# 컴퓨터 그래픽스 입문

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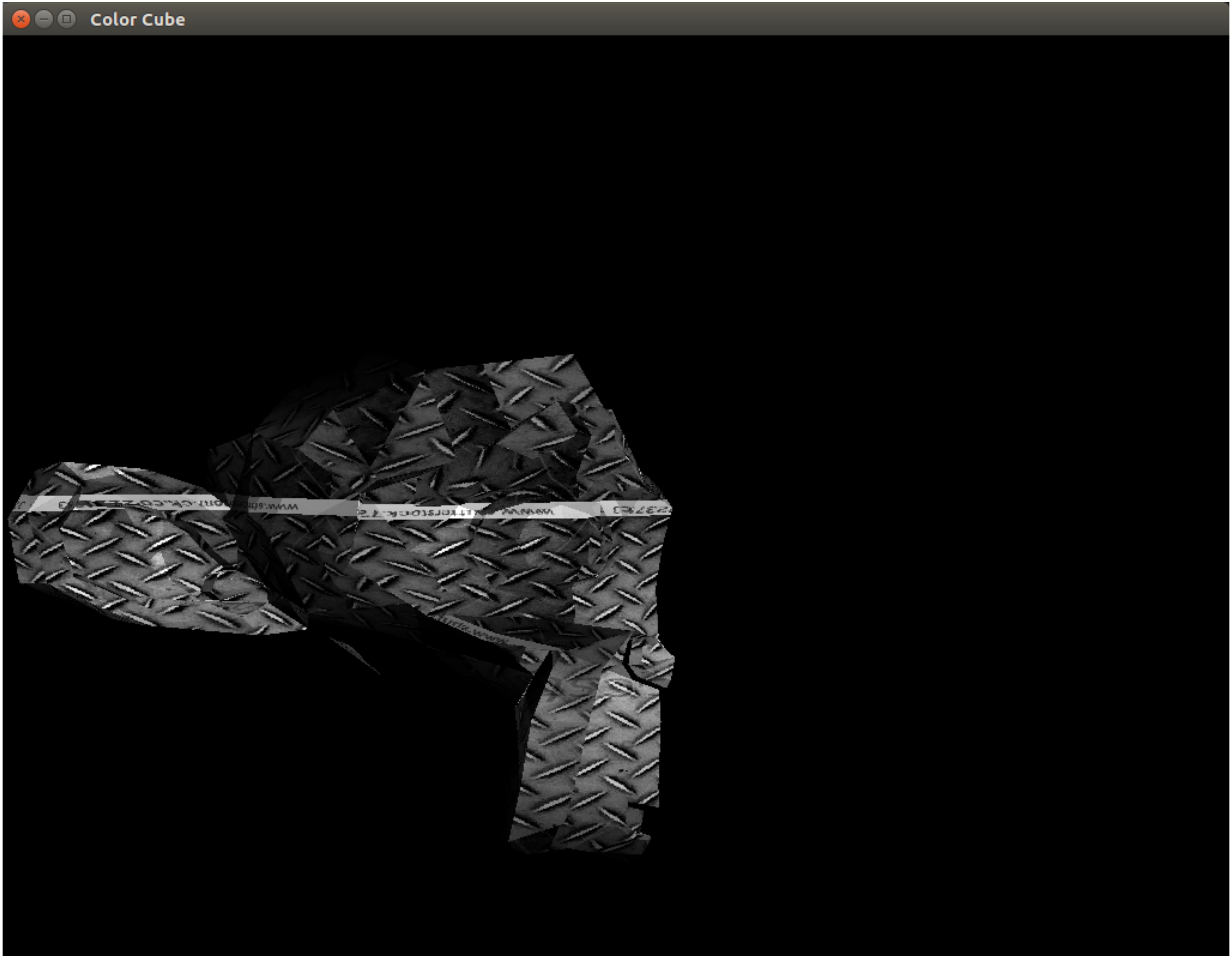
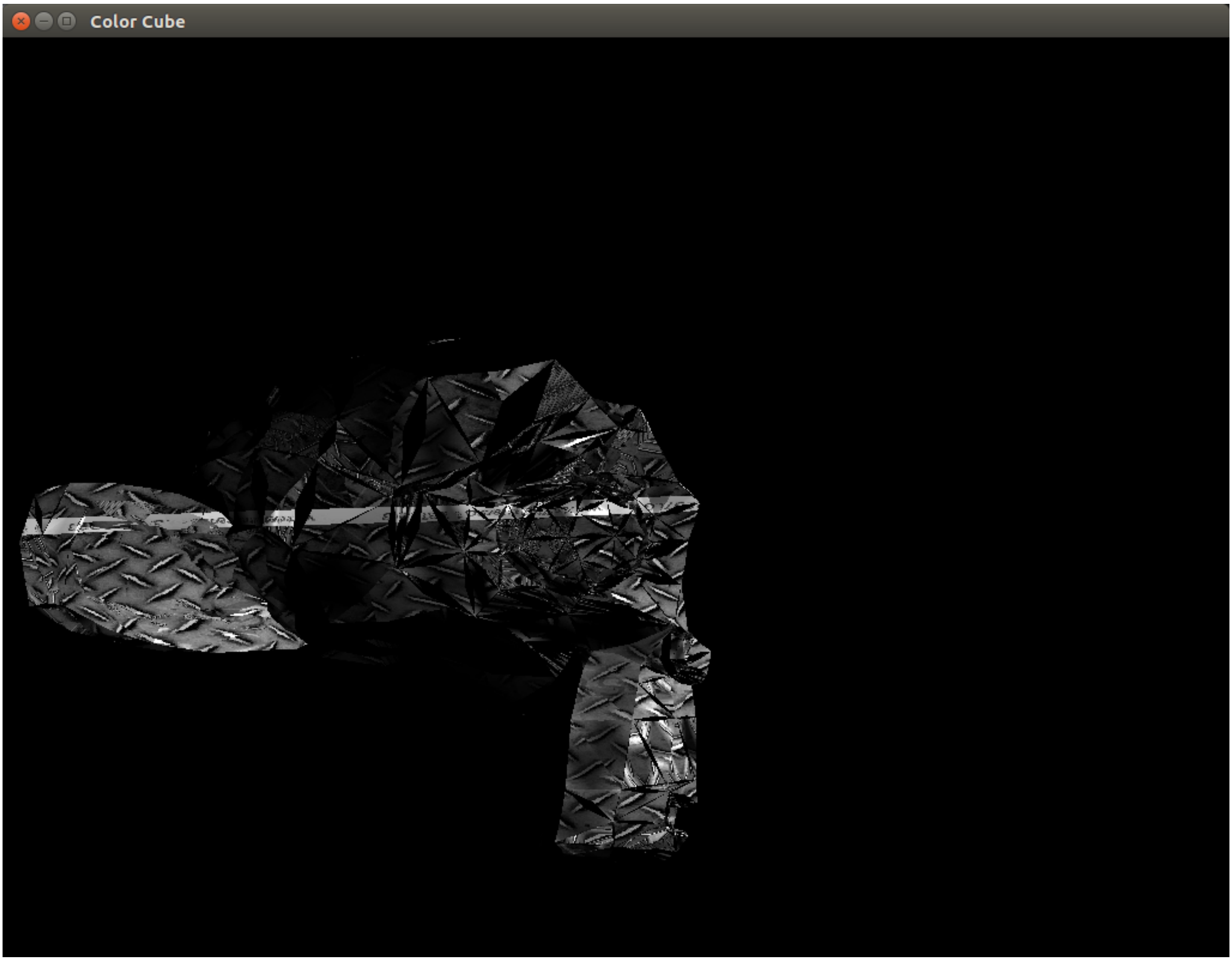
# Lab 11. Texturing

```
Pick a relatively low resolution 3D model from the thingiverse.

Step 1. Apply the butterfly subdivision. Show the difference before and after

Step 2. Apply the Loop subdivision. Show the difference before and after apply

Step 3. Show the difference between the butterfly and the Loop subdivision. (4
```

블렌더의 대표 마스코트인 몽키를 triangle subdivision했다. 위가 loop이고, 아래가 butterfly이다. 그런데, normal에서의 버그가 있어서인지, 트라이앵글을 나누어서 노말을 자체적으로 계산했을때, 원숭이의 얼굴 반만이 나왔다.





```
#include<fstream>
#include<GL/glew.h>
#include<highgui.h>
#include”globj.h”
using namespace std;

GLObject::GLObject() : matrix_{4,4} {
    matrix_.E();
}
void GLObject::matrix(const Matrix<float>& m) { matrix_ = m; }
void GLObject::mode(GLenum md) { mode_ = md; }
void GLObject::vertexes(const vector<Matrix<float>>& v) { vertexes_ = v; }
void GLObject::vertexes(vector<Matrix<float>>&& v) { vertexes_ = move(v); }
void GLObject::colors(const vector<Matrix<float>>& v) { colors_ = v; }
void GLObject::colors(vector<Matrix<float>>&& v) { colors_ = move(v); }
void GLObject::indices(const vector<unsigned>& v) { indices_ = v; }
void GLObject::indices(vector<unsigned>&& v) { indices_ = move(v); }
void GLObject::texture_file(string f) { texture_file_ = f; }
void GLObject::subdiv_triangle()
```

```
{
    assert (mode_ == GL_TRIANGLES);
    vector<Matrix<float>> v;
    vector<unsigned> ix;
    try {
        for(int i=0; i<indices_.size(); i+=3) {
            auto a = vertexes_[indices_[i]];
            auto b = vertexes_[indices_[i+1]];
            auto c = vertexes_[indices_[i+2]];
            v.push_back(a);
            v.push_back(b);
            v.push_back(c);
            v.push_back((a + b) * 0.5f);
            v.push_back((b + c) * 0.5f);
            v.push_back((c + a) * 0.5f);
            unsigned rel_pos[] = {0, 3, 5, 3, 1, 4, 3, 4, 5, 5, 4, 2};
            for(unsigned j : rel_pos) ix.push_back(i*2 + j);
        }
    } catch(const char* e) { cerr << e << endl; }
    vertexes_ = v;
    indices_ = ix;
    normals_.clear();
}

void GLObject::butterfly()
{
    assert (mode_ == GL_TRIANGLES);
    vector<Matrix<float>> v;
    vector<unsigned> ix;
    try {
        for(int i=0; i<indices_.size(); i+=3) {
            auto a = vertexes_[indices_[i]];
            auto b = vertexes_[indices_[i+1]];
            auto c = vertexes_[indices_[i+2]];
            v.push_back(a);
            v.push_back(b);
            v.push_back(c);
            auto m1 = (a+b) * .5f;
            auto m2 = (b+c) * .5f;
            auto m3 = (c+a) * .5f;
            v.push_back(m1 + (m1-c) * 0.1);
            v.push_back(m2 + (m2-a) * 0.1);
            v.push_back(m3 + (m3−b) * 0.1);
            unsigned rel_pos[] = {0, 3, 5, 3, 1, 4, 3, 4, 5, 5, 4, 2};
            for(unsigned j : rel_pos) ix.push_back(i * 2 + j);
        }
    } catch(const char* e) { cerr << e << endl; }
    vertexes_ = v;
    indices_ = ix;
    normals_.clear();
}

void GLObject::normals()
{///should come after setting mode
    if(normals_.size() == vertexes_.size()) return;
    normals_.resize(vertexes_.size());
    int face;
    switch(mode_) {
        case GL_TRIANGLES: face = 3; break;
        case GL_QUADS: face = 4; break;
        default: face = 3;
    }
    try{
        for(int i=0; i<indices_.size(); i+=face) {
            auto v1 = vertexes_[indices_[i+1]] − vertexes_[indices_[i]];
            auto v2 = vertexes_[indices_[i+2]] − vertexes_[indices_[i]];
            auto n = cross(v1, v2);
            for(int j=0; j<face; j++)
                normals_[indices_[i+j]] = normals_[indices_[i+j]] + n;
        }
    } catch(const char* e) { cerr << e << endl; }
    for(auto& a : normals_) {
        a = a * (1.0f / sqrt(a[1][1]* a[1][1] + a[1][2]* a[1][2] + a[1][3]* a[1][3]));
        a[1][4] = 1;
    }
}

Matrix<float> GLObject::cross(const Matrix<float>& v1, const Matrix<float>& v2)
{
    Matrix<float> m{v1[1][2] * v2[1][3] − v1[1][3] * v2[1][2],
                    v1[1][3] * v2[1][1] − v1[1][1] * v2[1][3],
                    v1[1][1] * v2[1][2] − v1[1][2] * v2[1][1]};
    float r = sqrt(m[1][1] * m[1][1] + m[1][2] * m[1][2] + m[1][3] * m[1][3]);
    m = m * (1.0f/r);
    m[1][4] = 1;
    return m;
}

unsigned GLObject:: read_obj_file ( string  file )
{
    int face = 0;
    string s;
    ifstream f( file );
    while(getline (f, s)) {
        stringstream ss{s};
        ss >> s;
        if(s == ”v”) {
            float x,  y, z;
            ss >> x >> y >> z;
            vertexes_ .push_back(Matrix<float>{x,y,z});
        } else if(s == ”f”) {
            while(getline (ss , s, '/')) {
                indices_ .push_back( stoi (s)−1);
                getline (ss , s, ' ');
                face++;
            }
            if(face == 3) mode(GL_TRIANGLES);
            else if(face == 4) mode(GL_QUADS);
        } else if(s == ”vn”) {
            float x, y, z;
            ss >> x >> y >> z;
            normals_.push_back(Matrix<float>{x, y, z});
        }
    }
    cout << file << ”\'s indices  size : ” << indices_. size ()  << endl;
    return vertexes_ . size () ;
}


void GLObject:: colors ()
{//change to fit to texture u,v position
    if( texture_file_  == ””) return;
    colors_ . clear () ;
    normalize_vertex () ;
    for(int i=0; i<normals_.size () ; i++) {
        float x = normals_[i ][1][1];
        float y = normals_[i ][1][2];
        float z = normals_[i ][1][3]; //find biggest abs->vertex coord
        float vx = vertexes_[i ][1][1];
        float vy = vertexes_[i ][1][2];
        float vz = vertexes_[i ][1][3];

//      if(abs(x) > abs(y) && abs(x) > abs(z)) colors_.push_back({x>0?1:-1, vy, vz});
//      else if(abs(y)>abs(z) && abs(y)>abs(x)) colors_.push_back({vx, y>0?1:-1, vz});
//      else colors_.push_back({vx, vy, z>0?1:-1});

        if(abs(x) > abs(y) && abs(x) > abs(z)) //map to 육면체 전개도
            colors_.push_back({x > 0 ? 0.5 + (1 - vz) / 8 : (vz + 1) / 8,
                    1.0f / 3 + (vy + 1) / 6, 0});
        else if(abs(y)>abs(z) && abs(y)>abs(x))
            colors_.push_back({0.25 + (vx + 1) / 8,
                    y > 0 ? (vz + 1) / 6 : 2.0f / 3 + (1 - vz) / 6, 0});
        else colors_.push_back({z > 0 ? 0.25 + (vx + 1) / 8 : 0.75 + (1 - vx) / 8,
                1.0f / 3 + (vy + 1) / 6, 0});
    }

    cout << "colors_ size : " << colors_.size() << endl;
    for(auto& a : colors_) {
        assert(a[1][1] >= -1 && a[1][1] <= 1);
        assert(a[1][2] >= -1 && a[1][2] <= 1);
        assert(a[1][3] >= -1 && a[1][3] <= 1);
    }
}

void GLObject::normalize_vertex()
{
    float xmin, xmax, ymin, ymax, zmin, zmax;
    xmin = xmax = vertexes_[0][1][1];
    ymin = ymax = vertexes_[0][1][2];
    zmin = zmax = vertexes_[0][1][3];
    for(auto& a : vertexes_) {
        if(xmin > a[1][1]) xmin = a[1][1];
        if(xmax < a[1][1]) xmax = a[1][1];
        if(ymin > a[1][2]) ymin = a[1][2];
        if(ymax < a[1][2]) ymax = a[1][2];
        if(zmin > a[1][3]) zmin = a[1][3];
        if(zmax < a[1][3]) zmax = a[1][3];
    }
    float x = xmax − xmin;
    float y = ymax − ymin;
    float z = zmax − zmin;
    float rate = max(x, max(y,z));
    for(auto& a : vertexes_) {
        a[1][1] −= xmin;
        a[1][2] −= ymin;
        a[1][3] −= zmin;
        for(int i=1; i<4; i++) {
            a[1][i] /= rate;
            a[1][i] −= 0.5;
            a[1][i] *= 2;
        }
    }
    for(auto& a : vertexes_) {
        assert(a[1][1] >= −1 && a[1][1] <= 1);
        assert(a[1][2] >= −1 && a[1][2] <= 1);
        assert(a[1][3] >= −1 && a[1][3] <= 1);
    }
}
```

Listing 1: main함수

```
#include<chrono>
#include<thread>
#include<iostream>
#include"glutil.h"
#include"globj.h"
#include"spring.h"
using namespace std;
extern Matrix<float> KeyBindMatrix;

int main(int ac, char** av)
{
    if (!glfwInit()) return −1;
    GLFWwindow* window = glfwCreateWindow(1024, 768, "Color Cube", NULL, NULL);
    if (!glinit(window)) return −1;

    Matrix<float> m{4,4};
    GLObject obj3d;
    obj3d.read_obj_file(av[1]);
    obj3d.matrix(m.glrotateY(−M_PI/2) * m.glrotateX(−M_PI/2) * m.glscale(0.8,0.8,0.8));

//  obj3d.subdiv_triangle();
//  obj3d.subdiv_triangle();
//  obj3d.butterfly();
//  obj3d.butterfly();
    obj3d.texture_file(av[2]);
    GLObjs stage;
    stage += obj3d;
    stage.transfer_all();
    float th = 0;
    Matrix<float> lt {
        {0.1, 0.1, 0.1, 1}, //ambient
        {0.5, 0.5, 0.5, 0.5}, // diffuse
        {1, 1, 1, 1}, // specular
        {3, 3, -3, 1} // position 1 means a point 0 means a vector light
    };
    SpringModel sp, sp2;
    float t = 0;
    while (!glfwWindowShouldClose(window)) {
        glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);

        float y = sp2.time_pass(sp.time_pass(sin(t += 0.05)));
        stage.matrix(KeyBindMatrix * m.gltranslate(0,y,0) * stage[0]);
        stage(0);

        glfwSwapBuffers(window);
        glfwPollEvents();
        // this_thread::sleep_for(chrono::milliseconds(50));
    }
    glfwTerminate();
}
```

k=스프링상수, m=질량, x=위치, c=damping, x0=스프링이 달린 부분의 움직임,위치

$$F = ma = -k(x - x_0) - c\frac{dx}{dt}$$

$$m\frac{d^2x}{dt^2} + c\frac{dx}{dt} + k(x - x_0) = 0 \tag{1}$$

$$let \quad \frac{dx}{dt} = z(t)$$

$$\frac{x(t + \Delta t) - x(t)}{\Delta t} = z(t)$$

$$x(t + \Delta t) = z(t)\Delta t + x(t) \tag{2}$$

$$from(1) \quad m\frac{dz}{dt} + cz(t) + k(x - x_0) = 0$$

$$m\frac{z(t + \Delta t) - z(t)}{\Delta t} + cz(t) + k(x - x_0) = 0$$

$$z(t + \Delta t) = (cz(t) + k(x - x_0))\frac{\Delta t}{-m} + z(t) \tag{3}$$

위의 식 2,3으로부터 수치해석적으로 x(t)를 구할 수 있다.

```
float SpringModel::time_pass(float x0, float dt) {
    x = z * dt + x;
    z = (c*z + k*(x - x0)) * dt / -m + z;
}
```