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THE INTERACTIVE MULTI-TOUCH TABLE

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Acknowledgements

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ABSTRACT

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The Interactive multi-touch table is a customised bar table that combined multi-touch technology and ordinary bar table looking. It is intend to be located in public environment as in airport, office, school and shopping mall in order to offer people several application to interact with. The purpose of the application is let people spend their idle moment on the interactive table, enjoy the fun and relax themselves. The main technology chosen in this project is FTIR as hardware part, in software part are the Flash and Touchlib. This paper covers the whole design and development process of the project as well as the all necessary works.

Keywords   Multi-touch, FTIR, Touchlib, Flash

Contents

1. Introduction

Nowadays, as the multi-touch became to the one of the hottest technology in the world, people's view focus on it so long, and almost every young people is talking about iPhone, ipad and so on. Since Apple launched the new MacBook Air which with the multi-touch pad features, the birth of iPhone and iPad brings it to a totally new level hight.

Multi-touch technology brings us such a impaction of vision and unlimited a various of expansion space, this project is intend to explore and develop sort of application can be running based on self-made multi-touch platform. And this project will make a similar multi-touch platform and develop a application that try to use features of multi-touch technology.

The project carried out during 2008 in a group of people who have a huge interesting in this filed of technology under supervision of Chalmers university of Technology. The idea is about make some kind of daily used item with the multi-touch technology, and this item should be put in some public and social environment in order to gain enough amount of people's visiting and further interact with it. Then the decision made as make a customised table that can be put in place like office hall, railway station, school, airport and so on, and the table should integrated a multi-touch surface to provide sort of application or games for the people, in case to let people can interact with the application with other people or table itself. The multi-touch technology chosen with FTIR[1] (frustrated total internal reflection) and in software parts are Touchlib [2] and Flash[3].

The project would like taking the multi-touch usage to new direction beyond small daily used electronic devices such as laptop, mobile, but beyond these, it would like bring a new approach to multi-touch technology into people's life. People will use it as an ordinary furniture, meanwhile it provide an opportunity for fun, relax and interaction, with these unique features, the table may become ice-breaker in the industry.

2. Background

Nowadays, the touch technology [4] has already be part of our life, rely on its the unique user-friendly perspective，it has been used ever more than before, and you can it everywhere. The ordinary touch screen is a special type of visual display with a screen which is sensitive to single pressure or touching. The screen can detect the position of the point of touch. Figure 1 and 2 shows the touch-technology applied in our life:

Figure 1: the vehicle center control panel

Figure 2: automatic ticket machine

The 2 examples, the vehicle center control panel and a ticket machine. With only one display and a programmable microprocessor inside, the touch panel instead of huge number of physical buttons, work become easy and fast.

In 2006, Jeff Han whom from New York university has firstly presented his multi-touch platform and the presentation brings a quite shock in the field. Since then, people have a new vision of making such multi-touch surface by his introduction of FTIR technology, which the same one applied in this project, the variety of application demonstration gives people a lot of inspiration as well.

The application include drawing, photo album, map display and so on, in each application, user can use multi finger to draw picture, rotate, drag photos, zoom in and zoom out maps, and so on. Figure 3 shows the demonstration of Jeff Han's demonstration:

Figure 3: Jeff Han's demonstration of multi-touch technology

3. Aim

The aim of the project is to exploring some new concept to applied multi-touch technology, the initially idea is to make something big, different with iPhone, though it may not easy to carry with, I hope it still can be useful to the people. And basis on research of related work, I found lots of multi-touch application is aiming on a "tool", which mean they normally act as a functional software, such as the photo display, drawing application. Some other simple application are focus on sort of beautiful visual display, for instance, smoke effect, water effect and so on. Finally, I decide to make a ordinary looking table, with a multi-touch surface and a small application of electronic pet, the core concept is let people have fun and relax with the table. Figure 4 is the firstly design of the table:

Figure 4: the firstly design of the table

3.1 Scenarios

The general scenario is let user treat it as a normal table at those public environment which can be use to put tea and cafe cup on it, and chatting with other people. As soon as someone put his cup on the table, a beautiful visual effect of colour circle appears around the cup, and the same image will display as well as when user put finger on the surface. There will be some little pet floating on the surface in looking of sleeping, they will be wake up as soon as somebody touched them. After they waked up, there will be different emotion and face looking randomly shows, for instance, angry, smile, fighting. They will keep floating and move around on the surface unless you use finger to press them, when you press on them, they will stop moving, and then you can use multi finger to drag them, rotate, and even resize them.

In functionality aspect, the pet should basically move around the surface randomly in tow mode of sleep and wake up. They should be wake up by touch and press, and drag and stop by single touch, resize and rotate in multi-touch. These pet should looks cute and very mischievous thus makes people have interesting to play with them.

3.2 Objective

The objective of the project is to make the table as a life partner only for relaxation and fun. The table is intend to be put in place of public environment such as office hall, cafe shop, school, shopping mall etc, in one hand, it is looks like and use as a regular table that people can reading, eating, or just putting stuffs on it, the out look of the table should capable with these environment; in another hand, with some attractive application such beautiful visual effects and digital pet, the table offer numbers of people joyful and relax moment at the same time. By play with the application itself, or interact with other people, I hope the table could let people killing some board time.

To take a step forward, with the multi-touch technology, this kind of table not only a single game anymore, it will encourage people getting closer and play together through spend time with the table, thus people may have much more communication with strangers in those public places.

Some basic objective of the project would be:

- A table with regular and good looking, and can be use in home and public environment as furniture or decorations

- Integrated with multi-touch technology, and should have a big touch able surface

- Provide applications such as game, digital pet, nice visual effect to people

3.3 Target user group

The table itself actually does not have certain user group, since the table is designed for put in public environment and as well as home. Depends on different application, for the current scenario, the digital pet, everybody could be the potential user of the table, because any people who wanna have some fun and relax moment could play with it. But later on, when multiple usage of application has been developed, for example, navigation software, picture and file transfer application, the user group may divided on these specific category of applications So, in the testing and evaluation part, the group will invite different people to try to play the table in order to get a roundly feedback.

4. Design Process

The design process follow the sequence of: discussion of idea inspiration, literature and related work research, hardware and software development.

4.1 Inspiration

The initially inspiration should back to Mr Jeff Han again. There are lot of research work has been done about his theory and presentation, as well as the variety application that he represented. The group discuss about his applications, the technology that his used, meanwhile, the method of brainstorming carried out in order to find out the best way to utilise or improve some application with the technology of multi-touch. Figure 5 shows variety of the application of Jeff Han demonstrated on presentation:
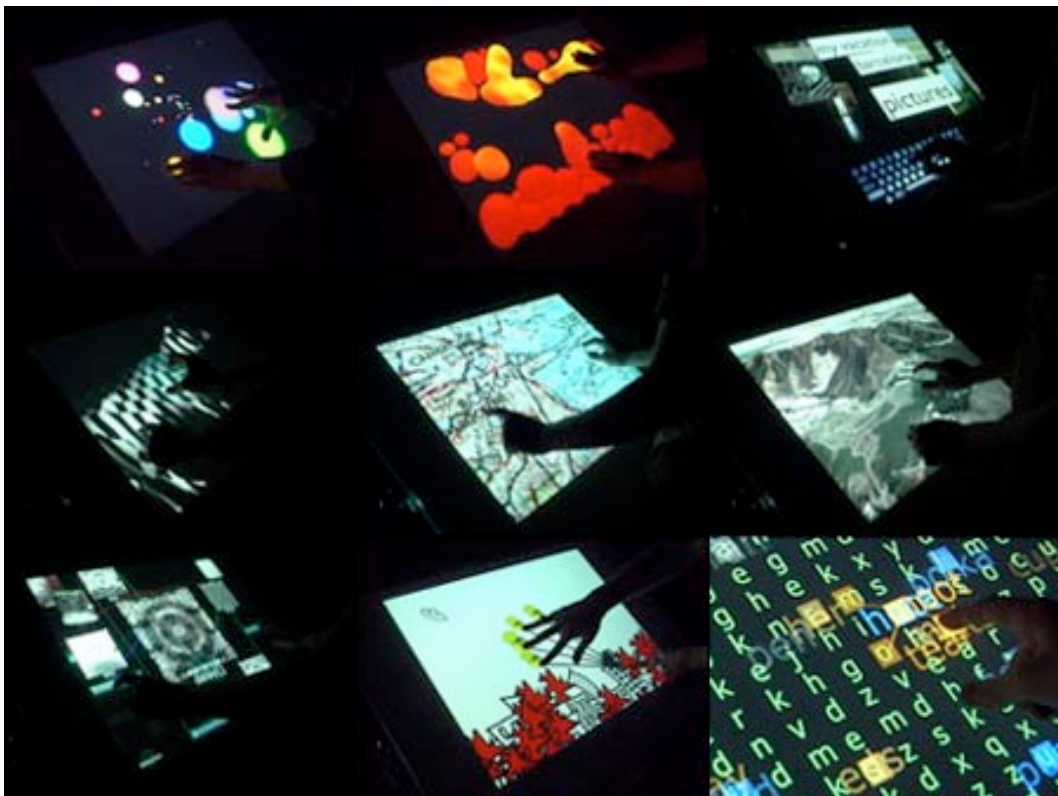

Figure 5: Applications of Jeff Han

As it showed on the picture, those wonderful application brought a lot of idea. I take more research about multi-touch utilisation, and find out there are distinction applied way of it, such as a table, a multi-touch wall. Finally, by some limitation of the skill and budget, the table idea seems the best choice since it is easy to implement hardware hidden, and a table may easy to build, at last, the table like object should be easy to fit larger range of environments.

Another other inspiration come from Apple, the macbook multi-touch pad and iPhone, as them shows in figure 6 and 7:

Figure 6: Multi-touch pad   **Figure 7: iPhone**

Especially on Macbook's multi-touch pad [5], single finger as single click, double finer as right click and scroll page, three finger to forward and backward pages and this pad support up-to 4 finger gestures, this features gives user a wider range of control and a huge freedom compare to the ordinary tack pad.

And the last one is a self-made multi-touch platform [6]. This project is from internet, it is 100 present self-made project, step by step, author also provide a guideline to tell people the process that how to build such a platform, and the highlight of this project would be the low cost of its components and feasibility for home made. Figure 8 displays how it looks like:

Figure 8: Self-made multi-touch platform

The structure is quite similar with our eventually outcome since is home made platform is really great project. The detail of the working theory will be introduced later.

4.2 Literature research and related works

After the idea decided, a lot of literature research work carried out as well as study the related works of multi-touch technology.

There are two technologies for building hardware for multi-touch, one is the DI [7] (Diffused Illumination) and the other one is FTIR. Numbers of project will be introduced below, most of them made with DI or FTIR technology, they brought a lot of inspiration to the this project in hardware implementation part. Beside research on the hardware aspect of these project, the distinction applications of these project are important too. There are generally tow types of multi-touch technology have been applied in the projects. First type is about making some colourful and cool visual effects and images, the theory is that as soon as surface

has been touched, there should be some reaction feedbacks, they focus on multi-touch detector. Another type aims to implement the basis functionality of the multi-touch technology, as mentioned above, picture and map viewing, with different multi-touch gesture, the application could achieve the most obviously feature of multi-touch technology such as drag, resize, zoom in, zoom out, and rotate.

4.2.1 The Microsoft Surface

The Microsoft surface [8] seems the firstly commercial product on the field of big multi-touch screen product. But it is hard to define whether it is successful or not, indeed it accomplish lots of function and made those function working perfectly smoothing and well, but due to the unbelievable retail prise, it still not get popular in the market.

It look as a modern coffee table with huge glass surface, but it is more than meet the eyes. The product faced both to home user and business users, the features include:

- **Direct interaction.** Users can grab digital information with their hands and interact with content on-screen by touch and gesture – without using a mouse or keyboard.

- **Multi-user experience.** The large, horizontal, 30 inch display makes it easy for several people to gather and interact together with Microsoft Surface - providing a collaborative, face-to-face computing experience.

- **Multi-touch.** Microsoft Surface responds to many points of contact simultaneously - not just from one finger, as with a typical touch screen, but from dozens of contact points at once.

- **Object recognition.** Users can place physical objects on the screen to trigger different types of digital responses – providing for a multitude of applications and the transfer of digital content to mobile devices.

Anyway, it is a very advanced product in multi-touch technology field, figure 9 shows what is it looks like:

Figure 9: The Microsoft Surface

4.2.2 FOOBAR

FOOBAR [9] is made by student's company named Touchtech AB and had some corporation with famous beer brand Carlsberg. It is a customised bar table which offer multi-touch technology, the hardware build with DI technology and the software develop in Linux. This product can be put in bars since it focus on visual effect display and fiducial recording and menu-ordering. Beside multi-touch, this

project combine another idea of put ID tag under the beer bottle, so the receiver under the table could recognised different product thus achieve the menu-ordering functionality. FOOBAR see as figure 10.

Figure 10: The FOOBAR

4.2.3 IBar

IBar [10] is a similar impressive interaction system with the FOOBAR for bar-counter. The first highlight is its tracking system could find any kind of objects that put on the table, further, there will be some image and visual pattern appears on the surface to attract people's attention. With the different amount of touch spot and touch gestures, the pattern will be change and different, so the core idea is to make a very cool visual effect, and thus it is very suitable for the environment like night club and pubs.

4.2.4 Reactable

Reactable [11] is electronic music instrument with multi-touch table interface. Objects with different fiducial markers represent different sounds, and the sounds vary when rotating and moving the physical objects. Different objects can perform the harmony simultaneously. The Reactable team build an open source and cross platform framework themselves, called reacTIVsion. It is used for tracking the fiducial markers attached onto the physical objects. This project also took the fiducial marker detection into consideration at the beginning, However, it was realized that it cannot be used with the FTIR technology and later the plan was given up. Figure 11 shows the Reactable,

Figure 11: The Reactable

4.2.5 Remotable

The Remotable [12] actually does not provide any multi-touch functionality rather than only touch functions. This table looks no difference with the one as that people usually put in front of TV. "It is an interactive table with an integrated

media centre where the surface of the table is a tangible interface with which you can manage music, TV, DVD, lighting etc. The idea with remotable is to make the remote controls superfluous. Remote controls usually have numerous buttons and functionalities that are rarely used. Settings for the TV and DVD player are often done only once, which makes the majority of the controls unnecessary int he daily use. This abundance can be avoided by moving only the most important functionalities to the table. This way the table can also keep a minimalist appearance, which is the intention." from Remotable group. And figure 12 is the Remotable,

Figure 12: The Remotable

This project inspired our project in appearance aspect, because it is really give people a great feel, the quality of the table itself are very well.

4.3 Methodology

Several methodology applied in this project, and the basis method choose for the design process is waterfall model. A description for waterfall model from wikipedia is "The waterfall model is a sequential design process, in which progress is seen as flowing steadily downwards (like a waterfall) through the phases of Conception, Initiation, Analysis, Design, Construction, Testing. The waterfall development model originates in the manufacturing and construction industries; highly structured physical environments in which after-the-fact changes are prohibitively costly, if not impossible. " [13] Figure 13 is the structure of waterfall model.
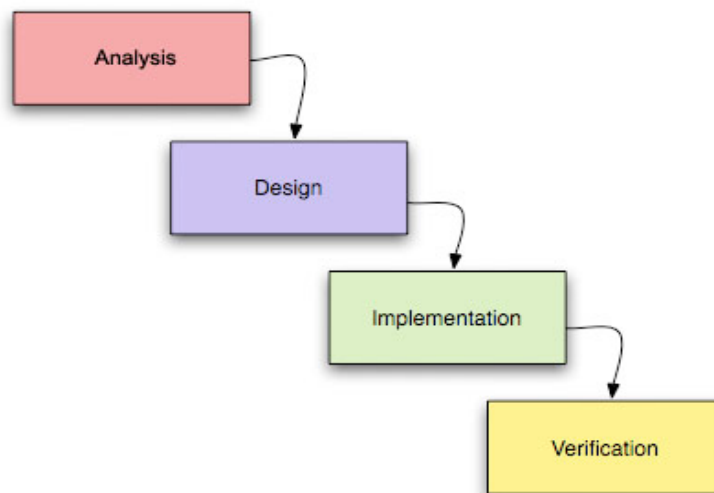

Figure 13: Waterfall Model

Consider the limitation of the project time, also the possibility of coordinating different development both in software, hardware and graphic works. The waterfall mode seems to be the best choice, the advantages of this design cycle model include:

- A linear model and the most simple to be implemented

- Stages and Activities are well defined

- Helps to plan and schedule the project

- Verification at each stage ensures early detection of errors/misunderstanding

Though there are some limitations of waterfall life cycle model should take care about: the biggest disadvantage of this model is that you cannot go back, which means if the previously design phase goes wrong, it might be get very complicated to correct the mistakes, and small change may cause a lot of problems.

The group analyse both advantage and disadvantage of the waterfall model, and finally decide choose it, at the same, in order to help carry out the design process, a time table has been made as figure 14, and its based on waterfall model too.

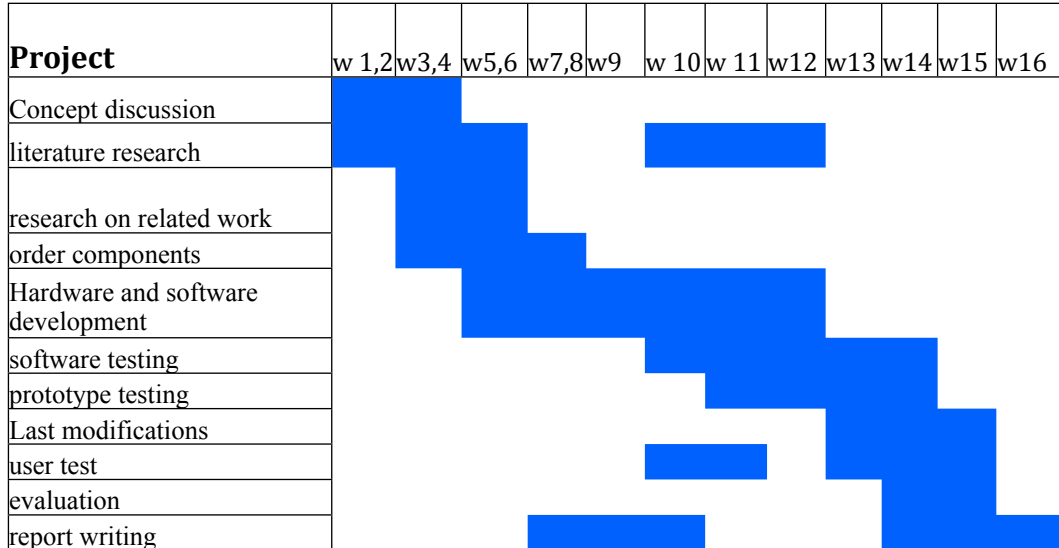| Project	w 1,2	w3,4	w5,6	w7,8	w9	w 10	w 11	w12	w13	w14	w15	w16
Concept discussion												
literature research												
research on related work												
order components												
Hardware and software development												
software testing												
prototype testing												
Last modifications												
user test												
evaluation												
report writing												

Figure 14: Project time plan

In user testing phase, a lot of data gathering work need to do, so there are several method has been applied here.The choice of method depends on what kind of participants involved too, therefore, accordingly to the certain participants and the question itself, three methods [14] have been chosen and they go through in order:

a. Questionnaire.

A questionnaire is a research instrument consisting of a series of questions and other prompts for the purpose of gathering information from respondents. The questions can be design as open or closed as well.

One issue is to understand participants' general background, especially their experience background of the system before participants get start of testing with mediating tools. Since it need a clearly sequence and progress directions instead of collecting too much free ideas and opinions in this step, a alternative choice is semi-structured questionnaire contain both semi open and closed questions.

The below question may appears during the interview or questionnaire:

- *Age, gender, education background.*

- *If he use the multi-touch system before?*

- *Have you tried any similar system before?*

- *If you have tried one or more before, a short description please.*

b. User testing with mediating tools

The first time that mediating tool has employed could be in previously phase. Sometimes when the questions posted during questionnaire, text only seems not enough to describe itself clearly, hence it is very helpful to combine with some mediating tools, sketches, photos or paper draft in order to increase user study working efficiency.

When come into the actual step of user testing, mediating tool may be used in with the purpose of evaluate design solutions. Hence both group and user need a further step of experience for their demands: the group would provide user a roundly and deeply experience of system testing in order to receive a comprehensive and precise feedback from users in next phase; in the other hand, user wish to fully experience the system especially the realistic one in order to help themselves to make a decision of purchase. Therefore, provide the real product or the interactive prototype to the participants to maximize these outcomes.

c. Survey

After the testing, a survey need to be made with participants' feedback. Normally another questionnaire is a good option. The differ with first step is, more open question will be put in this time, the company could be ask like:

- *Which feature/or specific one do you like best, why?*

- *Which one do you unsatisfied the most, why?*

- *What is your most important impression of the table? why?*

After got these feedback from testing, a traditional method which contain 4 steps used as: reducing the data, select out effective information, abandon the one which are not useful; analyze the reduced data using different methods, depending on the different type data, the quantitative and quantitative, applied suitable method for analyzing; identifying and searching, based on analyzing, do research of claims, requirement, causes of problem and etc.

5. Technology

The overview of system can be describe as present a table surface to user with the multi-touch functionality and meanwhile build a direct dialogue between user and the hardware components which hide in the table. Figure 15 shows the architecture of the whole system, as it displayed, the whole system consist of input, output hardware components and software processing components. The mechanism is use projector put application image on the acrylic surface, a IR camera to detect the position of IR lightwave reflection from the surface when finger or other object on the it, the software will process the signal and response the movement and gesture change through the touch, next software will calculate and give the further order to the screen.
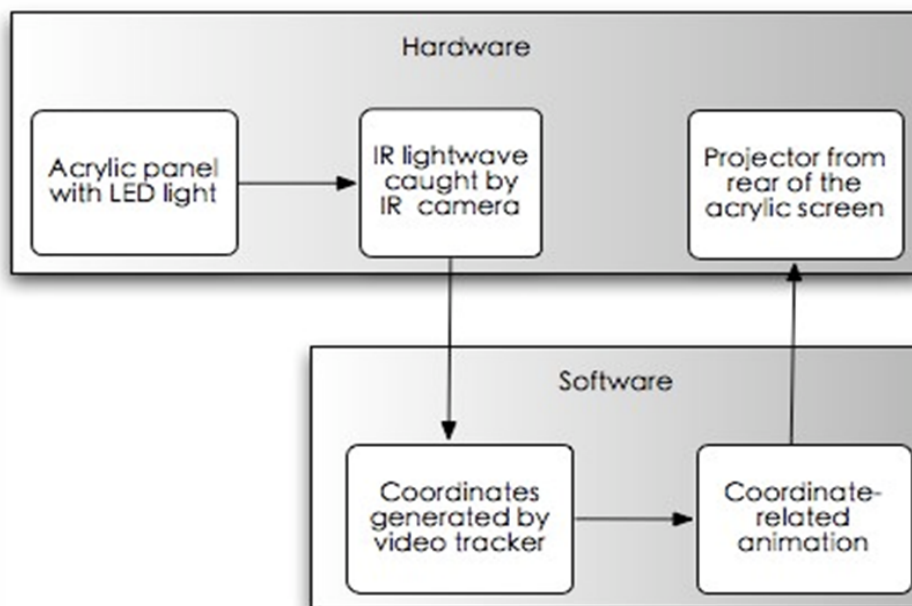

Figure 15: Overview of the system

The key point is connection software and hardware part very well, and ensure the sensitive of the detection, at the same time, software should coordinate related animation by suitable design.

5.1 Hardware development

FTIR and DI are the two basic technologies in hardware development of multi-touch. Although the mechanism of these two technologies are remain the same, use camera detect and calculate the position of IR reflection which triggered by object touch the multi-touch screen, there are still some distinction between them. The main difference is on the method of how to let the IR light can be reflected and triggered by a touch. I will give a introduction in both of them. [15]

5.1.1 Diffused Illumination

In fact, the Microsoft surface is applied the diffused illumination as its technology. As figure 16 shows, a IR camera put in the button, the acrylic surface on the top; there are several IR light in each side and keep sending IR light to the surface, thus the diffuse of the IR light happens, when someone point on the screen, the reflection will be triggered.
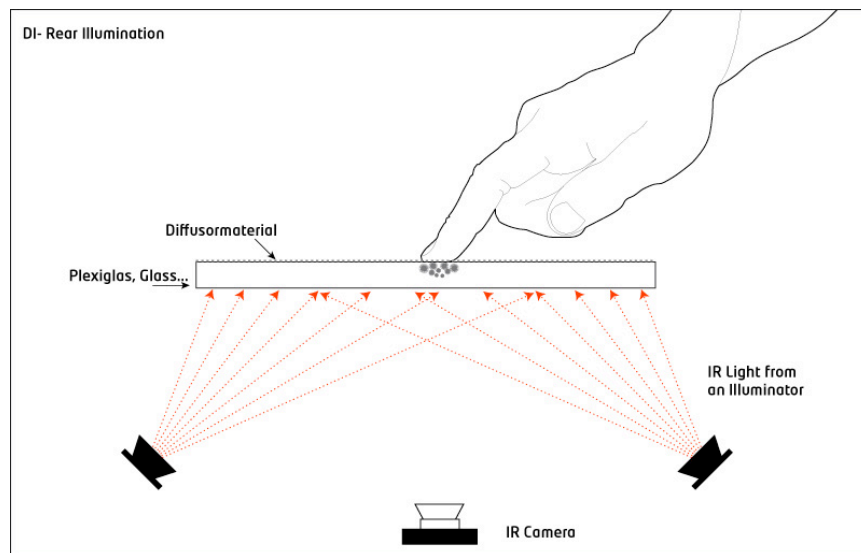

Figure 16: Diffused Illumination

The advantage of this technology contains:

- The wide range of the surface. Almost any kind of transparent media could be choose as the screen.

- No restrict rules of the IR light position, you can put them based on the spaces that you have in the table. As long as the IR light could reach the screen, the reflection will happen successfully.

- The most important different between DI and FTIR is DI can recognise the objects other than finger much more easily

The most disadvantage are:

- Brightness sensitive. For example, if the environment light is too bright, the detection of the touch action may fail. FOOBAR employed this technology, so it is recommend that choose FOOBAR for a night bar club rather than a bright cafe house.

- Since the illuminate of IR light may not applied very evenly, the blobs triggered by touch may less clear than the other technology.

5.1.2 Frustrated Total Internal Reflection

This technology is the one that employed in Jeff Han's project. And it has been developed a little bit early than the Diffused Illumination technology. Figure 17 shows how it works, as you can see, screen and IR camera remain the same, but instead of IR light beamer, there are numbers of IR led will be put around the screen, thus to let IR light going into the screen and keep locked in it. To enhance the touch action, a layer of silicone rubber will be put on the screen.
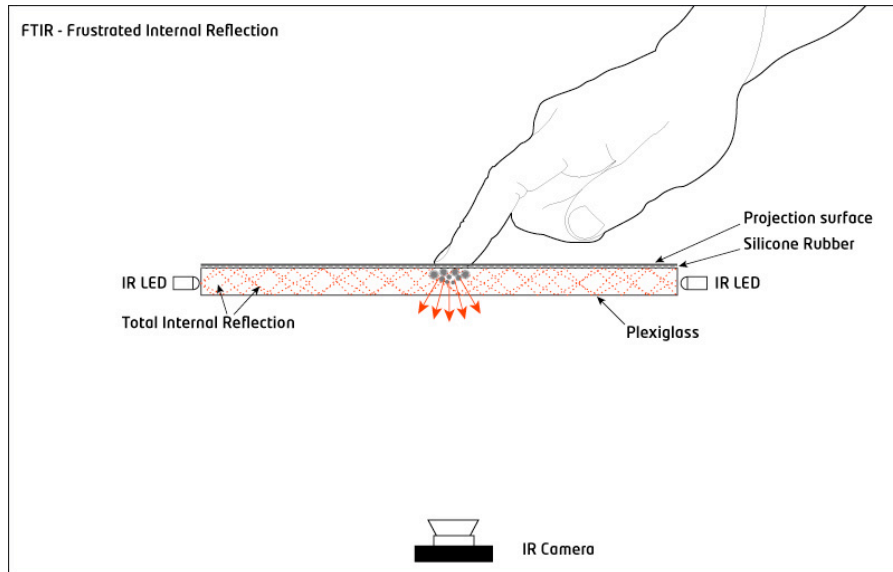
Figure 17: Frustrated Total Internal Reflection

A reference from Jeff Han can't be any more fit here: "When light encounters an interface to a medium with a lower index of refraction (e.g. glass to air), the light becomes refracted to an extent which depends on its angle of incidence and beyond a certain *critical* angle, and it undergoes total internal reflection (TIR). However, another material at the interface can *frustrate* this total internal reflection, causing light to escape the waveguide there instead"

The advantages of FTIR include:

• Lower requirement to the ambient light, therefore extend its usage to a much more wider range.

• Though it can only detected the blob triggered by fingers, but it is very clear on this sort of detection, both the position and gestures

• The cost might be lower in implementation

And the disadvantages could be:

• Restricted IR light sources position. The IR led must be put around the screen's edge evenly in order to provide a balance lighting effect. Even so, there still

might be different sensitive level of IR light in edge and centre of the screen.

- Restricted media of touch screen. Only the acrylic acrylic glass or plexiglass can be used for the surface

- Extra layer like silicon rubber may need applied during the project, and it is not easy to make it work perfectly.

After doing the literature research as well as learnt about the related work, the decision is to choose FTIR as the one in the project. The consideration include these issues:

- Budget and cost

The money problem alway need to be considered, and sometimes even need to be put in primary position. Although the FTIR requires the unique touch screen of a acrylic or plexiglass, the total cost of DI technology may still higher than FTIR, especially the IR light source may not easy to select as well as the IR camera which suitable in DI technology.

Meanwhile by think about the ordering shipping problem, since some of the components may order through oversea shops.

- Implementation

A comparison analyse has been carried out between DI and FTIR technologies. As it mentioned above, the DI technology is sensitive to the ambient light. Once the project applied DI technology, the usage of the table might be narrowed, and the intention idea is about put the table in school, railway station, airport and so on. All these place are normally with a very brightness environment, the DI technology seems can not work at all.

In another side, the application focus on human interaction with the table, so finger touch is the most event during the application running, it is not necessary to detect blob triggered by other object at this moment, one most advantage of DI technology does not required here.

5.1.3 Hardware Components

In this phase, more details of every hardware components which used in the project will be represented. I will start form the touch screen, there are several layers consist the touch screen in sequence of protection Layer, projection screen, tracing paper, silicon rubber and the acrylic glass. Due to variety situation in implementations, not all these layers are forced to applied, but at least one layer should put on the acrylic glass in order to enhance the performance of the the touch screen.

• Projection layer / Projection screen

"Projection screen / projection layer is an installation consisting of a surface and support structure for displaying a projected image for the view of an audience" But different from the normal one which used for get image from the projector on the wall, the Layer used here is in combination with such as acrylic glass and a blocking filter to block stray light, in order to get the best effect of IR reflection caught. But during the experiment, this kind of black projection layer seems hard to fix on the screen, and the outcome by applied it into the project not as expected, finally, this layer abandoned in experiment period.

- Tracing paper

A tracing paper is used as the second layer on the top of silicone rubber, it normally put between projection paper and silicone rubber to guarantee there will be no sticking happens between projection paper layer and the silicone when getting blobs by human finger press on the screen, or any object put the screen.

One problem is that tracing paper may only work good with particular silicone layers. I have tried serval kind of tracing paper as well as many kind of silicone rubber layer, it is hard to avoid the sticking issues at all. But alternative choice is to use sort of paint paper that sold in normal paint shop to instead of it. There is a little bit difference in thickness of them, but anyway, the paint paper works and the cost also lower.

- Silicon rubber layer

The intension of silicone rubber layer is about improve the touch event much more clear, so the receiver may easier to catch every touch event and calculate the blob position correctly at the same time. In the situation of multi-touch event are much more seriously, since the IR reflection may differ due to the pressing strength, the silicone creates an amplified effect to help blob formed.

Silicon rubber layer is the most tricky one in the whole project. The most suitable kind for making a multi-touch screen is one named *sorta clear 40*, and it cost 800kr per kilogram. Due to the budget issues, it not possible to buy this kind of specially produced silicon rubber lay for multi-touch screen, thus I put a lot of effort on test so much different silicon rubbers.

Then I pick the alternative, buying silicone rubber normally used for seal windows from local shop. The model is Sikasil-E, and mixing with toluene of Benco 14, the portion has been test for several time in order to get the perfect

transparency level of the silicone rubber. The disadvantage of this self made silicone rubber is that it takes up to 15 days to cure.

• Acrylic

As it mentioned above, finally I choose the technology of FTIR, then acrylic glass or plexiglass would be the only choice of the multi-touch screen. This acrylic glass is order from a local factory, the size is 720mm*540mm*10mm, I choose this size because it need to be fit the 4:3 ratio of the projector's image as well as the IR camera, another reason is I want it as big as a cafe table and allow up to 4 people play it at same time. There are also rules for thickness of the screen due to the fact of surface need to be thick enough to lock the IR light inside the surface, in order to achieve this, the edges of the surface haven polished too.

• IR led set

IR led set is the source of IR light. The model picked here is Osram SFH485P, and the angle was appropriate for lighting whole surface from the edge to the centre of the surface, so hopefully it does not require a very hard press to trigger the blob, and the price are acceptable too. Figure 18 shows the method that how these led sets has been connected:
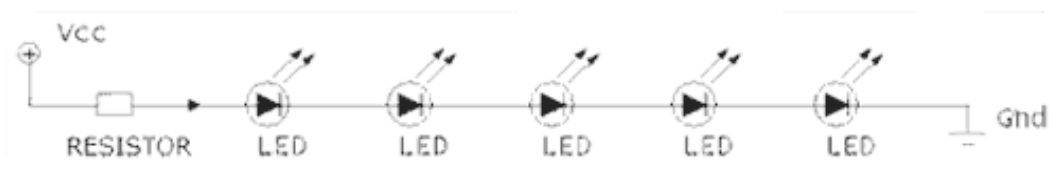

Figure 18: IR led set

• IR camera

IR camera is one the key component in the whole project. It is used for track IR light that reflected from the surface on the top when any touch event has been triggered.

The type of the camera used here also has been applied in many other multi-touch project, FIre-I board camera. It is one-board operational 1394 400Mbps camera, complying with IIDC 1.04 specification for industrial uncompressed VGA picture acquisitions, the latest Texas Instruments chipset and ICX098BL CCD sensor provide high quality subassembly for OEM use. The unique feature include, uncompressed picture up to 30 fps, square pixels, progressive scan 1/4" CCD, high horizontal and vertical resolution, low power consumption1.0w max. Figure 19 shows how it look like:

Figure 19: IR camera

By calculating the distance from screen to the button of the table, it is ensure that the camera can get the image at the hight of our table, and that's the reason why choose the original 4.3 mm type lens instead the wide fisheye lens.

- Band pass filter

IR light is the only light source that needed in blob tracking, all other ambient light should be eliminated, therefore a filter is required for pass those kind of light in order to get purely IR light and prevent the influences to the IR camera from ambient light.

There is original appendix filter of the IR camera on sell, but due to this extra cost, an alternative is use exposed film, and it is the most cheap and easy method to get the same outcome.
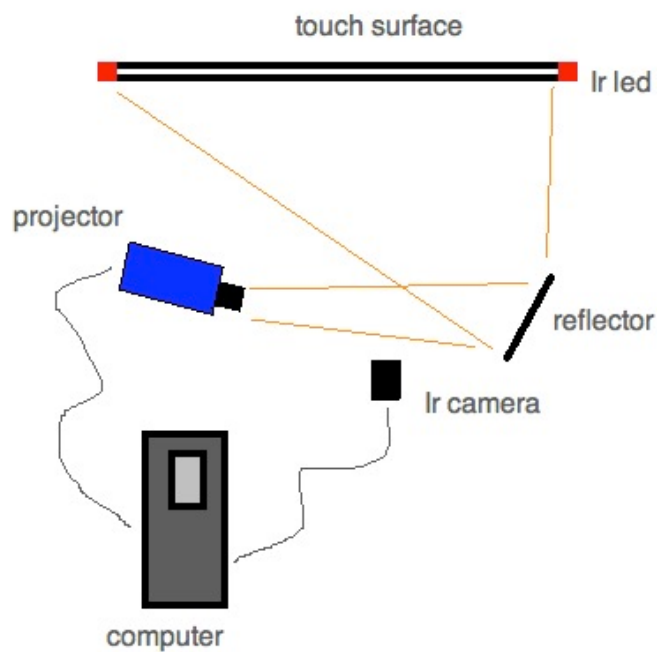
5.2 Hardware Implementation

Figure 20: Hardware structure

The figure 20 indicate the briefly framing work of the hardware system. Table surface which as the multi-touch screen on the top, several sets of IR led around the surface, a projector will be hang on inside the table and project the image to a reflector or a mirror, the reason to use a reflector here is intend to reduce the

distance that projector acquired for the suitable size to the screen. People will see the image which transfer by reflector, and start to play the IR camera underneath keep tracking the touch blob. Both projector and IR camera will be connected to a computer that put inside table as well, computer will running the application and give the image to the project, at the same time, computer receiver the signal from IR camera, and computer will give the new image to projector by the software processed the datas.

5.2.1 Table design

The woodwork seems kind of non related work to us whom in program of Information Technology, but it is part of the project, and even same important with other works since the quality of the table would influence the hardware system implementation.

The Remotable project gave us a lot of inspiration, I really want to build a nice looking table. The software used for designing the table is Sketchup [16] from google. There are some issues involved while design the table:

- The table should be looks like a ordinary coffee table or bar table, as a decoration and can be put in the place of airport, school, office hall, railway station and so on.

- Capable with the framing work of the hardware system.Which means it should big enough in length and width to put all the hardware components inside, otherwise the concept of decoration will be useless.

- Budget issues and ability issues. Think about the cost for build such a table as well as if it could finished in a limited period by ourselves.

Follow issues above, I draw the sketch picture as figure 21 looks, as you can seen, multi-touch screen in the right middle place, down to about 30mm form the wood frame surface to ensure its stable, the IR led is put inside the wood frame and around the whole touch screen. At last, the support as table's legs is empty, IR camera, computer, projector will be put inside.
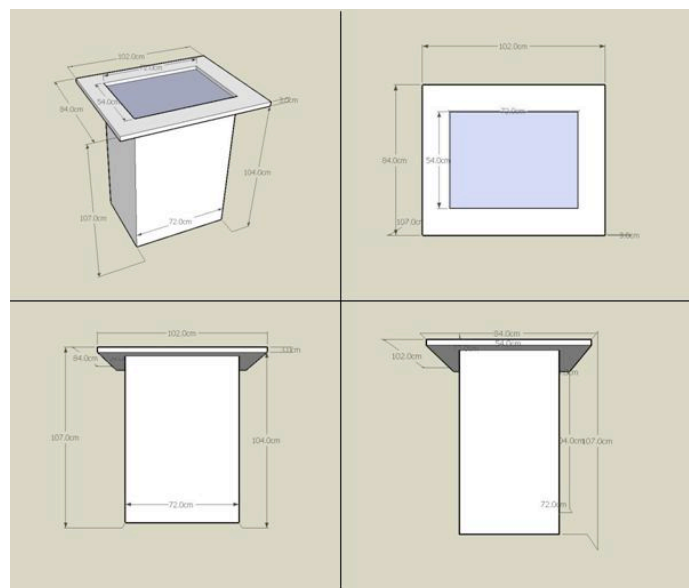

Figure 21: Sketch paint of table

Figure 22: Sketch paint of table

Further, I use the Sketchup generate the dimensions of the table as the figure 22 and figure 22 shown above.

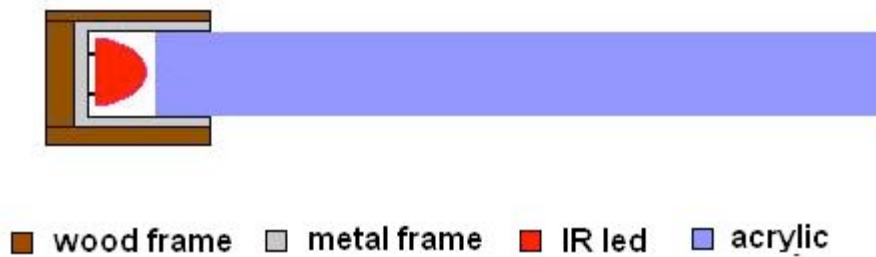*5.2.2 The IR led sets design*

Figure 23: Frame work of led sets

I have tried several different way to hold the IR Led aound the screen. And figure 23 is the final solution for the project. As you can seen from the picture, two frame hold the acrylic actully. The inside gray one indecate the metal frame, I bought this frame from home decoration shop, and these frame inicially designed for furnitures. The metal frame hold the glass very stable, and there are some spaces left for the IR led sets. The outside frame is the wood, and tow purposes of this design, one is double ensure the stable of the arcylic glass, the other one is artstic, make it is a woodern table.

PCB board has been cut into slim and long pieces in order to fit the spaces of the metal frame, there 30 led toally in two sets, 15 on each of the longer sides of the glass with a distance of 40mm in between. The criticle point is to make the IR light evenly come into the acrylic glass and cover the surface as much as possible, especially need pay attention in the other short side of the surface since there is no Led light source directly come out.

5.3 Application development

What kind of application would be attractive? And how does the application could let people stay to play? These are two of the representative question in the application design phase. Brainstorming method applied here again in order to generate some new scenarios, the idea is to find some feature different from the project in related works and enrich the multi-touch application.

5.3.1 Concept design

The basis idea is about touch. There should be something appear when someone simply touch the surface, thus that person will attract by the feedback/reaction and know he has done something, the feedback should quickly, obviously, and attractively. The outcome of discussion is use colorful circle here, whenever one person touch the surface, a colorful ring will appear around the touch point hence react the touch event.

This kind of visual effect is just the beginning, the final idea is to make some application that can really interact with people, so the pet design comes. As it mentioned in previously phase, the pet application is focus on interaction with human. Therefore the theory of the application design as:

- The interaction aspect. The behaviours design of the pet should focus on make people feel that they are controlling the pets. So at the beginning, pet are just floating on the surface in model of sleeping, and as soon as they have been touched by people, they will be wake up. After they waked up, there will be different emotion and face looking randomly showing to the people. For instance, it will be angry and try to fighting when some one press on and stop it.

- The multi-touch aspect. For the purpose of demonstrate features of multi-touch. The pet should be designed to fit these features. Therefore, they should able to be drag, resize, rotate and so on.

5.3.2 Software tools of application development

Numbers of softwares involved of the application developing process, At the very begging, the author choose software named VVVV [17] as the developing tool, the best feature of this toolkit is its real time 3D graphic rendering, but after deeper study with this software, much more problem and difficult appears, especially in connecting the software to the multi-touch surface, it lag with library and existed database, therefore Flash AS3 and Touchlib become the main developing software for the project.

Beside application development itself, another part of software is about to achieve touch blob detection, and how to read and process the date of the touch event. A seamless communication between multi-touch surface and pet application is the core problem in software development aspect.I will introduce the software like Flash and Touchlib, etc in below.

- Flash ActionScript 3.0

An official description of Flash AS3 from adobe is "ActionScript 3.0 is a powerful, object-oriented programming language that signifies an important step in the evolution of the capabilities of the Flash Player runtime. The motivation driving ActionScript 3.0 is to create a language ideally suited for rapidly building rich Internet applications, which have become an essential part of the web experience.ActionScript 3.0 now further advances the language, providing superb performance and ease of development to facilitate highly complex applications, large datasets, and object-oriented, reusable code bases. With ActionScript 3.0, developers can achieve excellent productivity and performance with content and applications that target Flash Player." One reason to choose this software is because author has develop experience with Flash, meanwhile Flash is object oriented program, unlike VVVV apply visual programming.

- Touchlib

A lot of project applied Touchlib as their developing software, so there are many information related in multi-touch, DI, FTIR and so on. Touchlib is a software library that could be applied for multi-touch applications, and it provide numbers of demonstration application which developed both in C language and Flash. The mechanism of Touchlib is detect blobs simultaneously and then transmit these touch event to the computer. Some of the demo application in Touchlib's library also inspired this project, for instance, the application that allow people use different gesture to interact with picture and photos, and by learnt of some visual effect application, the project has been improved as well. Figure 24 shown the situation of simulating,
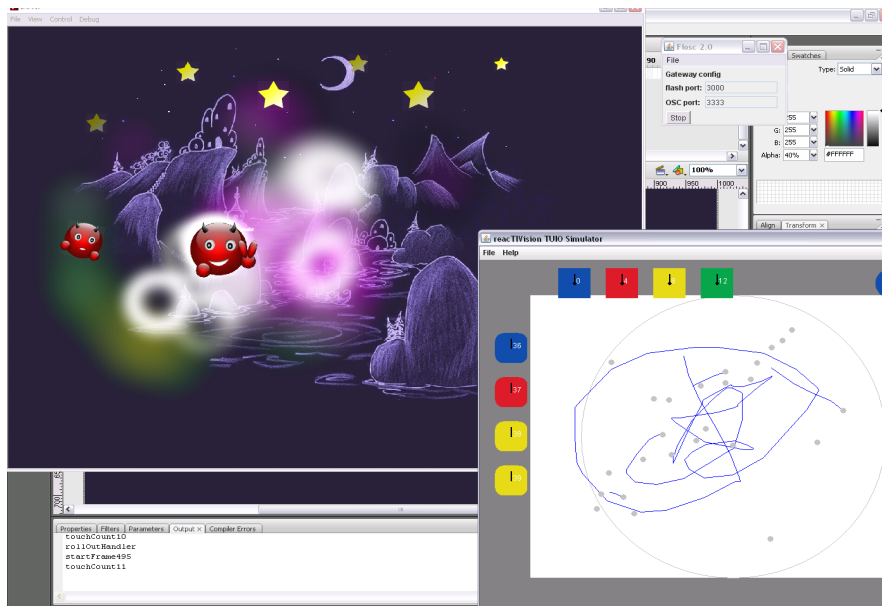

Figure 24: Application simulating

- TUIO Simulator

TUIO [18] is a simulator based on JAVA application platform, it provide a simulated platform like environment thus user could continue the testing work without real multi-touch system. Figure 25 is the mechanism of TUIO
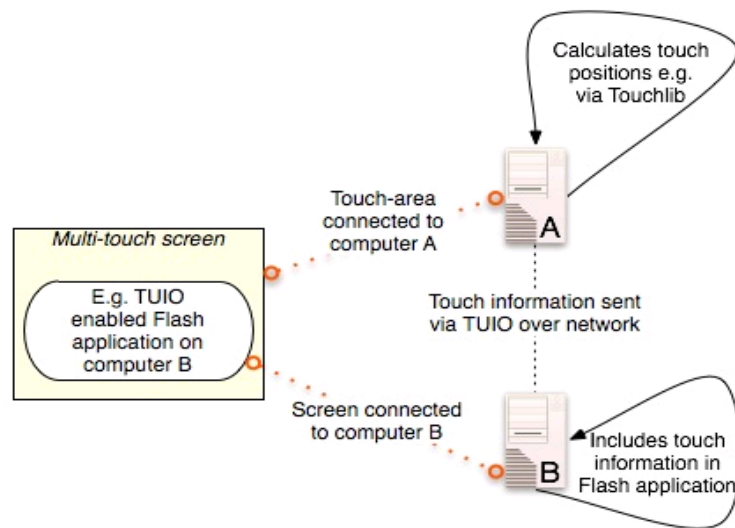

Figure 25: Mechanism of TUIO

a. Multi-touch events has been collected, information and data send to computer A which is connected to multi-touch hardware.

b. Computer A wraps the receiving data from multi-touch hardware into TUIO data, and sends the data to B via network.

c. A Flash application runs on computer B, it retrieve the TUIO data from A within Flash application.

d. Multi-touch screen display Flash application on Computer B

In interactive table project, only one computer will be used

• Flash Open Sound Control

Also refer as FLOSC [19]. It allow Flash can be connect to the software and send OSC date. It converts the OSC (UDP) data into XML (TCP), since Flash client cannot read UDP data from OSC.

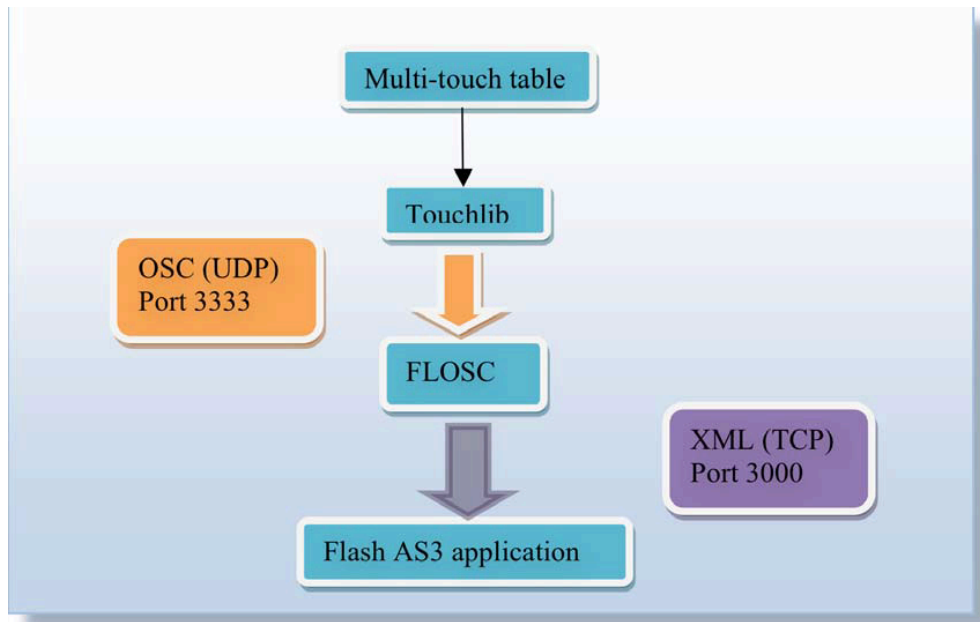### 5.3.3 Software communication frame work

Figure 26 is the software communication frame work

As the figure 26 shown, the software communication frame work will be like this, Firstly, touch event found from the multi-touch surface by Touchlib, and then send captured data and information into TUIO, in next step, processed data send to a Flash application, the FLOSC was used to convert OSC data into XML, for flash application cannot read UDP data but TCP.

5.3.4 Configuration

Calibration is one significant issue both testing and configuration step. Whenever the position of surface and camera has been changed, a calibration work should be done in Touchlib in order to coordinate initially touch spot. After each calibration, the IR camera should read the position of fingers correctly. Figure 27 is the screen shot of a calibration work,
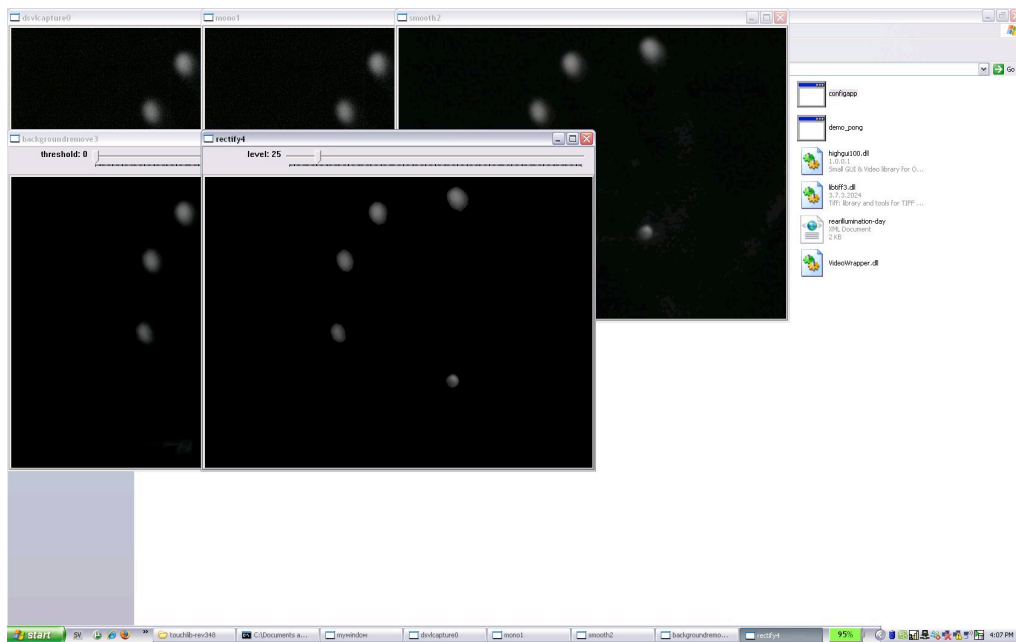

Figure 27: Calibration

5.3.5 Graphics works

The last work in application development phase is graphic design. Since the basic idea of the application is let people have fun and play with the pet, therefore the pet should looks like lovely and mischievous. Firstly, red colour would be a good choice, and then the idea of "a little mischievous red evil" come up, though it is not real evil, just a cute little boy-like pet.

The next move is design variety emotions based on the previously scenario, some learning have been carried out through the pictures from some instance chatting

software. Nine face expression has been done such as sad, angry and smile etc. The idea is to prevent the possible boring after people play with a single emotional pet. All these design increased the entertainment of the application and made good use of the multitouch technology as well. The pet was design in a way that it needed attention all the time, if the user did not interact with it after a while it went to sleep, and if the user touched it, it woke up again. In this way, pets behaved more intelligent and users should feel they were more controllable. Figure 28, shown some part of graphic work. All the works make by Photoshop. [20]

Figure 28: Graphic design

6. Testing

Testing work has been carried out in several phase. When the prototype of multi-touch surface not ready, testing work carried out as internal testing work since the software could not combine with the hardware system yet, so the testing taken with Touchlib and in the environment of a simulating interface.

When is application development reach the end, and hardware implementation getting finished, the first prototype ready to go, and the testing work comes to the public. And this is the last phase of the whole development process.

The idea is invite some people to try to play the table, and let them find out bugs during the time, meanwhile take the method that mentioned in methodology phase to record necessary data from the testing work.

Based on the result from those testing, adjustment will be done to eliminate bugs and improve both software and hardware, in order to reach a better final outcome.

7. Evaluation

After the project is done, evaluation work should execute as follow:

Check the basic criteria

- Looks like an coffee table

- Multi-touch feature working on the surface

- Many people play at one time

- Visual effect implement

Check high level criteria

- Variety finger gesture could be recognised by application

- Application running without bug and stable

- User willing play the application long time

- Table made with a good looking

- Cost keeping lower

The criteria should be set before the project started, different criteria could be set to help evaluating. For example, in basic criteria of visual effect implement, evaluation work must judge how much visual effect has been done, one pr many? Also the situation of implementation. And about "table made with a good looking" of the high level criteria, the judgement should be make compare with the table product that sold in real shops, if the table of the project have a same good quality as the retail product.

In this project, the final outcome achieved all basic criteria: it is with coffee table looking and multi-touch functionality, the table allow multi user to play at same time, beside application, some visual effect does work.

About the high level criteria, the outcome does not fully fill them. The cost keep in a acceptable level, the table has a good looking, and variety finger gesture could be recognised by the application. But there are still some bugs during the application is running, for instance, sometimes the pet are hard to catch or stop, and resize function is not very sensitive. Further, people shows great interesting with the table and application at the beginning, after 10-20 minutes, they seems feel kind of boring, therefore the entertainment of the application need to be improved. However, some unexpected results were noticed, they may make adjustment in future works.

8. Discussion

This project brought a lot to myself. From the very beginning with question as: "Is this topic can be a thesis project?", "Am I capable to do such a project?", " Does it hard to get multi-touch done?", to the final prototype is done. I learnt so much from it, some of them I would emphasis are:

- Make a plan, either a time table or a project schedule. It is really important, and a good plan will very helpful to the work and increase the your efficiency.

- Be prepared for risk, for unexpected problem, for everything. Problem always appear without any predictable sign, though the project is a process of problem occur and solving, I think a well plan can help to avoid some unnecessary mistake.

- Literature review and related work research are very important. A good work on them may let you avoid a lot of problems and might lead you to the correctly direction very soon.

If turn back to the beginning of the project now, the outcome would different, and might better. But anyway, this is a great experience for me.

9. Future Works

Technically, there are lots of work to do such as: improve the quality of table itself, reduce the bug of the application and make it running more stable, and also lower the cost of hardware.

When it comes to the word of "future", more idea comes out immediately:

• A customized looking retail product?

• More applications, more fun?

• Be a working partner?

• Be a game device?

• Or be a part of you life?

Beyond technical aspect, the 5 question above brings kind of business idea to me. In fact, I would like to start think about whether the multi-touch technology will really bring the new life to such a product. However, the table still as a platform, the real future of the multi-touch technology will rely on the better applications.

10. References

1. **FTIR** Low-Cost Multi-Touch Sensing through Frustrated Total Internal Reflection. *Han, J.Y.* [Online] http://www.cs.nyu.edu/~jhan/ftirsense/

2. **Touchlib.** NUI Group open source. *Wikipedia.* [Online] http://nuigroup.com/touchlib/

3. **Flash AS3.0.** Flash actionScript. *Adobe.* [Online] http://www.adobe.com/devnet/actionscript/articles/actionscript3_overview.html

4. **Touchscreen.** Touch teconolgy. *wikipedia.* [Online] http://en.wikipedia.org/wiki/Touchscreen

5. **Multi-touch Pad.** Macbook. *Apple.* [Online] http://www.apple.com/mac/

6. **Self-make multi-touch platform**. *turkey tek.* [Online] http://www.instructables.com/id/Interactive-Multitouch-Display/

7. **D.I.** Diffused illumination. *wikipedia.* [Online] http://wiki.nuigroup.com/Diffused_Illumination

8. **Microsoft Surface**. *Microsoft.* [Online] http://www.microsoft.com/surface/en/us/default.aspx

9. **FooBar**. *Touchtech AB.* [Online] http://www.touchtech.se/Home.php

10. **iBar**. *Intelligent surface system.* [Online] http://www.i-bar.ch/info/

11. **Reactable**. *Music Technology Group.* [Online] http://mtg.upf.edu/research/interaction

12. **Remotable**. *Remotable group.* [Online] http://remotable.se/

13. **Waterfall model**. *wikipedia.* [Online] http://en.wikipedia.org/wiki/Waterfall_model

14. **Statistical survey**. *wikipedia.* [Online] http://en.wikipedia.org/wiki/Statistical_survey

15. **Mechanism of FTIR&DI**. [Online] http://sethsandler.com/technology-multitouch/hardware/ftir-and-di-how-they-work/

16. **Sketchup**. *Google group.* [Online] http://sketchup.google.com/

17. **VVVV**. [Online] http://vvvv.org/

18. **TUIO**. A Protocal for Table-Top Tangible User Interfaces.*Martin Kaltenbrunner, Ross Bencina.* [Online] http://mtg.upf.edu/reactable/pdfs/ GW2005-KaltenBoverBencinaConstanza.pdf

19. **FLOSC**. *benchun.net.* [Online] http://www.benchun.net/flosc/

20. **Photoshop**. *Adobe.* [Online] http://www.adobe.com/products/photoshop/ photoshop/whatisphotoshop/