Department of Computer Science and Engineering

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5 August 2021

UCS1712 - Graphics and Multimedia Lab

Exercise 4 : Midpoint Circle Drawing Algorithm in C++ using OpenGL

Objective:

To plot points that make up the circle with center (xc,yc) and radius r using Midpoint circle drawing algorithm. Give atleast 2 test cases with centre as origin and elsewhere.

Code:

```
#ifndef LOPENGL_H
#define LOPENGL_H

#include <GL/freeglut.h>
#include <GL/gl.h>
#include <GL/glu.h>
```

```
#include <math.h>
#include <stdio.h>
#include<iostream>
#include<vector>
#include<ctime>
using namespace std;

#endif
```

```
#ifndef LUTIL_H
#define LUTIL_H

#include "Headers.h"

//Screen Constants
const int SCREEN_WIDTH = 640;
const int SCREEN_HEIGHT = 480;
const int SCREEN_FPS = 60;
const int POINT_SIZE=2;
int X0,Y0, radius;

const int coords[][3] ={{0, 0, 6},
                        {2, 3, 6},
                       };

bool initGL();

void update();

void render();

void y_axis();

void x_axis();

void selectCenter(int option);

vector<pair<int, int>> Midpoint();

#endif
```

```
#include "Signatures.h"

bool initGL(){
    //Initialize Projection Matrix
    glMatrixMode( GL_PROJECTION );
```

```
6       glLoadIdentity();
7       gluOrtho2D(0.0,640.0,0.0,480.0);
8
9       //Initialize Modelview Matrix
10      glMatrixMode( GL_MODELVIEW );
11      glLoadIdentity();
12
13      glTranslatef( SCREEN_WIDTH / 3.f, SCREEN_HEIGHT / 3.f, 0.
        f );
14
15      //Initialize clear color
16      glClearColor( 0.f, 0.f, 0.f, 1.f );
17
18      glPointSize(POINT_SIZE);
19      glEnable(GL_POINT_SMOOTH);
20
21      //Check for error
22      GLenum error = glGetError();
23      if( error != GL_NO_ERROR )
24      {
25          printf( "Error initializing OpenGL! %s\n",
        gluErrorString( error ) );
26          return false;
27      }
28
29      return true;
30  }
31
32  void update(){
33
34  }
35
36  void render(){
37      vector<pair<int, int>> points = Midpoint();
38      y_axis();
39      x_axis();
40      // glClear(GL_COLOR_BUFFER_BIT);
41      glColor3f(1,1,1);
42      glBegin(GL_POINTS);
43          for(pair<int, int> p: points){
44              glVertex2d(p.first, p.second);
45          }
46      glEnd();
47      glFlush();
48  }
```

```
49
50 void y_axis(){
51     // glClear(GL_COLOR_BUFFER_BIT);
52     glBegin(GL_LINES);
53         glVertex2d(0, -480.0);
54         glVertex2d(0, 480.0);
55     glEnd();
56     glFlush();
57 }
58
59 void x_axis(){
60     // glClear(GL_COLOR_BUFFER_BIT);
61     glBegin(GL_LINES);
62         glVertex2d(-640.0, 0);
63         glVertex2d(640.0, 0);
64     glEnd();
65     glFlush();
66 }
67
68 void selectCenter(int option){
69     X0 = coords[option-1][0]*20;
70     Y0 = coords[option-1][1]*20;
71     radius = coords[option-1][2]*10;
72 }
73
74 vector<pair<int, int>> Midpoint(){
75
76     int x = radius;
77     int y = 0;
78
79     int p = 1 - radius;
80
81     int point_x = x + X0;
82     int point_y = y + Y0;
83
84
85     vector<pair<int, int>> points;
86
87     points.push_back(pair<int, int>(point_x, point_y));
88
89     if( radius<0){
90         point_x = x + X0; point_y = -y + Y0;
91         points.push_back(pair<int, int>(point_x, point_y));
92
93         point_x = y + X0; point_y = x + Y0;
```

```
94          points.push_back(pair<int, int>(point_x, point_y));
95
96          point_x = -y + X0; point_y = x + Y0;
97          points.push_back(pair<int, int>(point_x, point_y));

98      }
99
100     while(x > y){
101         y++;
102         if(p <=0){
103             p += ((2*y) + 1);
104         }
105         else{
106             x--;
107             p += ((2*y) - (2*x) + 1);
108         }
109         if(x < y)
110             break;
111
112         point_x = x + X0; point_y = y + Y0;
113         points.push_back(pair<int, int>(point_x, point_y));
114
115         point_x = -x + X0; point_y = y + Y0;
116         points.push_back(pair<int, int>(point_x, point_y));
117
118         point_x = x + X0; point_y = -y + Y0;
119         points.push_back(pair<int, int>(point_x, point_y));
120
121         point_x = -x + X0; point_y = -y + Y0;
122         points.push_back(pair<int, int>(point_x, point_y));
123
124         if( x != y ){
125             point_x = y + X0; point_y = x + Y0;
126             points.push_back(pair<int, int>(point_x, point_y)
    );
127
128             point_x = -y + X0; point_y = x + Y0;
129             points.push_back(pair<int, int>(point_x, point_y)
    );
130
131             point_x = y + X0; point_y = -x + Y0;
132             points.push_back(pair<int, int>(point_x, point_y)
    );
133
134             point_x = -y + X0; point_y = -x + Y0;
```

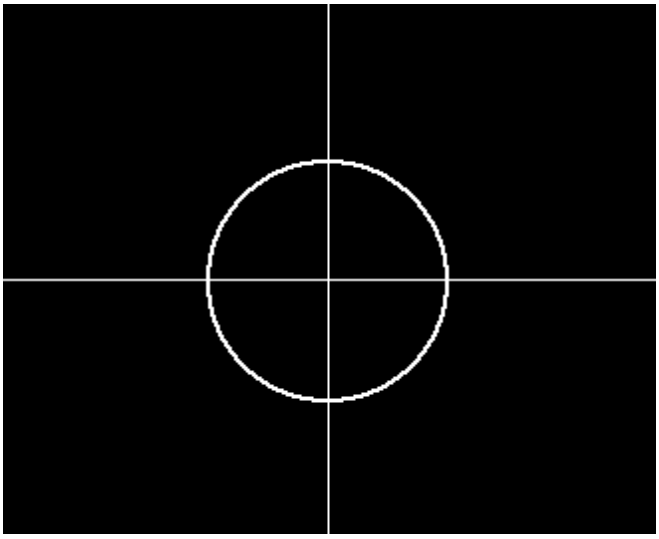
```
            points.push_back(pair<int, int>(point_x, point_y));
        }
    }
    return points;
}
```

```
#include "Helpers.h"

void runMainLoop(int val);

int main( int argc, char* args[] ){

    glutInit( &argc, args );

    glutInitContextVersion( 2, 1 );

    glutInitDisplayMode( GLUT_SINGLE|GLUT_RGB );
    glutInitWindowSize( SCREEN_WIDTH, SCREEN_HEIGHT );
    glutCreateWindow( "OpenGL" );

    int option=0;
    cout<<"Choose center: (1 for origin, 2 for elsewhere): ";
    cin>>option;

    selectCenter(option);
    cout<<"Center: ("<<X0<<", "<<Y0<<")"<<endl;
    cout<<"Radius: "<<radius<<endl;

    if( !initGL() )
    {
        printf( "Unable to initialize graphics library!\n" );
        return 1;
    }

    vector<pair<int, int>> points = Midpoint();
    int count=0;
    cout<<"Points plotted: "<<endl;
    for(pair<int, int> p: points){
        cout<<"("<<p.first<<", "<<p.second<<")"<<" ";
        count++;
        if(count==4){
            count=0;
            cout<<endl;
        }
    }
```

```
40
41      glutDisplayFunc( render );
42
43      glutTimerFunc( 1000 / SCREEN_FPS, runMainLoop, 0 );
44
45      glutMainLoop();
46
47      return 0;
48  }
49
50  void runMainLoop( int val ){
51      update();
52      render();
53
54      glutTimerFunc( 1000 / SCREEN_FPS, runMainLoop, val );
55  }
```

Output:

Center at origin:

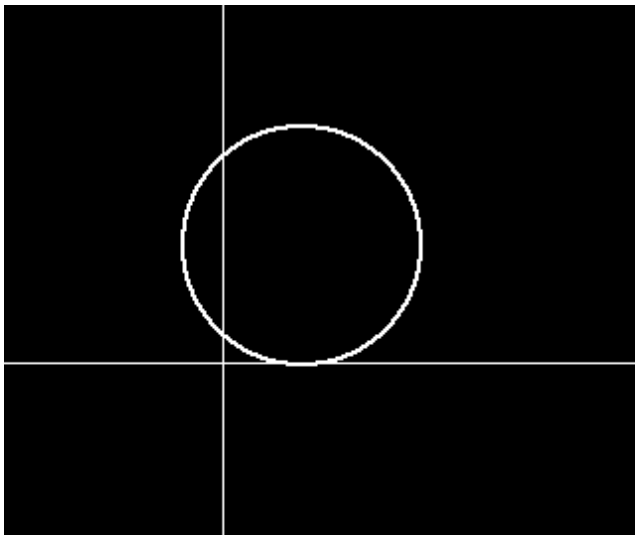


Choose center: (1 for origin, 2 for elsewhere): 1
Center: (0, 0) **Radius:** 60

Points plotted: (60, 0) (60, 1) (-60, 1) (60, -1) (-60, -1) (1, 60) (-1, 60) (1, -60) (-1, -60) (60, 2) (-60, 2) (60, -2) (-60, -2) (2, 60) (-2, 60) (2, -60) (-2, -60) (60, 3) (-60, 3) (60, -3) (-60, -3) (3, 60) (-3, 60) (3, -60) (-3, -60) (60, 4) (-60, 4) (60, -4) (-60, -4) (4, 60) (-4, 60) (4, -60) (-4, -60) (60, 5) (-60, 5) (60, -5) (-60, -5) (5, 60) (-5, 60) (5, -60) (-5, -60) (60, 6) (-60, 6) (60, -6) (-60, -6) (6, 60) (-6, 60) (6, -60) (-6, -60) (60, 7) (-60, 7) (60, -7) (-60, -7) (7, 60) (-7, 60) (7, -60) (-7, -60) (59, 8) (-59, 8) (59, -8) (-59, -8) (8, 59) (-8, 59) (8, -59) (-8, -59) (59, 9) (-59, 9) (59, -9) (-59, -9) (9, 59) (-9, 59) (9, -59) (-9, -59) (59, 10) (-59, 10) (59, -10) (-59, -10) (10, 59) (-10, 59) (10, -59) (-10, -59) (59, 11) (-59, 11) (59, -11) (-59, -11) (11, 59) (-11, 59) (11, -59) (-11, -59) (59, 12) (-59, 12) (59, -12) (-59, -12) (12, 59) (-12, 59) (12, -59) (-12, -59) (59, 13) (-59, 13) (59, -13) (-59, -13) (13, 59) (-13, 59) (13, -59) (-13, -59) (58, 14) (-58, 14) (58, -14) (-58, -14) (14, 58) (-14, 58) (14, -58) (-14, -58) (58, 15) (-58, 15) (58, -15) (-58, -15) (15, 58) (-15, 58) (15, -58) (-15, -58) (58, 16) (-58, 16) (58, -16) (-58, -16) (16, 58) (-16, 58) (16, -58) (-16, -58)

(58, 17) (-58, 17) (58, -17) (-58, -17) (17, 58) (-17, 58) (17, -58) (-17, -58)
(57, 18) (-57, 18) (57, -18) (-57, -18) (18, 57) (-18, 57) (18, -57) (-18, -57)
(57, 19) (-57, 19) (57, -19) (-57, -19) (19, 57) (-19, 57) (19, -57) (-19, -57)
(57, 20) (-57, 20) (57, -20) (-57, -20) (20, 57) (-20, 57) (20, -57) (-20, -57)
(56, 21) (-56, 21) (56, -21) (-56, -21) (21, 56) (-21, 56) (21, -56) (-21, -56)
(56, 22) (-56, 22) (56, -22) (-56, -22) (22, 56) (-22, 56) (22, -56) (-22, -56)
(55, 23) (-55, 23) (55, -23) (-55, -23) (23, 55) (-23, 55) (23, -55) (-23, -55)
(55, 24) (-55, 24) (55, -24) (-55, -24) (24, 55) (-24, 55) (24, -55) (-24, -55)
(55, 25) (-55, 25) (55, -25) (-55, -25) (25, 55) (-25, 55) (25, -55) (-25, -55)
(54, 26) (-54, 26) (54, -26) (-54, -26) (26, 54) (-26, 54) (26, -54) (-26, -54)
(54, 27) (-54, 27) (54, -27) (-54, -27) (27, 54) (-27, 54) (27, -54) (-27, -54)
(53, 28) (-53, 28) (53, -28) (-53, -28) (28, 53) (-28, 53) (28, -53) (-28, -53)
(53, 29) (-53, 29) (53, -29) (-53, -29) (29, 53) (-29, 53) (29, -53) (-29, -53)
(52, 30) (-52, 30) (52, -30) (-52, -30) (30, 52) (-30, 52) (30, -52) (-30, -52)
(51, 31) (-51, 31) (51, -31) (-51, -31) (31, 51) (-31, 51) (31, -51) (-31, -51)
(51, 32) (-51, 32) (51, -32) (-51, -32) (32, 51) (-32, 51) (32, -51) (-32, -51)
(50, 33) (-50, 33) (50, -33) (-50, -33) (33, 50) (-33, 50) (33, -50) (-33, -50)
(49, 34) (-49, 34) (49, -34) (-49, -34) (34, 49) (-34, 49) (34, -49) (-34, -49)
(49, 35) (-49, 35) (49, -35) (-49, -35) (35, 49) (-35, 49) (35, -49) (-35, -49)
(48, 36) (-48, 36) (48, -36) (-48, -36) (36, 48) (-36, 48) (36, -48) (-36, -48)
(47, 37) (-47, 37) (47, -37) (-47, -37) (37, 47) (-37, 47) (37, -47) (-37, -47)
(46, 38) (-46, 38) (46, -38) (-46, -38) (38, 46) (-38, 46) (38, -46) (-38, -46)
(46, 39) (-46, 39) (46, -39) (-46, -39) (39, 46) (-39, 46) (39, -46) (-39, -46)
(45, 40) (-45, 40) (45, -40) (-45, -40) (40, 45) (-40, 45) (40, -45) (-40, -45)
(44, 41) (-44, 41) (44, -41) (-44, -41) (41, 44) (-41, 44) (41, -44) (-41, -44)
(43, 42) (-43, 42) (43, -42) (-43, -42) (42, 43) (-42, 43) (42, -43) (-42, -43)

Center at (xc, yc):



Choose center: (1 for origin, 2 for elsewhere): 2
Center: (40, 60) **Radius:** 60

Points plotted: (100, 60) (100, 61) (-20, 61) (100, 59) (-20, 59) (41, 120) (39, 120) (41, 0) (39, 0) (100, 62) (-20, 62) (100, 58) (-20, 58) (42, 120) (38, 120) (42, 0) (38, 0) (100, 63) (-20, 63) (100, 57) (-20, 57) (43, 120) (37, 120) (43, 0) (37, 0) (100, 64) (-20, 64) (100, 56) (-20, 56) (44, 120) (36, 120) (44, 0) (36, 0) (100, 65) (-20, 65) (100, 55) (-20, 55) (45, 120) (35, 120) (45, 0) (35, 0) (100, 66) (-20, 66) (100, 54) (-20, 54) (46, 120) (34, 120) (46, 0) (34, 0) (100, 67) (-20, 67) (100, 53) (-20, 53) (47, 120) (33, 120) (47, 0) (33, 0) (99, 68) (-19, 68) (99, 52) (-19, 52) (48, 119) (32, 119) (48, 1) (32, 1) (99, 69) (-19, 69) (99, 51) (-19, 51) (49, 119) (31, 119) (49, 1) (31, 1) (99, 70) (-19, 70) (99, 50) (-19, 50) (50, 119) (30, 119) (50, 1) (30, 1) (99, 71) (-19, 71) (99, 49) (-19, 49) (51, 119) (29, 119) (51, 1) (29, 1) (99, 72) (-19, 72) (99, 48) (-19, 48) (52, 119) (28, 119) (52, 1) (28, 1) (99, 73) (-19, 73) (99, 47) (-19, 47) (53, 119) (27, 119) (53, 1) (27, 1) (98, 74) (-18, 74) (98, 46) (-18, 46) (54, 118) (26, 118) (54, 2) (26, 2) (98, 75) (-18, 75) (98, 45) (-18, 45) (55, 118) (25, 118) (55, 2) (25, 2) (98, 76) (-18, 76) (98, 44) (-18, 44) (56, 118) (24, 118) (56, 2) (24, 2) (98, 77) (-18, 77) (98, 43) (-18, 43) (57, 118) (23, 118) (57, 2) (23, 2) (97, 78) (-17, 78) (97, 42) (-17, 42) (58, 117) (22, 117) (58, 3) (22, 3) (97, 79) (-17, 79) (97, 41) (-17, 41) (59, 117) (21, 117) (59, 3)

(21, 3) (97, 80) (-17, 80) (97, 40) (-17, 40) (60, 117) (20, 117) (60, 3) (20, 3) (96, 81) (-16, 81) (96, 39) (-16, 39) (61, 116) (19, 116) (61, 4) (19, 4) (96, 82) (-16, 82) (96, 38) (-16, 38) (62, 116) (18, 116) (62, 4) (18, 4) (95, 83) (-15, 83) (95, 37) (-15, 37) (63, 115) (17, 115) (63, 5) (17, 5) (95, 84) (-15, 84) (95, 36) (-15, 36) (64, 115) (16, 115) (64, 5) (16, 5) (95, 85) (-15, 85) (95, 35) (-15, 35) (65, 115) (15, 115) (65, 5) (15, 5) (94, 86) (-14, 86) (94, 34) (-14, 34) (66, 114) (14, 114) (66, 6) (14, 6) (94, 87) (-14, 87) (94, 33) (-14, 33) (67, 114) (13, 114) (67, 6) (13, 6) (93, 88) (-13, 88) (93, 32) (-13, 32) (68, 113) (12, 113) (68, 7) (12, 7) (93, 89) (-13, 89) (93, 31) (-13, 31) (69, 113) (11, 113) (69, 7) (11, 7) (92, 90) (-12, 90) (92, 30) (-12, 30) (70, 112) (10, 112) (70, 8) (10, 8) (91, 91) (-11, 91) (91, 29) (-11, 29) (71, 111) (9, 111) (71, 9) (9, 9) (91, 92) (-11, 92) (91, 28) (-11, 28) (72, 111) (8, 111) (72, 9) (8, 9) (90, 93) (-10, 93) (90, 27) (-10, 27) (73, 110) (7, 110) (73, 10) (7, 10) (89, 94) (-9, 94) (89, 26) (-9, 26) (74, 109) (6, 109) (74, 11) (6, 11) (89, 95) (-9, 95) (89, 25) (-9, 25) (75, 109) (5, 109) (75, 11) (5, 11) (88, 96) (-8, 96) (88, 24) (-8, 24) (76, 108) (4, 108) (76, 12) (4, 12) (87, 97) (-7, 97) (87, 23) (-7, 23) (77, 107) (3, 107) (77, 13) (3, 13) (86, 98) (-6, 98) (86, 22) (-6, 22) (78, 106) (2, 106) (78, 14) (2, 14) (86, 99) (-6, 99) (86, 21) (-6, 21) (79, 106) (1, 106) (79, 14) (1, 14) (85, 100) (-5, 100) (85, 20) (-5, 20) (80, 105) (0, 105) (80, 15) (0, 15) (84, 101) (-4, 101) (84, 19) (-4, 19) (81, 104) (-1, 104) (81, 16) (-1, 16) (83, 102) (-3, 102) (83, 18) (-3, 18) (82, 103) (-2, 103) (82, 17) (-2, 17)

Objective:

To draw any object using line and circle drawing lgorithms.

Code:

```
#ifndef LOPENGL_H
#define LOPENGL_H

#include <GL/freeglut.h>
#include <GL/gl.h>
#include <GL/glu.h>
#include <math.h>
#include <stdio.h>
#include<iostream>
#include<vector>
#include<ctime>
using namespace std;

#endif
```

```
#ifndef LUTIL_H
#define LUTIL_H

#include "Headers.h"

//Screen Constants
const int SCREEN_WIDTH = 640;
const int SCREEN_HEIGHT = 480;
const int SCREEN_FPS = 60;
const int POINT_SIZE=2;

bool initGL();

void update();

void render();


void circle(int X0, int Y0, int radius);
```

```
20
21 void line(int x1, int y1, int x2, int y2);
22
23 void lineloop(int x1, int y1, int x2, int y2);
24
25 void solidQuad(int x1, int y1, int x2, int y2);
26
27 void platform();
28
29 void human();
30
31 void head();
32
33 void body();
34
35 void brush();
36
37 void canvas();
38
39 void art();
40
41 void base();
42
43 void snowman();
44
45 #endif
```

```
1 #include "Signatures.h"
2
3 bool initGL(){
4     //Initialize Projection Matrix
5     glMatrixMode( GL_PROJECTION );
6     glLoadIdentity();
7     gluOrtho2D(0.0,640.0,0.0,480.0);
8
9     //Initialize Modelview Matrix
10    glMatrixMode( GL_MODELVIEW );
11    glLoadIdentity();
12
13    // glTranslatef( SCREEN_WIDTH / 3.f, SCREEN_HEIGHT / 3.f,
      0.f );
14
15    //Initialize clear color
16    glClearColor( 0.f, 0.f, 0.f, 1.f );
17
18    glPointSize(POINT_SIZE);
```

```
19      glEnable(GL_POINT_SMOOTH);
20
21      //Check for error
22      GLenum error = glGetError();
23      if( error != GL_NO_ERROR )
24      {
25          printf( "Error initializing OpenGL! %s\n",
        gluErrorString( error ) );
26          return false;
27      }
28
29      return true;
30  }
31
32  void update(){
33
34  }
35
36  void render(){
37
38      glClear(GL_COLOR_BUFFER_BIT);
39      platform();
40      human();
41      canvas();
42      art();
43      glFlush();
44  }
45
46  void line(int x1, int y1, int x2, int y2) {
47
48      glBegin(GL_LINES);
49
50      glVertex2d(x1,y1);
51      glVertex2d(x2,y2);
52
53      glEnd();
54  }
55
56  void lineloop(int x1, int y1, int x2, int y2) {
57
58      glBegin(GL_LINE_LOOP);
59
60      glVertex2d(x1,y1);
61      glVertex2d(x2,y1);
62      glVertex2d(x2,y2);
```

```
63      glVertex2d(x1,y2);
64
65      glEnd();
66  }
67
68  void solidQuad(int x1, int y1, int x2, int y2) {
69
70      glBegin(GL_QUADS);
71
72      glVertex2d(x1,y1);
73      glVertex2d(x2,y1);
74      glVertex2d(x2,y2);
75      glVertex2d(x1,y2);
76
77      glEnd();
78  }
79
80  void circle(int X0, int Y0, int radius){
81      int x = radius;
82      int y = 0;
83
84      int p = 1 - radius;
85
86      int point_x = x + X0;
87      int point_y = y + Y0;
88
89
90      glBegin(GL_POINTS);
91
92      glVertex2d(point_x, point_y);
93
94      if( radius<0){
95          point_x = x + X0; point_y = -y + Y0;
96          glVertex2d(point_x, point_y);
97
98          point_x = y + X0; point_y = x + Y0;
99          glVertex2d(point_x, point_y);
100
101         point_x = -y + X0; point_y = x + Y0;
102         glVertex2d(point_x, point_y);
103     }
104
105     while(x > y){
106         y++;
107         if(p <=0){
```

```
108             p += ((2*y) + 1);
109         }
110         else{
111             x--;
112             p += ((2*y) - (2*x) + 1);
113         }
114         if(x < y)
115             break;
116 
117         point_x = x + X0; point_y = y + Y0;
118         glVertex2d(point_x, point_y);
119 
120         point_x = -x + X0; point_y = y + Y0;
121         glVertex2d(point_x, point_y);
122 
123         point_x = x + X0; point_y = -y + Y0;
124         glVertex2d(point_x, point_y);
125 
126         point_x = -x + X0; point_y = -y + Y0;
127         glVertex2d(point_x, point_y);
128 
129         if( x != y ){
130             point_x = y + X0; point_y = x + Y0;
131             glVertex2d(point_x, point_y);
132 
133             point_x = -y + X0; point_y = x + Y0;
134             glVertex2d(point_x, point_y);
135 
136             point_x = y + X0; point_y = -x + Y0;
137             glVertex2d(point_x, point_y);
138 
139             point_x = -y + X0; point_y = -x + Y0;
140             glVertex2d(point_x, point_y);
141         }
142     }
143     glEnd();
144 }
145 
146 
147 void platform(){
148     solidQuad(100, 50, 600, 100);
149 }
150 
151 void human(){
152     head();
```

```
153     body();
154     brush();
155 }
156 
157 void head(){
158     circle(300, 300, 20);
159 }
160 
161 void body(){
162     //torso
163     line(300, 280, 300, 175);
164 
165     //arm
166     line(300, 260, 275, 235);
167     line(275, 235, 310, 190);
168 
169     line(300, 260, 325, 235);
170     line(325, 235, 360, 250);
171 
172     //legs
173     line(300, 175, 325, 100);
174     line(300, 175, 275, 100);
175 }
176 
177 void brush(){
178     line(345, 258, 385, 230);
179     line(346, 259, 386, 231);
180     line(347, 260, 387, 232);
181 
182     line(345, 258, 347, 260);
183     line(385, 230, 387, 232);
184 
185     //bristles
186     line(385, 230, 388, 228);
187     line(387, 232, 388, 228);
188 }
189 
190 
191 void canvas(){
192     lineloop(375, 150, 575, 340);
193 
194     line(475, 150, 445, 100);
195     line(475, 150, 505, 100);
196 }
197 
```

```
198 void art(){
199     base();
200     snowman();
201 }
202
203 void base(){
204     line(395, 170, 555, 170);
205 }
206
207 void snowman(){
208     //body
209     circle(475, 210, 40);
210     circle(475, 215, 2);
211     circle(475, 225, 2);
212     circle(475, 235, 2);
213
214     line(512, 220, 550, 218);
215     line(532, 219, 549, 208);
216     line(532, 219, 549, 228);
217
218     line(438, 220, 400, 218);
219     line(418, 219, 401, 208);
220     line(418, 219, 401, 228);
221
222     //head
223     circle(475, 270, 20);
224
225     //eyes
226     circle(467, 275, 4);
227     circle(483, 275, 4);
228
229     // circle(475, 265, 2);
230
231     //mouth
232     for(int x=465, y=260; x<475; x+=3, y-=1){
233         circle(x, y, 0);
234     }
235     for(int x=485, y=260; x>475; x-=3, y-=1){
236         circle(x, y, 0);
237     }
238
239
240 }
```

```
1 #include "Helpers.h"
2
```

```
3  void runMainLoop(int val);
4
5  int main( int argc, char* args[] ){
6
7      glutInit( &argc, args );
8
9      glutInitContextVersion( 2, 1 );
10
11     glutInitDisplayMode( GLUT_SINGLE|GLUT_RGB );
12     glutInitWindowSize( SCREEN_WIDTH, SCREEN_HEIGHT );
13     glutCreateWindow( "OpenGL" );
14
15     if( !initGL() )
16     {
17         printf( "Unable to initialize graphics library!\n" );
18         return 1;
19     }
20
21     glutDisplayFunc( render );
22
23     glutTimerFunc( 1000 / SCREEN_FPS, runMainLoop, 0 );
24
25     glutMainLoop();
26
27     return 0;
28 }
29
30 void runMainLoop( int val ){
31     update();
32     render();
33
34     glutTimerFunc( 1000 / SCREEN_FPS, runMainLoop, val );
35 }
```

Output: