



# Command & Pimpl

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# Input

Remember we discussed the game loop

```
bool do_continue = true;
while(do_continue)
{
    do_continue = process_input();
    update();
    render();
}
```

We discussed that `update()` , `render()` is covered in Graphics Programming 1 & 2.

Today we discuss `process_input()`

# Input

Comes from all kinds of devices

- Digital buttons
  - Down or Up, 0 or 1, circuit is open or closed.
- Analog Axes/Buttons
  - Range of values
    - Thumb RX -32768 -> 32768 (Xbox)
    - Trigger R 0 -> 255 (Xbox)
- Relative Axis
  - No defined center point, so no range possible
  - Delta position values (mouse for example)
- Accelerometers
  - Delta acceleration values (Wiimote, or VR controllers for example)
- Touch
  - Pressure ranges

# Input polling

One way to process input is via "polling"

- Periodically read the current state of the device
  - Periodically: once per frame in our example
- Often game pads, joysticks
- On windows, this is what the XInput API provides
  - `XInputGetState()`

```
XINPUT_STATE state;  
ZeroMemory(&state, sizeof(XINPUT_STATE));  
DWORD dwResult = XInputGetState(i, &state);
```

# XInput

```
typedef struct XINPUT_STATE {
    DWORD dwPacketNumber;
    XINPUT_GAMEPAD Gamepad;
} XINPUT_STATE
```

```
typedef struct XINPUT_GAMEPAD {
    WORD wButtons;
    BYTE bLeftTrigger;
    BYTE bRightTrigger;
    SHORT sThumbLX;
    SHORT sThumbLY;
    SHORT sThumbRX;
    SHORT sThumbRY;
} XINPUT_GAMEPAD
```

wButtons is a word with byteflags for each button.

| Device button                 | Bitmask |
|-------------------------------|---------|
| XINPUT_GAMEPAD_DPAD_UP        | 0x0001  |
| XINPUT_GAMEPAD_DPAD_DOWN      | 0x0002  |
| XINPUT_GAMEPAD_DPAD_LEFT      | 0x0004  |
| XINPUT_GAMEPAD_DPAD_RIGHT     | 0x0008  |
| XINPUT_GAMEPAD_START          | 0x0010  |
| XINPUT_GAMEPAD_BACK           | 0x0020  |
| XINPUT_GAMEPAD_LEFT_THUMB     | 0x0040  |
| XINPUT_GAMEPAD_RIGHT_THUMB    | 0x0080  |
| XINPUT_GAMEPAD_LEFT_SHOULDER  | 0x0100  |
| XINPUT_GAMEPAD_RIGHT_SHOULDER | 0x0200  |
| XINPUT_GAMEPAD_A              | 0x1000  |
| XINPUT_GAMEPAD_B              | 0x2000  |
| XINPUT_GAMEPAD_X              | 0x4000  |
| XINPUT_GAMEPAD_Y              | 0x8000  |

# XInput

Check for example if Gamepad button A is pressed:

```
bool IsButtonAPressed(const XINPUT_GAMEPAD& gamepad)
{
    return ((gamepad.wButtons & XINPUT_GAMEPAD_A) != 0);
}
```

Better, somewhere during `process_input()` :

```
CopyMemory(&previousState, &currentState, sizeof(XINPUT_STATE));
ZeroMemory(&currentState, sizeof(XINPUT_STATE));
XInputGetState(m_controllerIndex, &currentState);

auto buttonChanges = currentState.Gamepad.wButtons ^ previousState.Gamepad.wButtons;
buttonsPressedThisFrame = buttonChanges & currentState.Gamepad.wButtons;
buttonsReleasedThisFrame = buttonChanges & (~currentState.Gamepad.wButtons);
```

# XInput

Which enables us to implement the following:

```
bool IsDownThisFrame(unsigned int button) const
{
    return buttonsPressedThisFrame & button;
}

bool IsUpThisFrame(unsigned int button) const
{
    return buttonsReleasedThisFrame & button;
}

bool IsPressed(unsigned int button) const
{
    return currentState.Gamepad.wButtons & button;
}
```

# XInput

```
CopyMemory(&previousState, &currentState, sizeof(XINPUT_STATE));
ZeroMemory(&currentState, sizeof(XINPUT_STATE));
XInputGetState(m_controllerIndex, &currentState);
```

Which buttons do we check here?

```
(currentState.Gamepad.wButtons & 16) == 16
(currentState.Gamepad.wButtons & 68) == 68
```

Say

```
currentState.Gamepad.wButtons is 0b00010100
```

Which of the two return true?

| Device button                 | Bitmask |
|-------------------------------|---------|
| XINPUT_GAMEPAD_DPAD_UP        | 0x0001  |
| XINPUT_GAMEPAD_DPAD_DOWN      | 0x0002  |
| XINPUT_GAMEPAD_DPAD_LEFT      | 0x0004  |
| XINPUT_GAMEPAD_DPAD_RIGHT     | 0x0008  |
| XINPUT_GAMEPAD_START          | 0x0010  |
| XINPUT_GAMEPAD_BACK           | 0x0020  |
| XINPUT_GAMEPAD_LEFT_THUMB     | 0x0040  |
| XINPUT_GAMEPAD_RIGHT_THUMB    | 0x0080  |
| XINPUT_GAMEPAD_LEFT_SHOULDER  | 0x0100  |
| XINPUT_GAMEPAD_RIGHT_SHOULDER | 0x0200  |
| XINPUT_GAMEPAD_A              | 0x1000  |
| XINPUT_GAMEPAD_B              | 0x2000  |
| XINPUT_GAMEPAD_X              | 0x4000  |
| XINPUT_GAMEPAD_Y              | 0x8000  |



# XInput

```
auto buttonChanges = currentState.Gamepad.wButtons ^ previousState.Gamepad.wButtons;
buttonsPressedThisFrame = buttonChanges & currentState.Gamepad.wButtons;
buttonsReleasedThisFrame = buttonChanges & (~currentState.Gamepad.wButtons);
```

Say

`previousState.Gamepad.wButtons` is `0b00010000`

`currentState.Gamepad.wButtons` is `0b00010100`

What is `buttonChanges` ?

What is `buttonsPressedThisFrame` ?

What is `buttonsReleasedThisFrame` ?

Say

`previousState.Gamepad.wButtons` is `0b00010001`

instead

What is `buttonsReleasedThisFrame` now?

| Device button                 | Bitmask |
|-------------------------------|---------|
| XINPUT_GAMEPAD_DPAD_UP        | 0x0001  |
| XINPUT_GAMEPAD_DPAD_DOWN      | 0x0002  |
| XINPUT_GAMEPAD_DPAD_LEFT      | 0x0004  |
| XINPUT_GAMEPAD_DPAD_RIGHT     | 0x0008  |
| XINPUT_GAMEPAD_START          | 0x0010  |
| XINPUT_GAMEPAD_BACK           | 0x0020  |
| XINPUT_GAMEPAD_LEFT_THUMB     | 0x0040  |
| XINPUT_GAMEPAD_RIGHT_THUMB    | 0x0080  |
| XINPUT_GAMEPAD_LEFT_SHOULDER  | 0x0100  |
| XINPUT_GAMEPAD_RIGHT_SHOULDER | 0x0200  |
| XINPUT_GAMEPAD_A              | 0x1000  |
| XINPUT_GAMEPAD_B              | 0x2000  |
| XINPUT_GAMEPAD_X              | 0x4000  |
| XINPUT_GAMEPAD_Y              | 0x8000  |

# XInput

Why the hassle? So that instead of

```
bool IsDownThisFrame(unsigned int button) const
{
    return ((currentState.Gamepad.wButtons & button) != 0) &&
           ((previousState.Gamepad.wButtons & button) == 0);
}
```

We can now write

```
bool IsDownThisFrame(unsigned int button) const
{
    return buttonsPressedThisFrame & button;
}
```

# XInput

```
typedef struct XINPUT_STATE {  
    DWORD dwPacketNumber;  
    XINPUT_GAMEPAD Gamepad;  
} XINPUT_STATE
```

```
typedef struct XINPUT_GAMEPAD {  
    WORD wButtons;  
    BYTE bLeftTrigger;  
    BYTE bRightTrigger;  
    SHORT sThumbLX;  
    SHORT sThumbLY;  
    SHORT sThumbRX;  
    SHORT sThumbRY;  
} XINPUT_GAMEPAD
```

A byte for the triggers (8-bit unsigned)

- [0 – 255]

A short for the thumbsticks (16bit signed)

- [-32768 – 32767]

Take deadzones into account!

# Deadzones you say?

```
#define WIN32_LEAN_AND_MEAN
#include <windows.h>
#include <XInput.h>
#include <iostream>
#include <thread>

#pragma comment(lib, "xinput.lib")

int main()
{
    XINPUT_STATE currentState{};
    int controllerIndex{};

    while (true)
    {
        auto t = std::chrono::high_resolution_clock::now();

        ZeroMemory(&currentState, sizeof(XINPUT_STATE));
        XInputGetState(controllerIndex, &currentState);

        std::cout << "\rsThumbLX: " << currentState.Gamepad.sThumbLX
                  << " - sThumbRX: " << currentState.Gamepad.sThumbRX;

        if (currentState.Gamepad.wButtons & XINPUT_GAMEPAD_B)
            break;

        auto t2 = std::chrono::high_resolution_clock::now() - t;
        t += std::chrono::milliseconds(16) - t2; // we want ~60 fps
        std::this_thread::sleep_until(t);
    }
}
```

With both thumbs in opposite directions:

```
sThumbLX: -32660 - sThumbRX: 327674
```

Released again:

```
sThumbLX: -1126 - sThumbRX: -49207
```

In percentages:

```
sThumbLX: 1.47% - sThumbRX: -11.26%
```



# Input via interrupts

## Interrupts – IRQ

- When state of a device changes (p.ex. a mouse has moved) an interrupt request signal is sent to the CPU
- Main program is halted shortly, input data is processed (ISR), main continues and can work with the received data.
- When we process input, we process the received interrupts since the last frame one by one

```
// Main message loop:
while (GetMessage(&msg, nullptr, 0, 0)) {
    if (!TranslateAccelerator(msg.hwnd, hAccelTable, &msg)) {
        TranslateMessage(&msg);
        DispatchMessage(&msg);
    }
}
```

# Input via interrupts

## Interrupts – IRQ

- When state of a device changes (p.ex. a mouse has moved) an interrupt request signal is sent to the CPU
- Main program is halted shortly, input data is processed (ISR), main continues and can work with the received data.
- When we process input, we process the received interrupts since the last frame one by one

```
bool dae::InputManager::ProcessInput() {
    SDL_Event e;
    while (SDL_PollEvent(&e)) {
        if (e.type == SDL_QUIT) {
            return false;
        } else if (e.type == SDL_KEYDOWN) {

        } elseif (e.type == SDL_MOUSEBUTTONDOWN) {

        }
        // etc...
    }
    return true;
}
```

# Input

## Wireless input devices

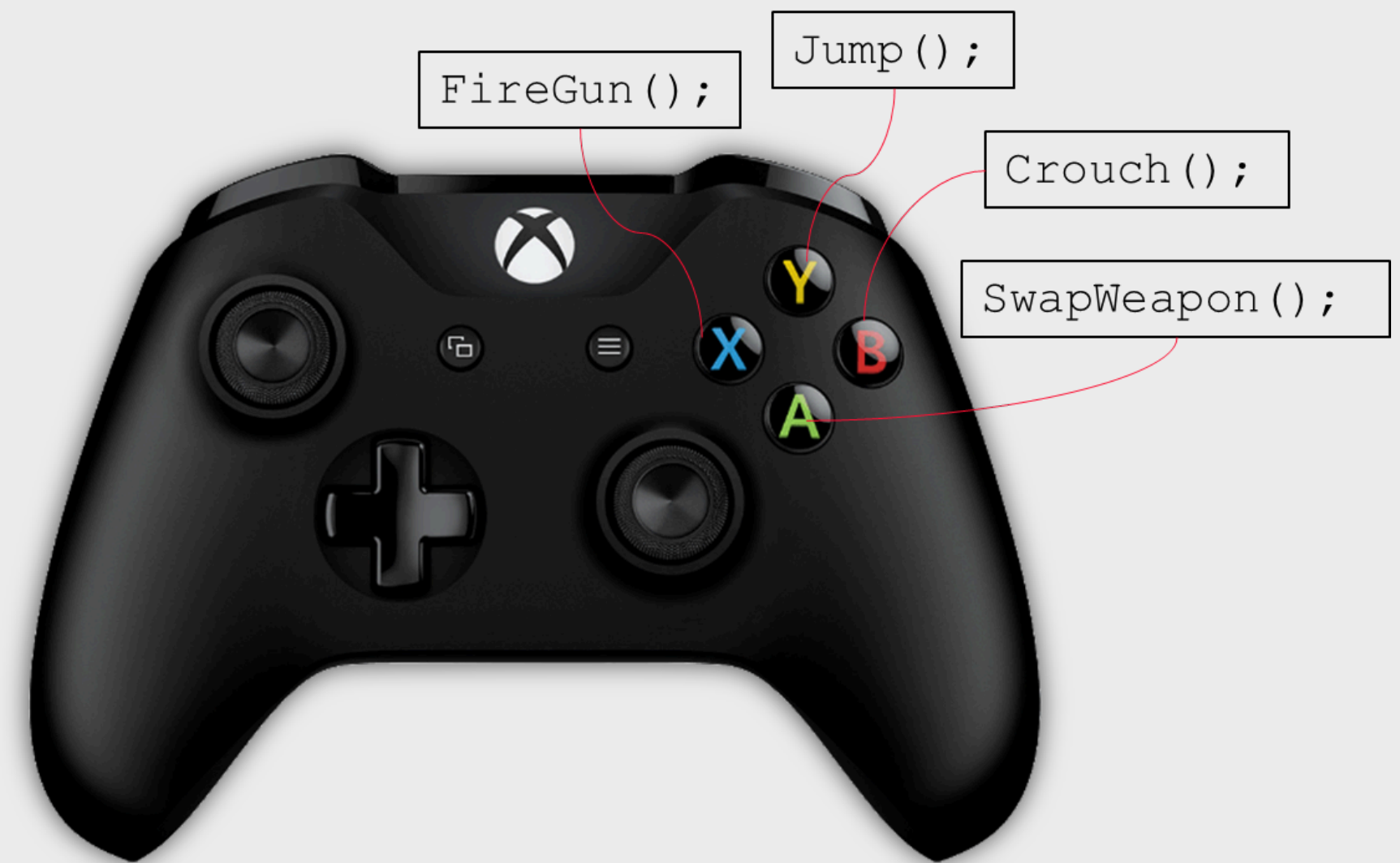
- Often via Bluetooth
- Need a separate thread to receive the data send by the device over the network
- And to send data back to the device (like sound and rumble data)
- Often abstracted away behind an API Layer.

# Problem statement

```
if(is_pressed(BUTTON_Y))  
    Jump();  
else if (is_pressed(BUTTON_X))  
    Firegun();  
else if (is_pressed(BUTTON_A))  
    SwapWeapon();  
else if (is_pressed(BUTTON_B))  
    Crouch();
```

What's wrong with this code?

How can we improve it?





# Command

```
class Command
{
public:
    virtual ~Command() = default;
    virtual void Execute() = 0;
}

class Jump : public Command
{
public:
    void Execute() override { Jump(); }
}

class Fire : public Command
{
public:
    void Execute() override { Fire(); }
}
```

# Command

Even better:

```
class GameActorCommand : public Command
{
    GameActor* m_actor;
protected:
    GameActor* GetGameActor() const { return m_actor; }
public:
    GameActorCommand(GameActor* actor);
    virtual ~GameActorCommand();
}

class Fire : public GameActorCommand {
public:
    void Execute() override
    {
        GetGameActor()->Fire();

        // additional code is possible too, of course
    }
}
```

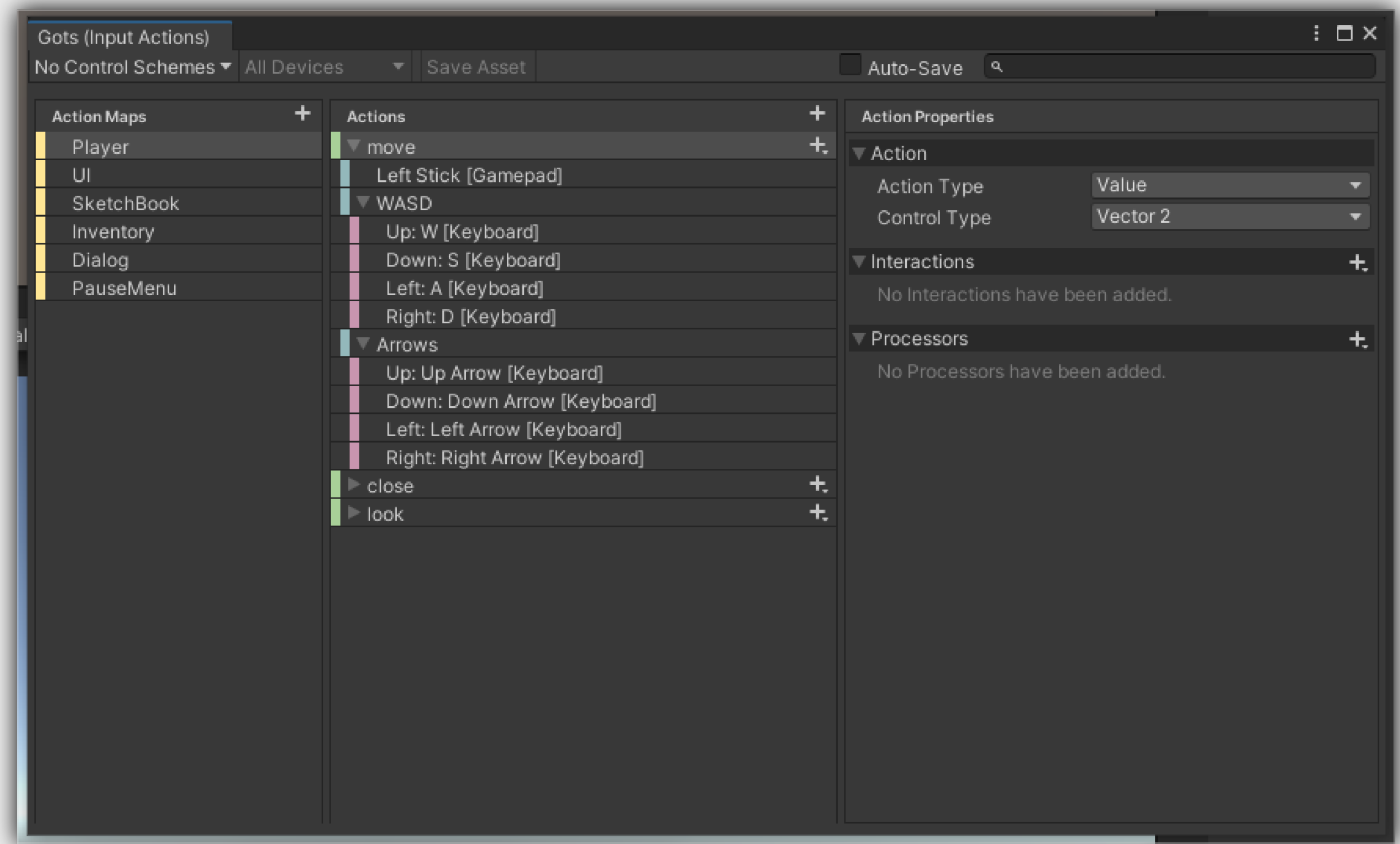
# Command

These commands need to be registered with the Input manager

- The input manager keeps track of all active commands
- Checks if the input for the command has been executed by the user
- Calls the Execute method on the registered command
- Don't forget to unregister!

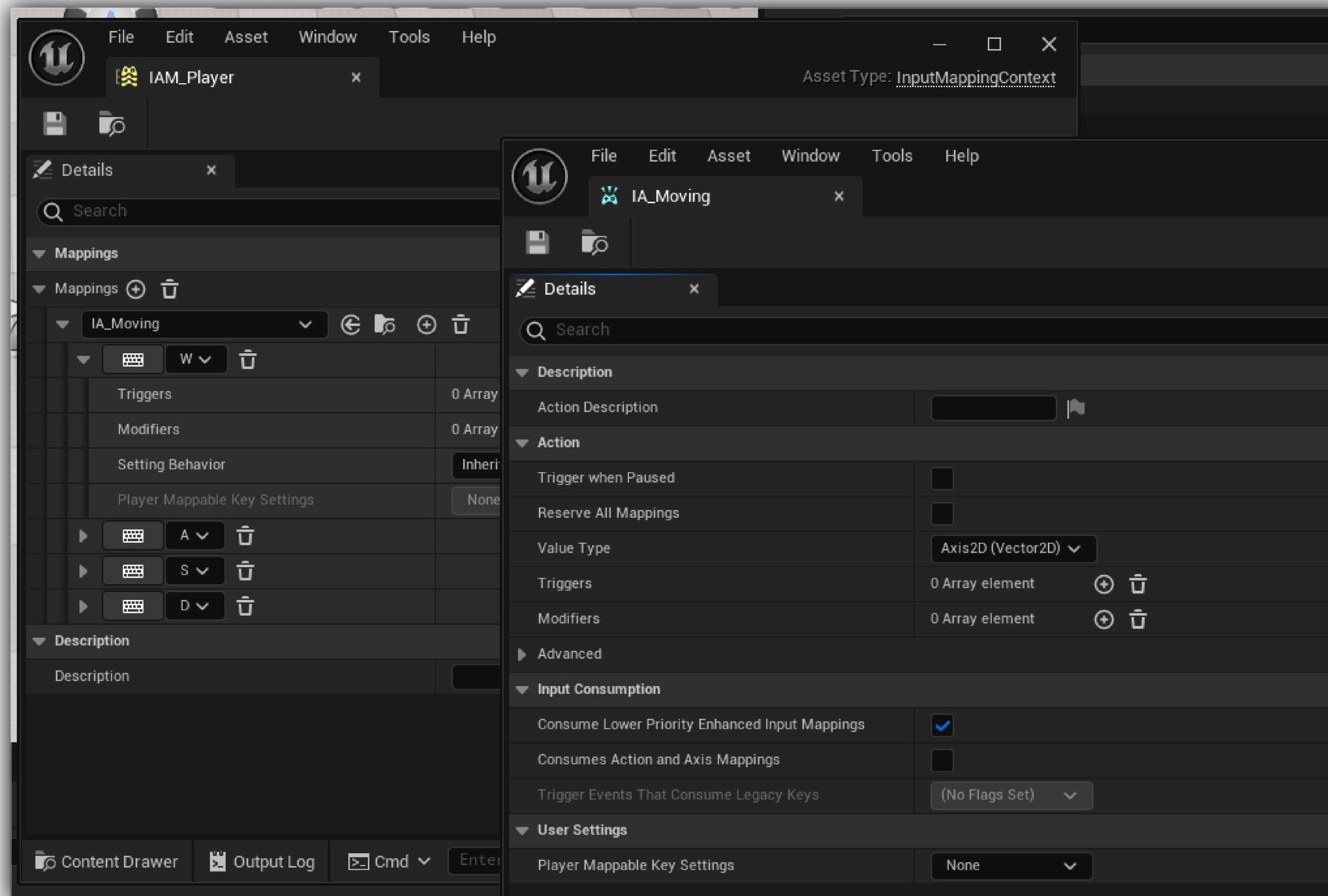
Mapping the input to the commands is up to you.

# Actions in Unity





# Actions in Unreal



# Actions

Actions is the mapping of some input to an ID. This id then gets mapped to a certain command or function.

```
if (auto EnhancedInputComponent = Cast<UEnhancedInputComponent>(InputComponent))  
{  
    EnhancedInputComponent->BindAction(MoveAction, ETriggerEvent::Triggered, this,  
        &AMyPlayerController::OnMove);  
}
```

# Command

Editors (not games) often (always?) work with stacked commands, to enable Undo/Redo functionality.

```
class EditorCommand : public Command
{
public:
    virtual ~EditorCommand() = default;
    virtual void Undo() = 0;
}
```

This is how virtually all commands in software works... Of course, in-game actions don't often need an Undo, so make a distinction!

# Pimpl

Is a C++ pattern/idiom

Remove compilation dependencies on internal class implementations and improve compile times

Item #43 from C++ Coding Standards by Herb Sutter: “Pimpl judiciously”

Advantages

- Faster compilation times
  - (easier project setup too)
- Avoids ambiguity

<https://cpppatterns.com/patterns/pimpl.html>



# Example

The Renderer - we want to dynamically choose between DirectX and OpenGL - do you see the problem?

Renderer.h:

```
class Renderer abstract
{
public:
    virtual void RenderTriangles(
        float* verts, int* indices) = 0;
};
```

OpenGLRenderer.h:

```
#include "Renderer.h"
#include <SDL.h>

class OpenGLRenderer : public Renderer
{
public:
    void RenderTriangles(
        float* verts, int* indices) override;
private:
    SDL_Texture* m_pRenderTexture;
};
```

DirectXRenderer.h:

```
#include "Renderer.h"
#include <d3d11.h>

class DirectXRenderer : public Renderer
{
public:
    void RenderTriangles(
        float* verts, int* indices) override;
private:
    ID3D11Texture2D* m_pRenderTexture;
};
```

# Example

Let's apply Pimpl.

OpenGLRenderer.h:

```
#include "Renderer.h"

class OpenGLRenderer : public Renderer
{
    class OpenGLRendererImpl;
    OpenGLRendererImpl* m_pImpl;
public:
    void RenderTriangles(
        float* verts, int* indices) override;
};
```

OpenGLRenderer.cpp:

```
#include "OpenGLRenderer.h"
#include <SDL.h>

class OpenGLRenderer::OpenGLRendererImpl
{
    SDL_Texture* m_pRenderTexture;
public:
    void DoRenderTriangles(
        float* verts, int* indices);
};

void OpenGLRenderer::OpenGLRendererImpl::
    DoRenderTriangles(float* verts, int* indices) {
    // the actual implementation
}

void OpenGLRenderer::RenderTriangles(
    float* verts, int* indices) {
    m_pImpl->DoRenderTriangles(verts, indices);
}
```