DIGITAL ARTS & ENTERTAINMENT

Command & Pimpl

howest
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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)

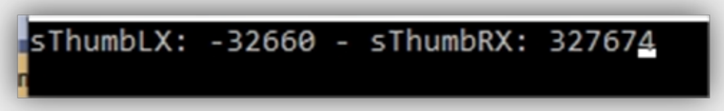
- [-32768 – 32767]

Take deadzones into account!

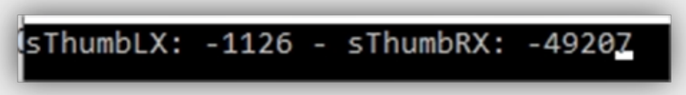
Deadzones you say?

```cpp
#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);
    }
}
```

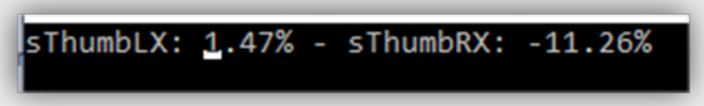
With both thumbs in opposite directions:



Released again:



In percentages:



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

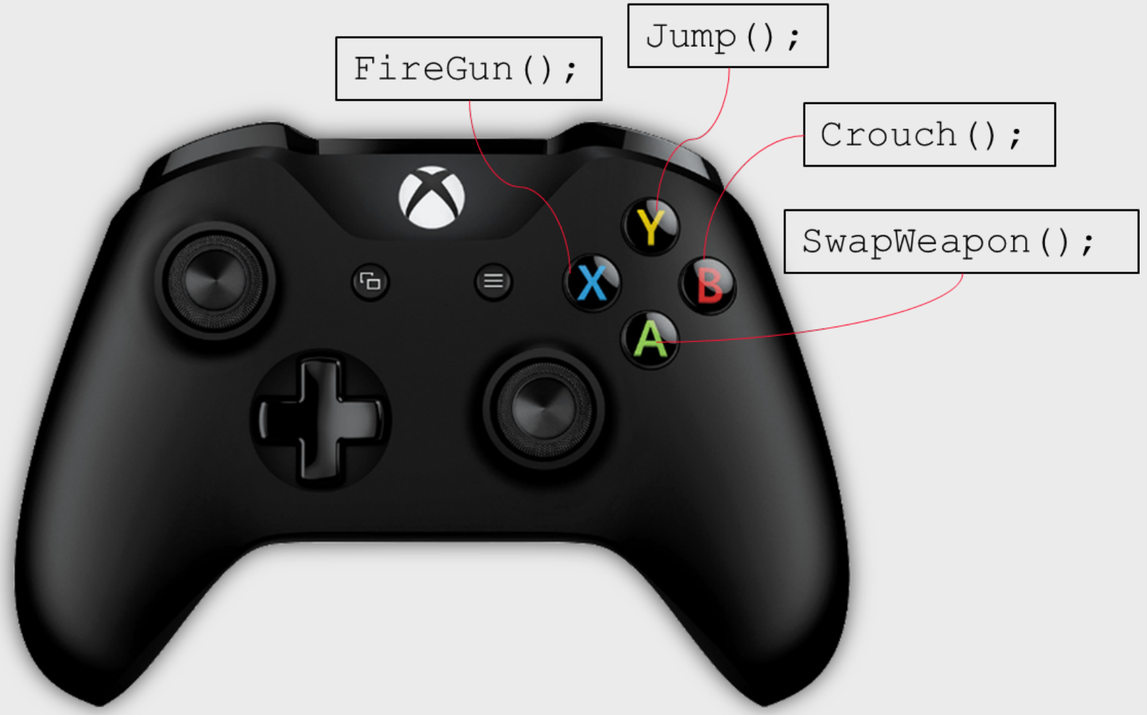
- Often via Bluetooth
- Need a separate thread to receive the data send by the device over the network
- And to send data back to the device (like sound and rumble data)
- Often abstracted away behind an API Layer.

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
  }
}
```

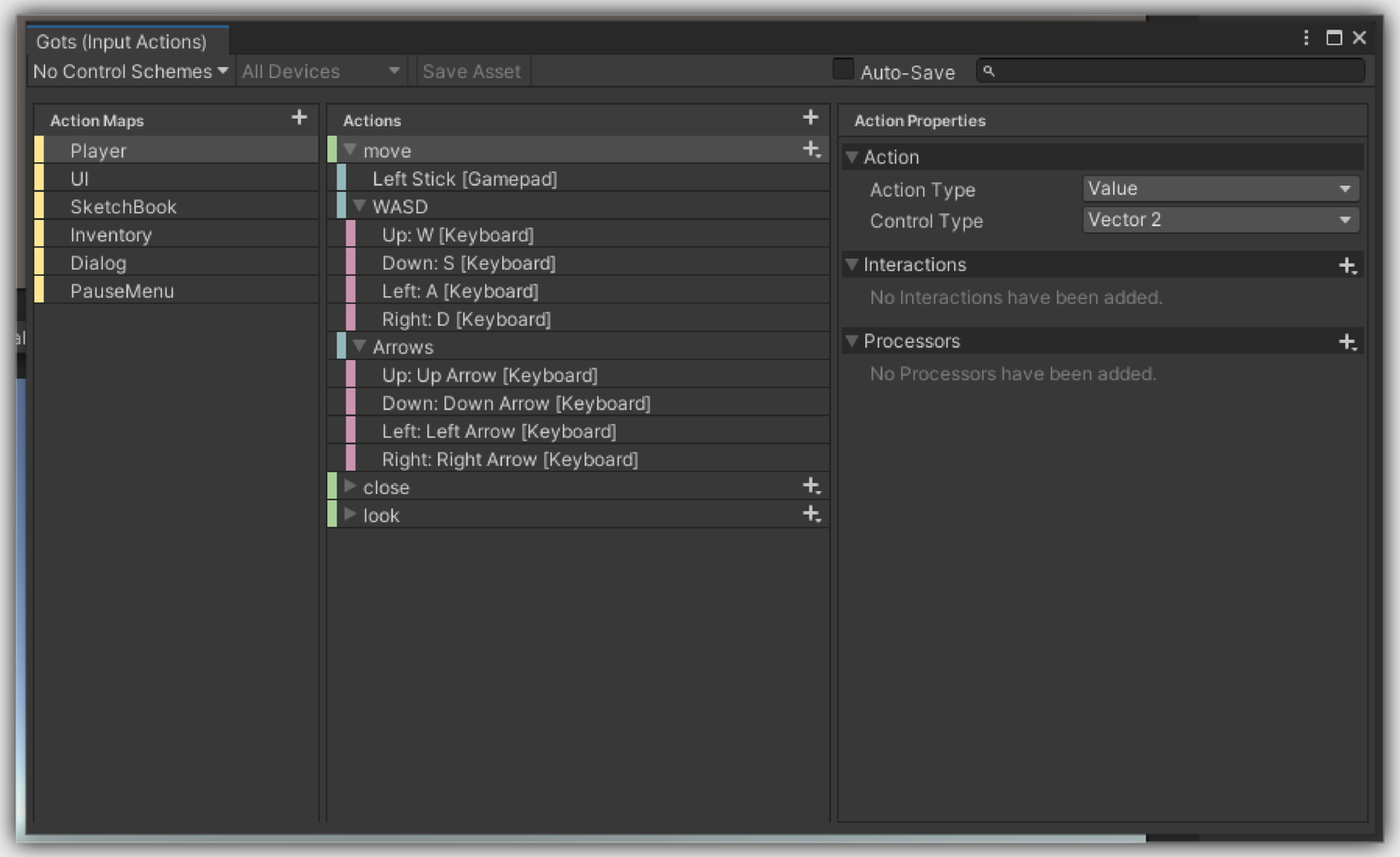
Command

These commands need to be registered with the Input manager

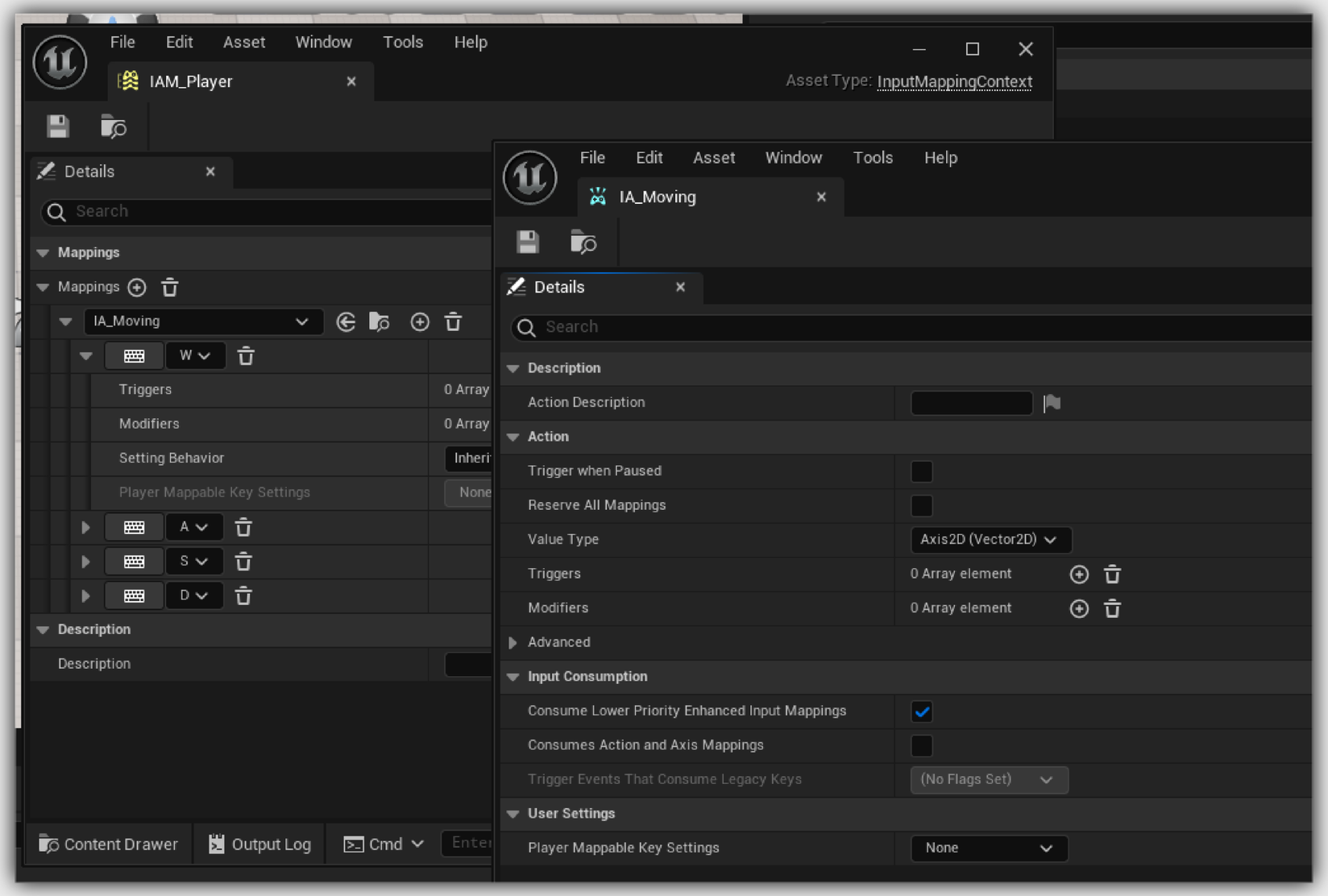
- The input manager keeps track of all active commands
- Checks if the input for the command has been executed by the user
- Calls the Execute method on the registered command
- Don't forget to unregister!

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

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);
}
```