PORTFOLIO

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1 | Introduction

About Me

Introduction About Me

- Changhwi Park
- smsychjy96@gmail.com
- https://github.com/ObjectOrientedLife
- Education - Seoul Nation University, Geography / Computer Science
- Interests - Game development / Computer graphics(realtime rendering, shader, ray tracing, humanoid animation) / Computer vision / Human pose estimation
- Languages - C#, C++, Python, Shader language(Cg, HLSL)
- Skills - Unity, OpenGL, OpenCV / Blender, ZBrush, Substance Painter

2 | With the Infantry

Top-view RTT game project

1) Roles
2) Programming
3) Art
4) Demo

1) Roles - One-man Development

Took charge of every stage of the game development

Design

- Gameplay concept
- Planning
- Background research

Art

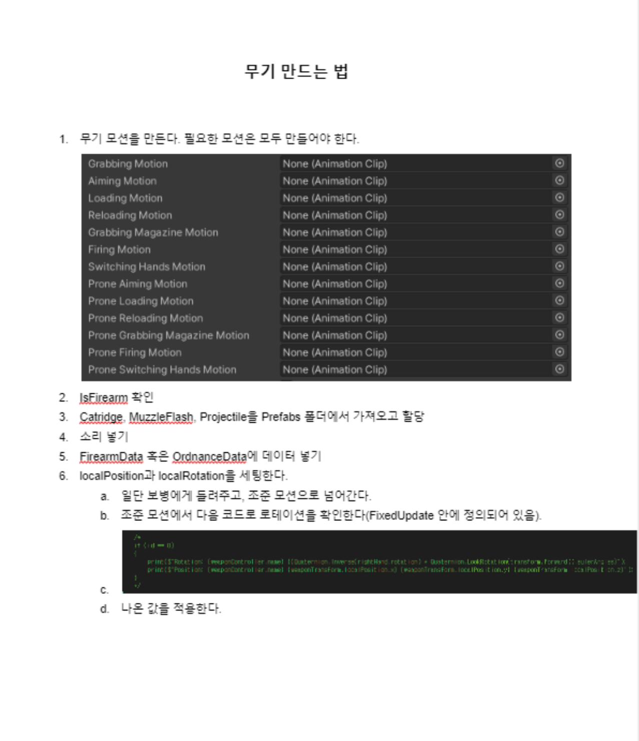
- Modeling
- Sculpting / texturing
- Rigging / skinning / animating

Programming

- Unity
- Client(C#)
- Server(Unity Mirror)
- Shader(Cg)

1) Roles After Building a Team

- Organized a team composed of three members
- Communication - hosting meetings, scheduling, feedback
- Establishing modeling processes
- Writing design specifications
- Tutoring how to utilize modeling tools



무기 만드는 법

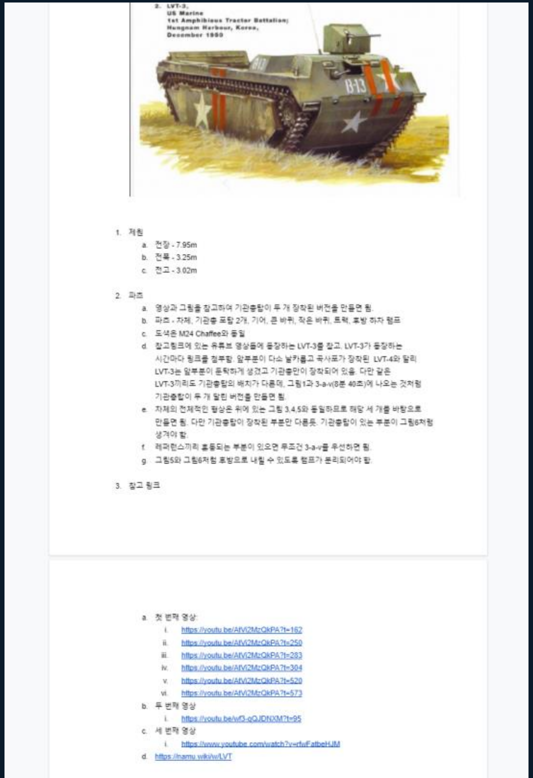
1. 무기 모션을 만든다. 필요한 모션은 모두 만들어야 한다.

Grabbing Motion	None (Animation Clip)
Aiming Motion	None (Animation Clip)
Loading Motion	None (Animation Clip)
Reloading Motion	None (Animation Clip)
Grabbing Magazine Motion	None (Animation Clip)
Firing Motion	None (Animation Clip)
Switching Hands Motion	None (Animation Clip)
Prone Aiming Motion	None (Animation Clip)
Prone Loading Motion	None (Animation Clip)
Prone Reloading Motion	None (Animation Clip)
Prone Grabbing Magazine Motion	None (Animation Clip)
Prone Firing Motion	None (Animation Clip)
Prone Switching Hands Motion	None (Animation Clip)

2. IsFirearm 확인
3. Catridge, MuzzleFlash, Projectile을 Prefabs 폴더에서 가져오고 할당
4. 소리 넣기
5. FirearmData 혹은 OrdnanceData에 데이터 넣기
6. localPosition과 localRotation을 세팅한다.
   a. 일단 보병에게 들려주고, 조준 모션으로 넘어간다.
   b. 조준 모션에서 다음 코드로 로테이션을 확인한다(FixedUpdate 안에 정의되어 있음).
   c.

```
/*
if (id == 0)
{
    print($"Rotation: {weaponController.name} {(Quaternion.Inverse(rightHand.rotation) * Quaternion.LookRotation(transform.forward)).eulerAngles}");
    print($"Position: {weaponController.name} {weaponTransform.localPosition.x} {weaponTransform.localPosition.y} {weaponTransform.localPosition.z}");
}
*/
```

   d. 나온 값을 적용한다.



2. LVT-3,
US Marine
1st Amphibious Tractor Battalion;
Hungnam Harbour, Korea,
December 1950

1. 제원
   a. 전장 - 7.95m
   b. 전폭 - 3.25m
   c. 전고 - 3.02m

2. 파츠
   a. 영상과 그림을 참고하여 기관총탑이 두 개 장착된 버전을 만들면 됨.
   b. 파츠 - 차체, 기관총 포탑 2개, 기어, 큰 바퀴, 작은 바퀴, 트랙, 후방 하차 램프
   c. 도색은 M24 Chaffee와 동일
   d. 참고링크에 있는 유튜브 영상들에 등장하는 LVT-3를 참고. LVT-3가 등장하는 시간마다 링크를 첨부함. 앞부분이 다소 날카롭고 곡사포가 장착된 LVT-4와 달리 LVT-3는 앞부분이 뭉툭하게 생겼고 기관총만이 장착되어 있음. 다만 같은 LVT-3끼리도 기관총탑의 배치가 다른데, 그림1과 3-a-v(8분 40초)에 나오는 것처럼 기관총탑이 두 개 달린 버전을 만들면 됨.
   e. 차체의 전체적인 형상은 위에 있는 그림 3,4,5와 동일하므로 해당 세 개를 바탕으로 만들면 됨. 다만 기관총탑이 장착된 부분만 다른듯. 기관총탑이 있는 부분이 그림6처럼 생겨야 함.
   f. 레퍼런스끼리 혼동되는 부분이 있으면 무조건 3-a-v를 우선하면 됨.
   g. 그림5와 그림6처럼 후방으로 내릴 수 있도록 램프가 분리되어야 함.

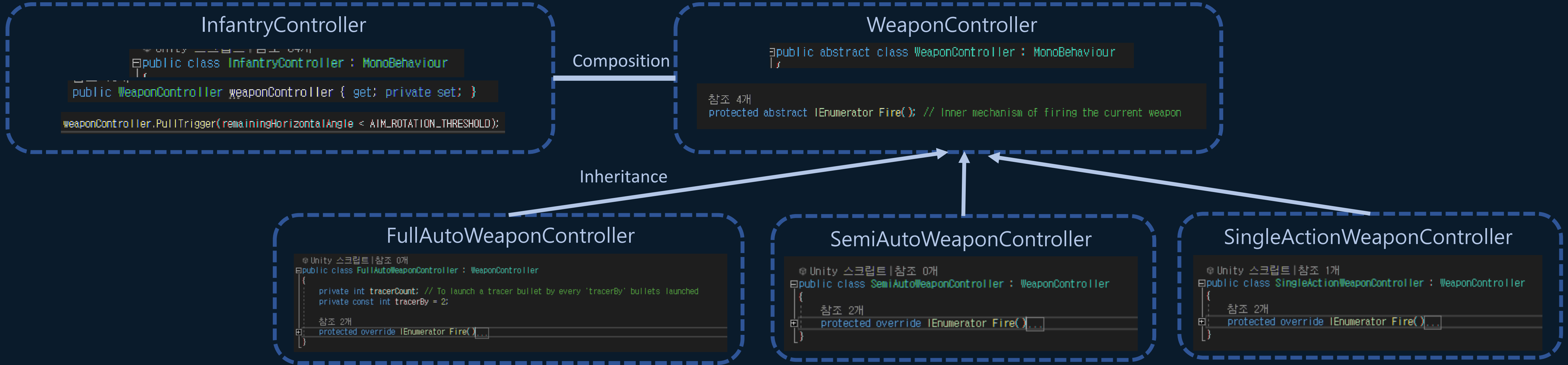
3. 참고 링크
   a. 첫 번째 영상:
      i. https://youtu.be/AfVi2MzQkPA?t=162
      ii. https://youtu.be/AfVi2MzQkPA?t=250
      iii. https://youtu.be/AfVi2MzQkPA?t=283
      iv. https://youtu.be/AfVi2MzQkPA?t=304
      v. https://youtu.be/AfVi2MzQkPA?t=520
      vi. https://youtu.be/AfVi2MzQkPA?t=573
   b. 두 번째 영상
      i. https://youtu.be/wf3-qQJDNXM?t=95
   c. 세 번째 영상
      i. https://www.youtube.com/watch?v=rfwFatbeHJM
   d. https://namu.wiki/w/LVT

2) Programming Client

Hardships	Solutions
• Codes becoming too verbose due to a variety of weapons(single action, automatic) and vehicles(howitzers, tanks, aircrafts) • Hard to understand interactions between modules	• Inheritance structure based on the SOLID principles that enhances reusability • Separation of interfaces and implementations using design patterns(singleton, abstract factory, strategy)
• Requirement for optimization • Readability - optimization tradeoff • Memory - time tradeoff(ex - object pooling)	• Classify game stages into four hierarchies(initialization - occasionally during a playtime - frequently during a playtime - every frame) and apply different levels of optimization
• Limited modeling capability • Hard to maintain coherency	• Rescues to the reusability of the resources • Customizable character

2) Programming Strategy Pattern - Weapon

- Every soldier owns a firearm
- Weapons feature several common functionalities, including launching bullets, ejecting cartridges, and reloading
- Make a WeaponController class that embraces all the weapons
- Classify weapons into full-auto / semi-auto / single-action, and their classes inherits from the WeaponController class
- A soldier can fire his weapon by just calling weaponController.PullTrigger(), without taking care of the actual mechanism
- Separation of the interface and the implementation



InfantryController

```
public class InfantryController : MonoBehaviour
{
public WeaponController weaponController { get; private set; }

weaponController.PullTrigger(remainingHorizontalAngle < AIM_ROTATION_THRESHOLD);
```

WeaponController

```
public abstract class WeaponController : MonoBehaviour
{

참조 4개
protected abstract IEnumerator Fire(); // Inner mechanism of firing the current weapon
```

FullAutoWeaponController

```
Unity 스크립트|참조 0개
public class FullAutoWeaponController : WeaponController
{
    private int tracerCount; // To launch a tracer bullet by every 'tracerBy' bullets launched
    private const int tracerBy = 2;

    참조 2개
    protected override IEnumerator Fire()...
}
```

SemiAutoWeaponController

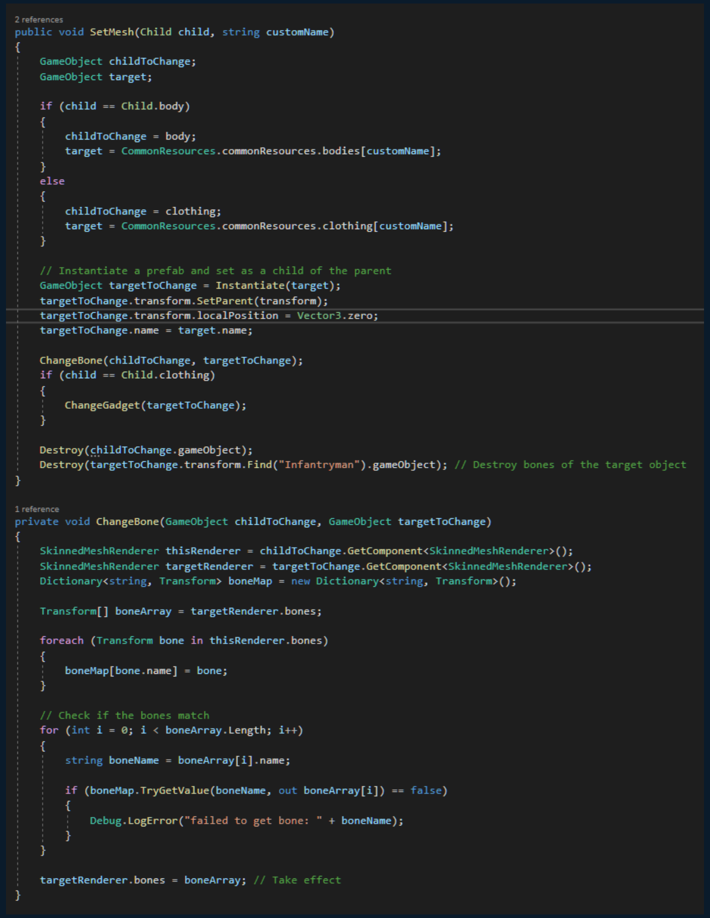
```
Unity 스크립트|참조 0개
public class SemiAutoWeaponController : WeaponController
{
    참조 2개
    protected override IEnumerator Fire()...
}
```

SingleActionWeaponController

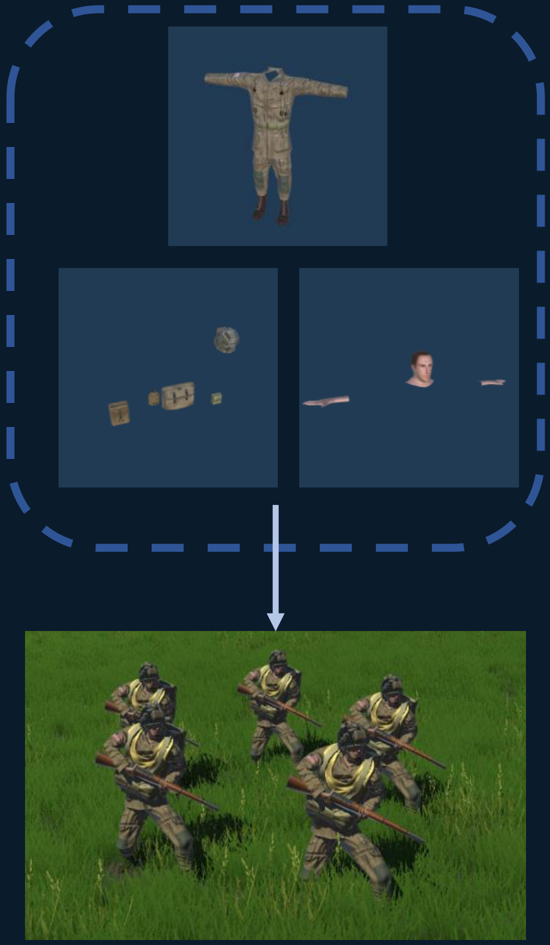
```
Unity 스크립트|참조 1개
public class SingleActionWeaponController : WeaponController
{
    참조 2개
    protected override IEnumerator Fire()...
}
```

2) Programming Character Customizer

- Too many combinations of clothing / bodies / gadgets
- Produce clothing / bodies / gadgets separately and combine them together in Unity
- Replace the deformable object itself and the bones
- Undeformable gadgets are managed through tags

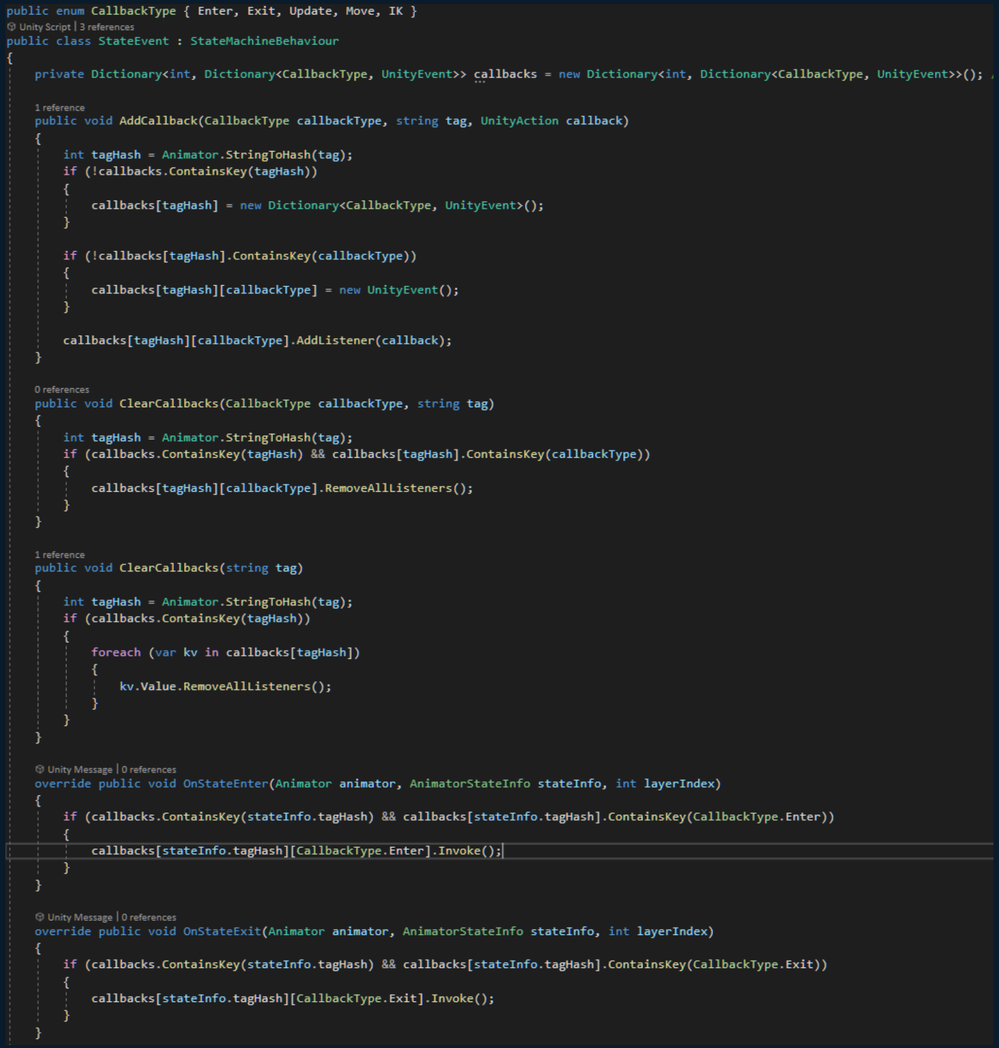


```
2 references
public void SetMesh(Child child, string customName)
{
    GameObject childToChange;
    GameObject target;

    if (child == Child.body)
    {
        childToChange = body;
        target = CommonResources.commonResources.bodies[customName];
    }
    else
    {
        childToChange = clothing;
        target = CommonResources.commonResources.clothing[customName];
    }

    // Instantiate a prefab and set as a child of the parent
    GameObject targetToChange = Instantiate(target);
    targetToChange.transform.SetParent(transform);
    targetToChange.transform.localPosition = Vector3.zero;
    targetToChange.name = target.name;

    ChangeBone(childToChange, targetToChange);
    if (child == Child.clothing)
    {
        ChangeGadget(targetToChange);
    }

    Destroy(childToChange.gameObject);
    Destroy(targetToChange.transform.Find("Infantryman").gameObject); // Destroy bones of the target object
}

1 reference
private void ChangeBone(GameObject childToChange, GameObject targetToChange)
{
    SkinnedMeshRenderer thisRenderer = childToChange.GetComponent<SkinnedMeshRenderer>();
    SkinnedMeshRenderer targetRenderer = targetToChange.GetComponent<SkinnedMeshRenderer>();
    Dictionary<string, Transform> boneMap = new Dictionary<string, Transform>();

    Transform[] boneArray = targetRenderer.bones;

    foreach (Transform bone in thisRenderer.bones)
    {
        boneMap[bone.name] = bone;
    }

    // Check if the bones match
    for (int i = 0; i < boneArray.Length; i++)
    {
        string boneName = boneArray[i].name;

        if (boneMap.TryGetValue(boneName, out boneArray[i]) == false)
        {
            Debug.LogError("failed to get bone: " + boneName);
        }
    }

    targetRenderer.bones = boneArray; // Take effect
}
```



2) Programming Animation State Callback

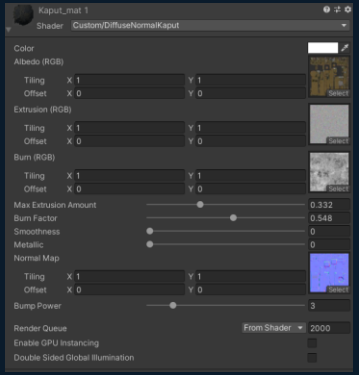
- Unity provides ways to detect animation state changes with the StateMachineBehaviour
- StateMachineBehaviour is hard to be modified during a runtime
- Wrote a trick script to resolve the limitation
- By hiring the callback pattern, the performance gets better and the code becomes more succinct
- Used for weapon reloading motions
    - Set a magazine as a child of a hand upon the reloading motion starts
    - Set the magazine as a child of the firearm upon the reloading motion ends



```
public enum CallbackType { Enter, Exit, Update, Move, IK }
Unity Script | 3 references
public class StateEvent : StateMachineBehaviour
{
    private Dictionary<int, Dictionary<CallbackType, UnityEvent>> callbacks = new Dictionary<int, Dictionary<CallbackType, UnityEvent>>();

    1 reference
    public void AddCallback(CallbackType callbackType, string tag, UnityAction callback)
    {
        int tagHash = Animator.StringToHash(tag);
        if (!callbacks.ContainsKey(tagHash))
        {
            callbacks[tagHash] = new Dictionary<CallbackType, UnityEvent>();
        }

        if (!callbacks[tagHash].ContainsKey(callbackType))
        {
            callbacks[tagHash][callbackType] = new UnityEvent();
        }

        callbacks[tagHash][callbackType].AddListener(callback);
    }

    0 references
    public void ClearCallbacks(CallbackType callbackType, string tag)
    {
        int tagHash = Animator.StringToHash(tag);
        if (callbacks.ContainsKey(tagHash) && callbacks[tagHash].ContainsKey(callbackType))
        {
            callbacks[tagHash][callbackType].RemoveAllListeners();
        }
    }

    1 reference
    public void ClearCallbacks(string tag)
    {
        int tagHash = Animator.StringToHash(tag);
        if (callbacks.ContainsKey(tagHash))
        {
            foreach (var kv in callbacks[tagHash])
            {
                kv.Value.RemoveAllListeners();
            }
        }
    }

    Unity Message | 0 references
    override public void OnStateEnter(Animator animator, AnimatorStateInfo stateInfo, int layerIndex)
    {
        if (callbacks.ContainsKey(stateInfo.tagHash) && callbacks[stateInfo.tagHash].ContainsKey(CallbackType.Enter))
        {
            callbacks[stateInfo.tagHash][CallbackType.Enter].Invoke();
        }
    }

    Unity Message | 0 references
    override public void OnStateExit(Animator animator, AnimatorStateInfo stateInfo, int layerIndex)
    {
        if (callbacks.ContainsKey(stateInfo.tagHash) && callbacks[stateInfo.tagHash].ContainsKey(CallbackType.Exit))
        {
            callbacks[stateInfo.tagHash][CallbackType.Exit].Invoke();
        }
    }
```

2) Programming Shader

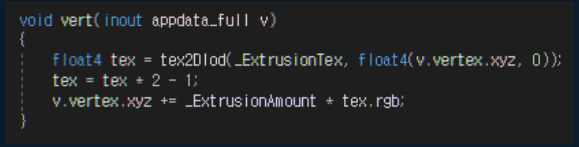
- Cg shader language
- Surface shader that simulates a destruction effect without making new models
  - Vertex shader extrudes vertices according to the 'noise texture'
  - Surface shader overlays the 'burn texture'
- Several parameters enable a variety of different destruction effects



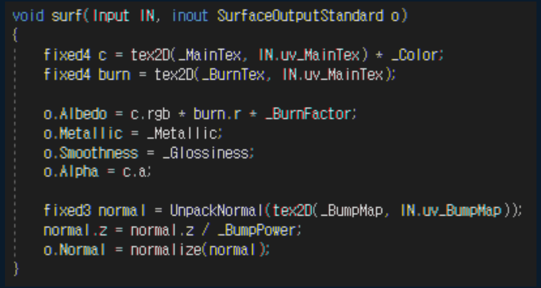
Kaput_mat 1
Shader Custom/DiffuseNormalKaput

Color
Albedo (RGB)
Tiling X 1 Y 1
Offset X 0 Y 0
Extrusion (RGB)
Tiling X 1 Y 1
Offset X 0 Y 0
Burn (RGB)
Tiling X 1 Y 1
Offset X 0 Y 0
Max Extrusion Amount 0.332
Burn Factor 0.548
Smoothness 0
Metallic 0
Normal Map
Tiling X 1 Y 1
Offset X 0 Y 0
Bump Power 3

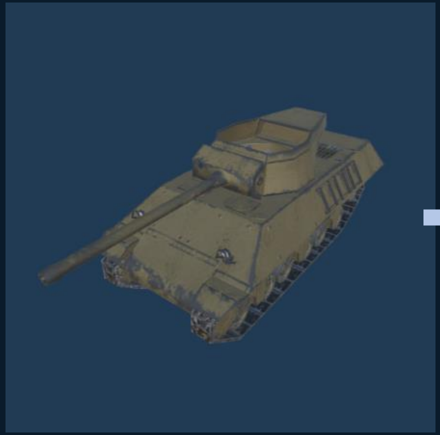
Render Queue From Shader 2000
Enable GPU Instancing □
Double Sided Global Illumination □



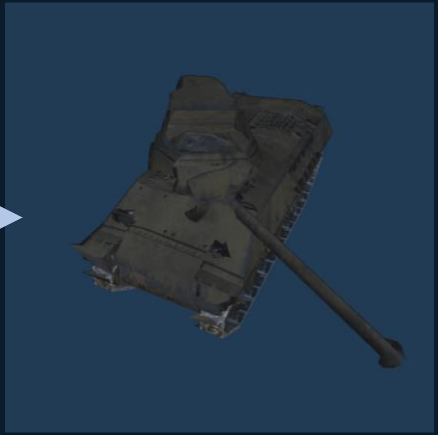
```
void vert(inout appdata_full v)
{
    float4 tex = tex2Dlod(_ExtrusionTex, float4(v.vertex.xyz, 0));
    tex = tex * 2 - 1;
    v.vertex.xyz += _ExtrusionAmount * tex.rgb;
}
```



```
void surf(Input IN, inout SurfaceOutputStandard o)
{
    fixed4 c = tex2D(_MainTex, IN.uv_MainTex) * _Color;
    fixed4 burn = tex2D(_BurnTex, IN.uv_MainTex);

    o.Albedo = c.rgb * burn.r * _BurnFactor;
    o.Metallic = _Metallic;
    o.Smoothness = _Glossiness;
    o.Alpha = c.a;

    fixed3 normal = UnpackNormal(tex2D(_BumpMap, IN.uv_BumpMap));
    normal.z = normal.z / _BumpPower;
    o.Normal = normalize(normal);
}
```

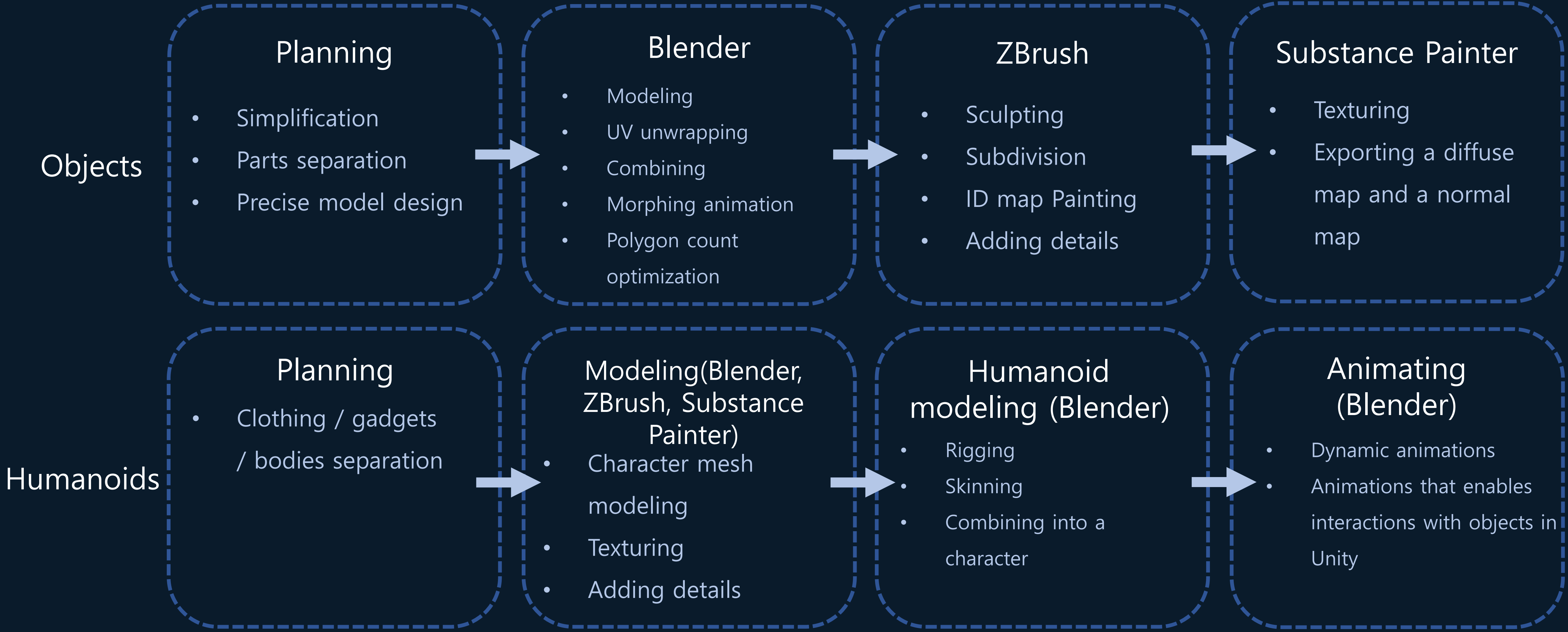


Original model



Destructed model

3) Art Objects / Humanoid Modeling



Objects

Planning

- Simplification
- Parts separation
- Precise model design

Blender

- Modeling
- UV unwrapping
- Combining
- Morphing animation
- Polygon count optimization

ZBrush

- Sculpting
- Subdivision
- ID map Painting
- Adding details

Substance Painter

- Texturing
- Exporting a diffuse map and a normal map

Humanoids

Planning

- Clothing / gadgets / bodies separation

Modeling(Blender, ZBrush, Substance Painter)

- Character mesh modeling
- Texturing
- Adding details

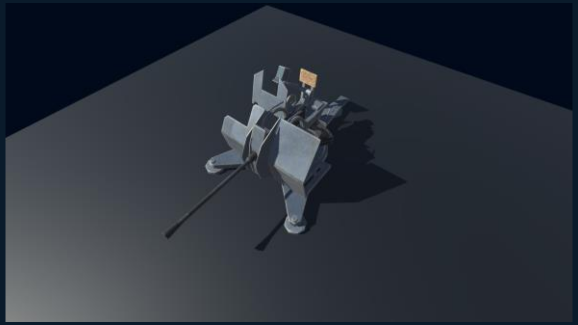
Humanoid modeling (Blender)

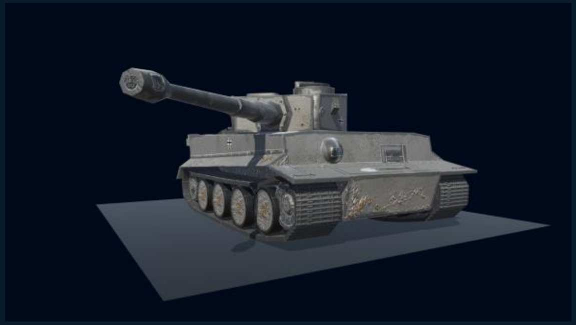
- Rigging
- Skinning
- Combining into a character

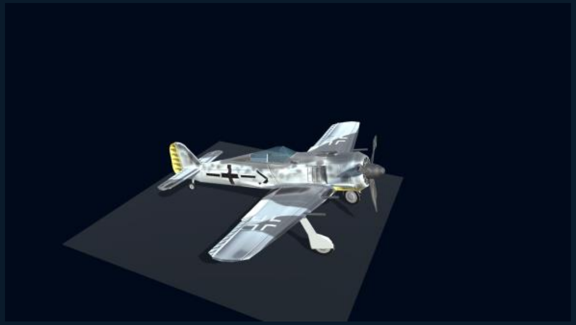
Animating (Blender)

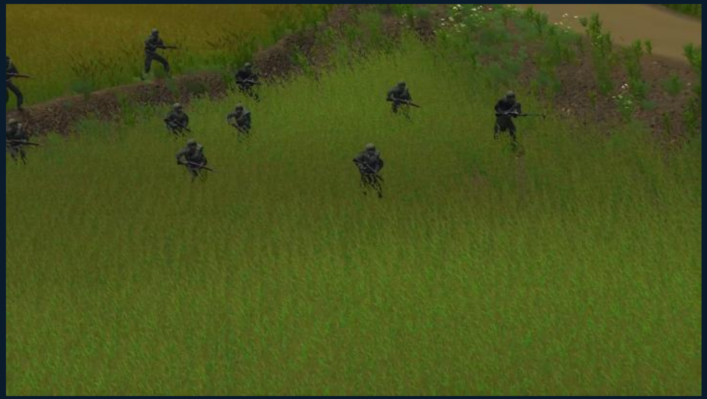
- Dynamic animations
- Animations that enables interactions with objects in Unity

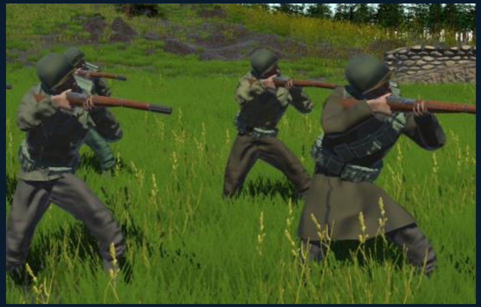
3) Art Works

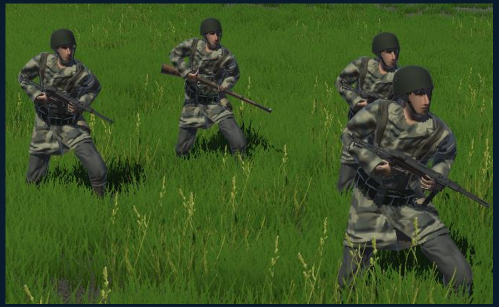


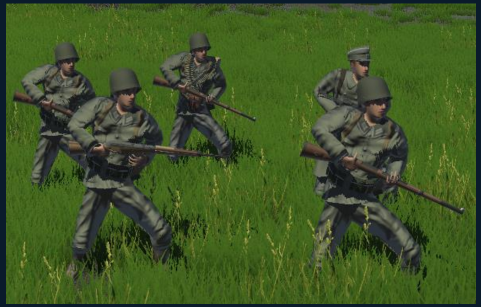


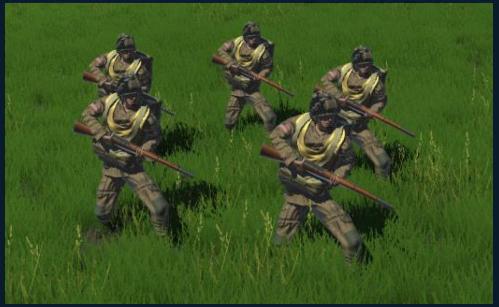












3) Demo Trailer

- https://www.youtube.com/watch?v=b9b-6MzOAi0
- https://www.youtube.com/watch?v=zgcS1foEgOA

3 | Computer Graphics Project

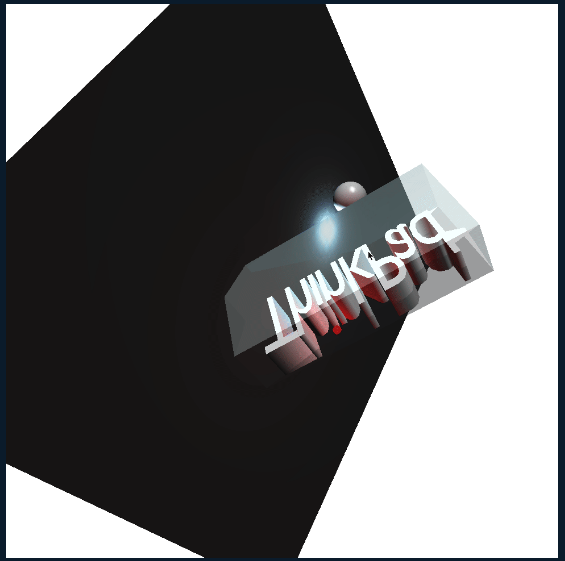
Binary Space Partitioning / Ray Tracing

Computer Graphics Project Binary Space Partitioning

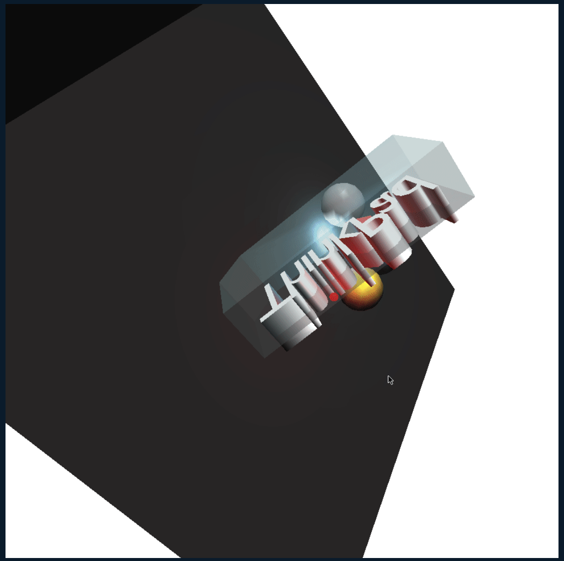
- C++ / OpenGL scene
- Default OpenGL depth test is erroneous when translucent and opaque objects are placed altogether

↓

- Binary Space Partitioning(BSP) to the rescue!
- Build a BSP tree once, traverse every frame
- Traversing the BSP tree correctly conducts a depth test regardless of the viewpoint
- Source code is available on https://github.com/ObjectOrientedLife/BinarySpacePartitioning



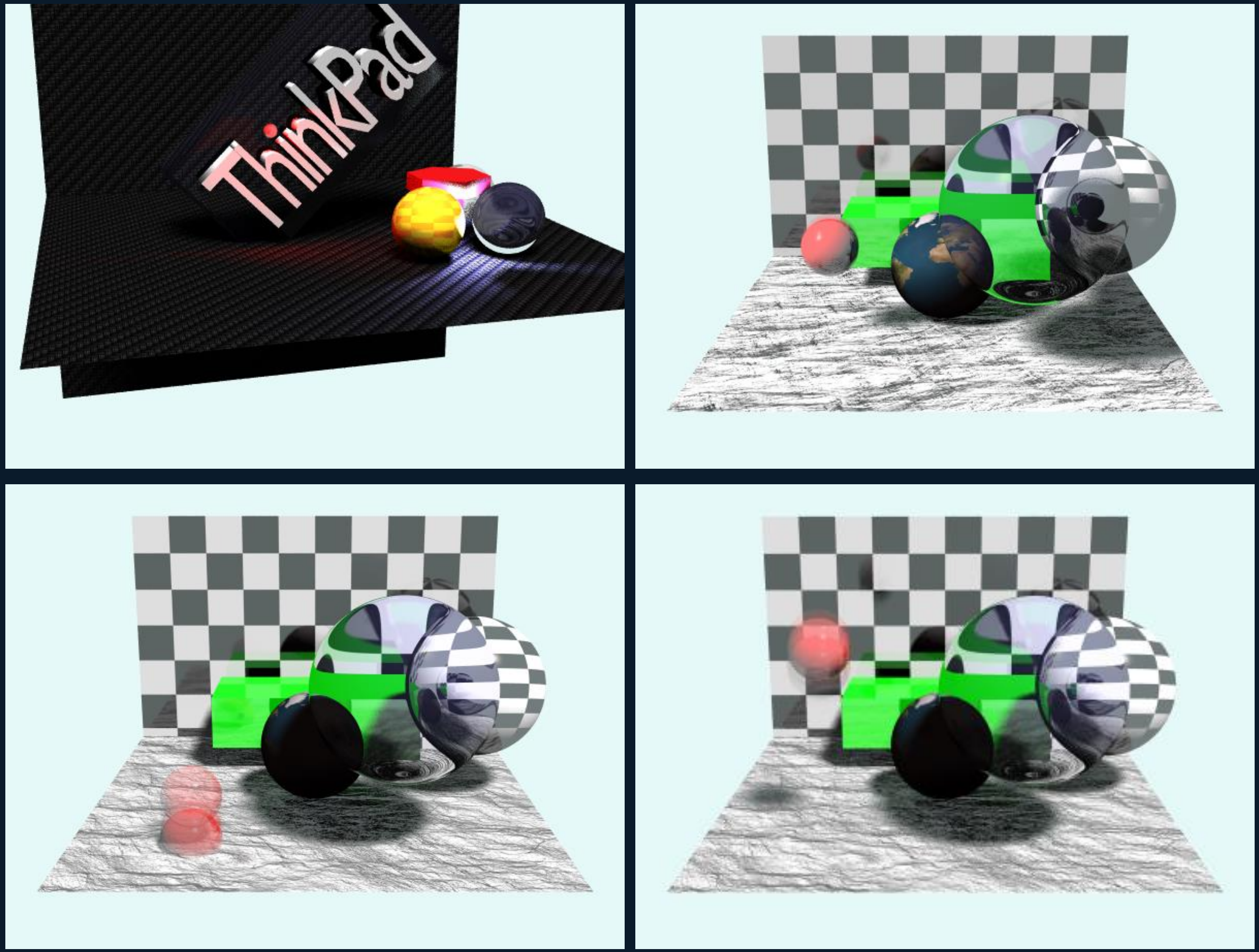
No BSP - objects behind are hidden by the translucent object



BSP - objects behind are rendered correctly without being hidden

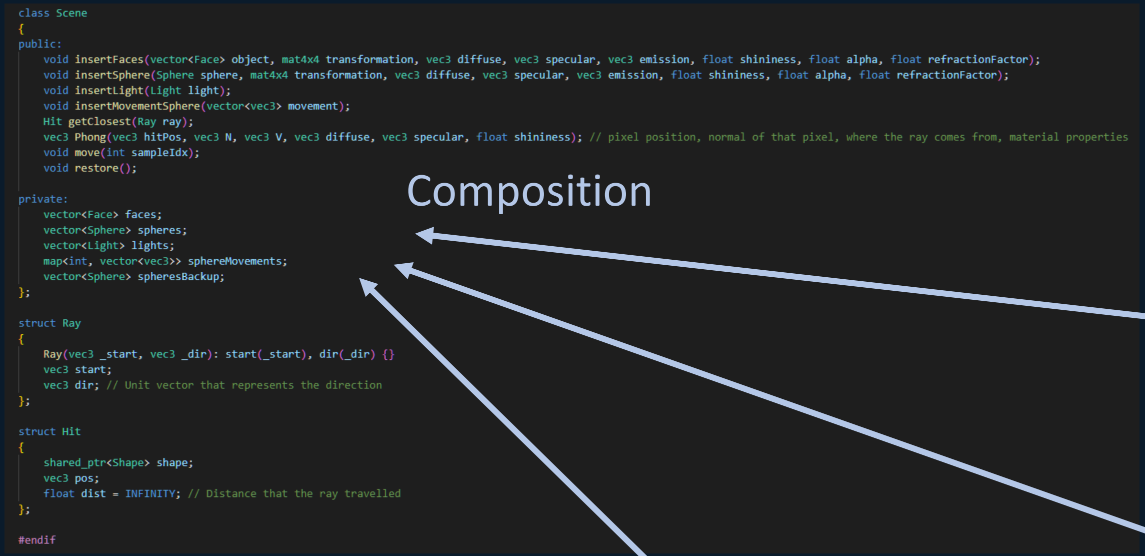
Computer Graphics Project Ray Tracing

- Implemented with pure C++(no OpenGL)
- Whitted Ray tracing based on the Phong illumination - recursive refraction, recursive refraction
- Stochastic ray tracing through subpixel sampling - soft shadow, motion blur
- Supports textures and normal maps
- Supports .obj parser
- Multithreading(x3 faster on a 8-core CPU)
- Source code is available on https://github.com/ObjectOrientedLife/RayTracing



Computer Graphics Project Ray Tracing

1. Modularized into Scene, Light, Shape(Face, Sphere)

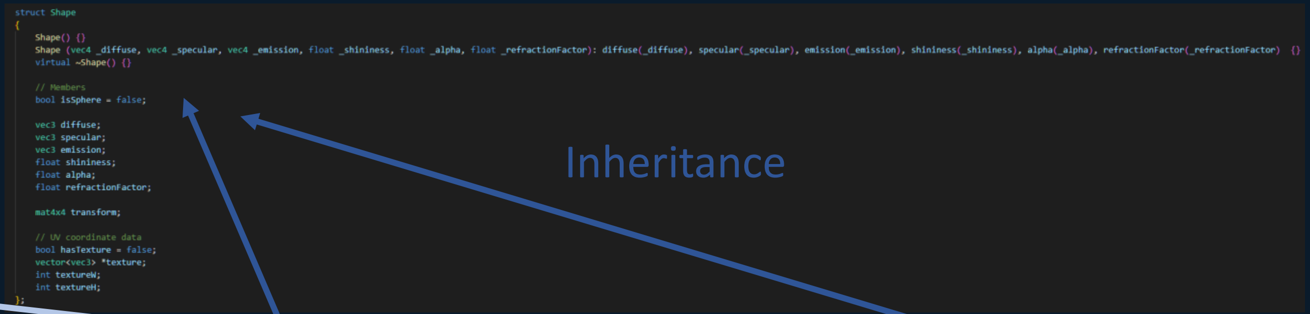


```
class Scene
{
public:
    void insertFaces(vector<Face> object, mat4x4 transformation, vec3 diffuse, vec3 specular, vec3 emission, float shininess, float alpha, float refractionFactor);
    void insertSphere(Sphere sphere, mat4x4 transformation, vec3 diffuse, vec3 specular, vec3 emission, float shininess, float alpha, float refractionFactor);
    void insertLight(Light light);
    void insertMovementSphere(vector<vec3> movement);
    Hit getClosest(Ray ray);
    vec3 Phong(vec3 hitPos, vec3 N, vec3 V, vec3 diffuse, vec3 specular, float shininess); // pixel position, normal of that pixel, where the ray comes from, material properties
    void move(int sampleIdx);
    void restore();

private:
    vector<Face> faces;
    vector<Sphere> spheres;
    vector<Light> lights;
    map<int, vector<vec3>> sphereMovements;
    vector<Sphere> spheresBackup;
};

struct Ray
{
    Ray(vec3 _start, vec3 _dir): start(_start), dir(_dir) {}
    vec3 start;
    vec3 dir; // Unit vector that represents the direction
};

struct Hit
{
    shared_ptr<Shape> shape;
    vec3 pos;
    float dist = INFINITY; // Distance that the ray travelled
};

#endif
```

Scene.h

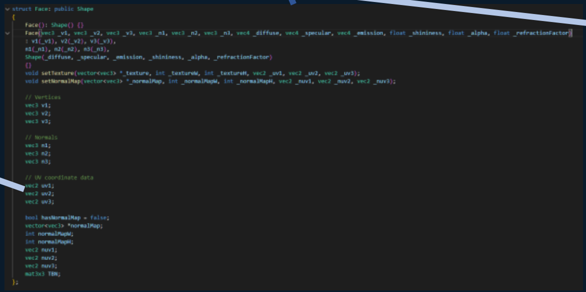
Composition

Shape.h

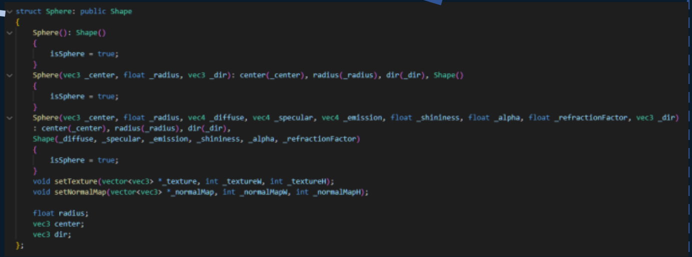


```
struct Shape
{
    Shape() {}
    Shape (vec4 _diffuse, vec4 _specular, vec4 _emission, float _shininess, float _alpha, float _refractionFactor): diffuse(_diffuse), specular(_specular), emission(_emission), shininess(_shininess), alpha(_alpha), refractionFactor(_refractionFactor)  {}
    virtual ~Shape() {}

    // Members
    bool isSphere = false;

    vec3 diffuse;
    vec3 specular;
    vec3 emission;
    float shininess;
    float alpha;
    float refractionFactor;

    mat4x4 transform;

    // UV coordinate data
    bool hasTexture = false;
    vector<vec3> *texture;
    int textureW;
    int textureH;
};
```

Inheritance

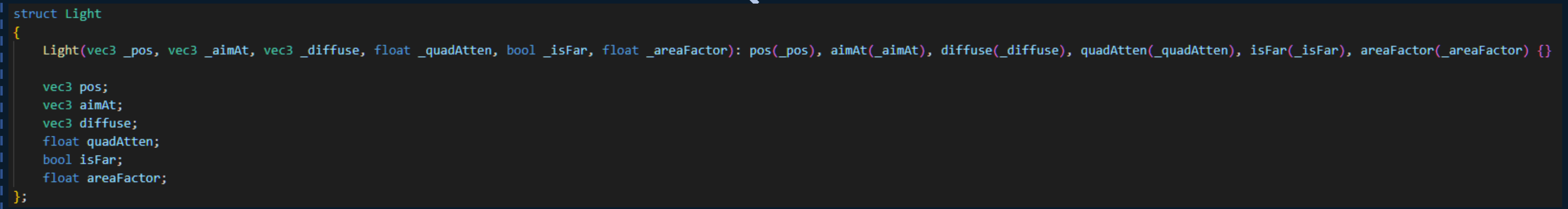


```
struct Face: public Shape
{
    Face(): Shape() {}
    Face(vec3 _v1, vec3 _v2, vec3 _v3, vec3 _n1, vec3 _n2, vec3 _n3, vec4 _diffuse, vec4 _specular, vec4 _emission, float _shininess, float _alpha, float _refractionFactor)
    : v1(_v1), v2(_v2), v3(_v3),
    n1(_n1), n2(_n2), n3(_n3),
    Shape(_diffuse, _specular, _emission, _shininess, _alpha, _refractionFactor)
    {}
    void setTexture(vector<vec3> *_texture, int _textureW, int _textureH, vec2 _uv1, vec2 _uv2, vec2 _uv3);
    void setNormalMap(vector<vec3> *_normalMap, int _normalMapW, int _normalMapH, vec2 _nuv1, vec2 _nuv2, vec2 _nuv3);

    // Vertices
    vec3 v1;
    vec3 v2;
    vec3 v3;

    // Normals
    vec3 n1;
    vec3 n2;
    vec3 n3;

    // UV coordinate data
    vec2 uv1;
    vec2 uv2;
    vec2 uv3;

    bool hasNormalMap = false;
    vector<vec3> *normalMap;
    int normalMapW;
    int normalMapH;
    vec2 nuv1;
    vec2 nuv2;
    vec2 nuv3;
    mat3x3 TBN;
};
```



```
struct Sphere: public Shape
{
    Sphere(): Shape()
    {
        isSphere = true;
    }
    Sphere(vec3 _center, float _radius, vec3 _dir): center(_center), radius(_radius), dir(_dir), Shape()
    {
        isSphere = true;
    }
    Sphere(vec3 _center, float _radius, vec4 _diffuse, vec4 _specular, vec4 _emission, float _shininess, float _alpha, float _refractionFactor, vec3 _dir)
    : center(_center), radius(_radius), dir(_dir),
    Shape(_diffuse, _specular, _emission, _shininess, _alpha, _refractionFactor)
    {
        isSphere = true;
    }
    void setTexture(vector<vec3> *_texture, int _textureW, int _textureH);
    void setNormalMap(vector<vec3> *_normalMap, int _normalMapW, int _normalMapH);

    float radius;
    vec3 center;
    vec3 dir;
};
```

Face.h, Sphere.h



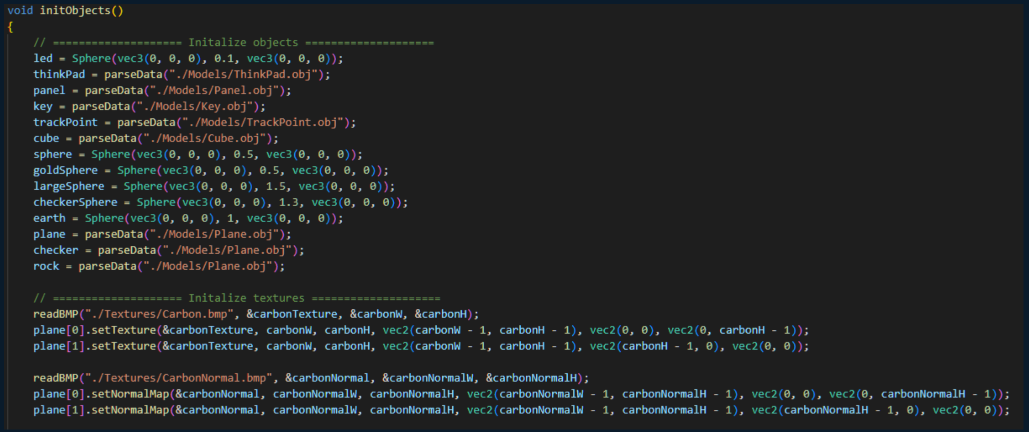
```
struct Light
{
    Light(vec3 _pos, vec3 _aimAt, vec3 _diffuse, float _quadAtten, bool _isFar, float _areaFactor): pos(_pos), aimAt(_aimAt), diffuse(_diffuse), quadAtten(_quadAtten), isFar(_isFar), areaFactor(_areaFactor) {}

    vec3 pos;
    vec3 aimAt;
    vec3 diffuse;
    float quadAtten;
    bool isFar;
    float areaFactor;
};
```

Light.h

Computer Graphics Project Ray Tracing

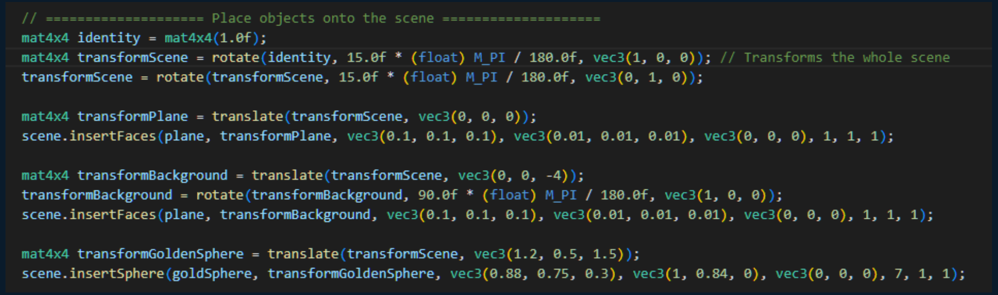
main.cpp

2. Load texture and .obj files



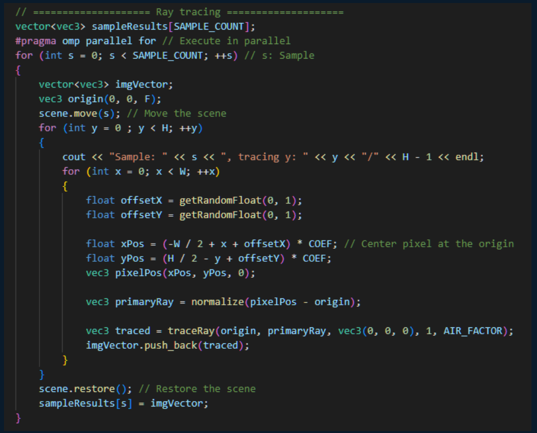
```cpp
void initObjects()
{
    // ==================== Initalize objects ====================
    led = Sphere(vec3(0, 0, 0), 0.1, vec3(0, 0, 0));
    thinkPad = parseData("./Models/ThinkPad.obj");
    panel = parseData("./Models/Panel.obj");
    key = parseData("./Models/Key.obj");
    trackPoint = parseData("./Models/TrackPoint.obj");
    cube = parseData("./Models/Cube.obj");
    sphere = Sphere(vec3(0, 0, 0), 0.5, vec3(0, 0, 0));
    goldSphere = Sphere(vec3(0, 0, 0), 0.5, vec3(0, 0, 0));
    largeSphere = Sphere(vec3(0, 0, 0), 1.5, vec3(0, 0, 0));
    checkerSphere = Sphere(vec3(0, 0, 0), 1.3, vec3(0, 0, 0));
    earth = Sphere(vec3(0, 0, 0), 1, vec3(0, 0, 0));
    plane = parseData("./Models/Plane.obj");
    checker = parseData("./Models/Plane.obj");
    rock = parseData("./Models/Plane.obj");

    // ==================== Initalize textures ====================
    readBMP("./Textures/Carbon.bmp", &carbonTexture, &carbonW, &carbonH);
    plane[0].setTexture(&carbonTexture, carbonW, carbonH, vec2(carbonW - 1, carbonH - 1), vec2(0, 0), vec2(0, carbonH - 1));
    plane[1].setTexture(&carbonTexture, carbonW, carbonH, vec2(carbonW - 1, carbonH - 1), vec2(carbonH - 1, 0), vec2(0, 0));

    readBMP("./Textures/CarbonNormal.bmp", &carbonNormal, &carbonNormalW, &carbonNormalH);
    plane[0].setNormalMap(&carbonNormal, carbonNormalW, carbonNormalH, vec2(carbonNormalW - 1, carbonNormalH - 1), vec2(0, 0), vec2(0, carbonNormalH - 1));
    plane[1].setNormalMap(&carbonNormal, carbonNormalW, carbonNormalH, vec2(carbonNormalW - 1, carbonNormalH - 1), vec2(carbonNormalH - 1, 0), vec2(0, 0));
```

3. Compose a scene from each module

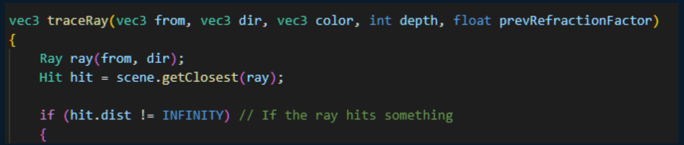


```cpp
// ==================== Place objects onto the scene ====================
mat4x4 identity = mat4x4(1.0f);
mat4x4 transformScene = rotate(identity, 15.0f * (float) M_PI / 180.0f, vec3(1, 0, 0)); // Transforms the whole scene
transformScene = rotate(transformScene, 15.0f * (float) M_PI / 180.0f, vec3(0, 1, 0));

mat4x4 transformPlane = translate(transformScene, vec3(0, 0, 0));
scene.insertFaces(plane, transformPlane, vec3(0.1, 0.1, 0.1), vec3(0.01, 0.01, 0.01), vec3(0, 0, 0), 1, 1, 1);

mat4x4 transformBackground = translate(transformScene, vec3(0, 0, -4));
transformBackground = rotate(transformBackground, 90.0f * (float) M_PI / 180.0f, vec3(1, 0, 0));
scene.insertFaces(plane, transformBackground, vec3(0.1, 0.1, 0.1), vec3(0.01, 0.01, 0.01), vec3(0, 0, 0), 1, 1, 1);

mat4x4 transformGoldenSphere = translate(transformScene, vec3(1.2, 0.5, 1.5));
scene.insertSphere(goldSphere, transformGoldenSphere, vec3(0.88, 0.75, 0.3), vec3(1, 0.84, 0), vec3(0, 0, 0), 7, 1, 1);
```

4. Conduct ray tracing

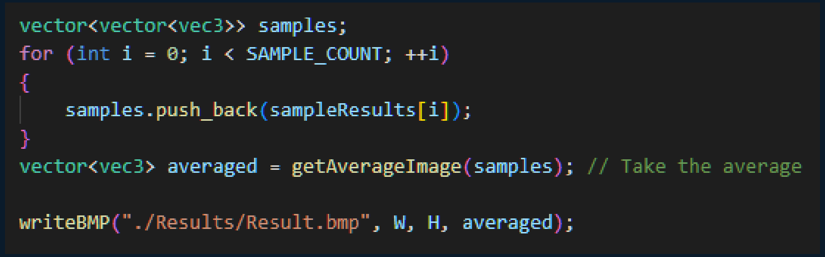


```cpp
// ==================== Ray tracing ====================
vector<vec3> sampleResults[SAMPLE_COUNT];
#pragma omp parallel for // Execute in parallel
for (int s = 0; s < SAMPLE_COUNT; ++s) // s: Sample
{
    vector<vec3> imgVector;
    vec3 origin(0, 0, F);
    scene.move(s); // Move the scene
    for (int y = 0 ; y < H; ++y)
    {
        cout << "Sample: " << s << ", tracing y: " << y << "/" << H - 1 << endl;
        for (int x = 0; x < W; ++x)
        {
            float offsetX = getRandomFloat(0, 1);
            float offsetY = getRandomFloat(0, 1);

            float xPos = (-W / 2 + x + offsetX) * COEF; // Center pixel at the origin
            float yPos = (H / 2 - y + offsetY) * COEF;
            vec3 pixelPos(xPos, yPos, 0);

            vec3 primaryRay = normalize(pixelPos - origin);

            vec3 traced = traceRay(origin, primaryRay, vec3(0, 0, 0), 1, AIR_FACTOR);
            imgVector.push_back(traced);
        }
    }
    scene.restore(); // Restore the scene
    sampleResults[s] = imgVector;
}
```



```cpp
vec3 traceRay(vec3 from, vec3 dir, vec3 color, int depth, float prevRefractionFactor)
{
    Ray ray(from, dir);
    Hit hit = scene.getClosest(ray);

    if (hit.dist != INFINITY) // If the ray hits something
    {
```

5. Export the result



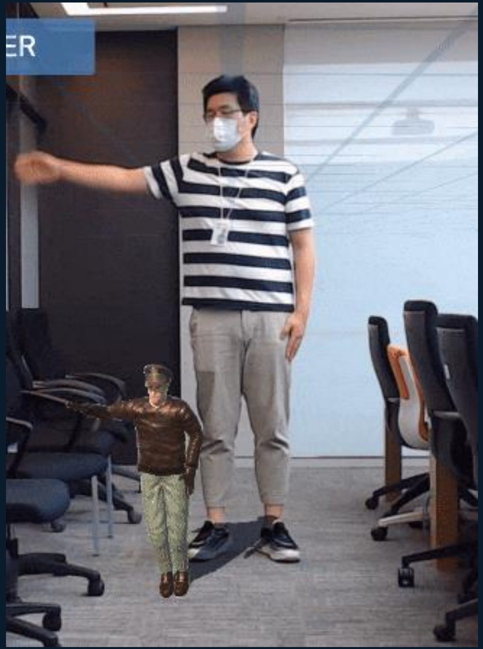
```cpp
vector<vector<vec3>> samples;
for (int i = 0; i < SAMPLE_COUNT; ++i)
{
    samples.push_back(sampleResults[i]);
}
vector<vec3> averaged = getAverageImage(samples); // Take the average

writeBMP("./Results/Result.bmp", W, H, averaged);
```

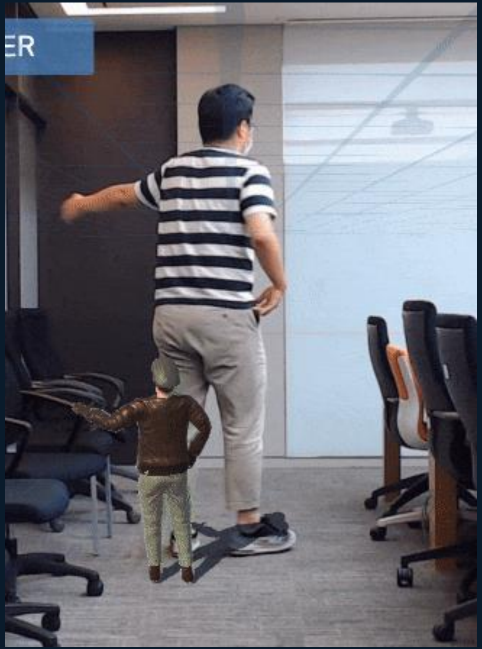
4 | Internship project

Development of an AR Demo Tool on Webcam Input

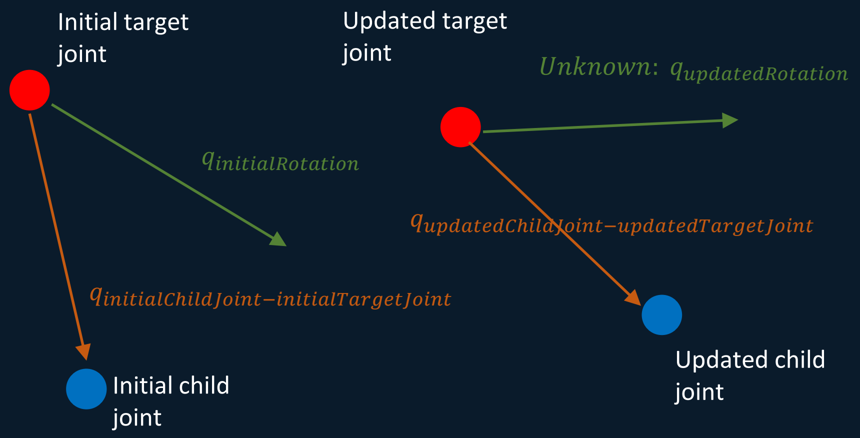
Internship project Development of an AR Demo Tool on Webcam Input

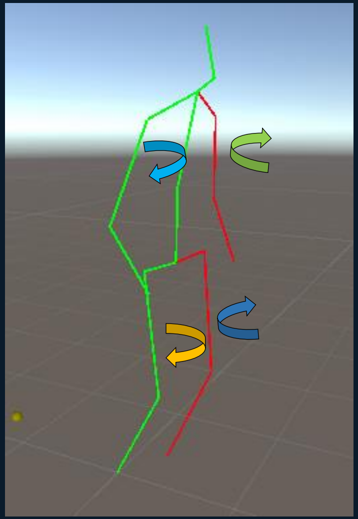
- NCSoft / Vision AI Lab / Human Pose Estimation team
- Conducted for two months(2021.07 - 2021.08)
- Feed webcam input into neural networks and present the results with a humanoid
- Kalman filter and low pass filter for smoothing motions
- Vanishing point determination / detection for deciding an AR ground
- Shadow shader that supports the AR component





Internship project Character Representation


Initial target joint
Updated target joint
Unknown: $q_{updatedRotation}$
$q_{initialRotation}$
$q_{updatedChildJoint-updatedTargetJoint}$
$q_{initialChildJoint-initialTargetJoint}$
Initial child joint
Updated child joint



$$q_{initialChildJoint-initialTargetJoint} \cdot q_{diff} = q_{initialRotation}$$

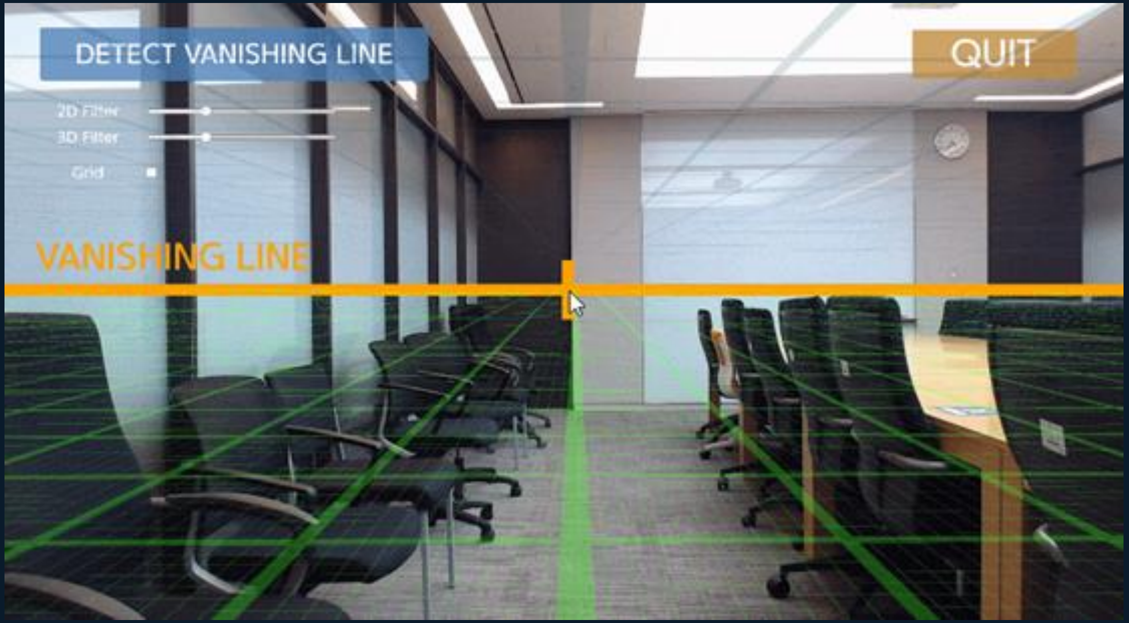
$$q_{initialChildJoint-initialTargetJoint}^{-1} \cdot q_{initialChildJoint-initialTargetJoint} \cdot q_{diff} = q_{initialChildJoint-initialTargetJoint}^{-1} \cdot q_{initialRotation}$$

$$q_{diff} = q_{initialChildJoint-initialTargetJoint}^{-1} \cdot q_{initialRotation}$$

$$q_{updatedRotation} = q_{updatedChildJoint-updatedTargetJoint} \cdot q_{diff}$$

- Presenting 3d keypoints correctly with a deformable character
- Derived quaternion expressions to rotate the character's bones
- Handle different rotations joint by joint
- Can accommodate different characters

Internship project Demo



Determining a ground using a the vanishing point

Human pose estimation

Thank you

Park Changhwi

smsychjy96@gmail.com

https://github.com/ObjectOrientedLife