above it.

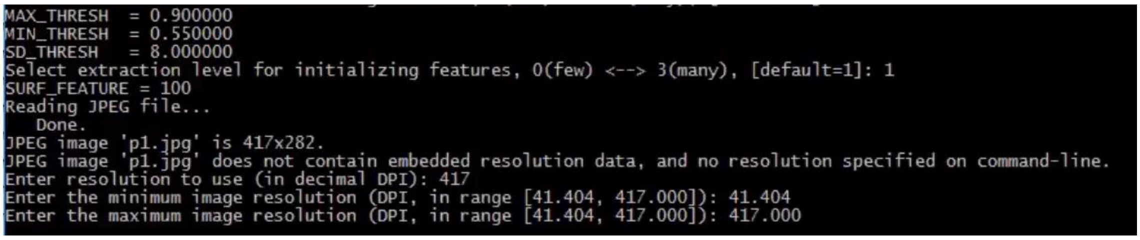
5.5.2 AR toolkit

The AR toolKit Library is available for download for the Windows, Linux, SGI and MacOS X operating systems. In addition to any base requirements for Unity, the AR toolKit for Unity plugin have the following requirements:

1. ARToolKit for Unity 5.3.2 requires Unity Pro v4.5.5f1 or later.
2. If targeting Android, Android v4.0.3 and later is supported.
3. If targeting iOS, Xcode tools v5.0.1 or later is required. iOS v7.0 and later is supported.
4. If targeting OS X, Xcode tools v5.0.1 or later is required. OS X v10.7 and later is supported.
5. If targeting Windows Phone 8.1 or Windows Store 8.1, Visual Studio 2013 SP2 running on Windows 8.1 or later is required.

After imported the SDK in unity3D, we can track the AR toolkit marker in our system.

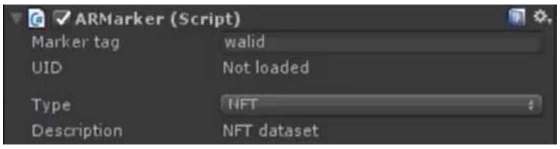
The marker building need to use the genTexData.exe file in the bin document we downloaded.



```
MAX_THRESH  = 0.900000
MIN_THRESH  = 0.550000
SD_THRESH   = 8.000000
Select extraction level for initializing features, 0(few) <--> 3(many), [default=1]: 1
SURF_FEATURE = 100
Reading JPEG file...
   Done.
JPEG image 'p1.jpg' is 417x282.
JPEG image 'p1.jpg' does not contain embedded resolution data, and no resolution specified on command-line.
Enter resolution to use (in decimal DPI): 417
Enter the minimum image resolution (DPI, in range [41.404, 417.000]): 41.404
Enter the maximum image resolution (DPI, in range [41.404, 417.000]): 417.000
```

Figure 53 Generating the AR toolkit marker by genTexData.exe.

The marker file name generated by genTexData.exe will be end with: fset, fset3 or iset. Then we can track them in our system.



ARMarker (Script)

Marker tag walid
UID Not loaded
Type NFT
Description NFT dataset

Figure 54 Setting the marker.

Then we can register the AR contents or some trigger event with the marker in unity.

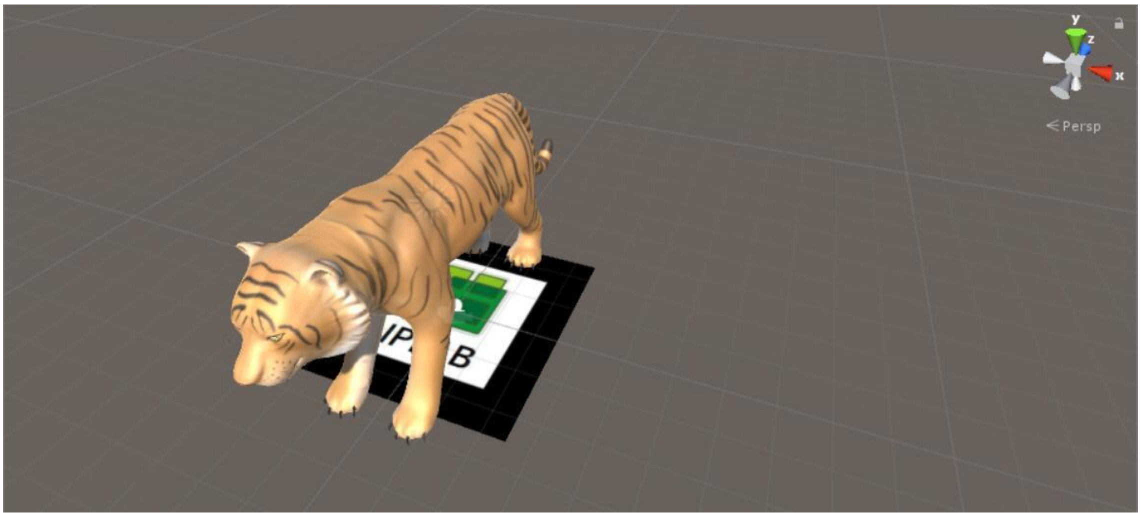
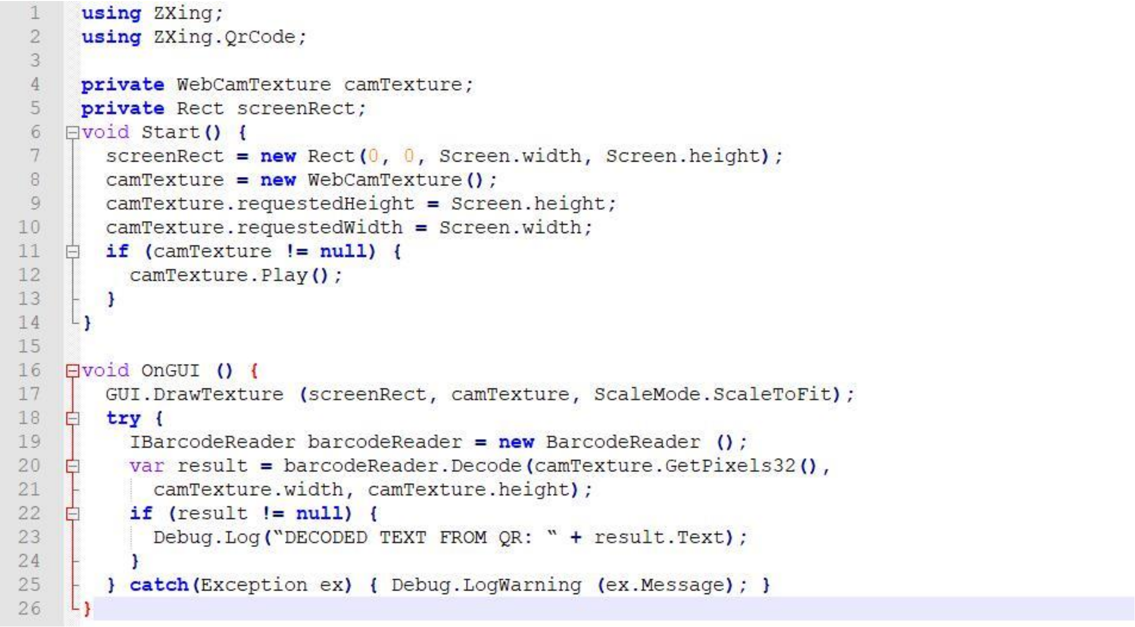


Figure 55 Register the AR content.

5.5.3 QR code

Before we write the QR code scanner script in our unity project, we need to install the zxing.unity.dll from the http://zxingnet.codeplex.com/ in our unity plugin folder. ZXing ("zebra crossing") is an open-source, multi-format 1D/2D barcode image processing library implemented in Java, with ports to other languages. Then we can build a QR code scanner script in our system.



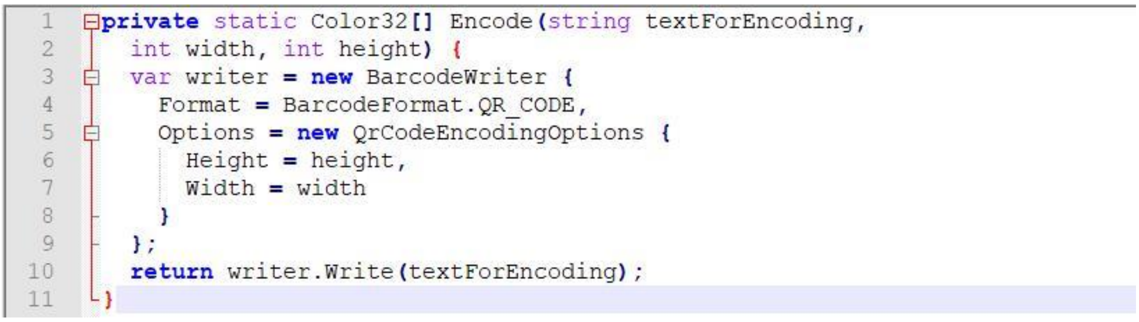
```
using ZXing;
using ZXing.QrCode;

private WebCamTexture camTexture;
private Rect screenRect;
void Start() {
  screenRect = new Rect(0, 0, Screen.width, Screen.height);
  camTexture = new WebCamTexture();
  camTexture.requestedHeight = Screen.height;
  camTexture.requestedWidth = Screen.width;
  if (camTexture != null) {
    camTexture.Play();
  }
}

void OnGUI () {
  GUI.DrawTexture (screenRect, camTexture, ScaleMode.ScaleToFit);
  try {
    IBarcodeReader barcodeReader = new BarcodeReader ();
    var result = barcodeReader.Decode(camTexture.GetPixels32(),
      camTexture.width, camTexture.height);
    if (result != null) {
      Debug.Log(“DECODED TEXT FROM QR: “ + result.Text);
    }
  } catch(Exception ex) { Debug.LogWarning (ex.Message); }
}
```

Figure 56 QR code reader script.

We also can render the QR code from text in unity to generate new markers in unity.



```
private static Color32[] Encode(string textForEncoding,
  int width, int height) {
  var writer = new BarcodeWriter {
    Format = BarcodeFormat.QR_CODE,
    Options = new QrCodeEncodingOptions {
      Height = height,
      Width = width
    }
  };
  return writer.Write(textForEncoding);
}
```

Figure 57 QR code render script.

As the example, we generate a QR code which can express IPLAB's homepage URL. The QR scanner can get the correct information from it and access to the webpage.

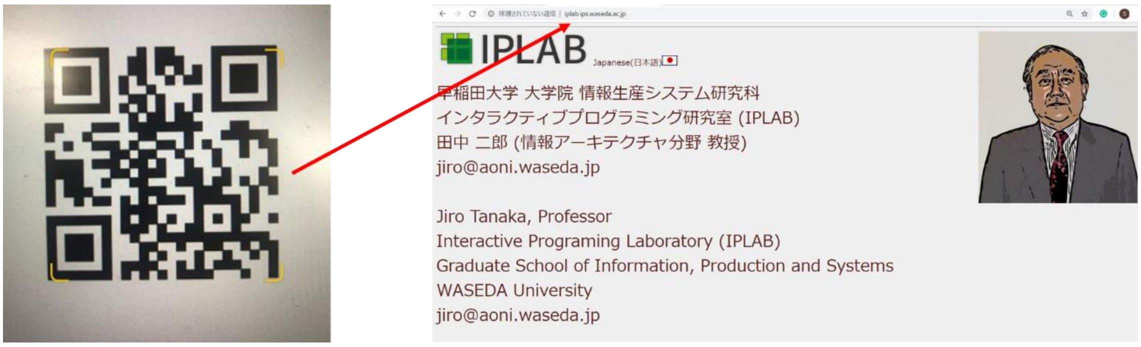


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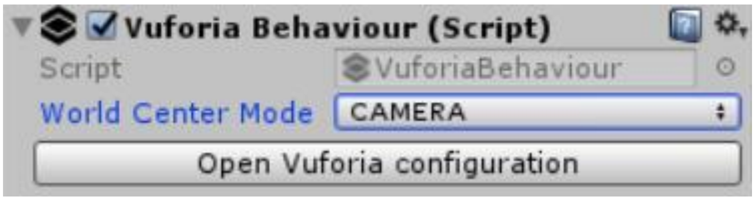
Figure 58 Scan the QR code and access to IPLAB home page.

5.5.4 Marker measuring

For the system can process multiple markers in a certain order, we need to measure the markers position at first. In the unity we need to set the world center mode as camera.



☑ Vuforia Behaviour (Script)

Script: VuforiaBehaviour

World Center Mode: CAMERA

Figure 59 Change the world center mode to camera.

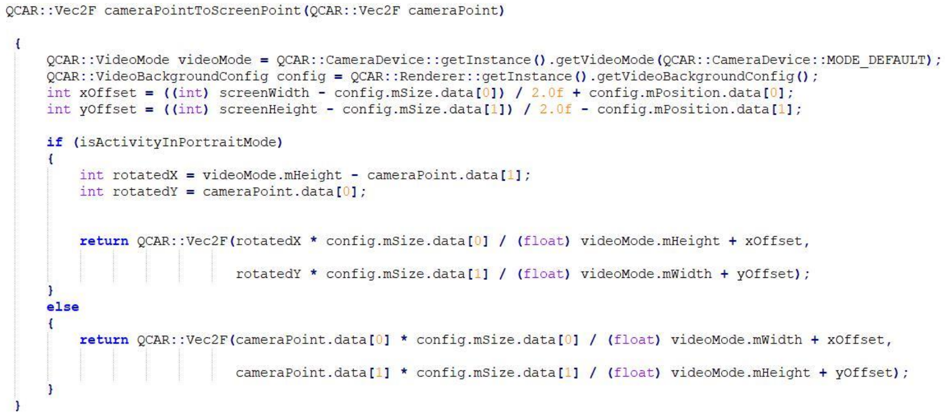
The World Center Mode allows specifying how the World reference frame is set during target / trackable tracking.

- FIRST_TARGET: The World is fixed with respect to the first detected

- SPECIFIC_TARGET: same as FIRST_TARGET, except here you explicitly specify (in the Editor) which target is the "anchor".

- CAMERA: in this case the AR Camera is fixed (fixed position and orientation) in the scene, while the Target objects move around it.

Then we try to get the pose matrix which returns the 3D position of the target in the center, assuming the camera is at (0,0,0), and then convert this into 2D camera space, and then transfer this into screen space.



```
QCAR::Vec2F cameraPointToScreenPoint(QCAR::Vec2F cameraPoint)

 {
     QCAR::VideoMode videoMode = QCAR::CameraDevice::getInstance().getVideoMode(QCAR::CameraDevice::MODE_DEFAULT);
     QCAR::VideoBackgroundConfig config = QCAR::Renderer::getInstance().getVideoBackgroundConfig();
     int xOffset = ((int) screenWidth - config.mSize.data[0]) / 2.0f + config.mPosition.data[0];
     int yOffset = ((int) screenHeight - config.mSize.data[1]) / 2.0f - config.mPosition.data[1];

     if (isActivityInPortraitMode)
     {
         int rotatedX = videoMode.mHeight - cameraPoint.data[1];
         int rotatedY = cameraPoint.data[0];


         return QCAR::Vec2F(rotatedX * config.mSize.data[0] / (float) videoMode.mHeight + xOffset,

                              rotatedY * config.mSize.data[1] / (float) videoMode.mWidth + yOffset);
     }
     else
     {
         return QCAR::Vec2F(cameraPoint.data[0] * config.mSize.data[0] / (float) videoMode.mWidth + xOffset,

                              cameraPoint.data[1] * config.mSize.data[1] / (float) videoMode.mHeight + yOffset);
     }
 }
```

Figure 60 Take the camera space point and transform it into screen space.

5.6 Hidden marker design

For designing the hidden marker, we need to define the button area at first. Because we achieve this function by Vuforia virtual button service, the image target marker’s natural feature points can help us to distinguish the different area we predefined if the image is recognizable enough.

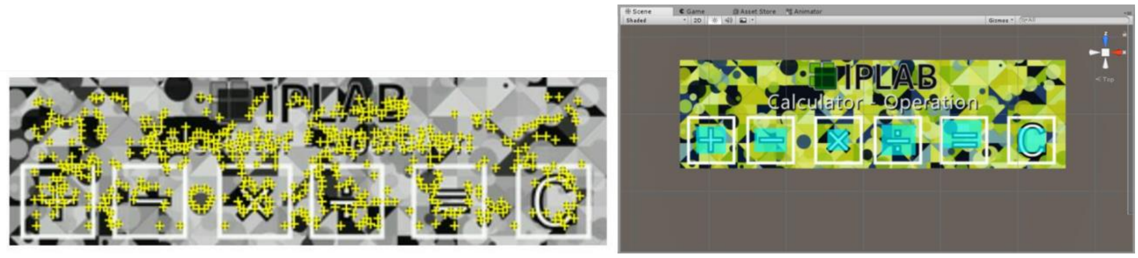


Figure 61 Feature points and button area.

We set the events are triggered when a significant proportion of the features underlying the button area we defined are concealed from the camera. This can occur when the user covers the button by their finger in the camera view. It also supports user can have multiple touch with the hidden marker and trigger the multiple events at the same time. After we designed and upload them to the Vuforia database as markers. We can import them into unity and start to define the button area. In our case, we are using green color to define the button area.

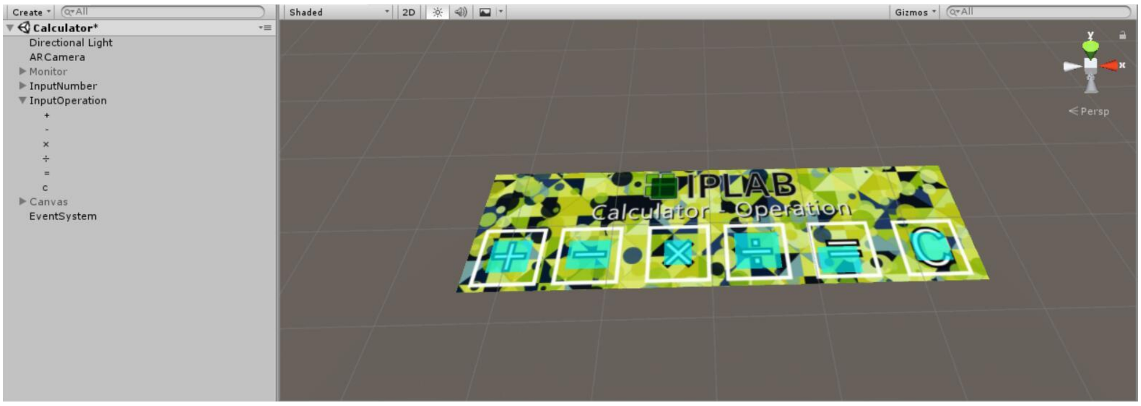
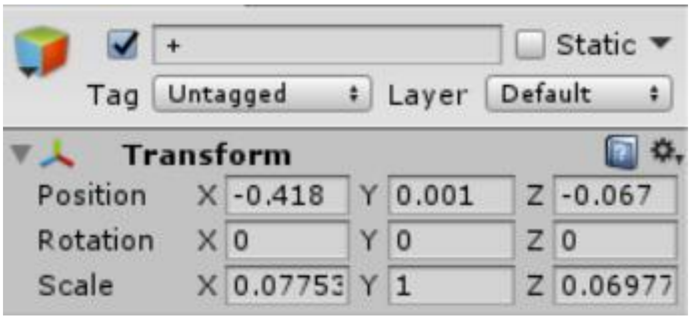


Figure 62 Define the area.

The shape of button area also can be changed.



☑ + □ Static

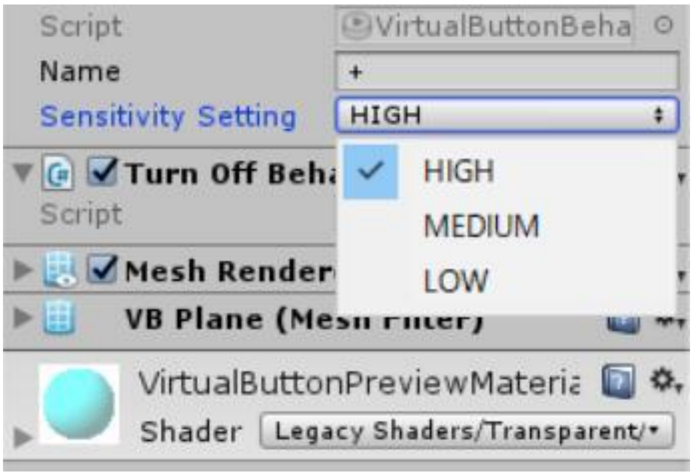
Tag Untagged Layer Default

Transform

Position	X	-0.418	Y	0.001	Z	-0.067
Rotation	X	0	Y	0	Z	0
Scale	X	0.07753	Y	1	Z	0.06977

Figure 63 Transform the button area.

The hidden area can be assigned multiple sensitivities, which define how readily the button's OnButtonPressed will fire. Buttons with a HIGH sensitivity will fire more easily than those with a LOW sensitivity. We need to test the responsiveness of each buttons in a real-world setting to verify that they perform as expected.



Script VirtualButtonBeha

Name +

Sensitivity Setting HIGH

✓ HIGH
MEDIUM
LOW

☑ Turn Off Beh

Script

☑ Mesh Render

VB Plane (Mesh Filter)

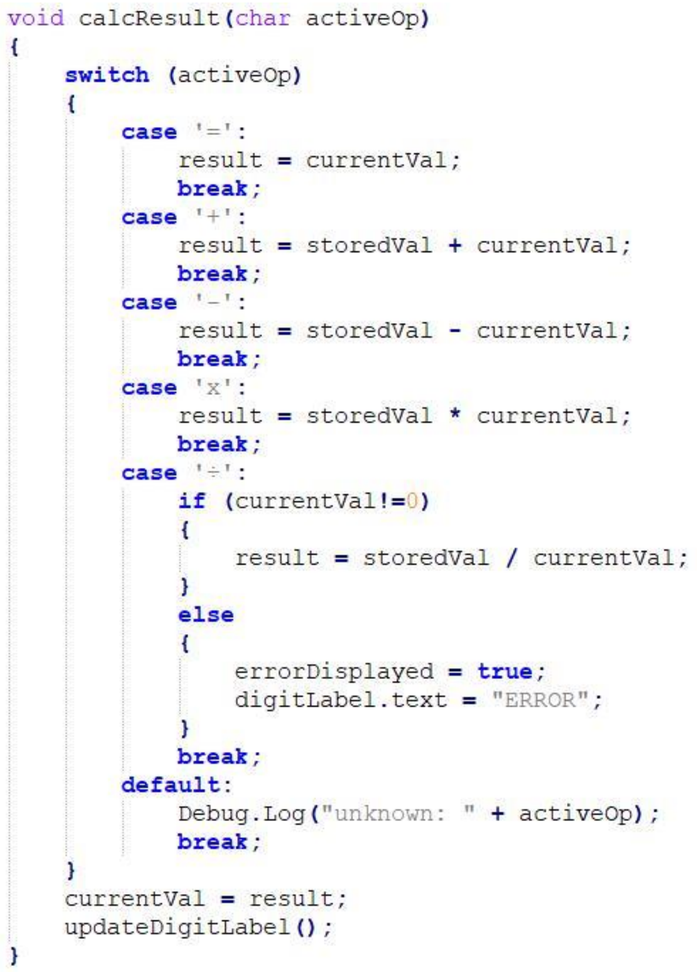
VirtualButtonPreviewMateria

Shader Legacy Shaders/Transparent/

Figure 64 Change the sensitivities.

In the example of AR Calculator, we use this hidden area to trigger the input event and the system can calculate the result after user input the number and operation commands. We use two function to achieve our goals and integrated them in one script we call it calculator manager.

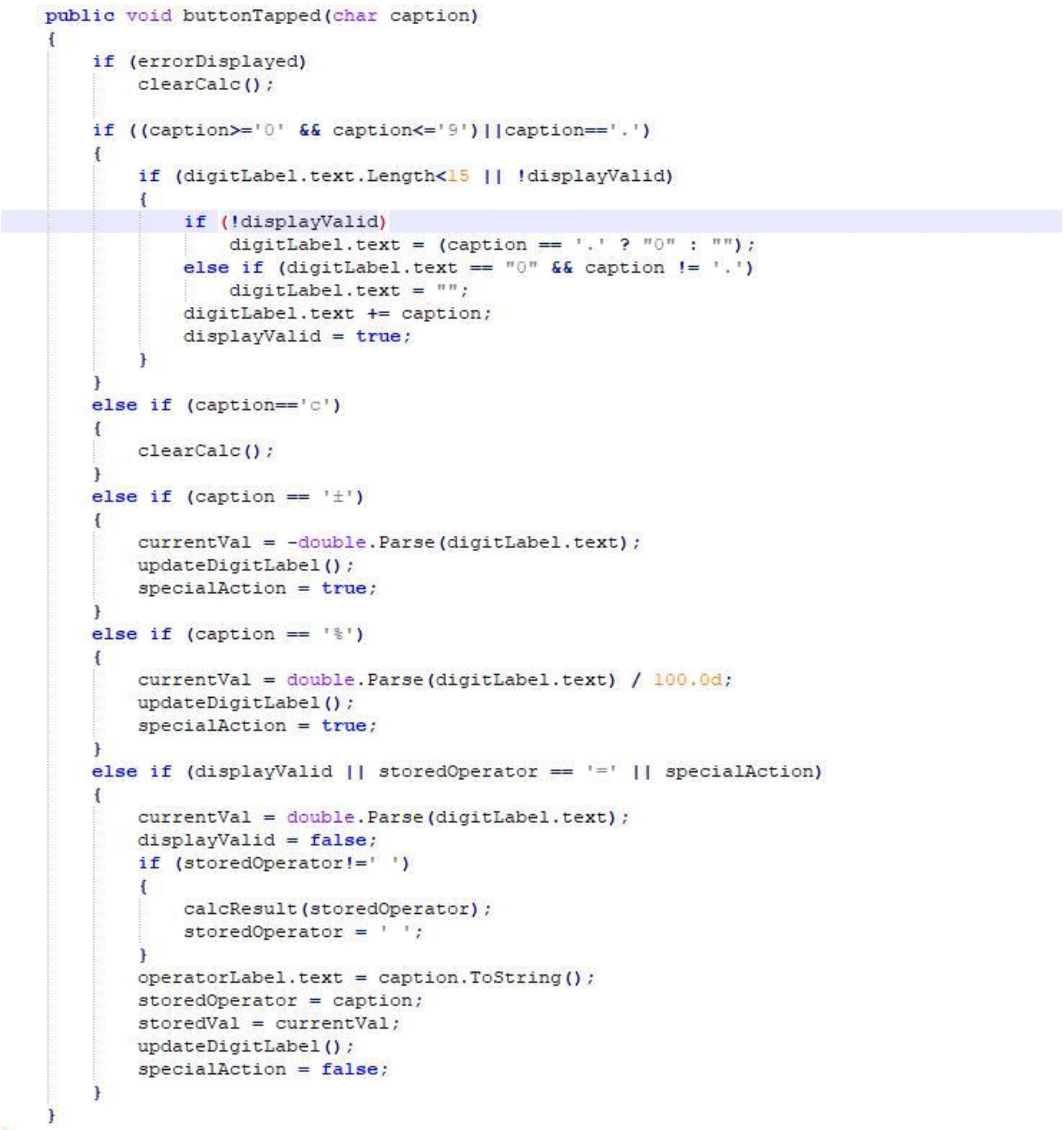
The first function is for the operation input, when system detect the user using his finger to hide some area of operation marker, it will start working to record which operation symbol and in which states has been pressed. Then change the storage information.



```
void calcResult(char activeOp)
{
    switch (activeOp)
    {
        case '=':
            result = currentVal;
            break;
        case '+':
            result = storedVal + currentVal;
            break;
        case '-':
            result = storedVal - currentVal;
            break;
        case 'x':
            result = storedVal * currentVal;
            break;
        case '÷':
            if (currentVal!=0)
            {
                result = storedVal / currentVal;
            }
            else
            {
                errorDisplayed = true;
                digitLabel.text = "ERROR";
            }
            break;
        default:
            Debug.Log("unknown: " + activeOp);
            break;
    }
    currentVal = result;
    updateDigitLabel();
}
```

Figure 65 Operation input.

The second function is for the number input, when system detect the user using his finger to hide some area of number marker, it will start working to record which operation symbol and in which states has been pressed. Then change the storage information.

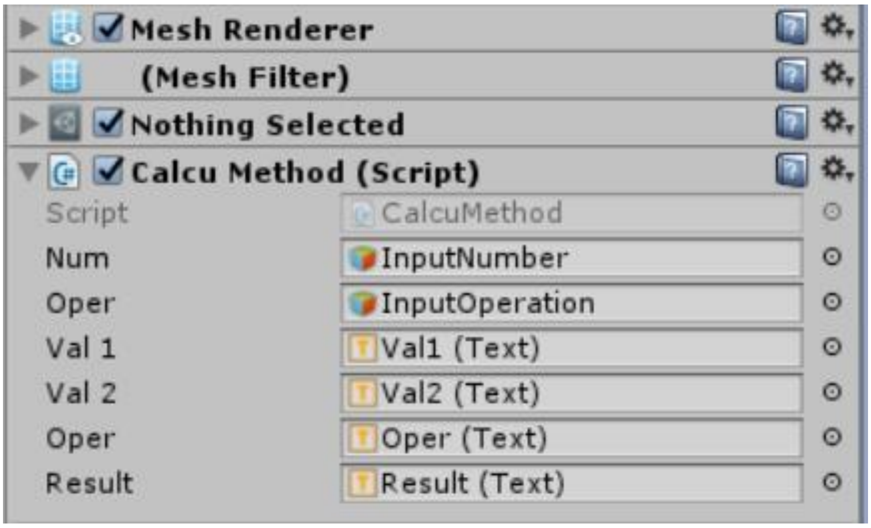


```
public void buttonTapped(char caption)
{
    if (errorDisplayed)
        clearCalc();

    if ((caption>='0' && caption<='9')||caption=='.')
    {
        if (digitLabel.text.Length<15 || !displayValid)
        {
            if (!displayValid)
                digitLabel.text = (caption == '.' ? "0" : "");
            else if (digitLabel.text == "0" && caption != '.')
                digitLabel.text = "";
            digitLabel.text += caption;
            displayValid = true;
        }
    }
    else if (caption=='c')
    {
        clearCalc();
    }
    else if (caption == '±')
    {
        currentVal = -double.Parse(digitLabel.text);
        updateDigitLabel();
        specialAction = true;
    }
    else if (caption == '%')
    {
        currentVal = double.Parse(digitLabel.text) / 100.0d;
        updateDigitLabel();
        specialAction = true;
    }
    else if (displayValid || storedOperator == '=' || specialAction)
    {
        currentVal = double.Parse(digitLabel.text);
        displayValid = false;
        if (storedOperator!=' ')
        {
            calcResult(storedOperator);
            storedOperator = ' ';
        }
        operatorLabel.text = caption.ToString();
        storedOperator = caption;
        storedVal = currentVal;
        updateDigitLabel();
        specialAction = false;
    }
}
```

Figure 66 Number input.

At last we connect the information we calculated and storage and send them to the monitor marker for showing result by AR.



☑ Mesh Renderer

(Mesh Filter)

☑ Nothing Selected

☑ Calcu Method (Script)

Script CalcuMethod

Num InputNumber

Oper InputOperation

Val 1 Val1 (Text)

Val 2 Val2 (Text)

Oper Oper (Text)

Result Result (Text)

Figure 67 Connect the information to AR monitor.

About the 2-dimensions buttons layout we designed an additional logic based on hidden algorithm:

1. When system detect the button area has been blocked, it will wait for 0.5s to give the time for the user slides his finger over the marker and stop to fix the gesture.
2. After 0.5s, system will detect all the blocked button and find which is the top one.
3. The top blocked button will be realized by system it is pressed by user’s finger. Then system will process this button trigger event.

To design this kind of hidden marker, we need to design the button area at first and make them clearly for user to understand and can be detected easily. We always draw them in some painting software.

Chapter6

Conclusion

6.1 Summary

In summary, we have raised the problem of the tradition marker-based AR system and design a new system to create new interactions between users and markers by combining multiple markers, hidden markers and auxiliary markers.

For combining multiple markers, we integrated three kind of markers in our system: Image target marker, AR Toolkit marker and QR code. Different kinds of markers have their own attributions and fit for different area. We due to their features give them different function and combine them in one system. The scanner in our system can detect these three kinds of markers at the same time and process them in a certain order with 2-dimension layout in one camera view.

The hidden marker is kind of additional controller for the AR marker in our marker-based AR system. These markers cannot generate any 3D virtual AR content in user view. But based on natural features that are extracted from the target image marker and then compared at run time with features in the live camera image, we can define several button areas on the marker. When a significant proportion of the features underlying the area of the button are concealed from the camera, it will trigger some events. This can occur when the user covers the button or otherwise blocks it in the camera view. As the result, the hidden marker can support user have very intuitive interaction with our AR system. We also enhance the recognition logic to make the system more effective that can support 2-dimension layout hidden marker working.

For the auxiliary markers, they always perform as a token or key to get specific or decrypted information. This kind of marker can help user to protect some unpublic AR contents in some cases. In personalization part, the system can display different 3D virtual content for users with different identities contained in the auxiliary marker. In encryption/decryption part, the system can unlock some encrypted AR contents by auxiliary marker which only for decrypting and does not contain any personal information. In this research, we also give some applications based our new system. We have implemented Multiple markers combination, AR Calculator and AR piano. We also discussed some usage scenario for personalization and encryption/decryption parts.

On the 13h International collaboration Symposium on Information, Production and Systems (ISIPS 2019) we presented our works and demonstration. People interested in our works and try to use our demonstrate system. After that, they gave lots of positive comments and advice. It is a kind of preliminary evaluation for our research. According their feedbacks, we refined our system and try to find some new possibility in the future work. We also got Finalist of the Best Presentation Award in this symposium.

Some comments after users used our demonstrate system on ISIPS:

C1: It is very interesting work; the meaning and usage of each marker are very understandable. I can use it without guidance.

C2: The method of this research can enhance the user experience in AR environment, and I expect it can be implemented on other platforms.

C3: The AR calculator is attractive. The input markers are sensitive, wrong input sometimes happened. You can try to enhance the layout or algorithm.

6.2 Future Work

Multiple Platform

In this paper, we used A PC with the windows 10 operation system and web camera to run our system. For the AR more and more popular, there are many kinds of new platform we can try to implement. For example, the smartphone, HoloLens and other AR glasses. By different hardware, the function of our system also can be extended.

New Markers

The multiple marker recognition part can add some new kind of markers. In fact, there are lots of kinds of markers in the AR world. They have different features to make them perform well in their own area. If we catch their points and integrate more kinds of markers and combine them, the system may generate some new possibility.

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