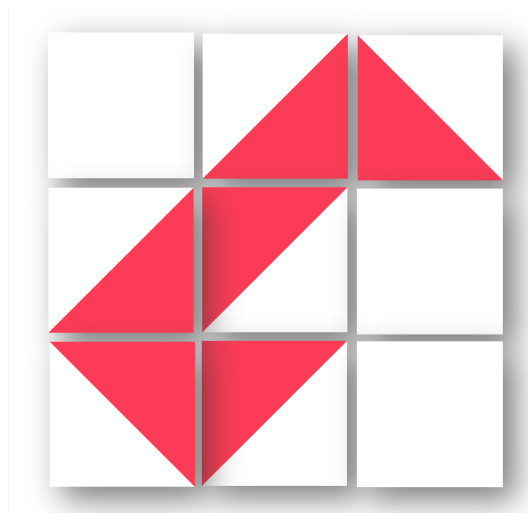


Undergraduate Project Report 2020/21

Design, Implementation and Testing of Applications Based on Touch and Gesture Technology to Stimulate Creativity and Learning in People with Disabilities



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Abstract

Though the Digital Age has made the technology landscape our new normal, people might forget to consider the effect it has had for handicapped people. Autism spectrum disorder (ASD) is a developmental disorder characterised by intellectual disability marked by pragmatic difficulties in communication delays and social impairments, and by restricted and repetitive behaviour. However, children with ASD sometimes show unusual abilities, wielding the power of technology could create useful tool to stimulate their memory, attention, and creativity.

In this project, we developed a software application for children with ASD in La Cañada High School in Valencia, Spain. A tangram puzzle game named “PuzzlePieces” interacting through Leap Motion – a tactile and gesture recognition hardware – was designed and implemented, tailored for children in La Cañada to train spatial imagination, memory and motor skills and therefore stimulate creativity. After implementation, usability tests were conducted to support amendments and improvements. This game receives high praises from teachers and children in La Cañada. In the future, we would expect this application could make a wider influence.

This project has completed the following three outputs: First, collect requirements from La Cañada teachers and complete the design of the game; Second, complete the game implementation and realise the Leap Motion gesture interaction; Thirdly, made improvements according to feedback from children with ASD in La Cañada.

In this report, we first will introduce the background about autism children and technology we use, then we will describe the work we have done following the order of software design, implementation and testing. Conclusion and possible improvements in future years will be presented in the end.

Chapter 1: Introduction

My final year project is a joint project between Beijing University of Posts and Telecommunications (BUPT, hereafter), Queen Mary University of London (QMUL, hereafter), and Universitat Politècnica de València (UPV, hereafter) in Spain, which uses technology to help handicapped children. My project this year is an implementation project which includes design, implementation and testing of an application tailored for children with autism spectrum disorder (ASD or autism, hereafter) in La Cañada High School.

The report is organised in a way that follows the project workflow. Chapter 2 introduces the background about autism children and technology we use. Chapter 3 to Chapter 5 describe the work we have done following the order of software design, implementation, and testing. Chapter 6 makes conclusion and discuss possible improvements in future years.

1.1 Project Description

1.1.1 Project History

At La Cañada High School in Valencian town of Paterna in Spain, there is a special class for children with ASD whose mental ages stop at a really young age, which results in their attention and memory might be relatively weak compared to normal children in the same age. Previous years in this project, a variety of digital and technology methods are being used to enhance their logical and thinking skills.

This project is a continuing project initiated in Spain which collaborates between the Higher Technical School of Telecommunication Engineering (ETSIT), the Institute of Secondary Education (IES) La Cañada, and it also has the support of the Spanish Foundation for Science and Technology of the Ministry of Science and Innovation. Students in BUPT works with the supervisor in UPV in the final year project to continuing develop hardware and software applications for children with ASD in La Cañada.

The iTeam in UPV has developed a SoundCool platform for children with disabilities. It is a music platform which can run on personal computer, tablet, and Kinect, in the purpose of experimenting a music therapy to those handicapped children with the help of technological applications^[1]. They are collaborating with Occupational Centre “La Torre”^[2], experimenting new technological possibilities of music therapy to help people with intellectual disability and physical disability. It is more than a valuable experience and socially responsible to conduct these meaningful projects. Last year’s work on this project has been on the Spanish local news^[3].

I am convinced that like my seniors and alumnus, I am participating in a meaningful project, and I am using technology I have learnt to help children in the same age as I do.

1.1.2 Project Motivation and Technology Highlight

The professors and teachers at La Cañada have figured out many methods and games to train children's attention and memory, as well as other abilities. After several visits paid to La Cañada and we have been through several talks and meetings, we decided that the work this year is to create a new tangram puzzle game, in particular, the game should be interacted by gesture recognition via the Leap Motion hardware.

The technology of implementing Leap Motion gesture utilises Leap Core SDK as a tool of transforming data collected by hardware to the software we develop. Leap *Interaction Engine* and *UI Input* module helps in implementing using gesture to interact with objects in the game. Further game design will be introduced in Chapter 3, technology detail on Leap Motion will be discussed in Section 4.3.

A version interacts via the Leap Motion Controller hardware is meaningful because it serves as a more challenging level for children with ASD. Different from playing the game by a tablet or mouse where every move creates immediate response which is perceptual intuitive, using the Leap Motion Controller requires them to imagine mapping real-world 3D space into 2D screen, predict what will occur after their gesture, and remember how each piece has been manipulated. Further background information of why this proves significant help to children with ASD will be introduced in Section 2.1.

1.2 Project Achievement

According to the project specification and requirements from La Cañada, we have finished the following three tasks in this project:

- 1) Analyse existing hardware and software of this project, as well as the nature and SDK of the Leap Motion gestural interface.
- 2) Design and develop the tangram puzzle game using Leap Motion Controller hardware as way of interaction.
- 3) Carry out test with children and teachers in La Cañada and gather feedback to make improvements that make the game more friendly, and more fitting for children with ASD.

The resulting software application (see Figure 1) is a tangram game in two versions which

Design, Implementation and Testing of Applications Based on Touch and Gesture Technology to Stimulate Creativity and Learning in People with Disabilities supports two platform, Windows PC and Android devices. It has 15 different levels divided into three difficulty categories. Children can login and play the games, and their records and progress will be recorded for their teachers and parents to know and analyse. The game can be interacted by gesture using the Leap Motion Controller.



Figure 1 Children in La Cañada playing the game with Leap Motion

1.3 Project Contribution

My project contributes in the following ways:

- 1) Developing an intellectual game application involving physical activities for children with ASD is an advancement to all the previous work in this project.
- 2) The gesture control of the game proves to be meaningful for children with ASD for imagination and memory training.
- 3) During the Covid-19 pandemic, children at school can play this game without touching the screen or any devices which reduces the probability of cross-infection.

Beyond those mentioned above, I also contributed to the Leap Motion SDK in finding a bug in the source code and raised the issue to the Leap Community. I hope I am contributing a little to the SDK as a Leap Motion user.

Chapter 2: Background

Play can not only help children develop gross and fine motor skills, but also intelligent skills, such as language and communication, logical thinking and problem-solving skills, and social skills as well^[4]. But for children with ASD, their playing skills develops in a different way that they might find some types of play difficult. They may be seen imperfection in the ability to copy simple actions, to explore the environment, to share objects and attention with others, to respond to others or to take turns^[5]. It is common for them to have very limited play, play with only a few toys, or play in a repetitive way. ^[4]

Every young child engages in six main types of play, which develop in stages: ^[5]

- 1) Exploratory play when children start exploring toys rather than playing with them.
- 2) Cause-and-effect play, which means children play with toys or games that requires certain actions to produce the desired result.
- 3) Toy play, or functional play, it is for children to learn how to use or play with toys and games in the way they were designed.
- 4) Constructive play, or structured play, when children start to build or make something.
- 5) Physical play that provides whole-body exercise and helps children to develop gross motor skills.
- 6) Pretend play, which is a higher-level play that children use their imaginations during play.

However, for many children with ASD, the various stages of play never truly develop, or they occur in a fragmented fashion^[4]. Approximately 75% of children with ASD also have an intellectual disability marked by significant pragmatic communication delays and social impairments (Starr, Foy, & Cramer, 2001). But ASD children are far from hopeless. They can learn the skills needed for play and thus develop intelligent skills, and we can help them during this process, especially through the power of technology.

2.1 Children with ASD in La Cañada High School

In La Cañada High School in Valencia, there is a special class of children with ASD. They have growing intellectual ability but uneven learning ability, some of them might have trouble communicating but be surprisingly fond of mathematics, or with superb talent in art. Therefore, discovering their potentials through play is a crucial work. In this project, we decided that a game intervening some of the six types of play, this could be a good way for children with ASD

Design, Implementation and Testing of Applications Based on Touch and Gesture Technology to Stimulate Creativity and Learning in People with Disabilities in La Cañada to learn play skills.

Structured play, as oppose to free play, is when a grown-up provides resources and usually offers children a clear guideline about the rule of the game, and the game is usually with a clear end point. For example, completing a jigsaw puzzle, a picture lotto, or a matching game are all classified as structured play^[4]. So, it is particularly useful for ASD children in La Cañada since a tangram puzzle game of structured play can help them understand the steps, skills, activities, and ideas that are needed to finally end and win the game.

Moreover, visual cue is a great incentive and attractiveness for children in the game, so we are to create a puzzle game involving various colours. In the meantime, we will be using the screen time to do physical play as well – utilise motion sensing device or gesture recognising hardware – as the input of interaction.

2.2 Leap Motion

The Leap Motion Controller is an optical hand tracking module that captures the movements of hands with unparalleled accuracy. From XR to touchless kiosks, the Leap Motion Controller makes interaction with digital content natural and effortless ^[7]. It is an economic, interesting, suitable hardware to be the interactive tool in our puzzle game.

The heart of a Leap Motion Controller is two cameras and some infrared LEDs. The LEDs illuminate the hands with infrared light for the sensors to recognise. The LEDs pulse in sync with the camera framerate so that in every rate, the device send data back to the computer, in real-time.^[7]

Leap Motion Controller recognises gesture based on the Skeleton Model, as Figure 2 below, it can recognise not limit to palm or fingertips, every joints and bones have their own position data indicating hand gesture and movement, and they are fed to the computer as a virtual model of the hand.



Figure 2 Leap Motion Controller recognise gesture using Skeleton Model

a) Interaction Engine

From the view of developers, the virtual model of hand movements is fed into the computer through the Interaction Engine. The Interaction Engine provides a unified physical interaction paradigm of hand movements like swiping, pinching, etc.

Interaction box is another concept in Leap Motion. The Leap Motion Controller has a recognition space like a 3D box of $140 \times 120^\circ$ field of view, and a maximum depth of 80cm, see Figure 3. Through sensing and processing, it matches the 3D space of our hand motion into a 2D screen on the computer. The Interaction Box exists in the Leap Motion SDK as a class, for developers to implement certain functions we need to realise the matching.

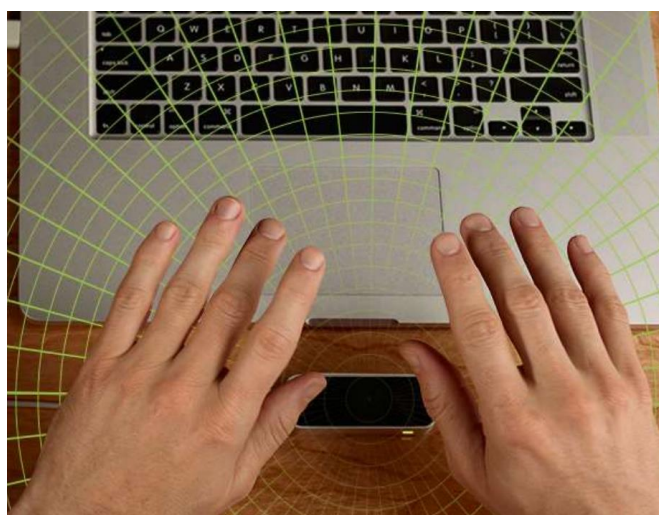


Figure 3 The space to get interaction with computer through the Leap Motion Controller

b) Frames

Frame is another important concept for developers. A Frame in Leap Motion provides all the data collected from the field of its view. The frame refreshes at the speed of 200 fps, and it has a buffer who stores a limit amount of information of previous frames. For developers, we need to pay extra attention to this concept since a Frame contains data we need to use during the implementation, for example, recognising the gesture, locate fingers or bones, etc.

These data are transmitted as a `LEAP_TRACKING_EVENT` struct. And we can get `LEAP_TRACKING_EVENT` object by calling the function `LeapPollConnection()` or `LeapInterpolateFrame()`.

c) Gestures

The Leap Motion Controller can recognise four main gestures: screen-tap, key-tap, circling, and swiping^[7]. The Leap Motion SDK has configurations for all gestures.

2.3 Unity

For developing a game, Unity is a popular development platform that supports 3D and 2D games, and then deploy them across mobile, desktop, consoles, or VR/AR applications. It is a powerful engine that offers primary scripting API in C#. Furthermore, Leap Motion has Unity Modules package that makes it smooth to design hand tracking in my game application. Figure 4 shows my working panel in Unity.

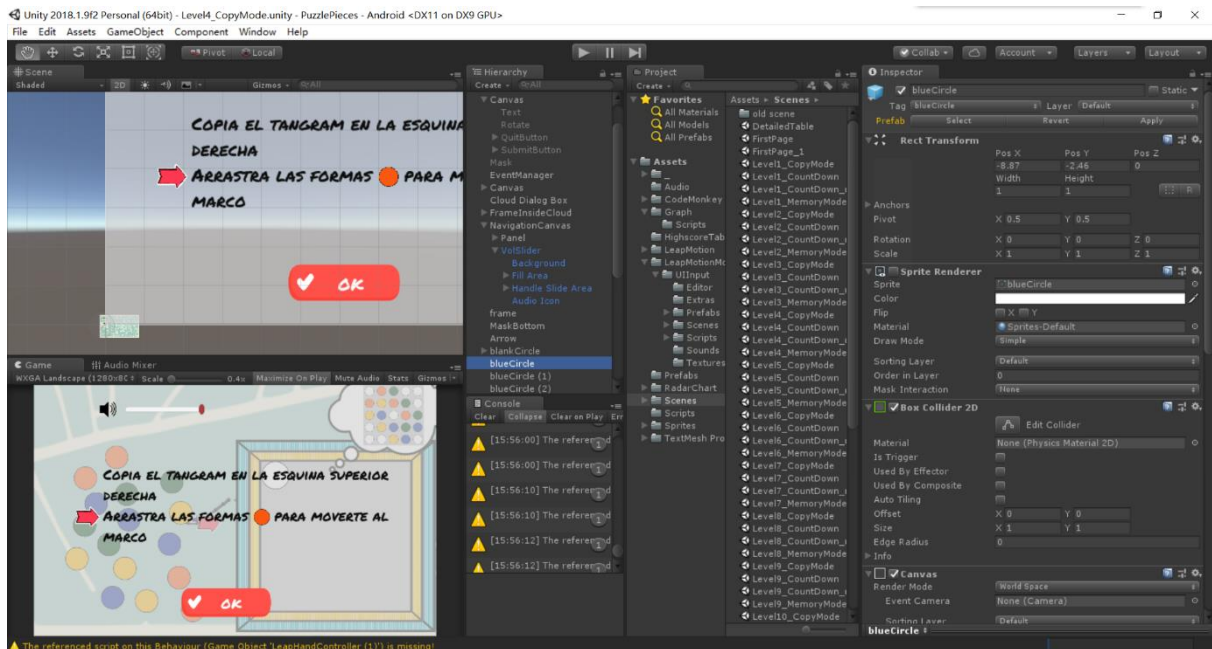


Figure 4 Unity Interface during my development

Chapter 3: Software Design

UPV has been part of in this project since the beginning and my supervisor, as a major leader and enthusiastic participant in this, knows the teachers and children in La Cañada quite well. As agreed between the teachers there, a tangram puzzle game that utilises gesture technology via Leap Motion is what we are going to work on this year, and in this chapter, we will introduce how we design and refine it, during the whole process of the project.

3.1 Requirement Gathering and Design Solutions

Since the game is tailored for the children with ASD in La Cañada High School, we have to gather requirements from their teachers before we can design the application. Normally I need to pay several visits to do the requirement gathering and communicate with children personally, however, under the situation of Covid-19, my supervisor in UPV has to go to La Cañada alone instead of we go there together.

After a few meetings online, we have figure out some design solutions of the game according to requirements or features of children from La Cañada and corresponding to ‘play stage’ mentioned in Section 2.1, listed in Table 1.

Table 1: Requirements and Design Solutions

Play Stage	Feature of autism children	Design Solution
Exploratory play	Have trouble differentiating shapes, colours, sizes, or textures	Use puzzle pieces with high contrast colour and designed size
	Find difficult to concentrate	
	Have difficulty understanding rules of how to play	Give clear written instructions before play the game
Structured play	Find hard to copy simple actions	Design a copy mode with a hint to complete the puzzle
	Have trouble memorizing simple patterns	

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Physical play	Gross motor function needs exercise	Implement gesture recognition for the game so that all of the game can be played using Leap Motion Controller
	Fine motor skills need exercise	The gesture recognition should be accurate to finger

In addition to the game playing, children’s progress needs to be recorded and analyse. Therefore, to create a complete game application, we should not only perfect the game itself but also include a module for their teachers to track and analyse their progress.

Eventually, we have drawn to a conclusion of modules and features to design in Table 2:

Table 2: Design of the Application

Section	Function	Description
Student (Game)	Settings	Login
		Select difficulty from: beginner, intermediate and advanced
		Select level
		Select mode, copy or memorize
	Game	Puzzle game in copy mode
		Puzzle game in memory mode
		Play result: win or fail, time used
Teacher (Analysis)	Record	Ranking list of all the players
		Detail table with every play of each player
	Analysis	Radar chart to analyse each player in three dimensions
		Progress Report, with number of attempts of each level passed

3.2 Logic Flow

The overall logic flow (see Figure 5) of the application is designed under the principle of easy and clear, with conspicuous headings and appropriate guidance. According to my supervisor in UPV, in general, teachers in La Cañada will assist children through all the settings before they start actually playing the game, which means sometimes children are directly given the game interface, rather than login and select levels by themselves. However, considering extend the training beyond school (maybe children can play the game at home, with friends and family) or eliminate the assistance of teachers or parents, we still want to keep clear and sufficient guidance everywhere in the game.

Note that not only in the game interface can children interact by gesture through Leap Motion, instead, every scene and button in the game can be clicked by gesture.

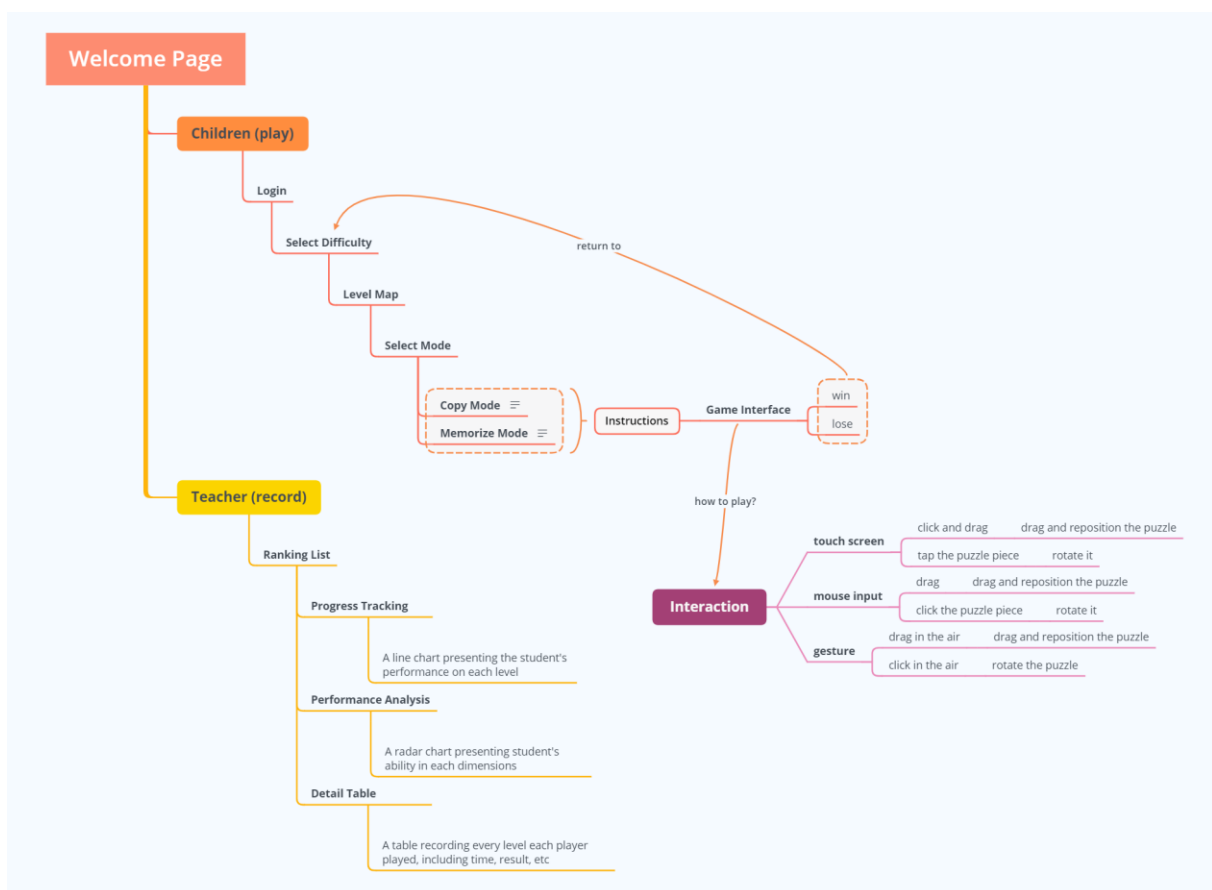


Figure 5 Logic Flow of the application

3.3 User Interface Design

The application ends up with 15 independent interfaces (corresponding to 58 separate scenes in the Unity Editor, we will further introduce the implementation of this in Section 4). In Figure 6, the blue rectangle on the left includes interfaces for teachers and the orange rectangle on the

Design, Implementation and Testing of Applications Based on Touch and Gesture Technology to Stimulate Creativity and Learning in People with Disabilities right includes game interfaces for children to play.

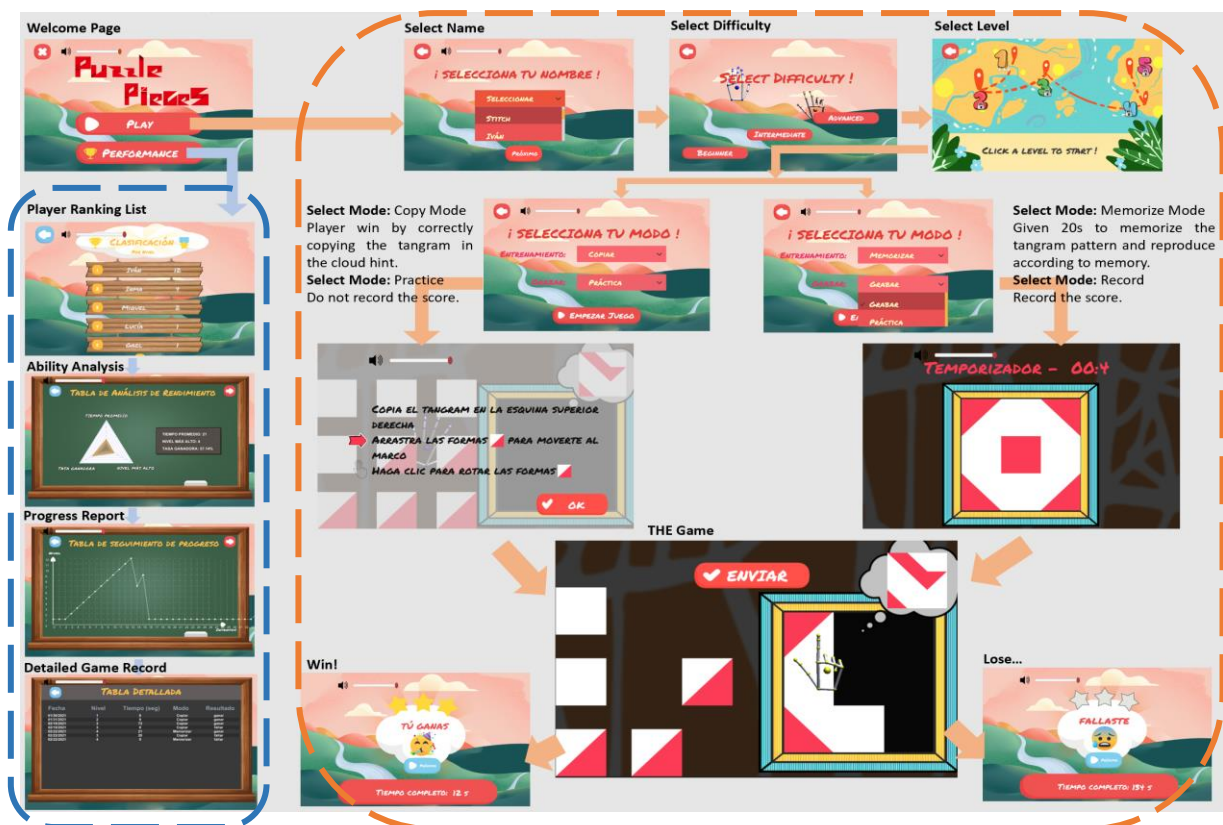


Figure 6 The User Interface of the Game

On launching the game, a welcome page with buttons directing to two sections – children to play game and teacher to check record – appears on the screen, and exit button to quit the program, and volume bar adjusting background music. The colour, elements and source material used will be friendly and favourable to children.

3.3.1 UI in the Game Module

Click ‘Play’ to enter the game. Then select a name for the player in the dropdown list, then select difficulty. There are three difficulties separating fifteen levels. By select a difficulty, the player will be navigated to the corresponding level map. Levels with yellow stars are the ones the player have passed before, level with white stars and a lock are the ones the player haven’t passed, so the next level is locked and cannot be clicked. Enter a level by clicking the number, then select play mode: ‘Memorizar’, which is the Spanish of memorize mode, gives 20 seconds for you to remember the tangram and you need to reproduce it (Figure 7); ‘Copiar’ which is the copy mode, gives the tangram in the top right corner as hint (Figure 8).



Figure 7 'Memory Mode' Instruction (20 seconds to remember)



Figure 8 'Copy Modes' Instruction (tangram in top right)

To play the game, the player can either use fingers on a touch screen (for Android version of the game), or use mouse/gesture recognised by Leap Motion Controller as input (for the Windows PC, with a Leap Motion Controller plugged in). Drag the tangram to the correct position or click to rotate it 90 degrees. Game scene with gesture is shown in Figure 9.

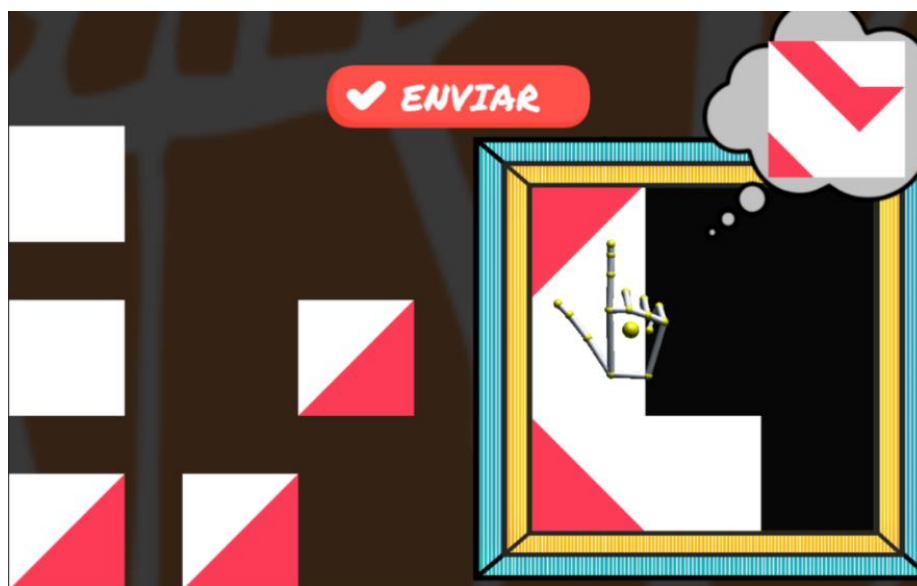


Figure 9 Drag the puzzle pieces by gesture

After the player click 'enviar' which means 'done', they could see win if you got it correct, otherwise fail, and also see the time used, see Figure 10.

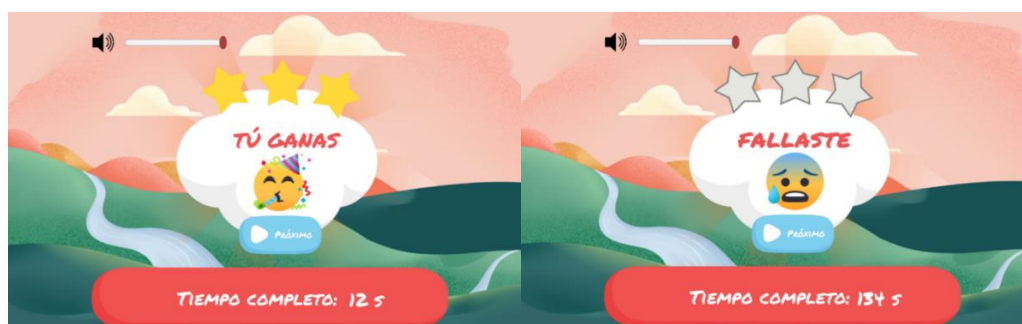


Figure 10 Win or Fail

3.3.2 UI in the Analysis Module

Click 'Record' in the home page to enter the performance analysis module. As designed in Section 3.1, we provide a ranking list containing all the players, and detailed information for each player including a progress chart, ability analysis radar chart and a record table.

The progress chart for each student is drawn by a 2D coordinates with axis of passed level and the number of attempts. The radar chart is an analysis of the player's performance in three dimensions, time used (in average), winning rate, and the highest level passed. The record table presents every detail of each attempt made by the player, including the date, which level, time

Design, Implementation and Testing of Applications Based on Touch and Gesture Technology to Stimulate Creativity and Learning in People with Disabilities used, play mode and result (win/fail).

All the record and analysis interfaces are shown in Figure 11.

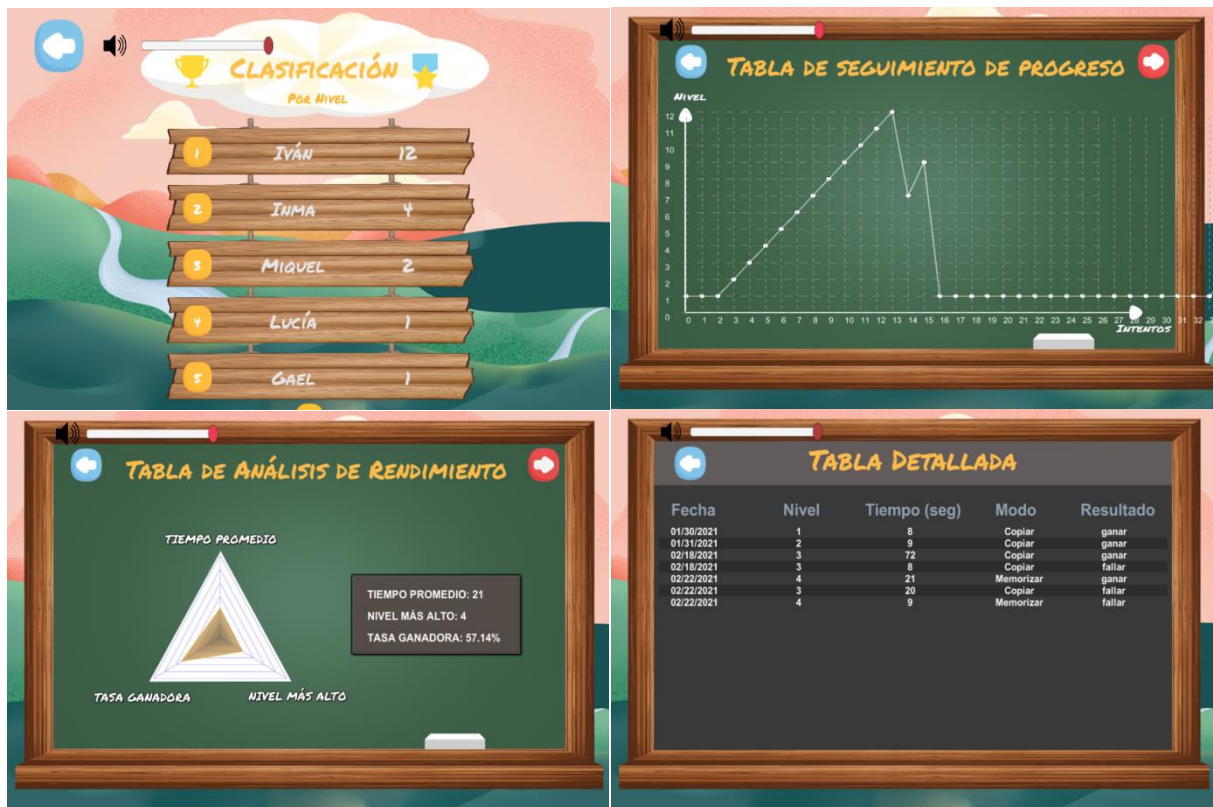


Figure 11 The Analysis Module

3.4 Level Design

To distinguish the difficulty of each level, the game exercises are divided into 3 difficulty categories: beginner, intermediate and advanced. The game exercise materials were given by the professors in the IET La Cañada whose research focuses on the therapy and development of children's mind. According to those material, I select and specify the levels based on:

- total number of pieces
- number of different colours
- type of symmetry
- the shape of pieces

Level 1-5 for beginners, 6-10 for intermediates and 11-15 for advanced, see Figure 12. Figure 12 Level Design

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Level 1	Level 2	Level 3	Level 4	Level 5
2*2 Bicolor; Asymmetric	Symmetric	2*4 Multicolor; Symmetric	Rotational symmetric	2*4 Multicolor; Symmetric
Level 6	Level 7	Level 8	Level 9	Level 10
2*4 Multicolor; Symmetric	3*3 Bicolor; Symmetric	Asymmetric	3*3 Bicolor; Asymmetric	Rotational symmetric
Level 11	Level 12	Level 13	Level 14	Level 15
4*4 Bicolor; Symmetric	4*4 Multicolor; Symmetric	Asymmetric	4*4 Bicolor; Asymmetric	4*4 Multicolor; Asymmetric

Figure 12 Level Design

Chapter 4: Implementation

4.1 Software Architecture

Layered architecture is the most common software architecture and is the de facto standard. This architecture divides the software into several horizontal layers, with each layer having a clear role and division of labour without knowing the details of the other layers, layers communicate with each other through interfaces^[9]. It makes layers isolated from each other which means that changes in one layer of the architecture do not affect other layers, the scope of these changes is limited to the current layer. This makes loose coupling in the application, with components do not depend on each other. This architecture can be easy to maintain. The testability of layered architecture is high.

We adopt the layered architecture in our game application, with layers and components specified in Figure 13 below:



Figure 13 Software Architecture

The presentation layer contains user interfaces, and it is responsible for visual and user interaction. The business layer realises the game logic, the data layer stores data, and the persistent layer provides data.

4.2 Game Logic Implementation

Scenes are generally managed by *SceneManager.LoadScene*.

4.2.1 Answer Validation in the Game

In Unity, the *2D Raycaster* raycasts against every 2D objects in the scene, which allows messages to be sent to 2D physics objects that implement event interfaces. So, we use *Physic2DRaycaster* to check whether there is expected object with expected colour and expected rotational angle on the correct position.

4.2.2 The Analysis Module

The analysis module contains a ranking list for all students, ranked by highest level they have achieved, which is sorted by a bubble sort. The progress chart for each player is drawn by a 2D coordinates with axis of passed level and the number of attempts. The record table contains every detail of each attempt made by the player, including date, level, time used, play mode and result (win/fail).

The radar chart provides an analysis of the player's game performance in three dimensions, time used in average, the rate of winning, and the highest level achieved. This is implemented by the mesh renderer: the three indicators are normalized according to their maximum and minimum values, respectively, and then the normalized values are converted into 18 vertices, which are then be grouped to complete the triangles that eventually form the mesh.

4.2.3 Retrieve and Save Data

Data in the game are all stored as *.json* file, to enable a persistent storage.

To start with, we have to select the player of our game before we play, this list of names is stored as an individual json file (*NameList.json*) and is loaded for the scene where player needs to select his/her name.

When the player is decided, he/she will need to pick a level to play. Here we need another file stores his/her playing history. A file of *{Name}.json* is created after the first time a user finishes a level. Inside this json, the data is structured like *{date, level, timeUsed, mode, result}*. When the player picks a level, the data will be stored into a Singleton for later modules or scenes to share. Every time the player finishes a level and sees the level map, this file will be refreshed for unlocking the next level.

For the levels, we have a separate file (*Level.json*) that stores the correct answer of all levels. The data is formatted like: *{level, shapePositionX[], shapePositionY[], shapesOrder[], shapeAngle[]}*. When a level is selected by the player, the application finds the corresponding level information and stores it into a Level Singleton.

Teachers are using the data supported by the above files as well in the analysis module. When teacher enters the ranking list and analysis charts, the application will loop through the $\{Name\}.json$ file to calculate results. If a new player is to be added, the teacher can click the “+” button in the ranking list to create a new player, and the *NameList.json* will be updated.

4.3 LeapMotion Interaction Implementation

Programming to realise gesture recognition in the game requires implementation to connect and configure the Leap Motion in Unity. This section introduces the component in the Leap SDK used, and how did we use them to assist implementation.

4.3.1 Leap Motion Core SDK

Leap Core SDK for Unity provides the basic hand objects and controllers that connects to the leap motion hardware. This helps us to develop logics based on the hand data that the leap hardware gathers. Here we introduce the key components of Leap Core SDK for Unity, also seen in Figure 14.

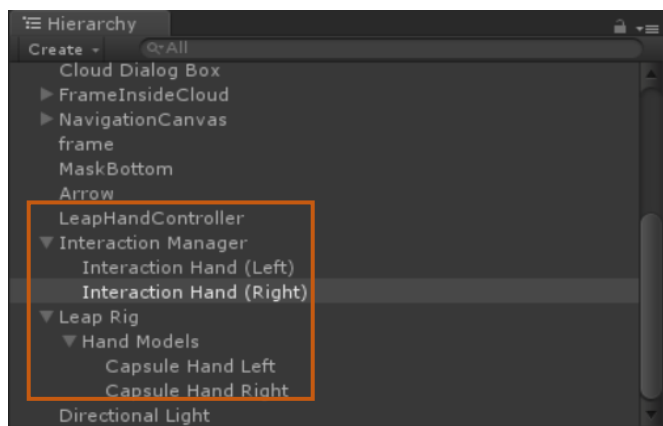


Figure 14 Components for Leap Motion in my scene

a) *LeapServiceProvider*

In the core Leap components, *LeapServiceProvider* is a class that communicates with the Leap service running on Windows platform and provides *Frame* objects containing Leap hands to our game application. Generally, a class that needs data of the movement of hands from the sensor will need a reference to *LeapServiceProvider* to get that data.

b) *LeapHandController*

HandController is a Unity *MonoBehavior* instance who serves as the interface between our Unity game application and the Leap Motion service. The *Controller* object instantiates hands and tools to represent the real-world hands and tools tracked by the Leap Motion

Design, Implementation and Testing of Applications Based on Touch and Gesture Technology to Stimulate Creativity and Learning in People with Disabilities device.

c) *HandModelManager* and *HandModel*

The Leap core SDK uses MVC design pattern. *HandModel* is an interface between *LeapHandController* object and concrete hand object contains the information of the physic and graphics of the user's hand. *HandModelManager* provides hand representation when a hand is detected from its configured *LeapServiceProvider*. With this component, I am able to create hands and identify the 3D coordinate of the player's physical hand.

4.3.2 Mapping 3D to 2D

The basic idea of gesture implementation is to map the 3D coordinate into the X-Y plane which enables the user to interact with the game items. So, we need to identify the position of finger and map the coordinate to the cursor location on the screen. During this process, we used two Leap Motion open-source SDKs.

a) Leap Motion Interaction Engine

Leap provides Interaction Engine SDK for interaction component development. In the game, we use Interaction Manager to control the interaction between the player's hand and the game graphics/objects. The Interaction Manager receives *FixedUpdate* from Unity and handles all the internal logic that makes interactions possible, including updating hand/controller data and interaction object data^[7]. See Figure 15.

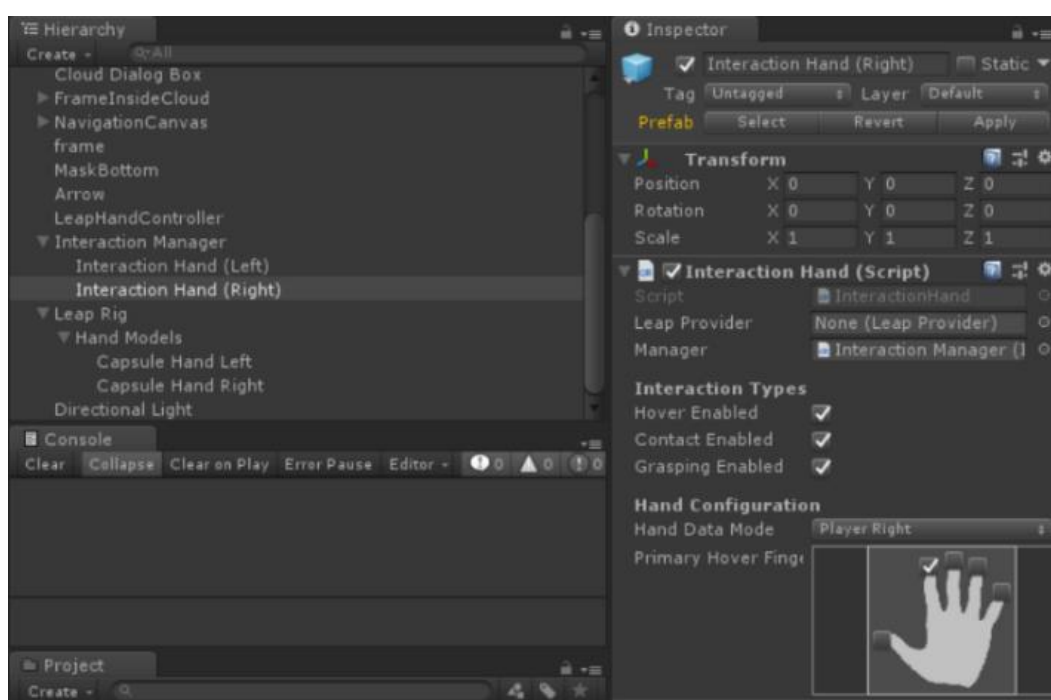


Figure 15 Leap Interaction Hand & Interaction Manager

We also need to make all the objects in the game become Interaction Objects (*GameObjects* with an attached *InteractionBehaviour* component, require a Rigidbody and at least one collider^[7]). All the blocks and circles are set to be 2D Interaction Objects so the user can interact with those graphics.

The Interaction Engine does not render hands on its own, it only instantiates physical representations of hands. Hands are rendered for us by Leap Core SDK (in Section 4.3.1) as a virtual model.

b) Leap Motion *UI Input* Module

Leap provides *UI Input* module to help developers to manipulate UI controls. In the *EventManager* object, Leap *UI Input* Module can be added to generate pointer as cursor and locate the player's finger location. We use this module to locate the position of the player's fingertip and process the interaction events. This module can be seen in Unity's inspector, see Figure 16.

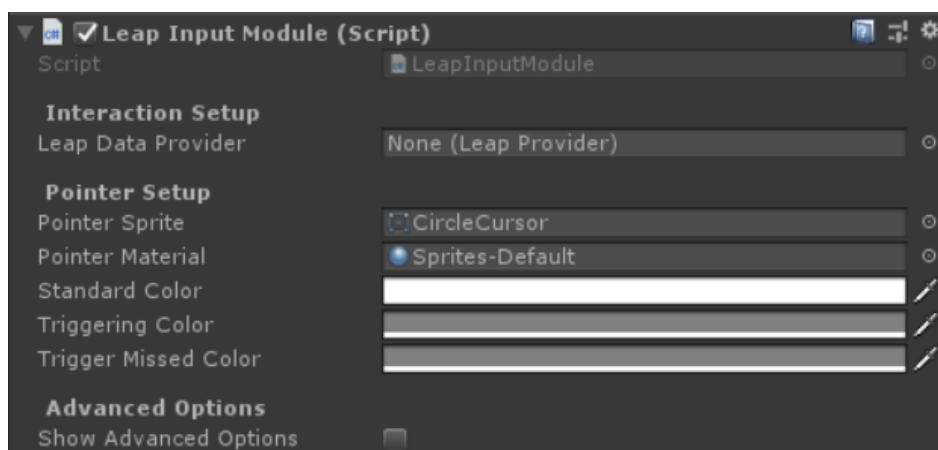


Figure 16 The *UI Input* Module

The idea comes from touchless button. In Figure 17, we can see that the button becomes red with an air push motion and our leap motion can provide similar motion recognition.



Figure 17 Touchless Button, with air push motion

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Referred to Section 2.2 a), the space Leap Motion sensed can be seen as a cone, while the screen is a plane. We need to choose a plane (i.e., a cross-section) in the cone space as the basic X-Y plane and make a reasonable arrangement of the depth (i.e., position Z-axis) of each element (puzzle pieces, buttons, background, etc.) in the game scene, so that their organisation can result in the gesture manipulation to them in line with people's normal way of thinking. Meanwhile, we also need to consider the spatial imagination of children and their ability to transform 3D space into 2D plane. Our design, after all, should be reasonable for children with ASD.

Here, we use the Interaction Engine to detect the location of hand and fingertip, and use Leap *Input* module to transfer the location into X-Y plane. The Z-axis is used to detect the select and release movement. When the player's finger moves at a depth lower than the plane, then it will detect a select motion; when the player's finger moves at a depth higher than the plane, it will detect a release motion. In this way, the operation of leap motion is similar to the tablet touch-screen operation. If we use hand gestures like grasp and release, then the accuracy of the cursor cannot guarantee the smoothness of the game.

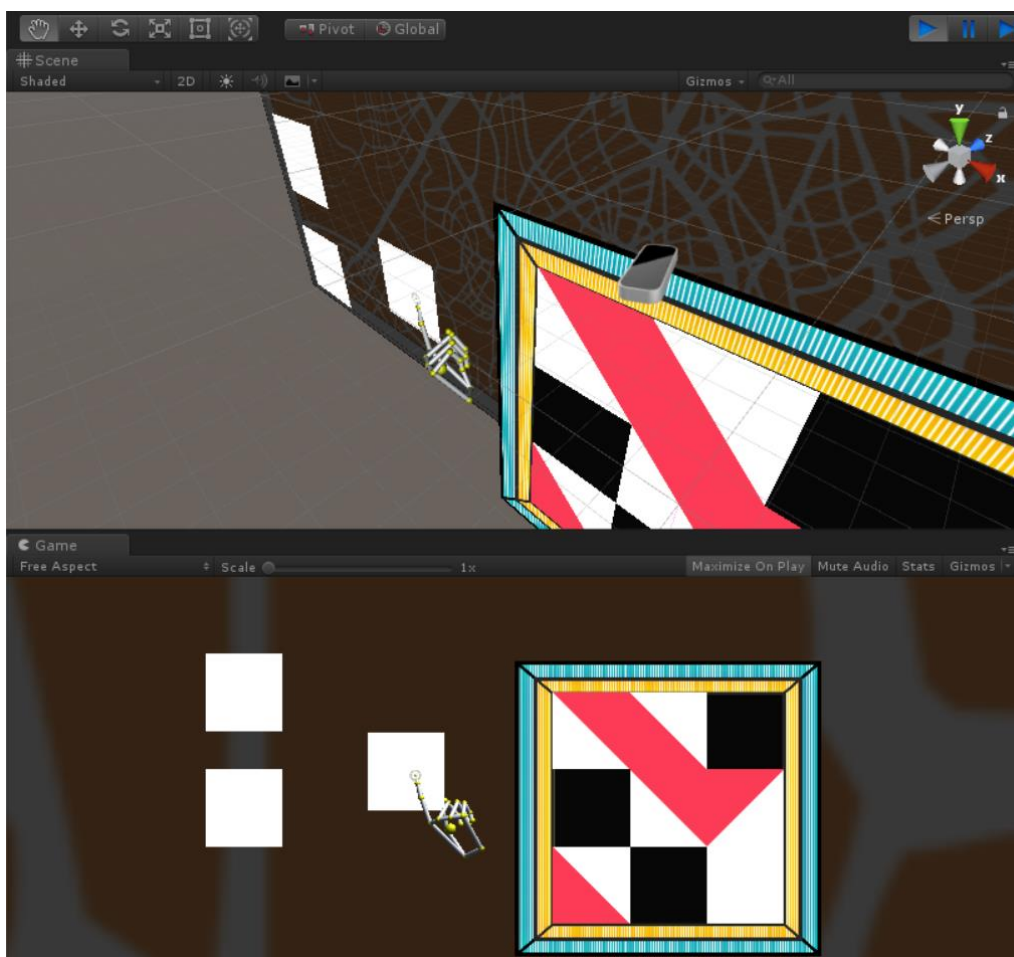


Figure 18 Relationship of Hand Model and the Object Plane, in 3D

Figure 18 shows how the hand is interacted with the block objects. The position of game plane and hand object is clearly shown in the scene.

The triggered event, *PointerDown*, *Drag* and *PointerUp* are used for dragging event and click event, we will introduce them in the Section 4.3.3.

4.3.3 Movement of the Puzzle Pieces

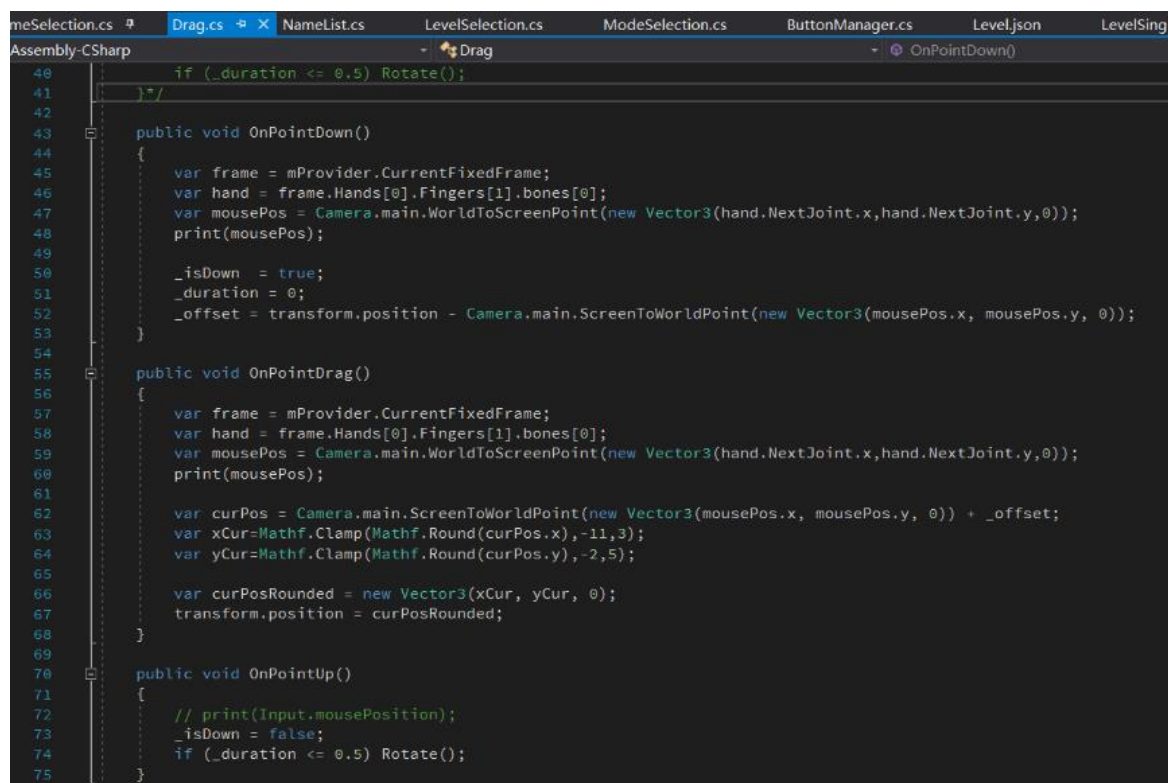
We are going to introduce how we realise dragging and clicking on the puzzle pieces.

4.3.3.1 Dragging a piece

The gesture movement of dragging a puzzle piece via Leap Motion is broke down into three parts: select with finger down, dragging, and release the piece with finger up. Each of the movement is controlled by an individual function.

1) Drag a piece

When the Interaction Engine detects a fingertip gets through an Interaction Object, it detects a select movement, then the *PointerDown* Event is triggered, and we here implement a certain function to realise what the selection leads to: the *OnPointDown* function here is implemented to set the cursor position on the X-Y plane according to the fingertip position provided by *frame*.



```
meSelection.cs # Drag.cs # X NameList.cs LevelSelection.cs ModeSelection.cs ButtonManager.cs Level.json LevelSing
Assembly-CSharp
40     if (_duration <= 0.5) Rotate();
41 }*/
42
43 public void OnPointDown()
44 {
45     var frame = mProvider.CurrentFixedFrame;
46     var hand = frame.Hands[0].Fingers[1].bones[0];
47     var mousePos = Camera.main.WorldToScreenPoint(new Vector3(hand.NextJoint.x, hand.NextJoint.y, 0));
48     print(mousePos);
49
50     _isDown = true;
51     _duration = 0;
52     _offset = transform.position - Camera.main.ScreenToWorldPoint(new Vector3(mousePos.x, mousePos.y, 0));
53 }
54
55 public void OnPointDrag()
56 {
57     var frame = mProvider.CurrentFixedFrame;
58     var hand = frame.Hands[0].Fingers[1].bones[0];
59     var mousePos = Camera.main.WorldToScreenPoint(new Vector3(hand.NextJoint.x, hand.NextJoint.y, 0));
60     print(mousePos);
61
62     var curPos = Camera.main.ScreenToWorldPoint(new Vector3(mousePos.x, mousePos.y, 0)) + _offset;
63     var xCur=Mathf.Clamp(Mathf.Round(curPos.x), -11,3);
64     var yCur=Mathf.Clamp(Mathf.Round(curPos.y), -2,5);
65
66     var curPosRounded = new Vector3(xCur, yCur, 0);
67     transform.position = curPosRounded;
68 }
69
70 public void OnPointUp()
71 {
72     // print(Input.mousePosition);
73     _isDown = false;
74     if (_duration <= 0.5) Rotate();
75 }
```

Figure 19 Code excerpt for dragging puzzle piece

While the finger selecting a piece and moving, the *OnPointDrag* linked to the *Drag* event is taking effect. We use *Clamp* to set the boundary so that the piece will not be dragged outside the screen.

When the finger is higher than the depth of the piece, this is a release motion and *PointerUp* event is triggered. We implement *OnPointUp* for the event.

Code excerpt in Figure 19 shows the three implemented functions for the Leap gesture events.

2) Rotate a piece

In the game, player sometimes needs to rotate the piece to make correct answer. Rotate corresponds to a click of gesture. Click is realised by evaluate the duration of selecting. We assume it to be a clicking event rather than selecting to drag when the cursor stays less than 0.5 second, implemented in *OnPointUp*.

Dragging event is linked with the objects in the scene through *Event Trigger*. For every piece object, we need to link it as an instance to our method. Figure 20 shows the *Event Trigger* setting of an object from Unity's inspector.

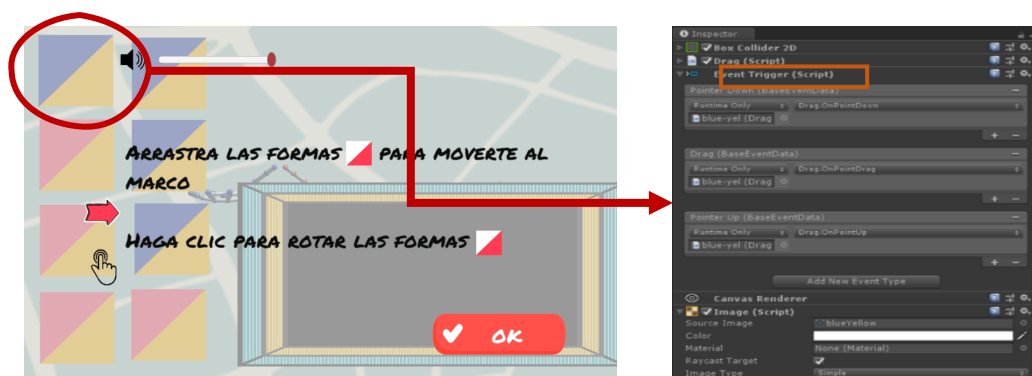


Figure 20 *Event Trigger* settings, from the inspector

4.3.3.2 A trick worth mention

Little tricks are used to enhance user experience. One of them are worth mention here, which achieves noticeable effect for Leap Motion, which is the ‘absorption’ feature. More importantly, it is most needed for children with ASD.

This feature enables the piece to be automatically absorbed to the nearest blank when the hand releases it. This is realised by rounding the coordinate when assigning the position value to the piece, when the piece is released in the designated area – area enclosed by the ‘boundary’, which are four public variables in the script who controls movement of pieces. See Figure 21.

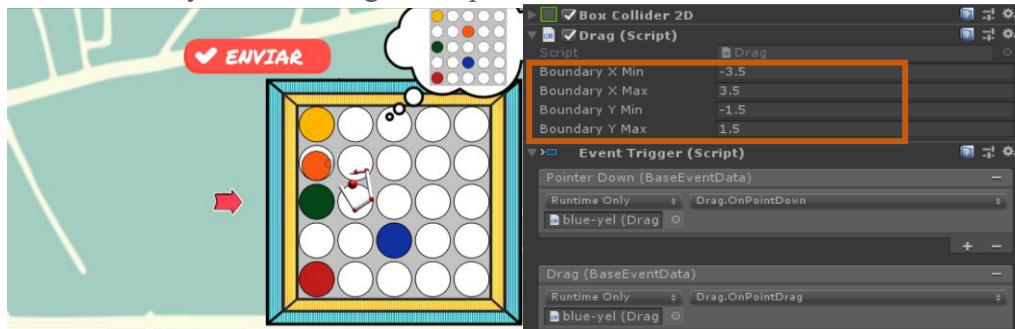


Figure 21 'Absorption' Feature, enabled when pieces released in designated area

This feature was designed because children with ASD, as mentioned in Section 2.1, have intellectual difficulties and this reflects in ability of 3D imagination. Children need to try to release the piece as close to the position as possible to get the answer correct, however, the pieces are not sticking to the exact position that player release when:

- 1) Children's hand slightly shake or quiver, or
- 2) Children have trouble imagine the 3D space in their head.

For the above reason, we decided that an 'absorption' would be an auxiliary to the children to use Leap Motion.

4.3.4 Contribution to the Leap Motion SDK

During development with Leap Motion, I found that every time I did a tap motion, the point event executes twice which leads to wrong behaviour. As I looked into the source code, I found that there is duplicated code which cause this problem.

Therefore, I started a topic in the Leap Motion community forum suggesting this problem with code excerpts, see Figure 22. We hope they can someday fix the source code someday.

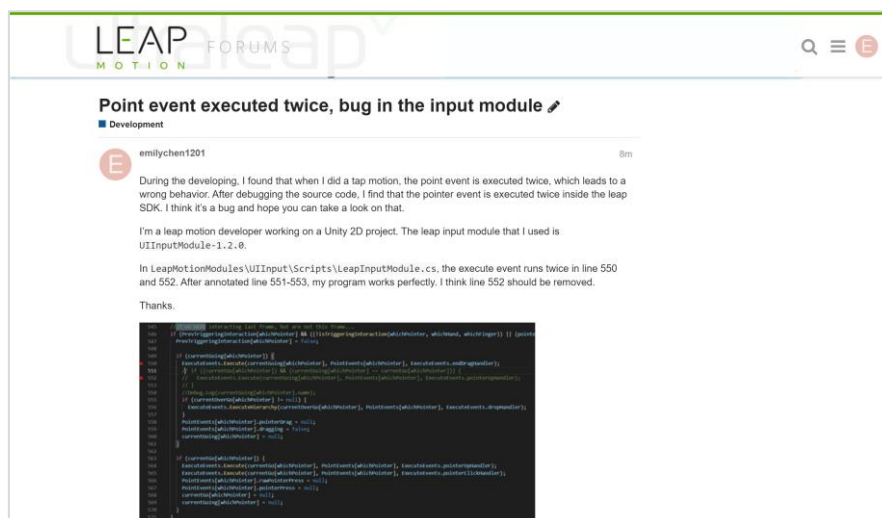


Figure 22 Suggestion made to the Leap Motion Community Forum

Chapter 5: Tests, Results and Discussion

The resulting application is a tangram puzzle game with Leap Motion Controller as a gesture recognition input hardware. Since this application is developed for the children in La Cañada, we need to pay visits to La Cañada to test the application with them, and make improvement wherever necessary.

5.1 Completeness

Reflect on the requirements gathering and design of the application in Chapter 3, we have achieved all the designed features and special highlights for the game, summarized in Table 3.

Table 3: Completeness

Section	Function	Description	Design Details	Done?
Student (Game)	Settings	Login by select name	<ul style="list-style-type: none"> ● Login name list can be added, modified ● Levels are only unlocked when player passed its previous level 	✓
		Select difficulty from: beginner, intermediate and advanced		✓
		A level map to select level		✓
		Select mode: memorize or copy		✓

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	Game	Puzzle game in copy mode	<ul style="list-style-type: none"> ● Give clear, detailed instructions of how to play ● Use puzzle pieces with high contrast colour and designed size 	✓
		Puzzle game in memory mode	<ul style="list-style-type: none"> ● There is an automatic absorption when pieces are put down near but not exact on a blank 	✓
		Play result: win or fail, time used	<ul style="list-style-type: none"> ● Has special sound effect for winning as encouragement 	✓
Teacher (Analysis)	Record	Ranking list of all the players		✓
		Detail table with every play of each player	<ul style="list-style-type: none"> ● Teacher can add a player in the player list 	✓
	Analysis	Radar chart to analyse each player in three dimensions		✓

		Progress Report, with horizontal axis indicating time and vertical axis indicating level passed		✓
--	--	---	--	---

5.2 Usability Test

5.2.1 Test plan

Prior to the mid-term check, we made test plan in order to conduct the test in La Cañada as soon as the software is ready. In addition, we made some materials for children to better understand the game before they play, include a user manual (in both Spanish and English) and two demo videos (available on: <https://youtu.be/CmedqjoOZ1Q> and <https://youtu.be/l9QReH6kJFg>), sent to the teachers in La Cañada before we made the trip to test with them.

Since I cannot personally go to La Cañada to participate in the test, my supervisor in UPV find a local student Yilong who speaks both Spanish and Chinese to work with me in this procedure.

a) Observation

Table 4: Test Plan - Observation

Date & Location	April 2021 and May 2021, La Torre Centre at La Cañada High School
Participants	Children with ASD, their teachers, my supervisor and Yilong
Procedure	<ul style="list-style-type: none"> i) Yilong introduce the game ii) Observe children when they play games, and take photos iii) Ask children to do questionnaire, discuss with teachers to get feedback
Evaluation metrics	<ul style="list-style-type: none"> ● Completeness of Application's Functionality ● Critical Error: error that causes deviations from the expected goal. ● Non-critical Error: error that do not result in unexpected outcomes but might frustrate player. E.g., excessive steps and keystrokes. ● Subjective Evaluation: feedback from individuals

b) Questionnaire

A questionnaire in Spanish has been created in advanced. Questions included are listed here (available on: <https://es.surveymonkey.com/r/N2J725Y>):

- How easy it is to find what you want in the game?
- How do you like the gesture feature in the game, using Leap Motion?

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- How do you like the visual effect in the game?
- Which part of the game do you like most?
- How will you rate this application?
- Comments and suggestions for future work

c) Interview

I also planned interview with teachers in La Cañada. Questions include:

- How would you comment this game?
- What do you think of the gesture control feature by Leap Motion?
- In what way does gesture control in the game help children?
- What other feature would you like to add to this game?
- Have the children been playing gesture game at school before? What was the game like, and how do they enjoy it?

5.2.2 Test result

Trip was made to La Cañada to test the application. This test is conducted with three children playing the game, and with Professor Kathy and Monica, and my supervisor in UPV presents. Table 5 summarize problem found and Figure 23 are pictures taken during the test.

Table 5: Test Result on Apr 22nd

Problem	Solution	Resolve Status
Children use whole hand to grip rather than fingertips to click and drag	Make a clearer demo video about how to use gesture	Resolved
Children click the 'enviar' ('complete') button during the game by accident	Disable the button clicking event by gesture	Resolved
Children could not imagine that the plane of the gesture control was perpendicular to the plane of the screen	Place the screen flat on (parallel to) the table	Resolved
Children's hands could be displayed behind the puzzle pieces if they do not lift hands high enough	The control of Leap Motion requires familiarity and practice	Needs children's practice in the future



Figure 23 Test on Apr 22nd

5.3 Feedback and Improvements

Combining the above test in Section 5.2, we have drawn to some conclusions.

5.3.1 Feedback Capture Grid

Feedback Capture Grid is used to analyse the feedback after the usability test. Four quadrants are filled in to capture ideas during testing in La Cañada. Amendment and improvements could be developed from it.

In Figure 24, the items marked with a check means they are completed in the final game version. The items listed by a box are questions found, or future work for later years.

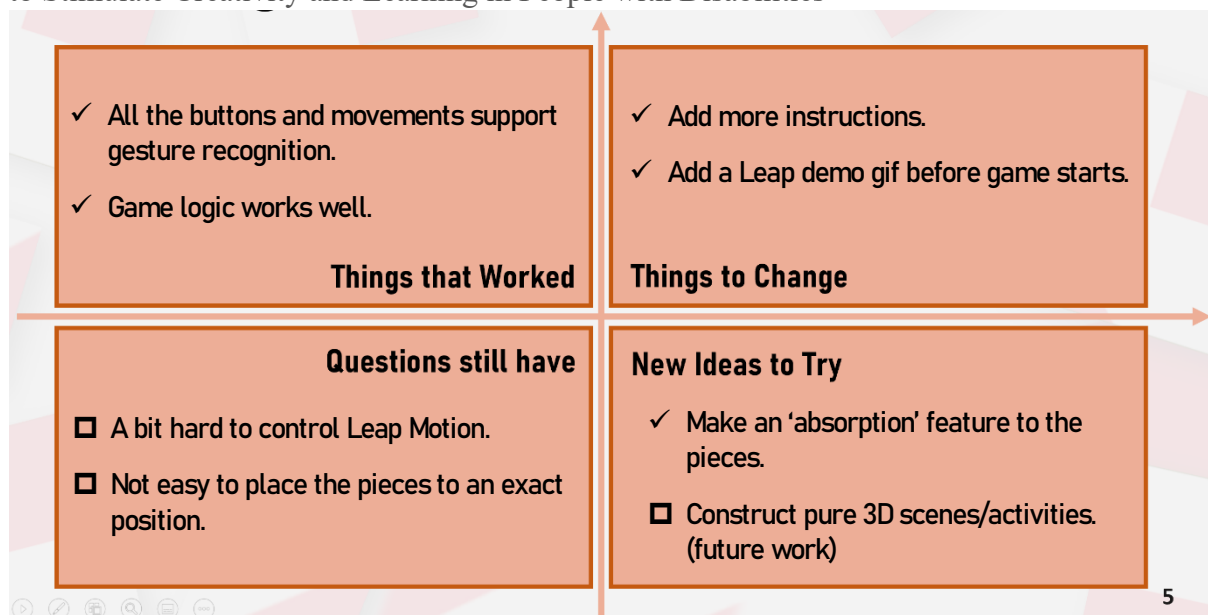


Figure 24 Feedback Capture Grid

After repeated tests and improvements, the only problem left is that Leap Motion could not sense the player's hand and capture every movement precisely. By discussion we found the reasons for this:

- 1) The accuracy and sensitivity of Leap Motion is not as high as expected, and
- 2) Children need more practice to adapt using Leap Motion, and this adaption is exactly the purpose of introducing Leap Motion gesture into the game for their intellectual training.

Solution can be sought from two aspects:

- 1) The 'absorption' feature of puzzle pieces, described and resolved in Section 4.3.3.2 already.
- 2) We can find other commercial product or develop one that has better precision than Leap Motion, which is mentioned in Section 6.2, b).

Chapter 6: Conclusion and Further Work

Through the whole process of design, implementation and testing, the game development comes to an end and proves to be satisfied. This chapter concludes the final year project, and we are now drawing a brief conclusion and summarize room of improvements in future years.

6.1 Conclusion

This project is about using gesture technology to help children with ASD in La Cañada High School, and we are trying to develop a tangram puzzle game application that utilises both gesture and tactile technology to train their intellectual ability through intervening some of the six stages of play, and further stimulate children's creativity.

Through online meetings with my supervisor and the teachers in La Cañada, we decided that we are going to develop a tangram puzzle game, using Leap Motion via Windows to achieve the goal of gesture technology, and we should also provide an Android version which can run on any Android devices, interacted by a touch screen.

The design and prototype of the application are carefully crafted according to the requirements set out by teachers in La Cañada. The tangram game is with 15 levels divided into three difficulty categories, and it provides an extra analysis module for teachers to see and analyse children's progress.

The uniqueness of this game application is that every page and button in it supports gesture recognition. To achieve this, we utilise build-in modules of Leap Motion services and implement certain functions and manage our game scenes to use this hardware in the best way we can. Gesture control is with progressive significance for two reasons:

- 1) Under the situation of Covid-19, contactless control is more urgently needed than ever.
- 2) For children with ASD, it is more challenging and more targeted since a game with gesture technology gives children spatial imagination challenge.

During developing, I was working online closely with my external supervisor distant in UPV. We had meetings by Microsoft Teams weekly to update progress and clear doubts, even during Spring Festival and Easter Holiday. Though it is a pity I did not make myself to La Cañada this year, but the communications proceeded are efficient, and we carried out test smoothly in La Cañada as planned. And I also find some flaw in the Leap source code so that I contribute a little bit in raised the issue to the Leap Community.

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Tests of the game with children took place on 22nd April after the Easter Holiday. Before that, I made demo videos and user manual for them to be familiar with the game. Children are thrilled to a game that uses gesture that although they might need some more practice to accommodate this new kind of playing, they are fond of the game and the game proves to be helpful for their imagination training and creativity stimulation. The test proved the game application to be satisfactory.

6.2 Further Improvements

I have tried my best to develop the application, however, if I were given more time, I would try to improve in these two aspect:

a) Construct a game with pure 3D scenes

The tangram puzzle game till now is still a 2D one. I have made inquiries and found that most of the commercial game supporting gesture technology is with 3D game scenes that provides a more immersive gaming experience. We can try to develop a pure 3D game for screen use next year, and we might consider trying AR/VR devices in the long run.

This is not necessarily limited to tangram puzzle games, other activities like shooting ball into a basket, whack-a-mole or archery game could also be considered. To design that, we still need advice from teachers in La Cañada since they know the children with ASD better about what level of challenge is best for their intellectual development, and what type of 3D scenes would not make them confuse.

b) Develop a hardware better than Leap Motion Controller

During development, I found an obvious bug in the source code of Leap Motion and raise the issue in the Leap Motion forum. Also, my supervisor and I agreed that the precision of Leap Motion's recognition performance still has a room to improve.

Leap Motion was acquired at a low price – much lower than its previous valuation – by Ultra Haptics (one of its main competitors) in 2019. And I have also noticed that the SDK provided on Leap Motion website and its components supports a relatively old version of Unity which indicates it has been long since last officially updated. we suspect that the likelihood of it improving is not substantially high. I would suggest in the future, when we are going to develop something that needs precise to a specific finger, we might want to explore other commercial products with better precision, or another excellent student from BUPT could just build one!

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In the future, we hope for a closer work environment and better communication between us and the La Cañada High School. In that way we can be more convenient in collecting requirements, deliver up-to-date version of game, and get fast feedback from them, eventually adds up to a better application.

We are pleased to see that this game application proved to be helpful for children in La Cañada, and children are excited as well to have such an interesting puzzle game they can wave their fingers to. It is a prideful experience to me that in the last period to finish my undergraduate study, I have this chance of using the technology I have learnt to create something that pragmatically helps a certain group of people in the world. Through this precious journey, I am convinced that technology can truly change people's lives and if I am willing to stick to it, I can explore more and contribute more through my work for the society, to everyone who is part of it.

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Acknowledgement

My External Supervisor

We met and worked together in this project during the hard times in Covid-19. As this project includes lots of communications to make – between teachers in UPV and La Cañada, between children in La Cañada and us, etc – he arranged meetings online and offline and collaborates everything and everyone closely. He is the grand marshal of this continuing project, who not only contributes a lot to local children, but also devotes enormous effort in helping me overcome lots of difficulties in this project.

Though we never met in person, but we talked a lot about children in La Cañada, our fluffy toys, the couplets in Spring Festival, etc. You are more than a supervisor to me but an older friend who can talk freely and seek guidance from. I sincerely hope that one day we can meet in Valencia or Macao where we can share more about our life in Valencia and in Beijing.

My Supervisor

In every meeting before a deadline of report held for Spanish external projects, my supervisor from Queen Mary scold me strictly, however, she is full of useful advice that better my reports, videos and presentations, and those advice always comes in a timely manner. Thank you for organising the meetings for us who is doing external projects. Though the meetings took hours and hours to finish, but every word proves to be useful.

My Alumnus

I sincerely appreciate all my seniors and alumnus who participated in this project in previous years, who have left precious materials and references for me to conduct my project this year, including the SoundCool Platform, analysis of Leap Motion, etc.

My New Friend in UPV

It is surprise and lucky for me to have a friend who speaks both Spanish and Chinese and study local in UPV, to conduct lots of experiments and pay several visits to La Cañada. My project goes more smoothly with your help.

My Family

My most sincere gratitude goes to my family. During tough times in Covid-19, family members tried their best to put my feet up and gave me enormous intellectual and mental support.

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Work Plan (Gantt Chart)

Fill in the sub-tasks and insert a letter X in the cells to show the extent of each task

	Nov 1-15	Nov 16-30	Dec 1-15	Dec 16-31	Jan 1-15	Jan 16-31	Feb 1-15	Feb 16-29	Mar 1-15	Mar 16-31	Apr 1-15	Apr 16-30
Task 1 Analyse the benefits of the current application as well as the operation of the Leap motion gestural interface												
Background reading of features of handicapped people	X	X										
Read and discuss relevant application designed for handicapped people	X	X	X									
Study the Leap Motion API			X	X								
Study how SoundCool platform is developed				X	X							
Task 2 Carry out tests of the application with the Students and Teachers												
Design the interaction flowchart, according to the requirements of people in “La Canyada”						X	X	X				
Design the user interface							X	X				
Program to build up the system and realize the functions							X	X	X	X		
Improve the system iteratively according to feedback in “La Canyada”										X	X	X
Task 3 Defining proposals for improvements its usability and new features												
Design the evaluation metrics								X				
Conduct usability tests in “La Canyada”						X			X		X	
Analyse the findings and solutions, conclude them in the report									X	X	X	X
Change and improve the hardware according to the usability tests.										X	X	X
Task 4 Summarise the results into meaningful set of publishable paper (Journal and/or Conference)												
Write down a user manual to facilitate tutorial									X			
Revise the user manual according to feedback from “La Canyada”										X		X
Write down the report						X	X	X	X	X	X	
Improve the report according to my supervisor’s feedback											X	X

Risk and environmental impact assessment

Risks are identified and measured in detail. The likelihood rating is 0-5 from impossible to certain, and the level of consequence is 0-5 from negligible to catastrophic. We give preventive measures after the table.

There is no environmental issue in my project.

Risks	Impact	Likelihood (<i>L</i>)	Level of consequence (<i>C</i>)	Level of Risk (<i>R</i>)
Children breaks the Leap Motion Controller	Test cannot continue. Children will be frustrated.	2	5	10
Children do not cooperate	No useful feedback for my game.	3	2	5
Children cannot understand how to play the game	Children will be impatient and frustrated.	2	4	8
The software crashes at runtime	Children will be impatient and frustrated.	1	2	2

Preventive measures for each risk event, by level of risk (*R*):

- 1) We should give clear guidance and make sure student plays Leap Motion under their teachers' supervision.
- 2) Follow the instruction of their teachers, and be patient and keep positive communication with them.
- 3) Write clear user manual and make clear video demo. Make the game interface nice and attractive, and give clear instructions in the game.
- 4) Design the software properly, and test the software frequently at home.