Implementation of 3D Graphics Engine Using LPC1769 CPU Modules

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Abstract

The Following project aims at displaying 3-Dimensional images on Liquid Crystal Display Module by interfacing it with an LPCXpresso 1769 Micro Controller. In this report we share our experience in achieving the above task.

First, we implemented the hardware system such that two LPC modules interface with each other as master and slave. Then a 3-Dimensional solid cube is displaying 3D coordinate system in which all the three axes are of different colors. The 3-Dimensional cube has three surfaces with three different patterns This report also describes the hardware and software requirements in order to establish the interface.

1. Introduction

The LPC1769 is an ARM Cortex-M3 based microcontroller for embedded applications requiring a high level of integration and low power dissipation. This module has USB, UART, SPI, I2C ports that helps us to communicate with it effectively. We make use of SPI protocol to communicate with the LCD module. In our project we are going to use SPI port 0 in both the program and the hardware connections for communication purpose. Figure 1 portrays the same.

The LPC1769 module is connected to the CPU via USB cable which powers up the module. The LCD and another LPC1769 is connected to this port by connecting the appropriate pins with the SPI port that was used earlier (port 0) which we are using for communication. When an USB is connected to the LPC 1769 module the LCD lights up, portraying that the connections made are correct and the Module is ready for communications with the LCD.

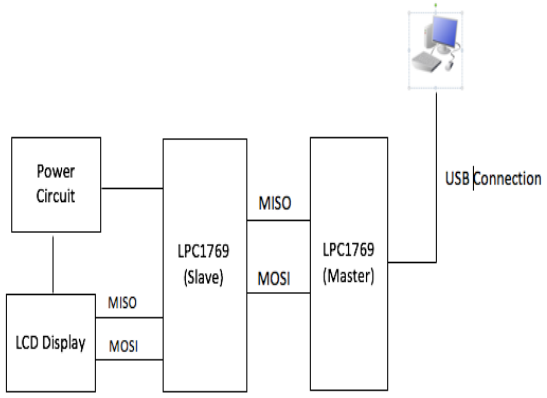

Figure 1: Block Diagram of the System Setup

2. Methodology

First, we build the entire circuit on the wire wrapping board. This interface is used by the CPU to send a data buffer to the module. The data is sent in the form of an opcode and dummy bytes to the external LCD which is connected to the LPC 1769 module. The opcode and dummy bytes initialize the LCD. The module then sends the data and opcode which is received from the CPU to the LCD to display the required 2-Dimensional images images such as a line, square, tree, background color and also display 3-Dimensional images. The Communication between the LCD and the LPC module happens serially. The LCD is connected properly to the CPU module to complete the communication. The SPI port of module and LCD must be defined and initialized properly.

2.1. Objectives and Technical Challenges

Following are the objectives and the challenges that we would be approaching in our project:

1. To build an interface circuit efficiently on a wire wrapping board using the external LCD.
2. Interface the GPIO pins.
3. To build a power circuit using a voltage regulator to output 5V, to drive the entire circuit.
4. To develop a program which initializes the LCD and perform all the tasks associated with it.
5. To develop a program to display a Line Segment on the LCD display.
6. To develop a program to create and display 10 squares of different sizes and rotate the squares by reducing the lengths of it by 20 percent at each iteration.
7. To develop a program to display a tree and convert it to display a thick forest.
8. To develop a program to display 3-Dimensional Coordinate system in which three axes have three different colors and design graphic engine logic display a cube which has three different patterns on each of its surfaces.

2.2. Problem Formulation and Design

The Project can be broadly divided into 2 parts, one being the hardware and the other being the software requirements. Both of these topics are explained below:

2.2.1. Hardware Requirements

In the hardware requirements, the power circuit is built on the wire-wrapping board using the resistors, capacitors, LED (Light Emitting Diode), switch and LM 7805 voltage regulator IC. The circuit diagram for the

same is shown below in figure 2. The output voltage is checked across the LED and the Ground using a digital multi meter and ensured that the required output voltage is achieved.

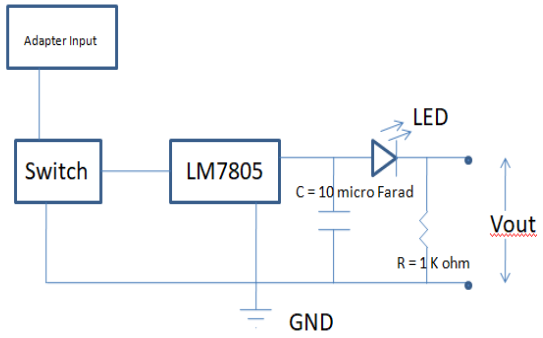

Figure 2: Power Circuit Block Diagram

After the power output is checked we then build the interface between the LCD and the two LPC modules. Figure 3 is a block diagram portraying these connections. Figure 3 also shows the port numbers and the pin numbers that are used for the sake of connections.

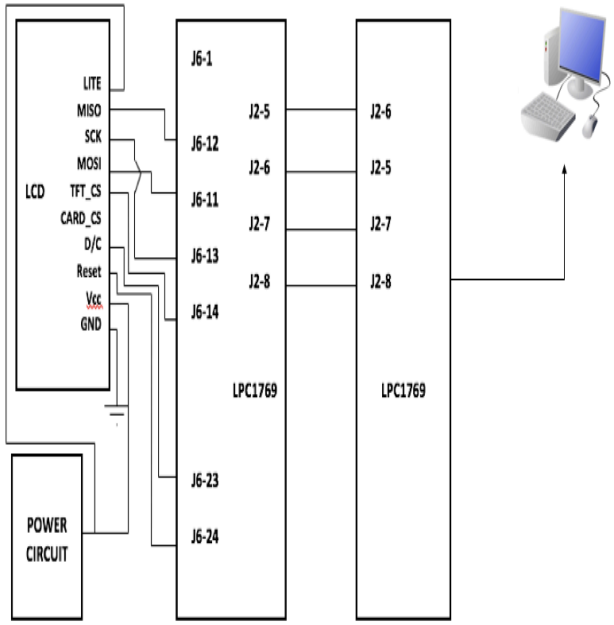

Figure 3: Block Diagram with all the Pin Number. (SPI Connections)

When we join the Figure 2 and Figure 3 we get the complete circuit and the module. Figure 4 shown below is the complete setup of the System on the wire wrapping board. Note the following is an actual picture of the circuit that has been built. The Second LPC module is used as a master where the LPC module connected to the LCD is used as slave.

A fair amount of space has been left for Flash Memory Debugging purpose. This part will be implemented during the second phase of the project.

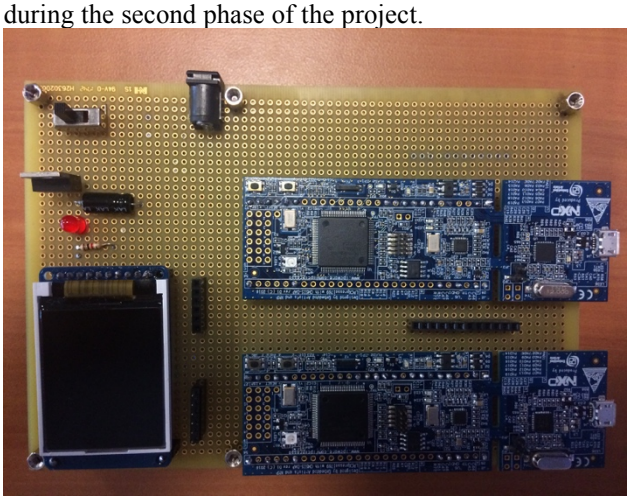

Figure 4: Complete Circuit on the wire wrapping board

Once all these connections are established a thorough check is done with the digital multi meter. Before implementing the software side and the USB from the Computer is connected to Mini USB port using a USB 2.0 cable to check if the LCD lights up. Figure 5 shows that the circuit is ready for debugging and we can move on with the software implementation.

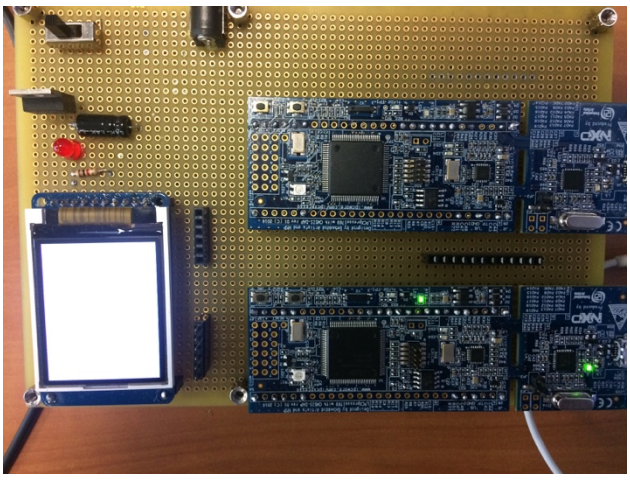

Figure 5: LCD glowing as soon as the USB is connected

2.2.2. Software Requirements

We need to build the code, debug the code and dump it onto the LPC 1769 module. For this purpose we use MCUXpresso IDE version - v10.1.1_606. The Software requirements involves initializing the LCD module, usage of Adafruit library for transmission of data buffer to LCD and polling the GPIO pins for external interrupt.

We make use of a drawline program which is already implemented by the graphic library of Adafruit LCD display. We import this module onto the IDE along with the GPIO project and LPC1769 patch that has been provided. After importing all these projects the build all function is used in IDE. Once the all the project is built we then place a connection between the LPC Module and the Computer. The system then detects the LPC Module.

After the Module has been detected we do a debug of the code. Figure 6 shows the output attained when the drawline project has been dumped on to the Microcontroller. With this we are ready to dig in to the main section of building the code and get our desired output that is to display 2-Dimensional images on our LCD screen.

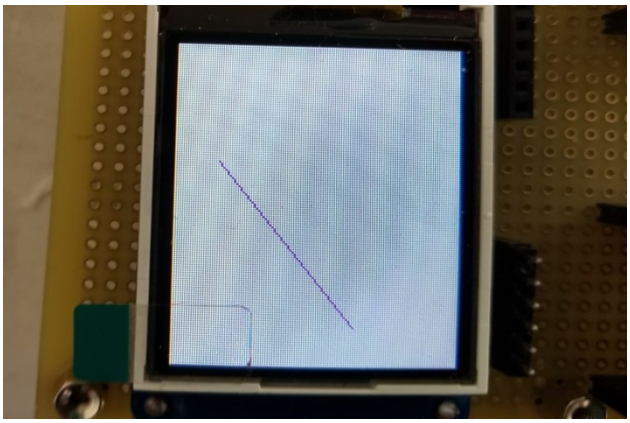

Figure 6: Displaying the draw line project by using the graphic library of Adafruit LCD display

2.2.3. Formulas used for calculation purpose

With the hardware and the software in place we are ready to move forward with our implementation part of the 3 Dimensional images on the LCD screen. We use certain vector concepts to attain our main objective. Below are the plans to design the patterns such as rotating squares and trees.

2.2.3.1. Rotating Squares

Firstly a square is connection of 4 lines that are equidistant from each other. Hence we first draw four lines on the LCD starting on any coordinates with any size. For the rotation part we use a 2D vector concept with the below formula.

P(x, y) = P_1(x_1, y_1) + lambda * (P_2(x_2,y_2) - P_1(x_1,y_1))

We try to decrease the length for each iteration by 20% hence making lambda to be as 0.8.

Once the points of the 4 coordinate moves the draw line function is called each time for these points. This would hence seem to be like rotating. This is carried up to 10 levels and then repeated for 10 different sets of squares.

Figure 7 shown is an example of one such square.

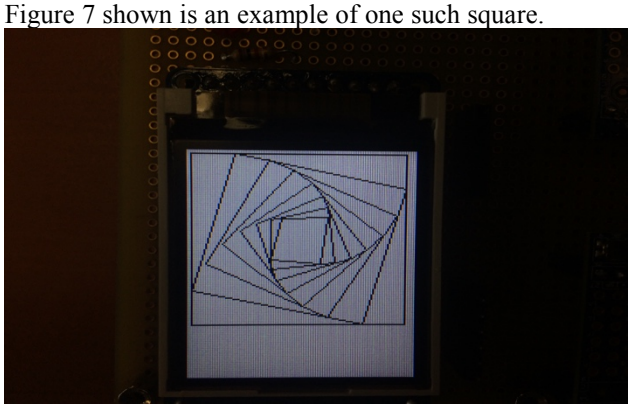

Figure 7: Displaying a single square that is made to rotate up to 10 levels.

2.2.3.2. Tree

Same formula is being used to generate the next coordinates in a tree. The difference here is to the number of levels that is being built and the angle at which each branch has been moved to. We then repeat this process to build up to the desired height.

The same function is called upon for spreading the tree throughout the entire display to make it look like a forest.

Figure 8 shows a sample tree that has been implemented with a sky on the back ground.

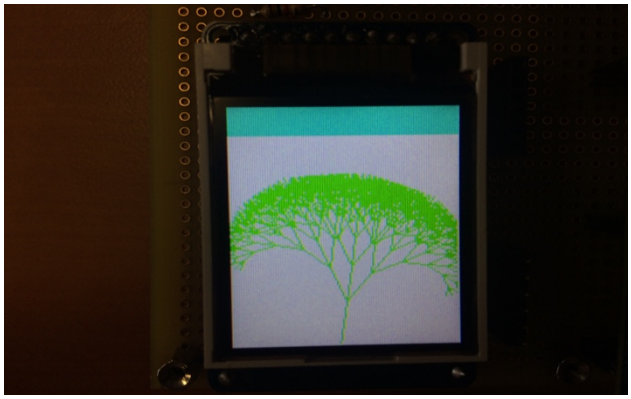

Figure 8: Display of a sample single tree.

2.2.3.3. Conversion of 3D points to 2D points

// xWorld, yWorld, zWorld are from world Coordinate System
// Ex, Ey, Ez are the Camera Positions

theta = Ex / sqrt((pow(Ex,2) + (pow(Ey, 2))
phi = Ez / sqrt((pow(Ex,2) + (pow(Ey, 2) + (pow(Ez, 2))
row = sqrt((pow(Ex,2) + (pow(Ey, 2) + (pow(Ez, 2))

xPoint = (yWorld * cos(theta)) - (xWorld * sin(theta))
yPoint = (zWorld * sin(phi)) - (xWorld * cos(theta) * cos(phi)) - (yWorld * cos(phi) * sin(theta))
zPoint = rho - (yWorld * sin(phi) * cos(theta)) - (xWorld * sin(phi) * cos(theta)) - (zWorld * cos(phi))
xScreen = xPoint * Distance / zPoint
yScreen = yPoint * Distance / zPoint

x2dPoint = xDiff + xScreen // xDiff and yDiff are points taken or hard coded
y2dPoint = yDiff - scrn_y

3. Implementation

This section describes the design and implementation of hardware part for SPI Interfacing. The entire design may be classified into sections that are described in the Hardware Design. The section also provides the algorithms and pseudo codes used for the implementation of the Rotating Squares and the Forest.

3.1. Hardware Design

3.1.1. Power Circuit Design

The power circuit should be designed such that we receive an output voltage of 3.3 to 5 Volts from the circuit that is shown in Figure 2.
The input to the power circuit is a 110V AC that is taken via an adapter that outputs 9V adapter to the first pin of the switch. The Switch is then connected to the first pin of the LM7805 power regulator. The third pin of the LM7805 voltage regulator is connected to a capacitor in parallel and a Light Emitting diode which is in series with a 1 Kilo ohm resistor. Then the desired voltage output is drawn from the LED and fed to the entire module. Table 1 shows the power unit specifications.

Power Connector	Connected to external Power Source
Wall Mount Power	9V DC 5V DC 1500mA
LM 7805	Voltage Regulator 5V
LED (Red)	Power Indicator -8mA, 1.8V

Table 1: Power Unit Specifications

3.1.2. Interfacing LCD module with LPC

The serial interface circuit is built on the wire wrapping board. It consists of an LCD and LPC1769 module. The wire wrapping board is connected to the computer using the USB cable. The detailed design and connections are shown in Figure 3. An entire circuit for is shown above in Figure 4. A pin connectivity table for the LCD and the LPC module is show in Table 2.

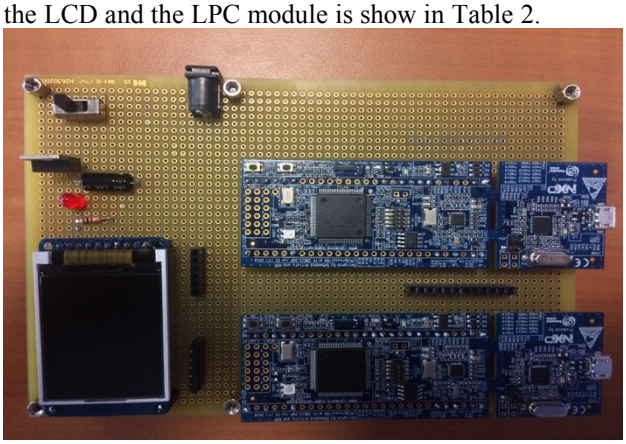

Figure 9: Shown again, the entire circuit Connections

LCD Module	LPC 1769	Description
LITE	J6-28 pin or Vout from power circuit	Accepted Voltage range from 3.3 to 5 V
MISO	J6 - 12	Master in Slave Out
SCK	J6 - 13	Serial Clock
MOSI	J6 - 11	Master Out Slave In
TFT_CS	J6 - 14	Slave Select
CARD_CS	X	Not Connected
D/C	J6 - 23	GPIO
RESET	J6 - 24	Reset pin
VCC	J6 – 28 pin or Vout from power circuit	Accepted voltage range 3.3 to 5V
GND	J6-1	Ground Pin

Table 2: Pin Connection of LPC and LCD Display

3.1.2. Interfacing LPC Module with another LPC Module

Serial Peripheral Interface(SPI) is an interface bus commonly used to send data between microcontrollers and flash memories. SPI devices communicate in full

duplex mode using master-slave architecture with a single master. The connections between master LPC and slave LPC on the wire wrapping board are shown in Figure 3.

A pin connectivity table for the two LPC modules is show in Table 3.

LPC1769(Master)	LPC1769(Slave)
MISO(J2-5)	MOSI(J2-6)
MOSI(J2-6)	MISO(J2-5)
SCK (J2-7)	SCK(J2-7)
SSEL(J2-8)	SSEL(J2-8)

Table 3: Pin Connection of the two LPC Modules

3.1.4. Bill of material

The materials used for the project are shown in the Table 3.

Description	Quantity
Wire Wrapping Board	1
Wire Wrapping Tool Kit	1
Wire Spec of 1500mA	20
DC Power Supply(Adapter)	1
½ Inch Stand Off's	6
Red LED	1
10 µF Capacitor	1
LM7805	1
Slide Switch	1
Adapter Jack	1
Resistor 1 Kilo Ohm	1
LPC Module 1769	2
LCD	1

Table 4: Bill of Materials

3.2. Software Design

As illustrated above in the software requirements part we first build the codes for the provided library. Then we implement our Squares and trees step by step. After implementing these squares and trees, it is then rotated, placed at random location and keeps generating till the keyboard interrupt has been pressed. The Algorithms, flowchart and pseudo code for building these modules are discussed in this section of the report.

3.2.1. Algorithms

There are few algorithms that have been implemented for this project. The first being the rotate square logic, that is to rotate a square by reducing its length by 20 percent in each iteration. The second being the deep forest emergence. The following algorithms are discussed in detail in this section of the report.

3.2.1.1. Rotating Square

1. Start
2. Initialize the SPI ports
3. Initialize the LCD with a white background
4. Generate Coordinates
5. Join these Coordinates using the drawline function.
6. The output received from step 5 would be a square. Reduce the length by 2-dimensional Matrix methods, as discussed in section **2.2.3.1.**
7. Join these new coordinates, hence making it look like a rotation.
8. Perform step 6 to step 7 up to 10 levels.
9. Perform the above 8 steps again for a different set of colors and the coordinates at least 10 times.

The Above logic can also be followed for generating squares at any desired location of users choice.

3.2.1.2. Generating Forest

1. Start
2. Initialize the SPI ports.
3. Initialize the LCD to a dark Back ground.
4. Generate the number of branch levels and the angle of the branches using random function.
5. Generate the coordinates of the tree's initial position.
6. Call the growTree Function with the attained parameters.
7. Use the drawline functionality to draw the first branch.
8. Calculate the next coordinates using the formulas discussed in section **2.2.3.2.**
9. Recursively call the treeGrow Function by decrementing the levels and drawing the corresponding lines using draw line function.
10. When the levels are between 0 to 3, change the color to Green to portray the leaves of the trees on the LCD.
11. Repeat these steps again and again by putting into an infinite loop.
12. This generates a series of trees at random location with random levels and angles.
13. When a keyboard interrupt is hit the loop must exit and the output in the LCD should not be erased.

3.2.1.3 Display Cube

1. Start
2. Cube is plotted on 3D Coordinate System
3. Coordinates X, Y, Z in world space are converted into camera space using transformation matrix.
4. These 3D coordinates are converted into 2D coordinates.
5. Using these 2D coordinates, a cube is plotted using drawline function
6. Flood fill Algorithm is used to colot the surfaces of the cube.

3.2.1.4 Display shadow of the cube

1. Consider an arbitrary point assuming it as a light source.
2. Calculate the intersecting points of light source and vertices of the cube using vector equation of the line.
3. 3D intersecting points are converted into 2D and then plotted on LCD.
4. Flood fill algorithm is used to display the shadow.

3.2.1.5 Master Handshake

1. Start
2. Initialize the SPI ports and run SSP in Master mode
3. Initialize CR1 register
4. Start the SendReceive("Start") method
5. Receive acknowledgement from slave
6. A loop is created until the data is completed and graphic points are computed
7. SendReceive(X,Y,Color) function is called iside the loop
8. Receive acknowledgement from slave
9. Stop

3.2.1.6 Slave Handshake

1. Start
2. Initialize the SPI ports and run SSP in Slave mode
3. Initialize CR0 register
4. Compute the val = SendReceive(0x00) method
5. A loop is created until val=Stop and compute xVal, yVal and Color
6. Compute drawPixel(xVal,yVal,Color)
7. Stop

3.2.2. Flowchart

Flowchart is the descriptive method of showing the logic implemented in a project. In this section we will show the rotating square algorithm in Figure 9 and the generating forest algorithm as in Figure 10 flowcharts. Flowchart to display a cube with patterns is shown in Figure 11.

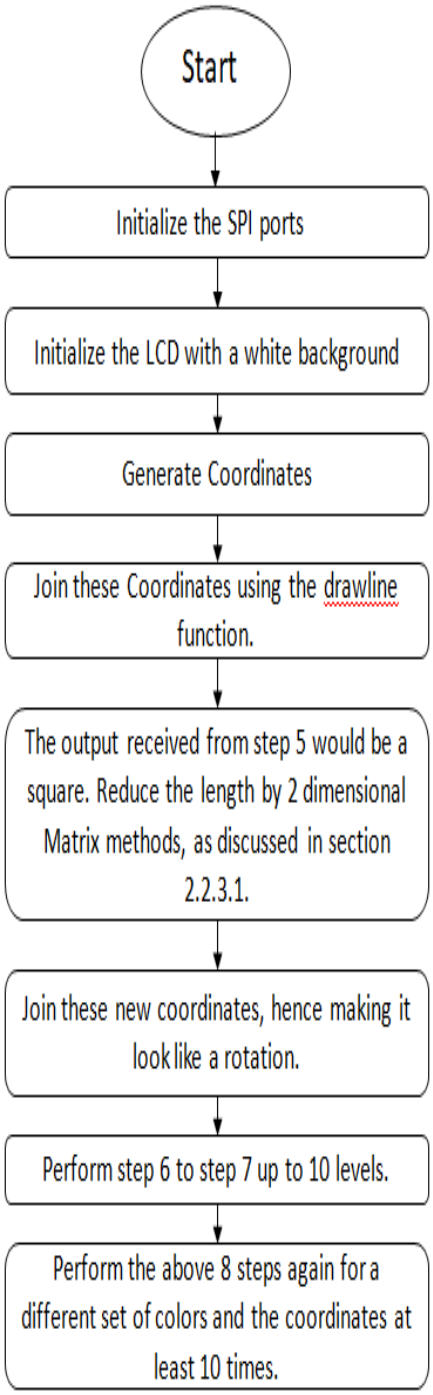

Figure 10: Flowchart for Rotating Square.

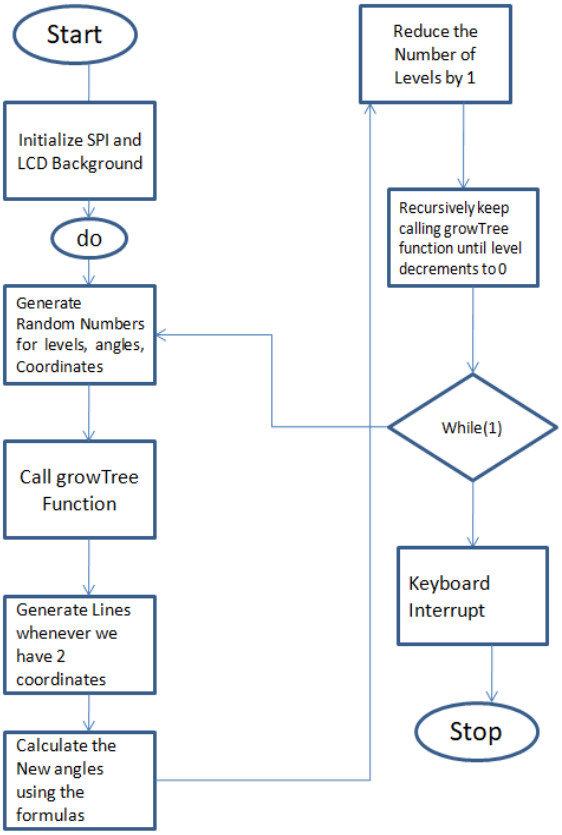

Figure 11: Flowchart for Forest Emergence.

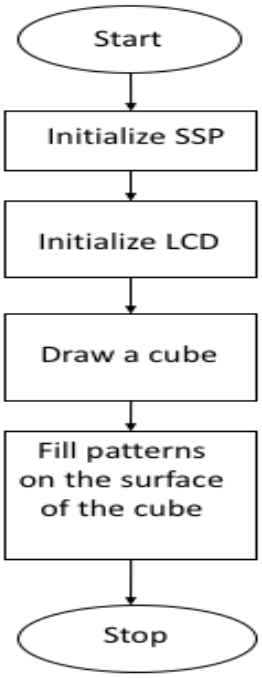

Figure 12: Flowchart for displaying a 3D cube

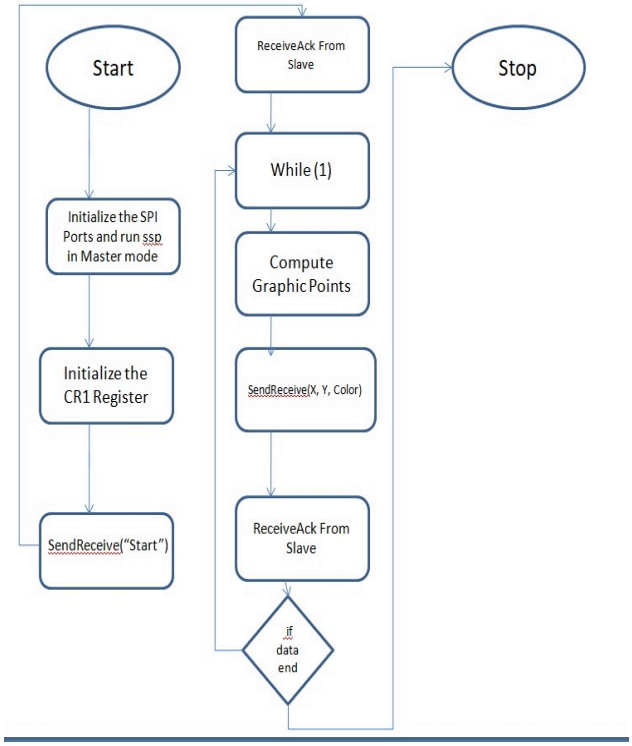

Figure 13: Flowchart for Master Handshake

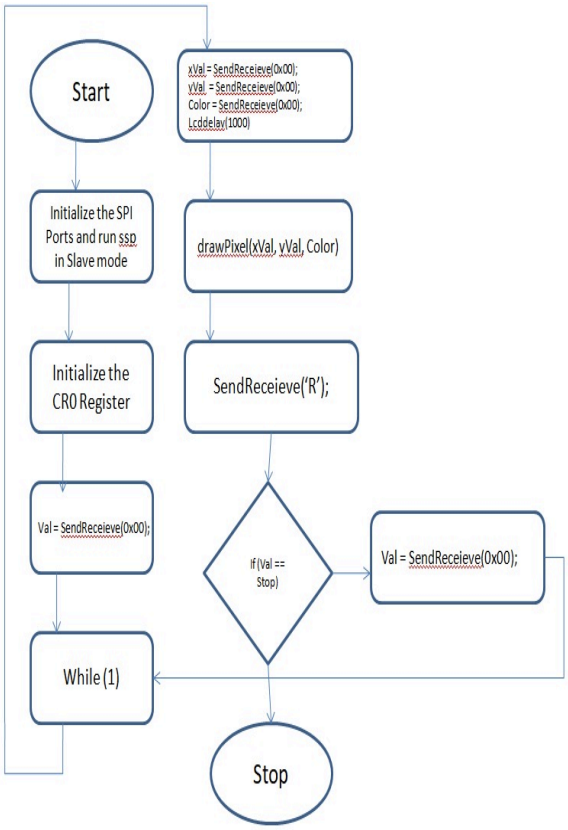

Figure 14: Flowchart for Slave Handshake

3.2.3. Pseudo codes

The transformation of an algorithm to a general programming language is known as a pseudo code. Below are the actual function written in our Project.

3.2.3.1. Rotating Square

Below is the function used for rotating the squares

```
void rotating_mysquare1(int x1, int x2, int x3, int x4,
int y1, int y2, int y3, int y4,int color1, float lambda)
{
int q1x=0, q2x=0, q3x=0, q4x=0,  q1y=0,q2y=0, q3y=0,
q4y=0;
int i;
        for(i=1;i<=11;i++){
                lcddelay(200);
                q1x = (x2+(lambda*(x1-x2)));
                q1y = (y2+(lambda*(y1-y2)));

                q2x = (x3+(lambda*(x2-x3)));

                q2y = (y3+(lambda*(y2-y3)));
                q3x = (x4+(lambda*(x3-x4)));


                q3y = (y4+(lambda*(y3-y4)));
                q4x = (x1+(lambda*(x4-x1)));
                q4y = (y1+(lambda*(y4-y1)));

        drawLine(q1x,q1y,q2x,q2y,color1);
        drawLine(q2x,q2y,q3x,q3y,color1);
        drawLine(q4x,q4y,q3x,q3y,color1);
        drawLine(q1x,q1y,q4x,q4y,color1);
                x1 = q1x;
                x2 = q2x;
                x3 = q3x;
                x4 = q4x;

                y1 = q1y;
                y2 = q2y;
                y3 = q3y;
                y4 = q4y;
        }
}
```

3.2.3.2. Grow Tree

Below is the function to generate a forest. Note this function is in an infinite while loop. Hence generating a forest.

```
void growTree(int x0, int y0, float angle, int length, int
level, int color){

        int x1, y1, length1;
        float angle1;

                if (level <= 2)
                        color = GREEN;
                if(level>0){
                x1 = x0+length*cos(angle);
            y1 = y0+length*sin(angle);
            drawLine(x0,y0,x1,y1,color);
            angle1 = angle + 0.52;

            length1 = 0.8 * length;
            growTree(x1,y1,angle1,length1,level-
1,color);

            angle1 = angle - 0.52;
            length1 = 0.8 * length;
            growTree(x1,y1,angle1,length1,level-
1,color);

            angle1 = angle;
            length1 = 0.8 * length;
            growTree(x1,y1,angle1,length1,level-
1,color);
                }
}
```

4. Testing and Verification

The connectivity of the hardware part is checked using a digital multi-meter keeping on connectivity mode. Similarly, the working on LPC board is checked using hello world program and then the rest of LCD work is done.

A Series of photos have been pasted to below that shows that the output we received is accurate and is as per project requirements.

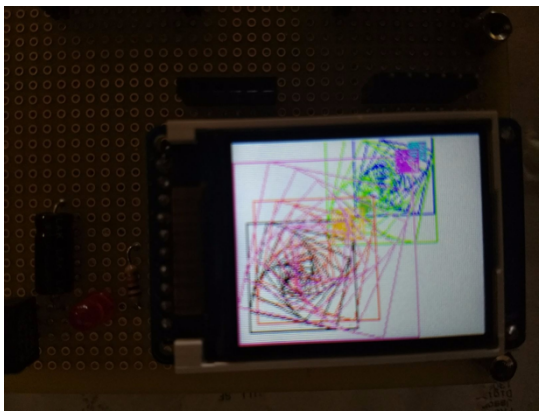

Figure 15: Generation of more Random Squares

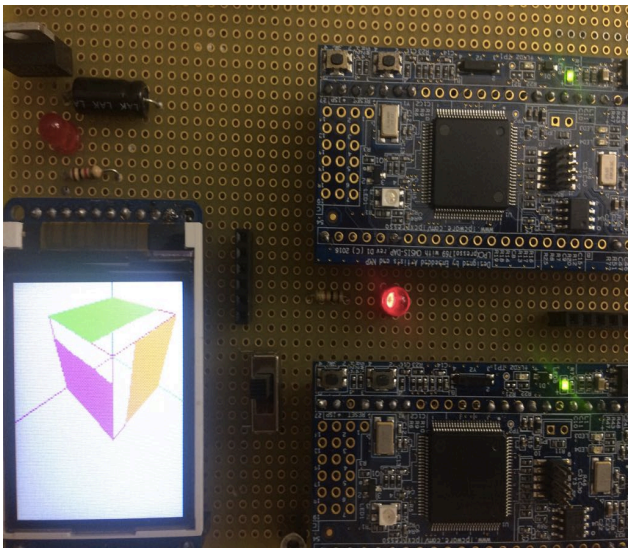

Figure 16: Filling the surfaces of the cube with colors

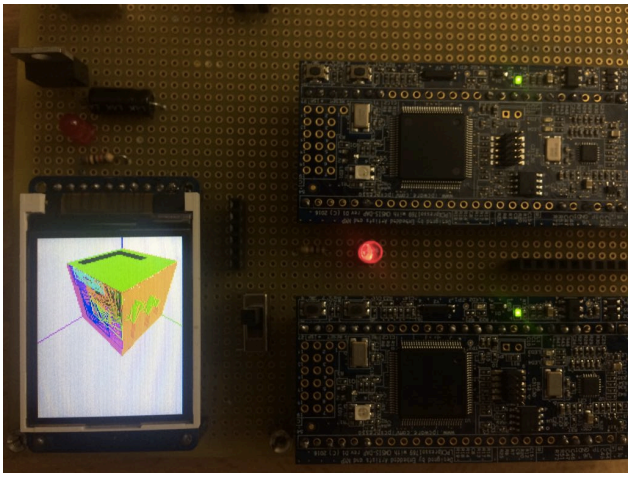

Figure 17: Cube generated with three different patterns on its surfaces

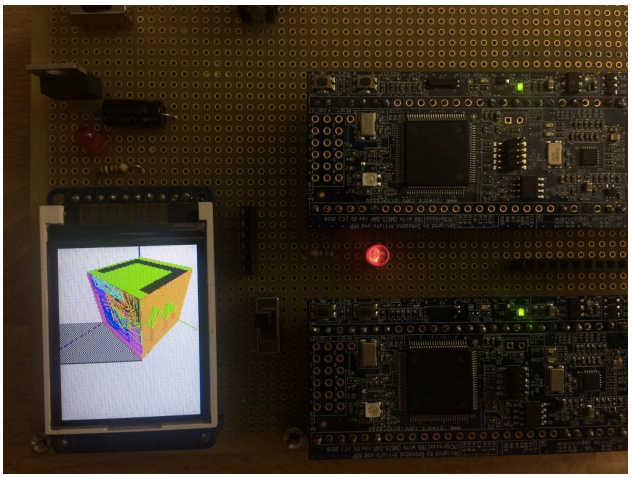

Figure 18: Cube generated with three different patterns on its surfaces along with a shadow

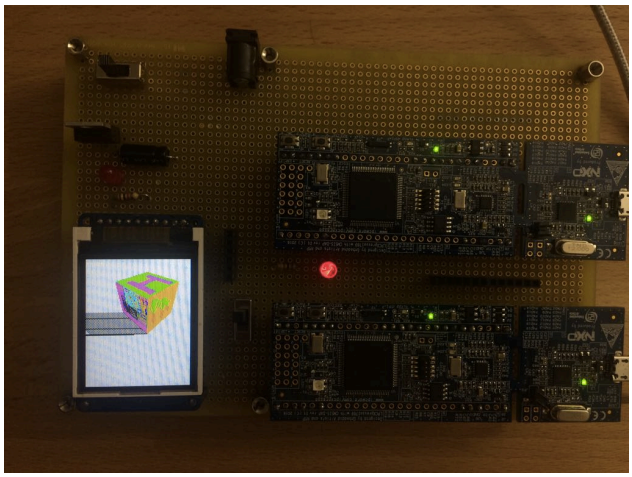

Figure 19: Cube generated with three more different patterns on its surfaces along with a shadow

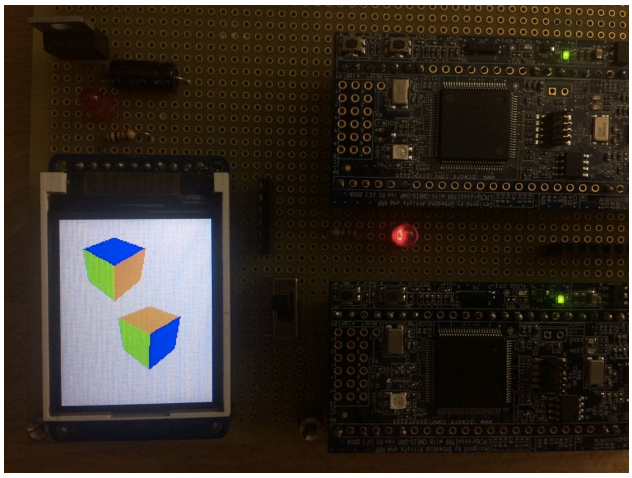

Figure 20: A cuboid broken into two cubes with white background

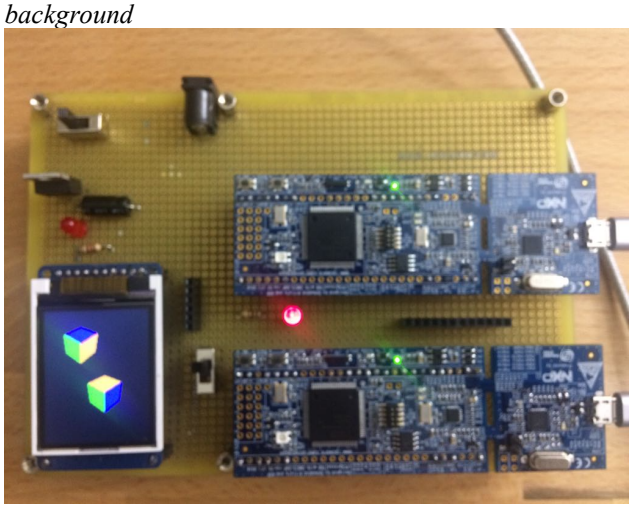

Figure 21: A cuboid broken into two cubes with black background

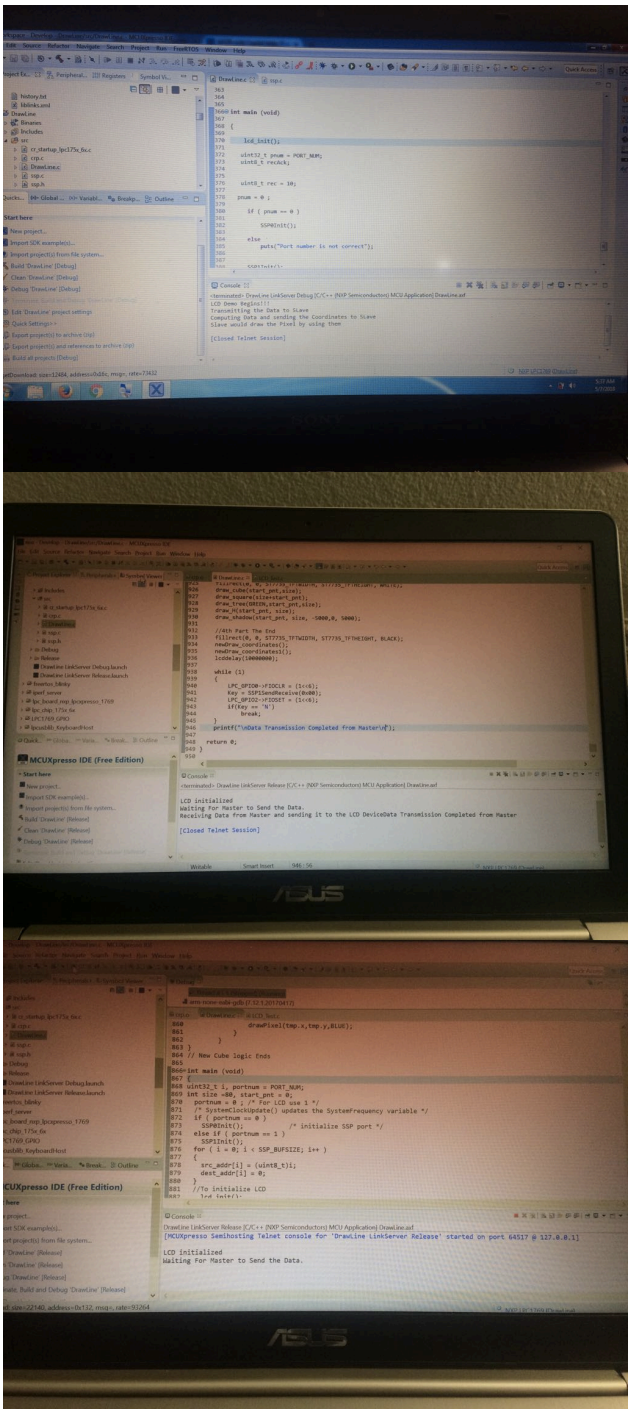

Figure 22: Parts of the program

5. Conclusion

The graphics engine design was tested successfully on the hardware connecting the LCD module with the LPCXpresso 1769. The image was displayed on LCD on running the program on NXP software. Hence, 3-Dimensional graphics has been successfully shown.

6. Acknowledgement

The work described in this paper was made possible and achievable by the contribution of Dr. Harry Li. The electrical and electronic components were made available by Mouser and Fries Electronics.

7. References

[1] H. Li, "Author Guidelines for CMPE 146/242 Project Report", *Lecture Notes of CMPE 146/242*, Computer Engineering Department, College of Engineering, San Jose State University, March 6, 2006, pp. 1.
[2] http://www.adafruit.com/products/358
[3] http://www.nxp.com/documents/data_sheet/LPC1769_68_67_66_65_64_63.pdf
[4] https://learn.adafruit.com/1-8-tft-display

8. Appendix

8.1 Source Code for the Entire Project

8.1.1 Slave Side Programming

```
//// Authors : Neeraj and Harika

#include <cr_section_macros.h>
#include <NXP/crp.h>
#include <math.h>
//#include "conio.h"
// Variable to store CRP value in. Will be placed automatically
// by the linker when "Enable Code Read Protect" selected.
// See crp.h header for more information

#include "LPC17xx.h"     /* LPC17xx definitions */
#include "ssp.h"
#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <math.h>

//LCD
#define ST7735_TFTWIDTH  137
#define ST7735_TFTHEIGHT 169

#define ST7735_CASET   0x2A
#define ST7735_RASET   0x2B
#define ST7735_RAMWR   0x2C
#define swap(x, y) { x = x + y; y = x - y; x = x - y; }

#define BLACK  0x000000
#define LIGHTBLUE 0x00FFE0
```

```
#define GREEN 0x00FF00
#define DARKBLUE 0x000033
#define BLACK 0x000000
#define BLUE 0x0007FF
#define RED 0xFF0000
#define MAGENTA 0x00F81F
#define WHITE 0xFFFFFF
#define PURPLE 0xCC33FF
#define LIGHTBLUE 0x00FFE0
#define GREEN 0x00FF00
#define DARKBLUE 0x000033
#define BLACK 0x000000
#define BLUE 0x0007FF
#define BROWN 0xA52A2A
#define RED 0xFF0000
#define MAGENTA 0xFF00FF
#define WHITE 0xFFFFFF
#define PURPLE 0xCC33FF
#define ORANGE 0xFFA500
#define INDIGO 0x4B0082
#define PINK 0xFF69B4
#define IR 0xCD5C5C
#define CHOC 0xD2691E
#define TGREEN 0x55AE3A


int height = ST7735_TFTHEIGHT;
int width = ST7735_TFTWIDTH;
int cursor_x = 0, cursor_y = 0;
int rotation = 0;
int textsize  = 1;
int x_diff = 64;
int y_diff = 80;

struct coordinate_pnt{
int x;
int y;
};

int cam_x = 100;
int cam_y = 100;
int cam_z = 100;
int light_x = 1000;
int light_y = 1050;
int light_z = 1050;


#define PORT_NUM            0
#define LOCATION_NUM        0

uint8_t src_addr[SSP_BUFSIZE];
uint8_t dest_addr[SSP_BUFSIZE];

int _height = ST7735_TFTHEIGHT;
int _width = ST7735_TFTWIDTH;
int colstart = 0;
int rowstart = 0;

void fill_LCDdisplay(uint32_t color) {
fill_rect(0,0,width,height,color);
}
void fill_rect(int16_t x, int16_t y, int16_t w, int16_t h,
uint32_t color) {
int16_t i;
for (i=x; i<x+w; i++) {
draw_fast_v_line(i, y, h, color);
}
}
void draw_rect(int16_t x, int16_t y,
int16_t w, int16_t h,
uint32_t color) {
draw_fast_h_line(x, y, w, color);
draw_fast_h_line(x, y+h-1, w, color);
draw_fast_v_line(x, y, h, color);
draw_fast_v_line(x+w-1, y, h, color);
}
void draw_fast_h_line(int16_t x, int16_t y,
int16_t w, uint32_t color) {
draw_line(x, y, x+w-1, y, color);
}
void draw_fast_v_line(int16_t x, int16_t y,
int16_t h, uint32_t color) {
// Update in subclasses if desired!
draw_line(x, y, x, y+h-1, color);
}

void spi_write(uint8_t c)
{
int portnum = 0;
src_addr[0] = c;
SSP_SSELToggle( portnum, 0 );
SSPSend( portnum, (uint8_t *)src_addr, 1 );
SSP_SSELToggle( portnum, 1 );
}

void spiwrite(uint8_t c)
{
spi_write(c);
}


void write_cmd(uint8_t c) {
LPC_GPIO0->FIOCLR |= (0x1<<21);
spi_write(c);
}

void writecommand(uint8_t c)
{
write_cmd(c);
}
```

```
void write_data(uint8_t c) {

LPC_GPIO0->FIOSET |= (0x1<<21);
spi_write(c);
}
void write_word(uint16_t c) {

uint8_t d;
d = c >> 8;
write_data(d);
d = c & 0xFF;
write_data(d);
}
void write888(uint32_t color, uint32_t repeat) {
uint8_t red, green, blue;
int i;
red = (color >> 16);
green = (color >> 8) & 0xFF;
blue = color & 0xFF;
for (i = 0; i< repeat; i++) {
write_data(red);
write_data(green);
write_data(blue);
}
}
void setAddrWindow(uint16_t x0, uint16_t y0, uint16_t
x1,
uint16_t y1) {

write_cmd(ST7735_CASET);
write_word(x0);
write_word(x1);
write_cmd(ST7735_RASET);
write_word(y0);
write_word(y1);
}

void fillrect(int16_t x0, int16_t y0, int16_t x1, int16_t
y1, uint32_t color)
{
int16_t i;
int16_t width, height;
width = x1 - x0 + 1;
height = y1 - y0 + 1;
setAddrWindow(x0, y0, x1, y1);
writecommand(ST7735_RAMWR);
write888(color, width * height);
}


void draw_pixel(int16_t x, int16_t y, uint32_t color)
{
if((x < 0) ||(x >= width) || (y < 0) || (y >= height))
return;
setAddrWindow(x,y,x+1,y+1);
write_cmd(ST7735_RAMWR);
write888(color, 1);
}

void drawPixel(int16_t x, int16_t y, uint32_t color)
{
draw_pixel(x, y, color);
}


void h_line(int16_t x0,int16_t x1,int16_t y,uint16_t
color){
width = x1-x0+1;
setAddrWindow(x0,y,x1,y);
write_cmd(ST7735_RAMWR);
write888(color,width);
}
void v_line(int16_t x,int16_t y0,int16_t y1,uint16_t
color){
width = y1-y0+1;
setAddrWindow(x,y0,x,y1);
write_cmd(ST7735_RAMWR);
write888(color,width);
}
void lcd_delay(int16_t delay)
{
int i,j;
for(i=0; i<=delay*10;i++)
{
j=0;
}
}
void lcddelay(int16_t delay)
{
lcd_delay(delay);
return;

}

void lcd_init()
{
uint32_t portnum = 0;
int i;
printf("LCD initialized\n");
if ( portnum == 0 )
{
LPC_GPIO0->FIODIR |= (0x1<<16);             /* SSP1,
P0.16 defined as Outputs */
}
else
{
LPC_GPIO0->FIODIR |= (0x1<<6);          /* SSP0 P0.6
defined as Outputs */
}
/* Set rs(dc) and rst as outputs */
LPC_GPIO0->FIODIR |= (0x1<<21);         /* rs/dc P0.22
defined as Outputs */
```

```
LPC_GPIO0->FIODIR |= (0x1<<22);          /* rst P0.21
defined as Outputs */
/* Reset sequence */
LPC_GPIO0->FIOSET |= (0x1<<22);

lcd_delay(500);                    /*delay 500 ms */
LPC_GPIO0->FIOCLR |= (0x1<<22);
lcd_delay(500);                    /* delay 500 ms */
LPC_GPIO0->FIOSET |= (0x1<<22);
lcd_delay(500);                    /* delay 500 ms */
for ( i = 0; i < SSP_BUFSIZE; i++ )     /* Init RD and
WR buffer */
{
src_addr[i] = 0;
dest_addr[i] = 0;
}
SSP_SSELToggle( portnum, 0 );
src_addr[0] = 0x11;    /* Sleep out */
SSPSend( portnum, (uint8_t *)src_addr, 1 );
SSP_SSELToggle( portnum, 1 );

lcd_delay(200);

SSP_SSELToggle( portnum, 0 );
src_addr[0] = 0x29;    /* Disp On */
SSPSend( portnum, (uint8_t *)src_addr, 1 );
SSP_SSELToggle( portnum, 1 );
/* delay 200 ms */
lcd_delay(200);
}

// Drawline logic Taken from ADAFRUIT
void draw_line(int16_t x0, int16_t y0, int16_t x1, int16_t
y1,uint32_t color)
{
int16_t slope = abs(y1 - y0) > abs(x1 - x0);
if (slope) {
swap(x0, y0);
swap(x1, y1);
}

if (x0 > x1) {
swap(x0, x1);
swap(y0, y1);
}

int16_t x_diff, y_diff;
x_diff = x1 - x0;
y_diff = abs(y1 - y0);

int16_t err = x_diff / 2;
int16_t ystep;

if (y0 < y1) {
ystep = 1;
} else {
ystep = -1;
}
for (; x0<=x1; x0++) {
if (slope) {
draw_pixel(y0, x0, color);
} else {
draw_pixel(x0, y0, color);
}
err -= y_diff;
if (err < 0) {
y0 += ystep;
err += x_diff;
}
}
}

// Calculation of rho, phi, thetha for the conversion of 3d
to 2d points.
struct coordinate_pnt project_coordinates (int x_w, int
y_w, int z_w)
{
int scrn_x, scrn_y, Dist=100, x_diff=74, y_diff=50;
double x_p, y_p, z_p, theta, phi, rho;
struct coordinate_pnt screen;
theta = acos(cam_x/sqrt(pow(cam_x,2)+pow(cam_y,2)));
phi                                                    =
acos(cam_z/sqrt(pow(cam_x,2)+pow(cam_y,2)+pow(ca
m_z,2)));
//theta = 0.785;
//phi = 0.785;
rho=
sqrt((pow(cam_x,2))+(pow(cam_y,2))+(pow(cam_z,2)));
x_p = (y_w*cos(theta))-(x_w*sin(theta));
y_p      =      (z_w*sin(phi))-(x_w*cos(theta)*cos(phi))-
(y_w*cos(phi)*sin(theta));
z_p              =              rho-(y_w*sin(phi)*cos(theta))-
(x_w*sin(phi)*cos(theta))-(z_w*cos(phi));
scrn_x = x_p*Dist/z_p;
scrn_y = y_p*Dist/z_p;
scrn_x = x_diff+scrn_x;
scrn_y = y_diff-scrn_y;
screen.x = scrn_x;
screen.y = scrn_y;
return screen;
}

// Logic for Drawing the Coordinates and plotting them
onto it.
void draw_coordinates ()
{
struct coordinate_pnt lcd;
int x1,y1,x2,y2, x3,y3,x4,y4;
lcd = project_coordinates (0,0,0);
x1=lcd.x;
y1=lcd.y;
lcd = project_coordinates (180,0,0);
```

```
x2=lcd.x;
y2=lcd.y;
lcd = project_coordinates (0,180,0);
x3=lcd.x;
y3=lcd.y;
lcd = project_coordinates (0,0,180);
x4=lcd.x;
y4=lcd.y;

draw_line(x1,y1,x2,y2,0x00FF00FF);
          //x axis  red
draw_line(x1,y1,x3,y3,0x0000FF00);
          //y axis  green
draw_line(x1, y1, x4, y4,0x000000FF);                    //z
axis  blue
}

// Logic For Drawing the Cube with a coordinate System
//                    citation                    -
https://github.com/srinivasamaringanti/Interfacing-LCD-
LPCXpresso-1769-SPI
void draw_cube(int start_pnt, int size)
{
struct coordinate_pnt lcd;
int x1,y1,x2,y2,x3,y3,x4,y4,x5,y5,x6,y6,x7,y7;
cam_x = 120;
cam_y = 120;
cam_z = 120;

lcd                =                project_coordinates
(start_pnt,start_pnt,(size+start_pnt));
x1=lcd.x;
y1=lcd.y;
lcd                =                project_coordinates
((size+start_pnt),start_pnt,(size+start_pnt));
x2=lcd.x;
y2=lcd.y;
lcd                =                project_coordinates
((size+start_pnt),(size+start_pnt),(size+start_pnt));
x3=lcd.x;
y3=lcd.y;
lcd                =                project_coordinates
(start_pnt,(size+start_pnt),(size+start_pnt));
x4=lcd.x;
y4=lcd.y;
lcd                =                project_coordinates
((size+start_pnt),start_pnt,start_pnt);
x5=lcd.x;
y5=lcd.y;
lcd                =                project_coordinates
((size+start_pnt),(size+start_pnt),start_pnt);
x6=lcd.x;
y6=lcd.y;
lcd                =                project_coordinates
(start_pnt,(size+start_pnt),start_pnt);
x7=lcd.x;
y7=lcd.y;
draw_line(x1, y1, x2, y2,0x00FF0000);
draw_line(x2, y2, x3, y3,0x00FF0000);
draw_line(x3, y3, x4, y4,0x00FF0000);
draw_line(x4, y4, x1, y1,0x00FF0000);
draw_line(x2, y2, x5, y5,0x00FF0000);
draw_line(x5, y5, x6, y6,0x00FF0000);
draw_line(x6, y6, x3, y3,0x00FF0000);
draw_line(x6, y6, x7, y7,0x00FF0000);
draw_line(x7, y7, x4, y4,0x00FF0000);

struct coordinate_pnt s1;

int i,j;

size=size+start_pnt;

for(i=0;i<size;i++)
{
for(j=0;j<size;j++)
{
s1=project_coordinates(j,i,size);     //top fill green
draw_pixel(s1.x,s1.y,GREEN);

s1=project_coordinates(i,size,j);     // right fill yellow
draw_pixel(s1.x,s1.y,ORANGE);

s1=project_coordinates(size,j,i);     // left fill pink
draw_pixel(s1.x,s1.y,PINK);
}
}
}

// Logic for drawing the squares on the surface and
rotating them.
void draw_square(int angle)
{
int x0,y0,y1,x1,x2,y2,x3,y3,size,intColor=0,i=0;
struct coordinate_pnt lcd;
uint32_t color;
uint32_t colorArray [12]={ORANGE, MAGENTA,
BLUE, GREEN, RED, TGREEN, BLACK, PURPLE,
ORANGE, LIGHTBLUE, MAGENTA, PINK};
int count = 10;
//Drawing 10 rotating Squares
while(i < 10)
{
i++;
x0= 1+ rand() % (angle-count);
y0=1+ rand() % (angle-count);
size = 30 + rand() % (angle/4);
color = colorArray[intColor];
intColor++;
x1=size+x0;

if(x1>angle){
```

```
x1=angle-1;
}
x2=x1;
x3=x0;
y1=y0;
y2=size+y1;

if(y2>angle){
y2=angle-1;
}
y3=y2;

lcd = project_coordinates(angle,x0,y0);
x0=lcd.x;
y0=lcd.y;
lcd = project_coordinates(angle,x1,y1);
x1=lcd.x;
y1=lcd.y;
lcd = project_coordinates(angle,x2,y2);
x2=lcd.x;
y2=lcd.y;
lcd = project_coordinates(angle,x3,y3);
x3=lcd.x;
y3=lcd.y;

draw_line(x0, y0, x1, y1,color);
draw_line(x1, y1, x2, y2,color);
draw_line(x2, y2, x3, y3,color);
draw_line(x3, y3, x0, y0,color);
//for rotation
int it;
float lambda = 0.2;

// Rotating 6 times
for(it=0;it<6;it++)
{
x0=(x0+(lambda*(x1-x0)));
y0=(y0+(lambda*(y1-y0)));
x1=(x1+(lambda*(x2-x1)));
y1=(y1+(lambda*(y2-y1)));
x2=(x2+(lambda*(x3-x2)));
y2=(y2+(lambda*(y3-y2)));
x3=(x3+(lambda*(x0-x3)));
y3=(y3+(lambda*(y0-y3)));

draw_line(x0, y0, x1, y1,color);
draw_line(x1, y1, x2, y2,color);
draw_line(x2, y2, x3, y3,color);
draw_line(x3, y3, x0, y0,color);

}

}
}
```

```
// Logic for drawing the Tree on the 2nd Surface of the cube.
// Citation - https://github.com/Sashank1991/AdvancedComputerDesign/
void draw_tree(uint32_t color,int start_pnt, int size)
{
int i=0, angle;
struct coordinate_pnt lcd;
int tree_branch[3][3]={{start_pnt+10,start_pnt+30,0.5*size},{start_pnt+20,start_pnt+30,0.3*size},{start_pnt+15,start_pnt+37,0.8*size}};
while(i<3)
{
int x0, y0, y1, x1,xp0,xp1,yp0,yp1;
angle = start_pnt+size;
x0=tree_branch[i][0];
x1=tree_branch[i][1];
y0=tree_branch[i][2];
y1=y0;
i++;
lcd = project_coordinates (y0,angle,x0);
xp0=lcd.x;
yp0=lcd.y;
lcd = project_coordinates (y1,angle,x1);
xp1=lcd.x;
yp1=lcd.y;
draw_line(xp0, yp0, xp1, yp1,0x00FF8000);
        //level 0 straight line
draw_line((xp0+1), (yp0+1), (xp1+1), (yp1+1),0x00FF8000);  //level 0 straight line
draw_line((xp0-1), (yp0-1), (xp1-1), (yp1-1),0x00FF8000);  //level 0 straight line

int it=0;
for(it=0;it<5;it++){
int16_t x2=(0.6*(x1-x0))+x1;
        // length of level 1 = 0.8 of previous level
int16_t y2=y1;
lcd = project_coordinates (y2,angle,x2);
int xp2=lcd.x;
int yp2=lcd.y;
draw_line(xp1, yp1, xp2, yp2,color);
        //level 1 straight line

//for right rotated angle 30 degree
int16_t xr= ((0.134*x1)+(0.866*x2)-(0.5*y2)+(0.5*y1));
int16_t yr=((0.5*x2)-(0.5*x1)+(0.866*y2)-(0.866*y1)+y1);
lcd = project_coordinates (yr,angle,xr);
int xpr=lcd.x;
int ypr=lcd.y;

//for left rotated angle 30 degree
int16_t xl=((0.134*x1)+(0.866*x2)+(0.5*y2)-(0.5*y1));
```

```
int16_t yl=((0.5*x1)-(0.5*x2)+(0.134*y2)+(0.866*y1));
lcd = project_coordinates (yl,angle,xl);
int xpl=lcd.x;
int ypl=lcd.y;

draw_line(xp1, yp1, xpr, ypr,color);
draw_line(xp1, yp1, xpl, ypl,color);

int16_t xrLen = sqrt(pow((xr-x1),2)+pow((yr-y1),2)) ;
        //length of right branch
int16_t xrImag= (0.8*xrLen)+xr;
                //imaginary vertical line x coordinate, y= yr
int16_t xr1 = ((0.134*xr)+(0.866*xrImag)-(0.5*yr)+(0.5*yr));
int16_t yr1 = ((0.5*xrImag)-(0.5*xr)+(0.866*yr)-(0.866*yr)+yr);
lcd = project_coordinates (yr1,angle,xr1);
int xpr1=lcd.x;
int ypr1=lcd.y;
//for right branch
int16_t xrr,xrl,yrr,yrl;
xrr = ((0.134*xr)+(0.866*xr1)-(0.5*yr1)+(0.5*yr));
yrr = ((0.5*xr1)-(0.5*xr)+(0.866*yr1)-(0.866*yr)+yr);
lcd = project_coordinates (yrr,angle,xrr);
int xprr=lcd.x;
int yprr=lcd.y;
//for left branch
xrl = ((0.134*xr)+(0.866*xr1)+(0.5*yr1)-(0.5*yr));
yrl = ((0.5*xr)-(0.5*xr1)+(0.134*yr)+(0.866*yr1));
lcd = project_coordinates (yrl,angle,xrl);
int xprl=lcd.x;
int yprl=lcd.y;
//for branches on left rotated branch angle 30 degree
int16_t xlImag= (0.8*xrLen)+xl;
                //imaginary vertical line x coordinate, y= yr
int16_t xl1 = ((0.134*xl)+(0.866*xlImag)+(0.5*yl)-(0.5*yl));
int16_t yl1 = ((0.5*xl)-(0.5*xlImag)+(0.134*yl)+(0.866*yl));
lcd = project_coordinates (yl1,angle,xl1);
int xpl1=lcd.x;
int ypl1=lcd.y;
//for right branch
int16_t xlr,xll,ylr,yll;
xlr = ((0.134*xl)+(0.866*xl1)-(0.5*yl1)+(0.5*yl));
ylr = ((0.5*xl1)-(0.5*xl)+(0.866*yl1)-(0.866*yl)+yl);
lcd = project_coordinates (ylr,angle,xlr);
int xplr=lcd.x;
int yplr=lcd.y;
//for left branch
xll = ((0.134*xl)+(0.866*xl1)+(0.5*yl1)-(0.5*yl));
yll = ((0.5*xl)-(0.5*xl1)+(0.134*yl)+(0.866*yl1));
lcd = project_coordinates (yll,angle,xll);
int xpll=lcd.x;
int ypll=lcd.y;
draw_line(xpr, ypr, xpr1, ypr1,color);
draw_line(xpr, ypr, xprr, yprr,color);
draw_line(xpr, ypr, xprl, yprl,color);
draw_line(xpl, ypl, xpl1, ypl1,color);
draw_line(xpl, ypl, xplr, yplr,color);
draw_line(xpl, ypl, xpll, ypll,color);

x0=x1;
x1=x2;
}
}
}

void draw_shadow(double start_pnt, double size, double xShad, double yShad, double zShad)
{
int i,j,k;
int xs[8]={0}, ys[8]={0}, zs[8]={0};
struct coordinate_pnt s5,s6,s7,s8;
uint32_t color = 0x00000000;
double x[8] = {start_pnt,(start_pnt+size),(start_pnt+size),start_pnt,start_pnt,(start_pnt+size),(start_pnt+size),start_pnt};
double y[8] = {start_pnt, start_pnt, start_pnt+size, start_pnt+size, start_pnt, start_pnt, (start_pnt+size), (start_pnt+size) };
double z[8] = {start_pnt, start_pnt, start_pnt, start_pnt, (start_pnt+size), (start_pnt+size), (start_pnt+size), (start_pnt+size)};

for(i=0; i<8; i++){
xs[i]=x[i]-((z[i]/(zShad-z[i]))*(xShad-x[i]));
ys[i]=y[i]-((z[i]/(zShad-z[i]))*(yShad-y[i]));
zs[i]=z[i]-((z[i]/(zShad-z[i]))*(zShad-z[i]));
}
s5 = project_coordinates (xs[4],ys[4],zs[4]);
s6 = project_coordinates (xs[5],ys[5],zs[5]);
s7 = project_coordinates (xs[6],ys[6],zs[6]);
s8 = project_coordinates (xs[7],ys[7],zs[7]);
for(k = 0;k < size; k = k+2){
for(j = 0; j < size;j = j+2){
draw_line((s5.x)-j, s5.y, (s8.x)-j, s8.y,color);
draw_line((s5.x)-(j+1), s6.y, (s8.x)-(j+1), s8.y,color);
}
}
}

void draw_N(int start_pnt, int size)
{
struct coordinate_pnt p1;
int i,j;
size=size+start_pnt;
int map[size][size];

for(i=0;i<size;i++)
```

```
{
for(j=0;j<size;j++)
{
if(i>=start_pnt+5 && j>=start_pnt+10 && j<=size-10
&& i<=start_pnt+15)
map[i][j]=1;
else if(i>=start_pnt+15 && j>=start_pnt+10 &&
j<=start_pnt+20 && i<=size-5)
map[i][j]=1;
else if(i>=start_pnt+70 && j>=start_pnt+10 &&
j<=size-10 && i<=start_pnt+80)
map[i][j]=1;
else
map[i][j]=0;
}
}
for(i=0;i<size;i++)
{
for(j=0;j<size;j++)
{
if(map[i][j]==1)
{
p1 = project_coordinates(j,i,size);
draw_pixel(p1.x,p1.y,BLACK);
}
else if(map[i][j]==0)
{
p1 = project_coordinates(j,i,size);
}
}
}

}

void draw_H(int start_pnt, int size)
{
struct coordinate_pnt p1;
int i,j;
size=size+start_pnt;
int map[size][size];

for(i=0;i<size;i++)
{
for(j=0;j<size;j++)
{
if(i>=start_pnt+15 && j>=start_pnt+10 &&
j<=start_pnt+20 && i<=size-5)
map[i][j]=1;
else if(i>=start_pnt+30 && j>=start_pnt+10 &&
j<=size-10 && i<=start_pnt+40)
map[i][j]=1;
else if(i>=start_pnt+15 && j>=start_pnt+50 &&
j<=start_pnt+60 && i<=size-5)
map[i][j]=1;
else
map[i][j]=0;
}
}
for(i=0;i<size;i++)
{
for(j=0;j<size;j++)
{
if(map[i][j]==1)
{
p1 = project_coordinates(j,i,size);
draw_pixel(p1.x,p1.y,PINK);
}
else if(map[i][j]==0)
{
p1 = project_coordinates(j,i,size);
}
}
}

}

// Diffussed Reflection
int calIDiff(int16_t xPs, int16_t yPs, int16_t zPs, int16_t
xPi, int16_t yPi,
int16_t zPi, int16_t k) {
double cosVal;
double r = sqrt(pow((zPs - zPi), 2) + pow((yPs - yPi), 2)
+ pow((xPs - xPi), 2));
double rcos = sqrt(pow((zPs - zPi), 2));
cosVal = rcos / r;
return (255 * k * cosVal) / pow(r, 2);
}

// This part of the code is for the new Cube logic
struct coordinate_pnt newProject_coordinates(int x_w,
int y_w, int z_w) {
int scrn_x, scrn_y, Dist = 100, x_diff = 45, y_diff = 40;

//int scrn_x, scrn_y, Dist = 100, x_diff = 74, y_diff =
100;

double x_p, y_p, z_p, theta, phi, rho;
struct coordinate_pnt screen;
theta = acos(cam_x / sqrt(pow(cam_x, 2) + pow(cam_y,
2)));
phi = acos(cam_z / sqrt(pow(cam_x, 2) + pow(cam_y, 2)
+ pow(cam_z, 2)));
//theta = 0.785;
//phi = 0.785;
rho = sqrt((pow(cam_x, 2)) + (pow(cam_y, 2)) +
(pow(cam_z, 2)));
x_p = (y_w * cos(theta)) - (x_w * sin(theta));
y_p = (z_w * sin(phi)) - (x_w * cos(theta) * cos(phi))
- (y_w * cos(phi) * sin(theta));
z_p = rho - (y_w * sin(phi) * cos(theta)) - (x_w *
sin(phi) * cos(theta))
- (z_w * cos(phi));
```

```
scrn_x = x_p * Dist / z_p;
scrn_y = y_p * Dist / z_p;
scrn_x = x_diff + scrn_x;
scrn_y = y_diff - scrn_y;
screen.x = scrn_x;
screen.y = scrn_y;
return screen;
}
void newDraw_coordinates() {
struct coordinate_pnt lcd;
struct coordinate_pnt tmp;
int x1, y1, x2, y2, x3, y3, x4, y4, x5, y5, x6, y6, x7, y7,
x8, y8;
lcd = newProject_coordinates(0, 0, 0);
x1 = lcd.x;
y1 = lcd.y;
lcd = newProject_coordinates(45, 0, 0);
x2 = lcd.x;
y2 = lcd.y;
lcd = newProject_coordinates(0, 45, 0);
x3 = lcd.x;
y3 = lcd.y;
lcd = newProject_coordinates(0, 0, 45);
x4 = lcd.x;
y4 = lcd.y;
lcd = newProject_coordinates(45, 0, 45);
x5 = lcd.x;
y5 = lcd.y;
lcd = newProject_coordinates(45, 45, 0);
x6 = lcd.x;
y6 = lcd.y;
lcd = newProject_coordinates(45, 45, 45);
x7 = lcd.x;
y7 = lcd.y;
lcd = newProject_coordinates(0, 45, 45);
x8 = lcd.x;
y8 = lcd.y;
for (int i = 0; i <= 45; i++) {
for (int j = 0; j <= 45; j++) {
tmp = newProject_coordinates(i, j, 45);
drawPixel(tmp.x, tmp.y, BLUE);
}
}
for (int i = 0; i <= 45; i++) {
for (int j = 0; j <= 45; j++) {
tmp = newProject_coordinates (45,i,j);
drawPixel(tmp.x,tmp.y,GREEN);
}
}
for (int i = 0; i <= 45; i++) {
for (int j = 0; j <= 45; j++) {
tmp = newProject_coordinates (i,45,j);
drawPixel(tmp.x,tmp.y,ORANGE);
}
}
}
```

```
// Drawing Another Cube PAralleley

struct coordinate_pnt newProject_coordinates1(int x_w,
int y_w, int z_w) {
//int scrn_x, scrn_y, Dist = 100, x_diff = 45, y_diff = 40;

int scrn_x, scrn_y, Dist = 100, x_diff = 74, y_diff = 100;

double x_p, y_p, z_p, theta, phi, rho;
struct coordinate_pnt screen;
theta = acos(cam_x / sqrt(pow(cam_x, 2) + pow(cam_y,
2)));
phi = acos(cam_z / sqrt(pow(cam_x, 2) + pow(cam_y, 2)
+ pow(cam_z, 2)));
//theta = 0.785;
//phi = 0.785;
rho = sqrt((pow(cam_x, 2)) + (pow(cam_y, 2)) +
(pow(cam_z, 2)));
x_p = (y_w * cos(theta)) - (x_w * sin(theta));
y_p = (z_w * sin(phi)) - (x_w * cos(theta) * cos(phi))
- (y_w * cos(phi) * sin(theta));
z_p = rho - (y_w * sin(phi) * cos(theta)) - (x_w *
sin(phi) * cos(theta))
- (z_w * cos(phi));
scrn_x = x_p * Dist / z_p;
scrn_y = y_p * Dist / z_p;
scrn_x = x_diff + scrn_x;
scrn_y = y_diff - scrn_y;
screen.x = scrn_x;
screen.y = scrn_y;
return screen;
}

void newDraw_coordinates1() {
struct coordinate_pnt lcd;
struct coordinate_pnt tmp;
int x1, y1, x2, y2, x3, y3, x4, y4, x5, y5, x6, y6, x7, y7,
x8, y8;
lcd = newProject_coordinates1(0, 0, 0);
x1 = lcd.x;
y1 = lcd.y;
lcd = newProject_coordinates1(45, 0, 0);
x2 = lcd.x;
y2 = lcd.y;
lcd = newProject_coordinates1(0, 45, 0);
x3 = lcd.x;
y3 = lcd.y;
lcd = newProject_coordinates1(0, 0, 45);
x4 = lcd.x;
y4 = lcd.y;
lcd = newProject_coordinates1(45, 0, 45);
x5 = lcd.x;
y5 = lcd.y;
lcd = newProject_coordinates1(45, 45, 0);
x6 = lcd.x;
```

```
y6 = lcd.y;
lcd = newProject_coordinates1(45, 45, 45);
x7 = lcd.x;
y7 = lcd.y;
lcd = newProject_coordinates1(0, 45, 45);
x8 = lcd.x;
y8 = lcd.y;
for (int i = 0; i <= 45; i++) {
for (int j = 0; j <= 45; j++) {
tmp = newProject_coordinates1(i, j, 45);
drawPixel(tmp.x, tmp.y, ORANGE);
}
}
for (int i = 0; i <= 45; i++) {
for (int j = 0; j <= 45; j++) {
tmp = newProject_coordinates1 (45,i,j);
drawPixel(tmp.x,tmp.y,GREEN);
}
}
for (int i = 0; i <= 45; i++) {
for (int j = 0; j <= 45; j++) {
tmp = newProject_coordinates1 (i,45,j);
drawPixel(tmp.x,tmp.y,BLUE);
}
}
}
// New Cube logic Ends

int main (void)
{
uint32_t i, portnum = PORT_NUM;
int size =80, start_pnt = 0;
portnum = 0 ; /* For LCD use 1 */
/* SystemClockUpdate() updates the SystemFrequency variable */
if ( portnum == 0 )
SSP0Init();           /* initialize SSP port */
else if ( portnum == 1 )
SSP1Init();
for ( i = 0; i < SSP_BUFSIZE; i++ )
{
src_addr[i] = (uint8_t)i;
dest_addr[i] = 0;
}
//To initialize LCD
lcd_init();
fill_LCDdisplay(0x00FFFFFF);

printf("Waiting For Master to Send the Data.\n");
uint8_t Key;

SSP1Init();
while (1)
{
LPC_GPIO0->FIOCLR = (1<<6);
Key = SSP1SendReceive(0x00);
LPC_GPIO2->FIOSET = (1<<6);
if(Key == 'Y')
break;
}

printf("Receiving Data from Master and sending it to the LCD Device");

draw_coordinates();

// 1st PArt Completion
draw_cube(start_pnt,size);
draw_square(size+start_pnt);
draw_tree(GREEN,start_pnt,size);
draw_N(start_pnt, size);
draw_shadow(start_pnt, size, -5000,0, 5000);

cam_x = 90;
cam_y = 90;
cam_z = 90;

fillrect(0, 0, ST7735_TFTWIDTH, ST7735_TFTHEIGHT, WHITE);

//int change = 0;


// 2nd Part Completion
newDraw_coordinates();
newDraw_coordinates1();
lcddelay(10000000);
//
// 3rd and the Final Part
size = 70;
fillrect(0, 0, ST7735_TFTWIDTH, ST7735_TFTHEIGHT, WHITE);
draw_cube(start_pnt,size);
draw_square(size+start_pnt);
draw_tree(GREEN,start_pnt,size);
draw_H(start_pnt, size);
draw_shadow(start_pnt, size, -5000,0, 5000);

//          //4th Part The End
fillrect(0, 0, ST7735_TFTWIDTH, ST7735_TFTHEIGHT, BLACK);
newDraw_coordinates();
newDraw_coordinates1();
lcddelay(10000000);

while (1)
{
LPC_GPIO0->FIOCLR = (1<<6);
Key = SSP1SendReceive(0x00);
LPC_GPIO2->FIOSET = (1<<6);
if(Key == 'N')
break;
```

```
}
printf("\nData Transmission Completed from Master\n");

return 0;
}
```

8.2 Master Side Programming

```
/*
===============================================
Name        : DrawLine.c
Author      : Neeraj and Harika
Version     :
Copyright   : $(copyright)
Description : main definition
===============================================
*/

#include <cr_section_macros.h>
#include <NXP/crp.h>
#include "LPC17xx.h"                    /* LPC17xx definitions */
#include "ssp.h"
#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <math.h>



/* Be careful with the port number and location number, because

some of the location may not exist in that port. */

#define PORT_NUM          0


uint8_t src_addr[SSP_BUFSIZE];
uint8_t dest_addr[SSP_BUFSIZE];


#define ST7735_TFTWIDTH 127
#define ST7735_TFTHEIGHT 159

#define ST7735_CASET 0x2A
#define ST7735_RASET 0x2B
#define ST7735_RAMWR 0x2C
#define ST7735_SLPOUT 0x11
#define ST7735_DISPON 0x29



#define swap(x, y) {x = x + y; y = x - y; x = x - y ;}
```

```
// defining color values

#define LIGHTBLUE 0x00FFE0
#define GREEN 0x00FF00
#define DARKBLUE 0x000033
#define BLACK 0x000000
#define BLUE 0x0007FF
#define RED 0xFF0000
#define MAGENTA 0x00F81F
#define WHITE 0xFFFFFF
#define PURPLE 0xCC33FF



int _height = ST7735_TFTHEIGHT;
int _width = ST7735_TFTWIDTH;


void spiwrite(uint8_t c)

{

int pnum = 0;

src_addr[0] = c;

SSP_SSELToggle( pnum, 0 );

SSPSend( pnum, (uint8_t *)src_addr, 1 );

SSP_SSELToggle( pnum, 1 );

}


void writecommand(uint8_t c)

{

LPC_GPIO0->FIOCLR |= (0x1<<21);

spiwrite(c);

}



void writedata(uint8_t c)

{

LPC_GPIO0->FIOSET |= (0x1<<21);

spiwrite(c);
```

```
}

void writeword(uint16_t c)
{
uint8_t d;
d = c >> 8;
writedata(d);
d = c & 0xFF;
writedata(d);
}

void write888(uint32_t color, uint32_t repeat)
{
uint8_t red, green, blue;
int i;
red = (color >> 16);
green = (color >> 8) & 0xFF;
blue = color & 0xFF;
for (i = 0; i< repeat; i++) {
writedata(red);
writedata(green);
writedata(blue);
}
}

void setAddrWindow(uint16_t x0, uint16_t y0, uint16_t x1, uint16_t y1)
{
writecommand(ST7735_CASET);
writeword(x0);
writeword(x1);
writecommand(ST7735_RASET);
writeword(y0);
writeword(y1);
}

void fillrect(int16_t x0, int16_t y0, int16_t x1, int16_t y1, uint32_t color)
{
int16_t i;
int16_t width, height;
width = x1-x0+1;
height = y1-y0+1;
setAddrWindow(x0,y0,x1,y1);
writecommand(ST7735_RAMWR);
write888(color,width*height);
}

void lcddelay(int ms)
{
int count = 24000;
int i;
for ( i = count*ms; i--; i > 0);
}

void lcd_init()
{
```

```
int i;
printf("LCD Demo Begins!!!\n");
// Set pins P0.16, P0.21, P0.22 as output
LPC_GPIO0->FIODIR |= (0x1<<16);

LPC_GPIO0->FIODIR |= (0x1<<21);

LPC_GPIO0->FIODIR |= (0x1<<22);

// Hardware Reset Sequence
LPC_GPIO0->FIOSET |= (0x1<<22);
lcddelay(500);

LPC_GPIO0->FIOCLR |= (0x1<<22);
lcddelay(500);

LPC_GPIO0->FIOSET |= (0x1<<22);
lcddelay(500);

// initialize buffers
for ( i = 0; i < SSP_BUFSIZE; i++ )
{

src_addr[i] = 0;
dest_addr[i] = 0;
}

// Take LCD display out of sleep mode
writecommand(ST7735_SLPOUT);
lcddelay(200);

// Turn LCD display on
writecommand(ST7735_DISPON);
lcddelay(200);

}



void drawPixel(int16_t x, int16_t y, uint32_t color)

{

if ((x < 0) || (x >= _width) || (y < 0) || (y >= _height))

return;

setAddrWindow(x, y, x + 1, y + 1);

writecommand(ST7735_RAMWR);

write888(color, 1);

}
```

```
/****************************************************
*****************************

** Descriptions:        Draw line function

**

** parameters:              Starting point (x0,y0), Ending
point(x1,y1) and color

** Returned value:        None

**

****************************************************
*****************************/


void drawLine(int16_t x0, int16_t y0, int16_t x1, int16_t
y1, uint32_t color)

{

int16_t slope = abs(y1 - y0) > abs(x1 - x0);

if (slope) {

swap(x0, y0);

swap(x1, y1);

}

if (x0 > x1) {

swap(x0, x1);

swap(y0, y1);

}

int16_t dx, dy;

dx = x1 - x0;

dy = abs(y1 - y0);

int16_t err = dx / 2;

int16_t ystep;

if (y0 < y1) {
```

```
ystep = 1;

}

else {

ystep = -1;

}

for (; x0 <= x1; x0++) {

if (slope) {

drawPixel(y0, x0, color);

}

else {

drawPixel(x0, y0, color);

}

err -= dy;

if (err < 0) {

y0 += ystep;

err += dx;

}

}

}

/*

Main Function main()

*/



int main (void)

{

lcd_init();

uint32_t pnum = PORT_NUM;
uint8_t recAck;

uint8_t rec = 10;

pnum = 0 ;

if ( pnum == 0 )

SSP0Init();

else
puts("Port number is not correct");


SSP1Init();
LPC_GPIO0->FIOCLR = (1 << 6);
//send
printf("Transmitting the Data to SLave\n");
printf("Computing Data and sending the Coordinates to SLave\n");
printf("Slave would draw the Pixel by using them");

while(1)
{
LPC_GPIO0->FIOCLR = (1 << 6);
SSP1SendReceive('Y'); // Sending data via SPI
LPC_GPIO0->FIOSET = (1 << 6);

LPC_GPIO0->FIOCLR = (1 << 6);
SSP1SendReceive('N'); // Sending terminate Signal via SPI
LPC_GPIO0->FIOSET = (1 << 6);

}


return 0;

}
```