Tutorial: Create 2D Game Engine using C++

URL: https://www.youtube.com/playlist?list=PL-K0viiuJ2RctP5nlJlqmHGeh66-GOZR

Purpose

These notes summarize the you tube video playlist "How to Make a 2D Game Engine with C++ & SDL". We will follow the videos in order but will not hesitate to re-arrange the material to make it easier to read and follow and understand the concepts presented. I will make corrections to the code and provide additional material (without attribution) from the Internet. These are my notes in trying to follow and understand this video series.

I was going to use the latest version of SDL – SDL3 but found too many differences between SDL2 and SDL3 so decided to stick to the older version to match the video. I am using the latest version of SDL2 and `Code::Blocks`. Each section covers the material in the video faithfully[1]. So that I don't feel like a code monkey I do add a lot of notes on the specific SDL functions so that I understand how the SDL functions work.

Background

I am quite rusty with C++[2] and never worked with SDL2 library (I did start to write notes many years ago on SDL). I will describe things in a little bit more detail than what is covered in the video tutorial since I am using this tutorial to learn modern C++ and SDL2.

1. Setup SDL, SDL_image, SDL_ttf in Code::Blocks

The first video walks you through obtaining and installing the application `Code::Blocks`. `Code::Blocks` will be used to create our C++ source files and compile and run our game program.

In addition, this video creates the initial project to be used throughout the series, which of course starts as a "Hello, World" project. Lastly, we install the two main SDL libraries – SDL2 and SDL_image.

Why use Code::Blocks?

`Code::Blocks` is a free open-source, cross-platform Integrated Development Environment (IDE) primarily designed for C, C++ and Fortran programming. The IDE was originally released in

[1] We may remove the oversights, errors and corrections
[2] I last used C++ in a course I taught over 15 years ago. The concepts in modern C++ are new to me.

2005, and its development is driven by a team of contributors using `wxWidgets` library for its graphical user interface (GUI). The first official stable version was 8.02 released in 2008. The release marks the year and month of the `Code::Blocks` version. Like most modern IDEs it provides extensions via a plugin system.

What is `wxWidgets`?

`wxWidgets` is a free and open-source C++ library used for creating cross-platform graphical user interfaces (GUIs). It allows developers to write applications that can run on multiple operating systems, such as Windows, macOS, Linux, and more, without needing significant code changes. This is achieved by using the native API of each platform, ensuring that applications have a native look and feel.

Originally created in 1992 by Julian Smart, `wxWidgets` was initially called `wxWindows` but was renamed in 2004 due to a trademark issue. It supports a wide range of features, including GUI components, event handling, multithreading, file handling, and more. Additionally, it has bindings for other programming languages like Python, Perl, and C#.

Developers often use `wxWidgets` for its portability and ability to create sophisticated applications with minimal effort. Let me know if you'd like to explore its features further!

There are many other commercial[3] and open source projects[4] that utilize wxWidgets – Audacity (audio editor), FileZilla (server interface for popular FTP client), CMake, and many more.

The key feature of `Code::Blocks` is that you will be able to find an installation package for all modern operating systems – Windows, Linux and Mac OS. You should have no issue following the video tutorials using any operating system. In addition, the project uses all open source libraries.

Install Code::Blocks

The official website to obtain `Code::Blocks` is https://www.codeblocks.org/downloads/ . You have the option of:

- Downloading the setup file for `Code::Blocks` and executing it.
- Download the source code and build from scratch

The Binary release has a Windows, Linux and Mac OS X version. The fact that there is a version of `Code::Blocks` that runs on all three platforms is the primary reason it has been selected

[3] https://wiki.wxwidgets.org/Commercial_applications_using_wxWidgets
[4] https://wiki.wxwidgets.org/Project_List

for this and other tutorials. At the time of this writing the latest version is `25.03`, which means it was released in March of 2025.

My choices for Windows are:

Figure 1 - Selecting the right setup.exe to download

I decided to download `codeblock-25.03mingw-setup.exe` for 64-bit.

Why use mingw?

URL: https://www.incredibuild.com/glossary/mingw#:~:text=MinGW%20is%20primarily%20used%20for,lightweight%20executables%20without%20additional%20dependencies.

`MinGW` (short for Minimalist GNU for Windows), is a free and open-source development environment for compiling native Windows applications. It provides a collection of tools, enabling developers to build software without relying on proprietary compilers.

MinGW is primarily used for compiling C, C++, and Fortran programs on Windows.

Side note: I am surprised that the project has not moved to GitHub.

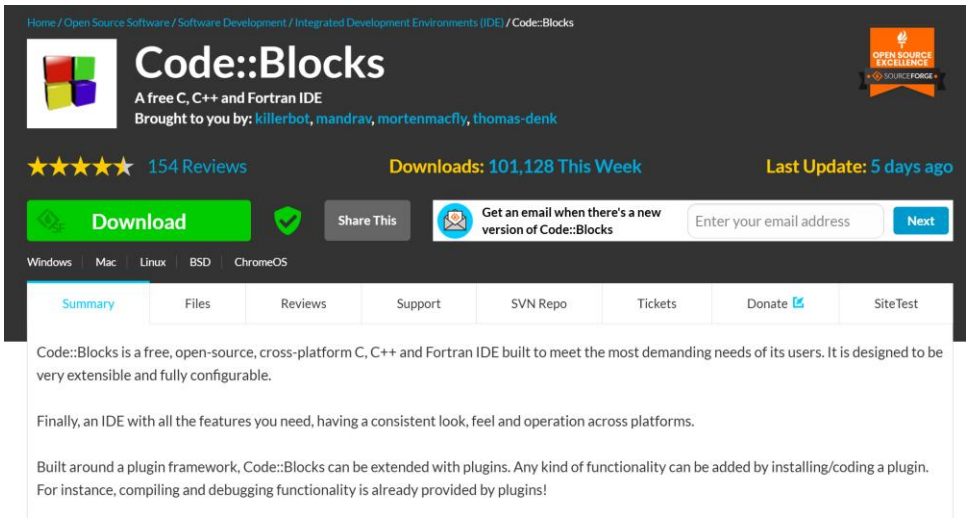


Figure 2 - Downloading file from Sourceforge

I then run the setup.exe file:

Figure 3 - Locating and executing the setup.exe file

Running the Setup

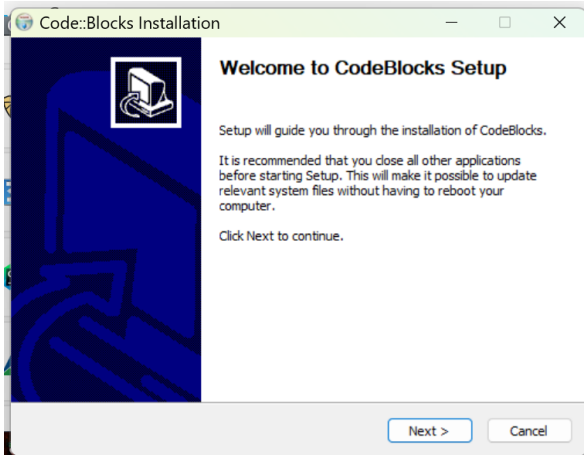


Figure 4 - Initial Code::Blocks Installation dialog

I did not find it necessary to close any other applications. I just pressed “Next >”.

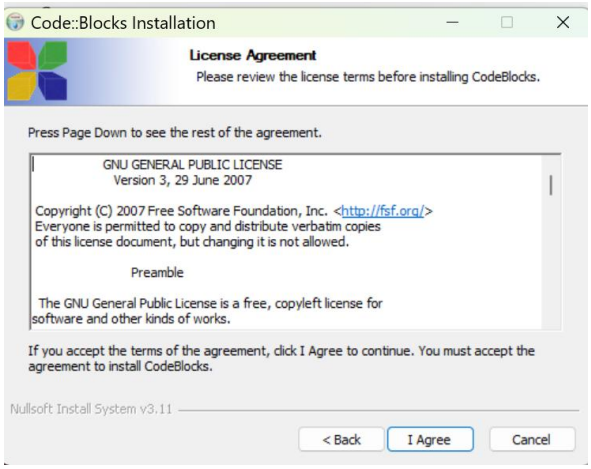


Figure 5 - The License Agreement screen

OK, I did not read the license agreement but knowing it is the GNU license assures me that it is open source and free. I just clicked on “I Agree”.

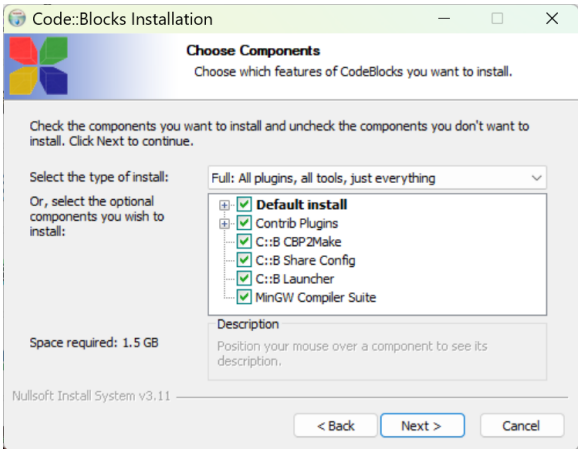


Figure 6 - The "Choose Components" screen

It appears by default all the components are selected. A quick description of each component:

- **Contrib Plugins** – these are additional plugins developed by the community to extend the functionality of the Code::Blocks IDE. These plugins are not part of the core set but have proven to be valuable enough to be included in the official Code::Blocks repository.
    - **Code Snippets Plugin**: Helps to manage and insert reusable code snippets.
    - **DoxyBlocks Plugin**: Integrates Doxygen for generating documentation from your code
    - **CppCheck Plugin**: Provides static code analysis to identify potential bugs or issues
    - **SpellChecker Plugin**: Checks spelling in comments and string literals
    - **Valgrind Plugin**: Integrates Valgrind for memory debugging and profiling

- **C::B CBP2Make** – is a tool designed to generate Makefiles from Code::Blocks project files (*.cbp) or workspace files. Essentially, it allows you to convert your Code::Blocks projects into Makefiles that can be used with GNU Make or other build systems.
- **C::B Share Config** – this is a tool that allows you to import and export parts of your Code::Blocks configuration. It's particularly useful when you want to transfer settings between different computers or configurations.
- **C::B Launcher** – is a utility that helps manage the launching of the Code::Blocks IDE. This tool is useful for advanced users.
- **MinGW Compiler Suite** – The MinGW (Minimalist GNU for Windows) is a development environment that provides a native Windows port of the GNU Compiler Collection (GCC). It allows you to build native Window applications without relying on third-party runtime libraries.

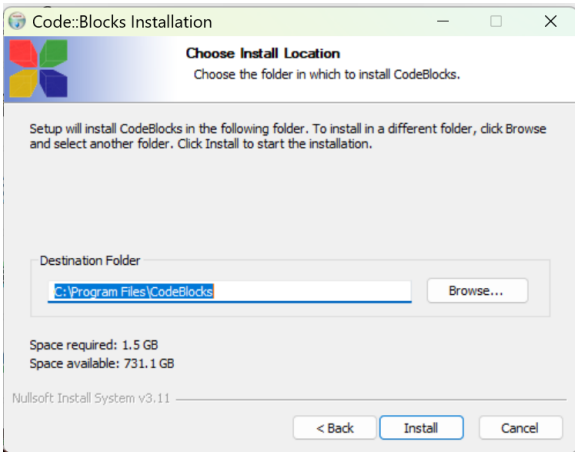


Figure 7 - Installation location on your PC

I usually take the default location.

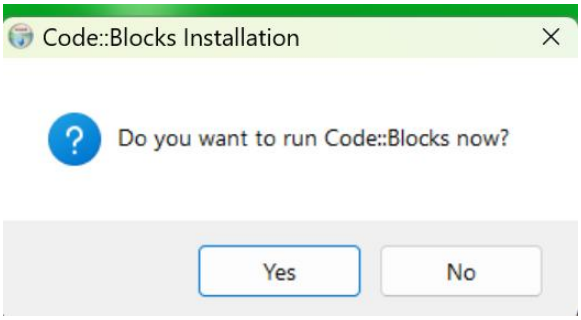


Figure 8 - Prompt to run Code::Blocks now?

I clicked on "Yes" so I can enter a simple "hello world" program to make sure everything works.

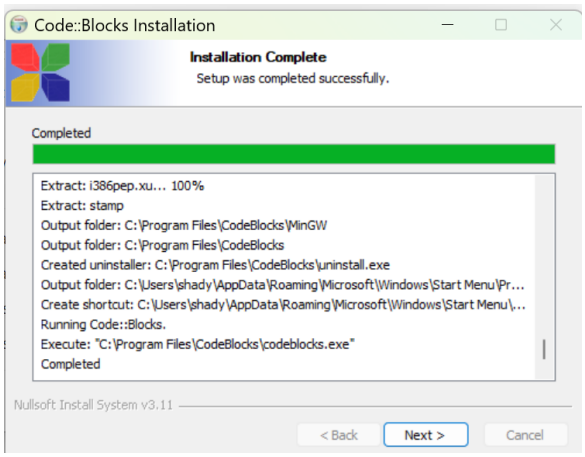


Figure 9 - Code::Blocks installation completed dialog

I clicked on “Next >”.

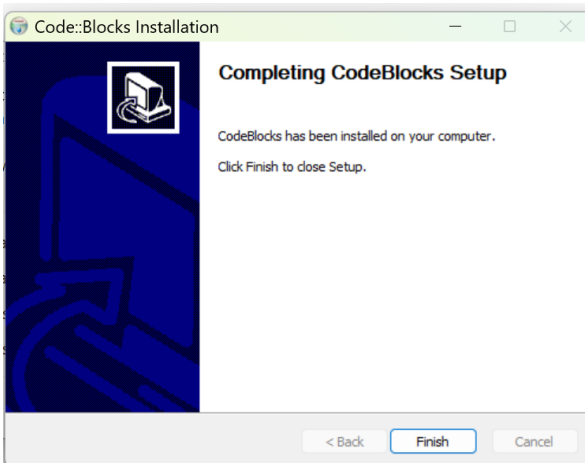


Figure 10 - The final Code::Blocks setup screen

Click on “Finish” and you will see Code::Blocks starting if you clicked “Yes” to start Code::Blocks now.

Starting up Code::Blocks

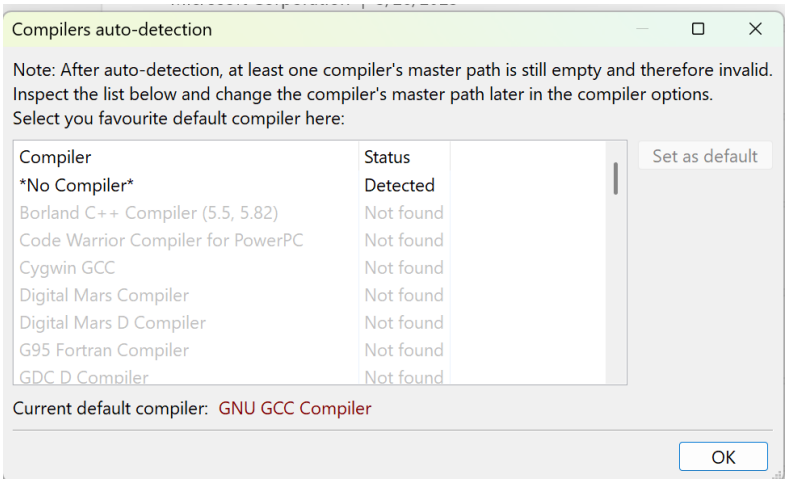


Figure 11 - Code::Blocks lists all the compilers it detected

As you can see from the list you have the option of using many different compilers in `Code::Blocks`. We do expect `Code::Blocks` to find `MinGW` compiler because that is the version we downloaded.

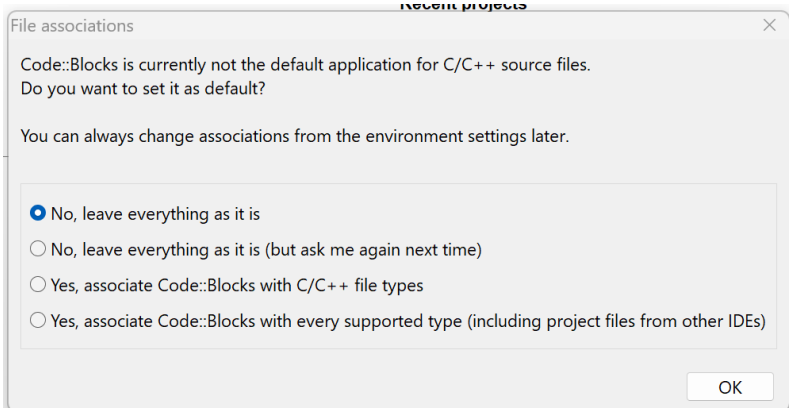


Figure 12 - Option to update file association

I opted for the default of “No, leave everything as it is” since I do use Visual Studio 2022 for other projects.

Setting Code::Blocks to use K&R Style braces

When Code::Blocks creates the initial code for you it does not use K&R brace style (also known as Kernighan and Ritchie style), you can adjust the formatting settings in the editor since a. I prefer K&R and b. the video presenter uses the Java style.

- Go to Settings ➔ Editor

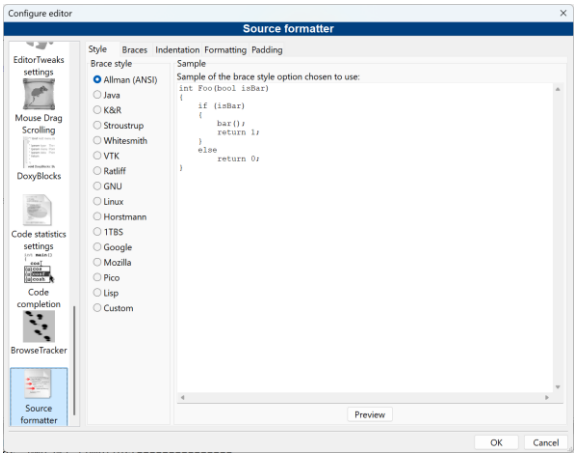


Figure 13 - Source formatter

- Select K&R

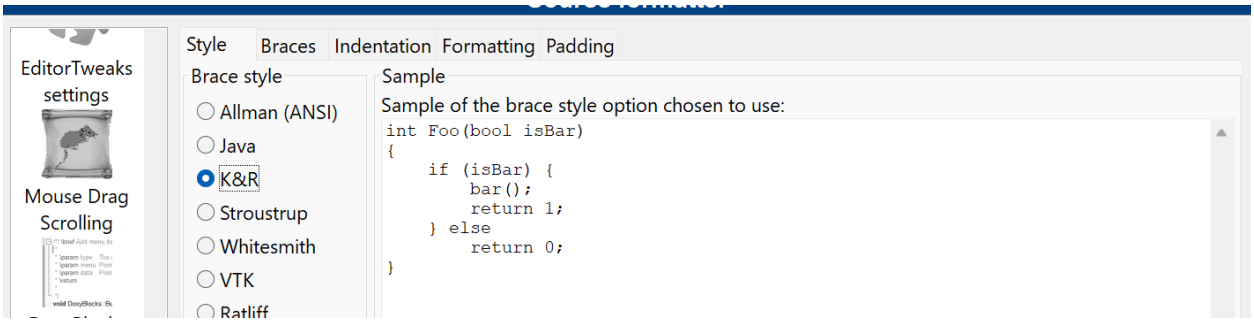


Figure 14 - Using K&R

I personally like Java style because I have mainly been a Java programmer for over 20 years (I know, I know, say no more!). I would suggest using the Java style if you want to match the presenters source code without having to manually move those braces around.

Note: I did not do this until after the end of video #3.

Starting a Project with Code::Blocks

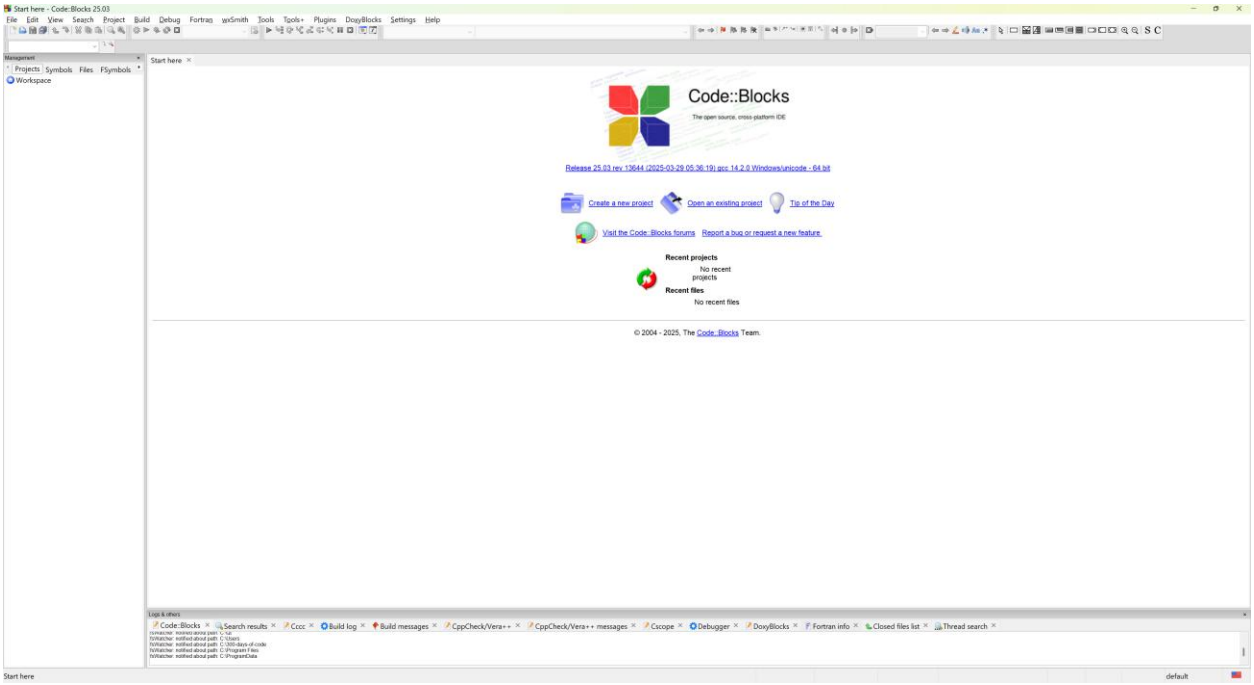


Figure 15 - The starting Code::Blocks screen

Note: I downloaded the `Code::Blocks` manual but the screenshots of the application appear to be dated!

Making Adjustments to the screen

Another note: The screen icons and fonts appear to be small to me (it is probably due to my screen resolution). I made things larger by doing the following:

- Go to Settings ➔ Environment ➔ View
- Increase Message logs' font size the Toolbar icon size

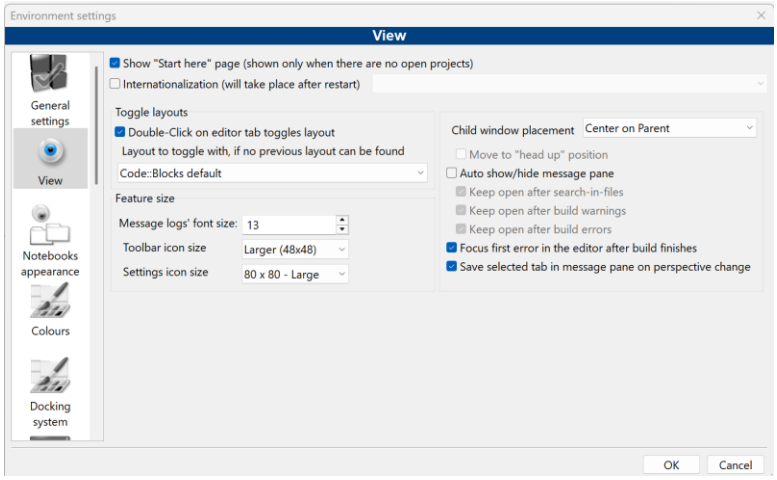


Figure 16 - Increasing the toolbar icon sizes

- Click “OK”
- Select File ➔ Save Everything
- Restart Code::Blocks

I also increased the font size used by:

- Select Settings ➔ Editor

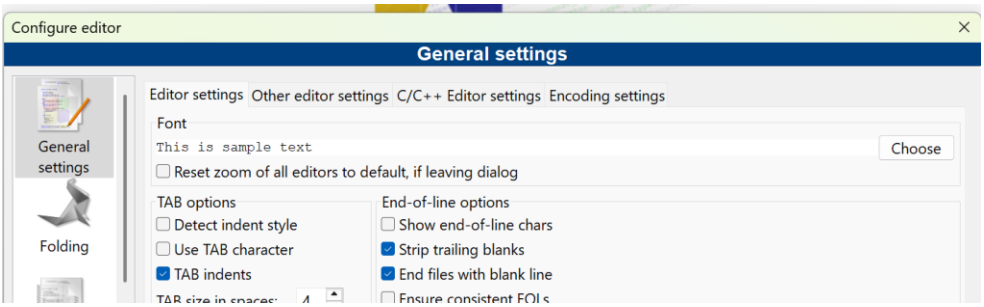


Figure 17 - Updating font-size

- Click on “Choose” button

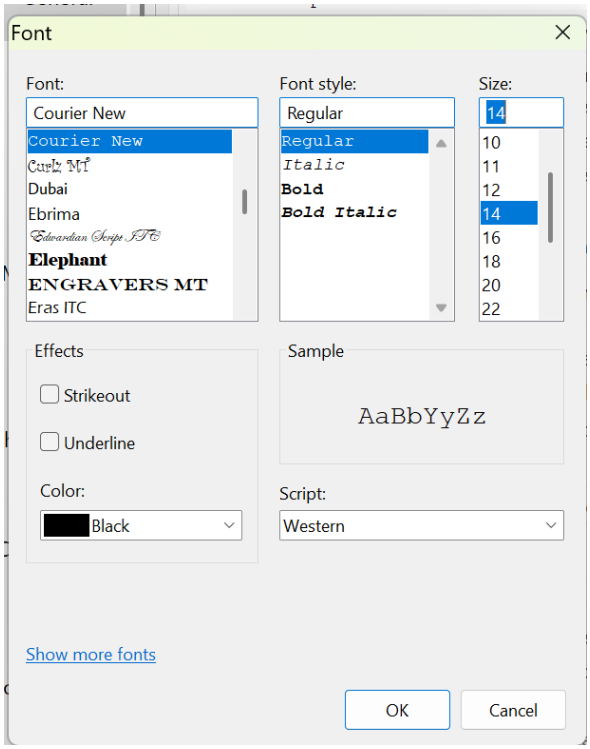


Figure 18 - Select desired font size

- I selected 14 and clicked on “OK”

Creating the Project

- Click on “Create a new project” link

Figure 19 - Creating a new Project

- Select “Console Application”

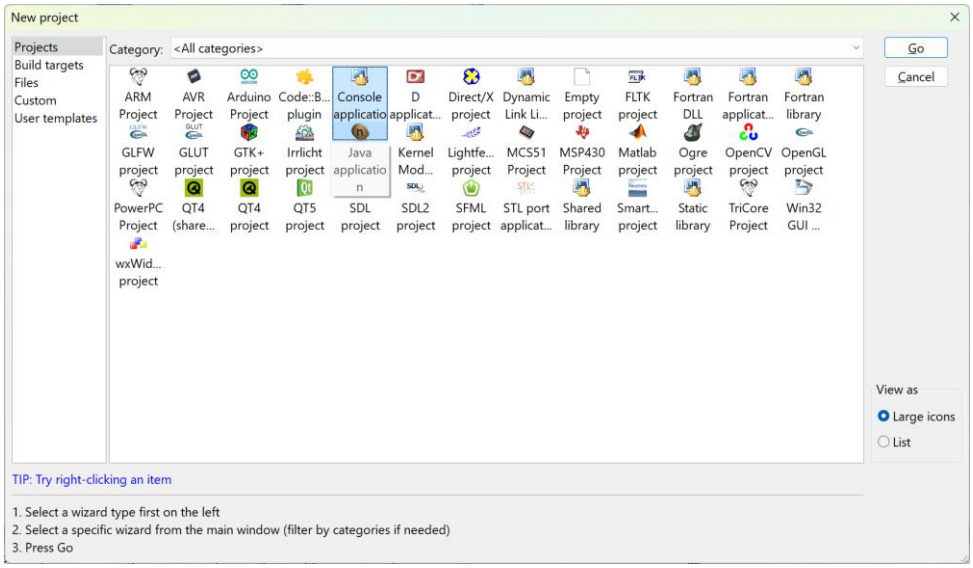


Figure 20 - Creating our first console application

- Click on “Go”, if this is your first time you will see the following dialog box appear:

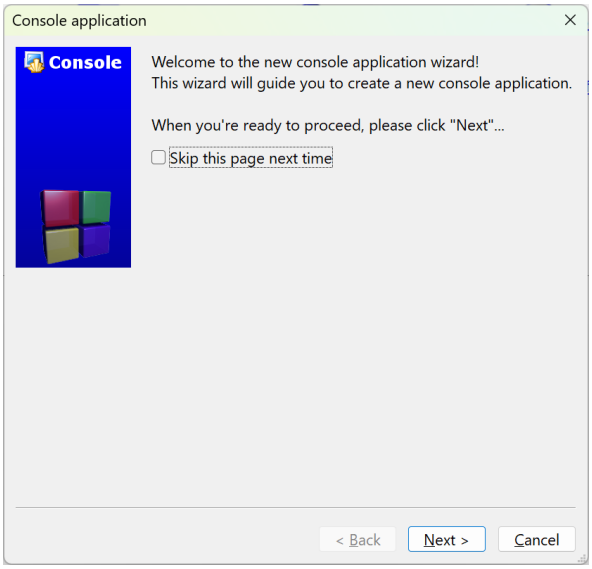
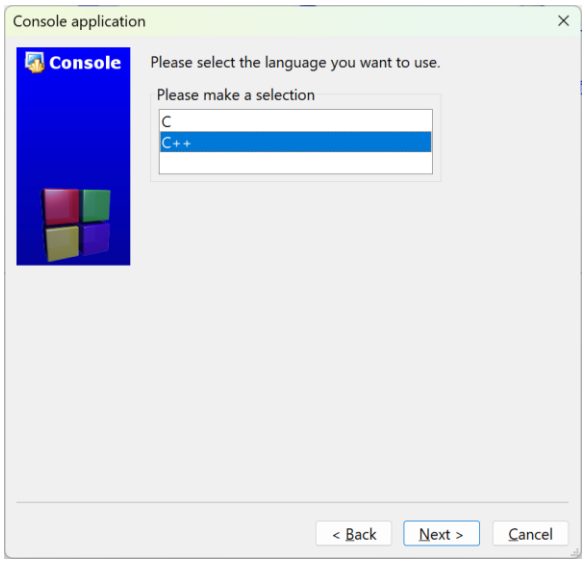


Figure 21 - The Console application wizard starting...

- Click on “Skip this page next time” and press on “Next >”



- Take the default C++ and click on “Next >”
- Fill in the Project information:

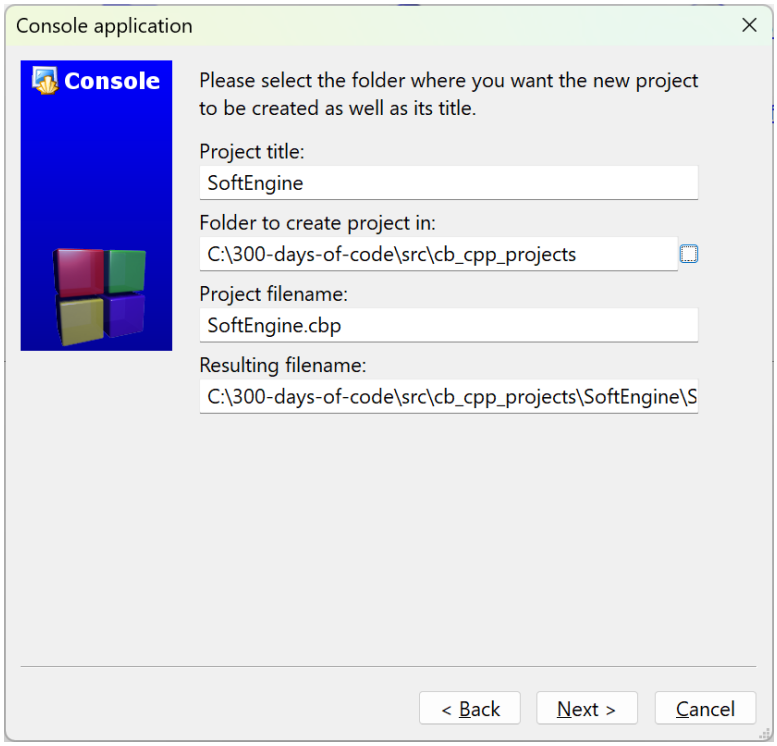


Figure 22 - Project information

The Project name will be `SoftEngine`. Since this is part of my 300-days-of-code effort I select a folder where I plan on placing all my `Code::Blocks` C++ projects. Enter a location that makes sense for your setup.

- Click on “Next >”

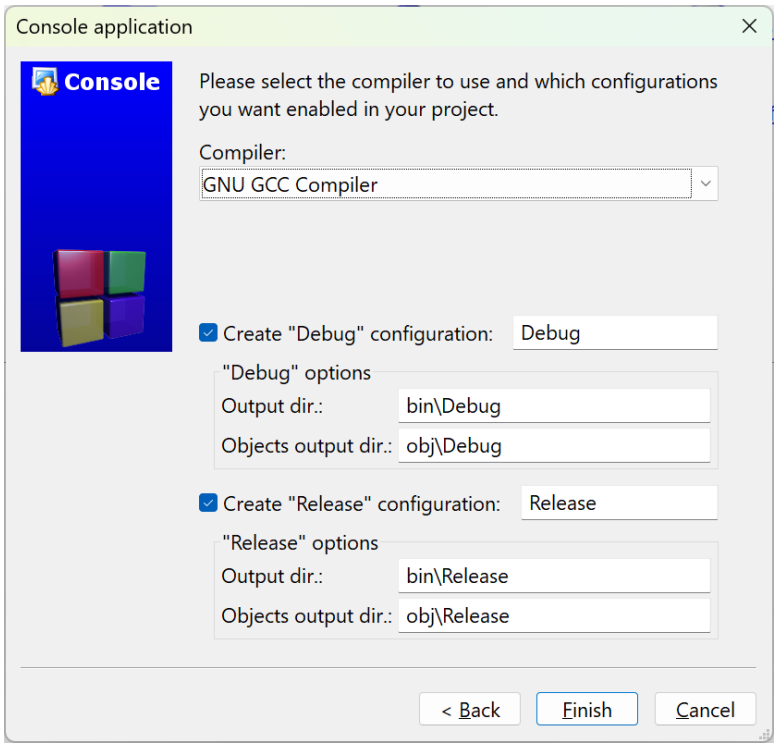


Figure 23 - Final step in creating our game engine project

- Make sure the “Debug” and “Release” configuration are selected and click on “Finish”

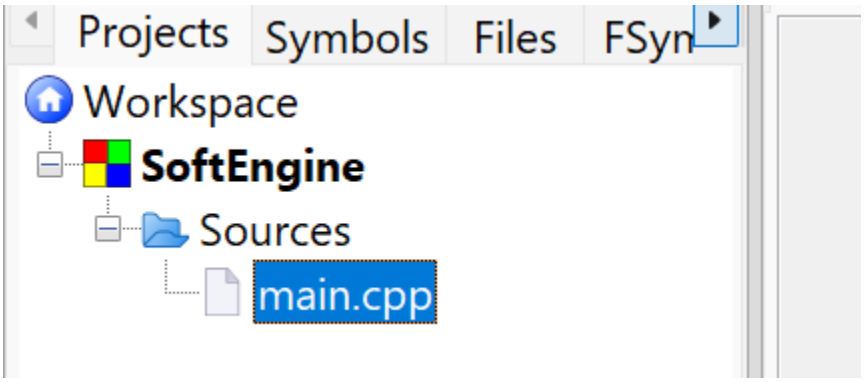


Figure 24 - Default main.cpp is created

- Following the video author’s convention, let’s rename the file main.cpp to Main.cpp
  - Right-click on the filename and select Rename file:

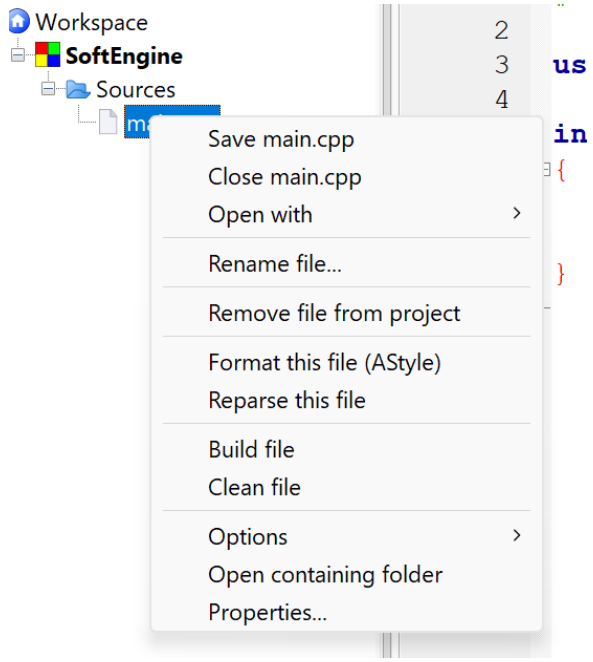


Figure 25 - Context menu for file

- Enter the name `Main.cpp`:

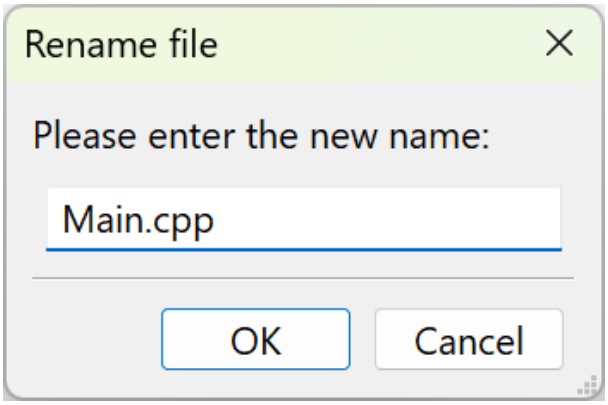


Figure 26 - Rename dialog box

- Click “OK”

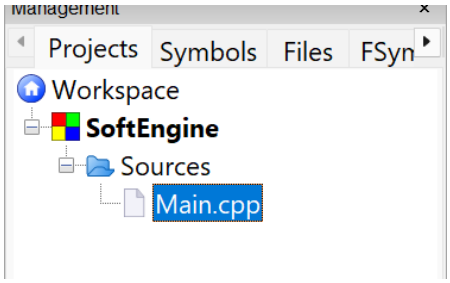


Figure 27 - Update name in Workspace

Build and Run the Program

The ***Workspace*** contains one or more projects, in our case it shall only contain one project – `SoftEngine`. The workspace is the most top-level container. A ***project*** contains one or more build targets and the project's files.

You should familiarize yourself with the following icons/operations:

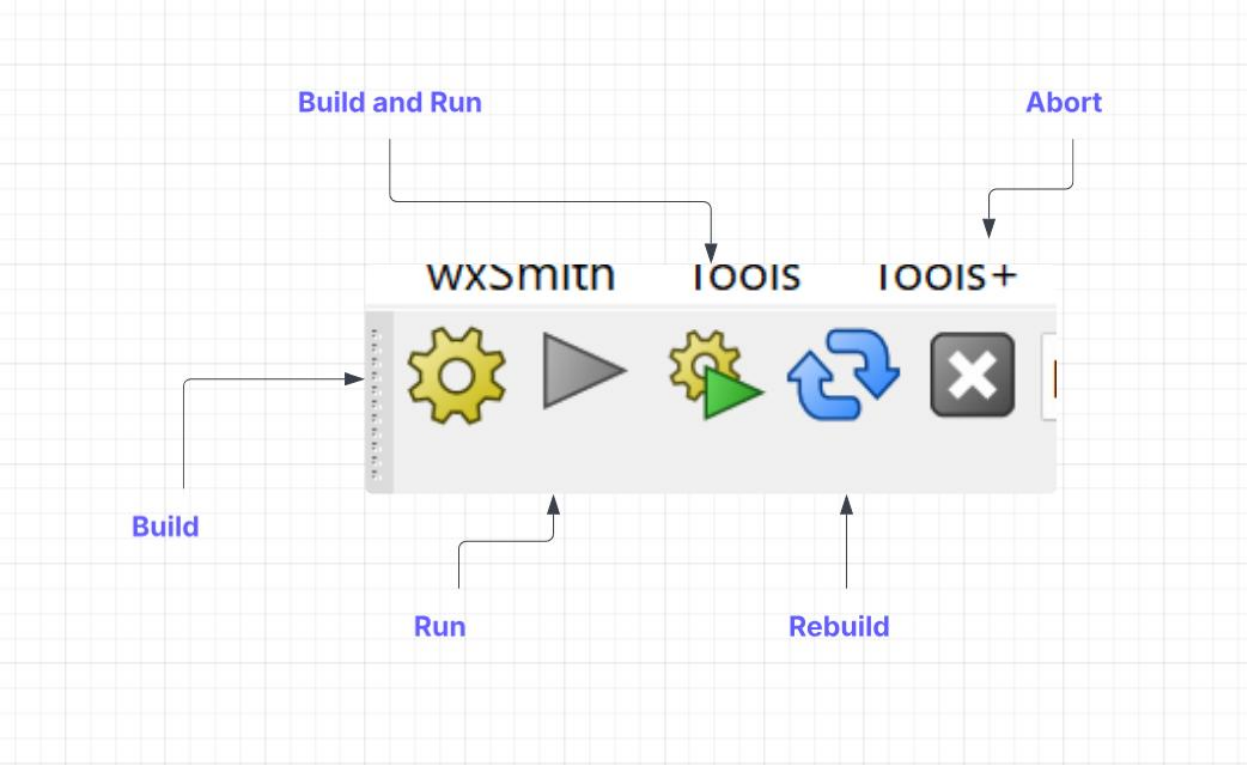


Figure 28 - Common operations

- **Build** – this function compiles your source code into an executable program. It processes the code files in your project, checks for errors, and links them to create a standalone application. This is where you written code is transformed into something that can run on your machine.
- **Run** – this function executes the program that you've built. If the program is a console application (which is true in our case), it will open a terminal or console window to display the output.
- **Build and Run** – it combines the two steps above
- **Rebuild** – This is a more thorough version of Build. While "Build" compiles *only* the files that have been modified since the last build, "Rebuild" forces the *entire* project to be recompiled from scratch, regardless of whether files have changed.
- **Abort** – this command is used to stop an ongoing build or compilation process. It is specifically for interrupting the build process.

Let's Build and run!

Our Main.cpp code is:

```
1. #include <iostream>
2.
3. using namespace std;
4.
5. int main()
6. {
7.     cout << "Hello world!" << endl;
8.     return 0;
9. }
10.
```

The code above is our simple "Hello, world!" program.

- Click on the "Build and Run" icon

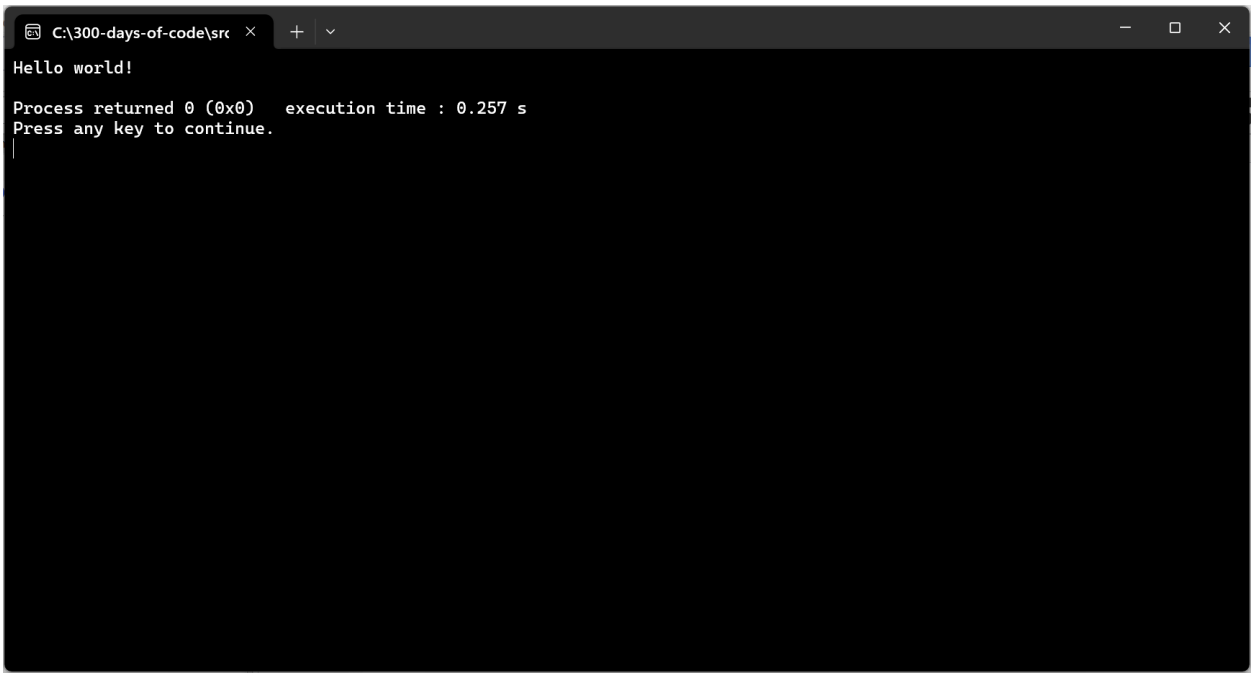


Figure 29 - Result of building and running our Main.cpp

- Press any key on the keyboard to dismiss

Install and Setup SDL

What is SDL?

SDL, or ***Simple DirectMedia Layer***, is a cross-platform software development library designed to provide a hardware abstraction layer for multimedia hardware components. It was originally

created by Sam Lantinga in 1998. SDL is widely used for developing high-performance computer games and multimedia applications across various operating systems, including Android, iOS, Linux, macOS, and Windows.

The library is written in C and provides an application programming interface (API) in C, with bindings available for other programming languages. Over the years, SDL has evolved significantly, with major updates like SDL 2.0 in 2013, which introduced better support for 3D hardware acceleration. SDL 3.0, released in January 2025, brought further enhancements and new features.

SDL is free and open-source software, licensed under the zlib License since version 2.0, allowing developers to use it in both open-source and closed-source projects. It has been extensively used in the industry, with hundreds of games, applications, and demos built using the library.

The website to obtain more information is: https://www.libsdl.org/

Installing SDL2 and SDL2_image

- Create a folder that will hold both SDL2 and SDL2_image download files. I will create the folder D:\SDL2_dev folder.
- Download the latest SDL2
    - Go to: https://github.com/libsdl-org/SDL

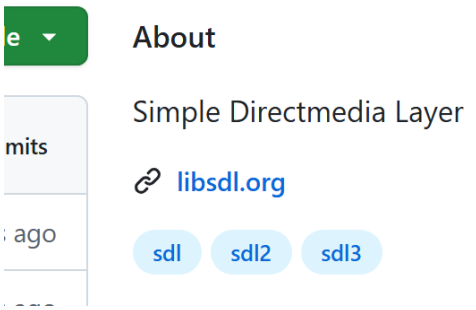


Figure 30 - Versions of sdl on Github

The sdl2 link displays a list of projects that uses sdl2.

- Go to https://github.com/libsdl-org/SDL/releases/tag/release-2.32.4 to get the latest SDL2 version.

Note: We will be using the latest version of SDL – SDL`2.32.4`. The video series uses SDL`2-2.0.10`.

Another note: I prefer to learn and use SDL3 but there are too many differences between SDL2 and SDL3 that will introduce another set of issues that will get in the way of the video series!

- Navigate to the release github url (for me it is: https://github.com/libsdl-org/SDL/releases/tag/release-3.2.10)

What version of SDL2 should I use?

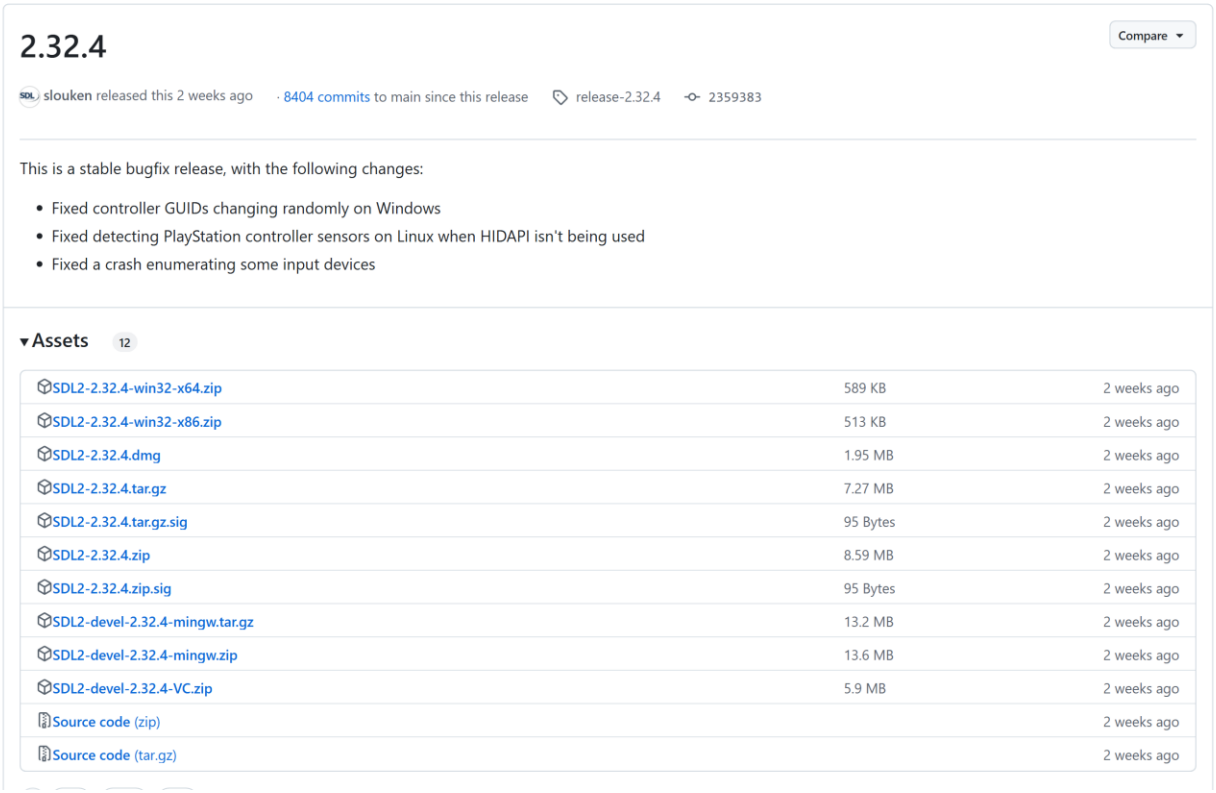


Figure 31 - Versions of SDL3 to choose from

Since I am using `Code::Blocks` with `mingw` I will utilize `SDL2-devel-2.32.4-mingw.zip` version. If you are using Visual Studio you should download and install SDL2-devel-2.32.4-VC.zip

Note: If you want to utilize SDL2 you can find the latest SDL2 release on the same github website: https://github.com/libsdl-org/SDL/releases

- Unzip the file[5] to D:\SDL2_dev:

[5] I use 7-zip to manage my zip files

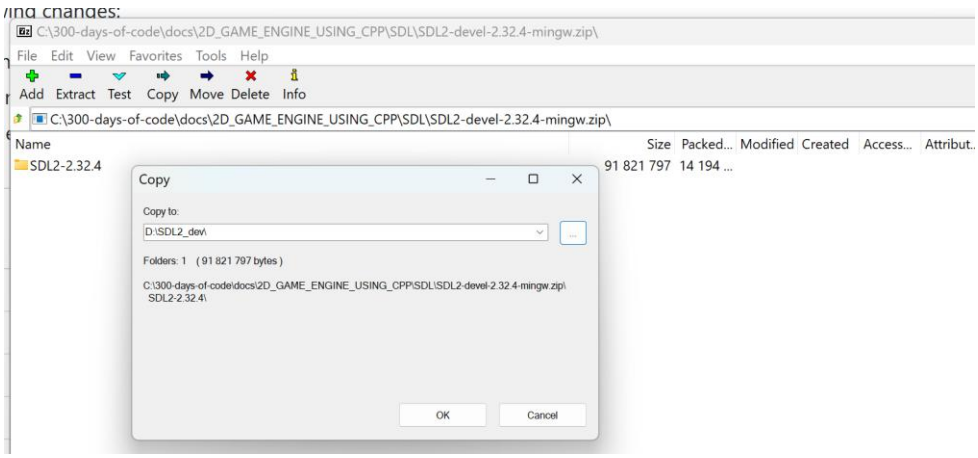


Figure 32 - Unzipping the SDL2 version

You will see:

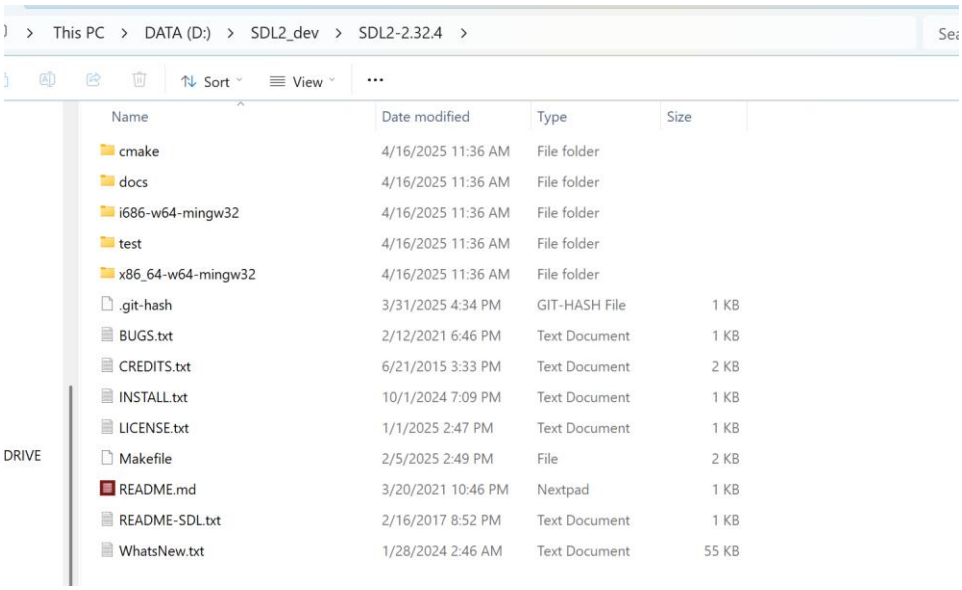


Figure 33 - Unzipped SDL2 file

- Open the INSTALL.md file to determine which of the folders you will use:

```
The 32-bit files are in i686-w64-mingw32
The 64-bit files are in x86_64-w64-mingw32
```

Figure 34 - Contents of INSTALL.txt file

I will be using the 64-bit architecture of the files in x86_64-w64-mingw32. Select the folder that makes sense for your machine and setup.

- Go to https://github.com/libsdl-org/SDL_image/releases to obtain the 2.8.9 release of SDL2_image

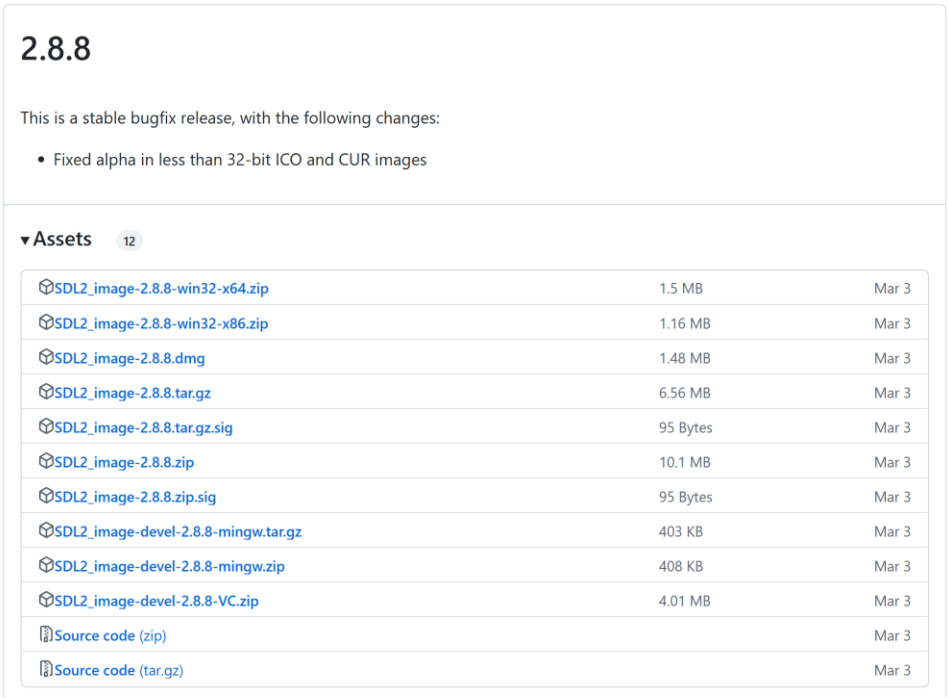


Figure 35 - SDL2_image choices

- I downloaded SDL2_image-devel-2.8.8-mingw.zip to be consistent with the version of SDL2 I downloaded.
- Unzip in the D:\SDL2_dev folder

You will see the following two top-level folders in D:\SDL2_dev:

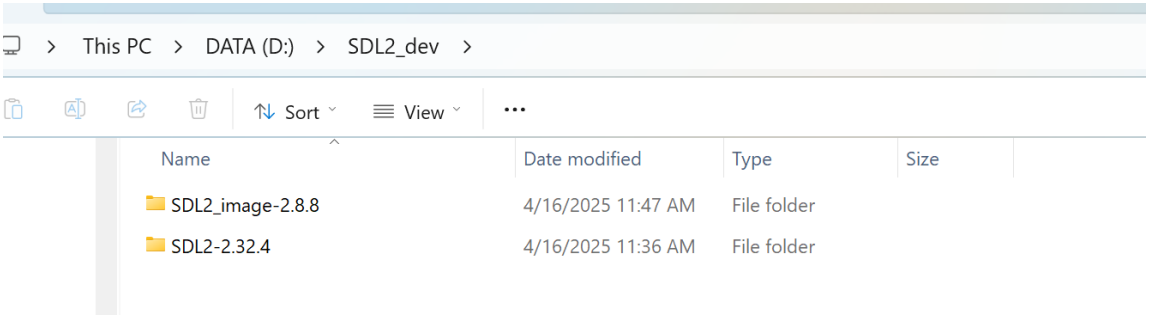


Figure 36 - Top-level folders

Note: Unlike the video – I will leave the files in the location I unzipped them.

Setting up Code::Blocks to access SDL folders

- Open the project (if not open) we created SoftEngine. To re-open the project
  - Open Code::Blocks
  - Click on “Open an existing project”
  - Navigate to the folder you placed your project and select SoftEngine.cbp and click “Open”

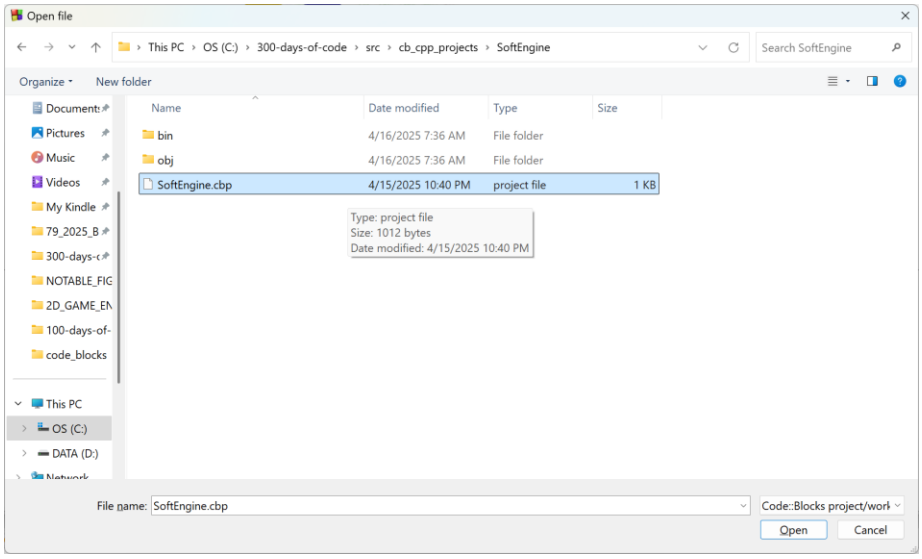


Figure 37 - Opening an existing project

Note: The following instructions should have directed the user to Project → Build options…

- Go to Settings ➔ Compiler…

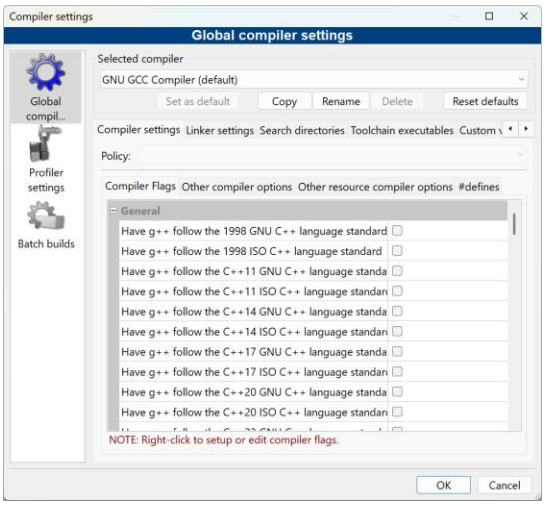


Figure 38 - Global compiler settings

Note: Going to Settings→Compiler… sets things up for this project and ALL future Code::Block project. Please use Project → Compiler options instead.

- Click on the “Linker settings” tab

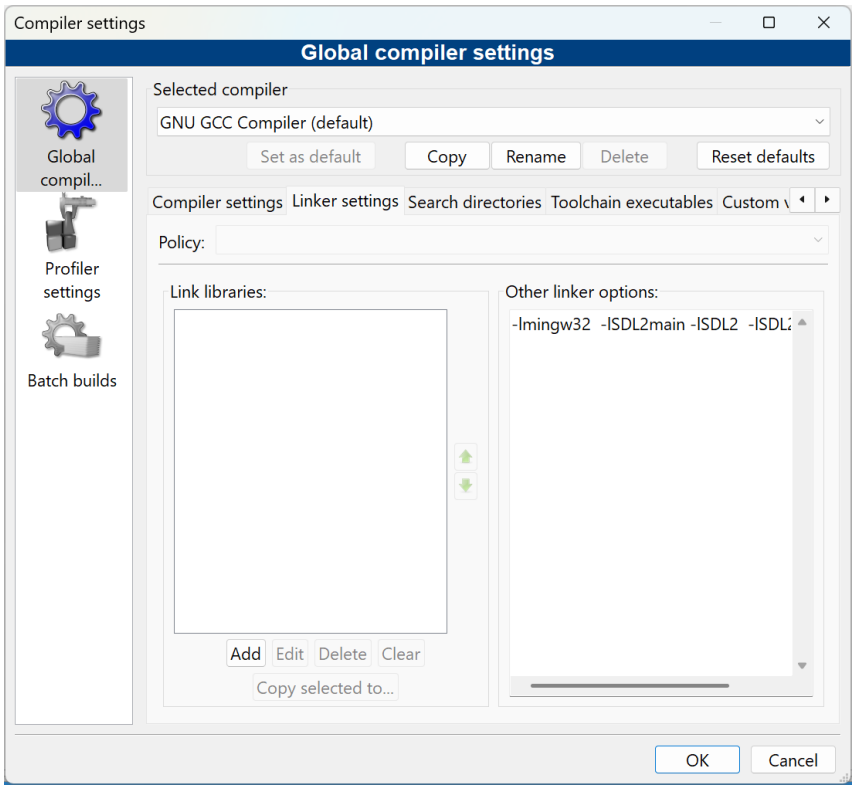
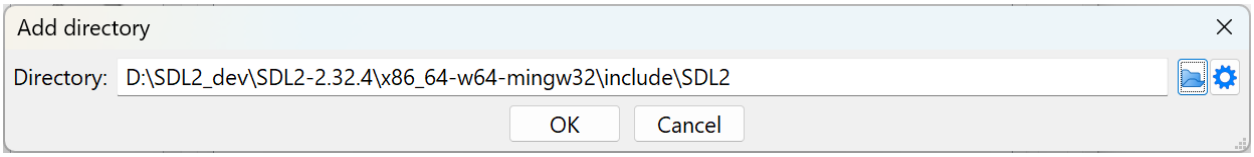


Figure 39 - Adding linker options

- In the “Other linker options:” input box enter:

```
-lmingw32 -lSDL2main -lSDL2    -lSDL2_image
```

- Click on the “Search directories” tab
- Make sure the “Compiler” tab is selected
- Click on “Add” and navigate to the include folder for SDL



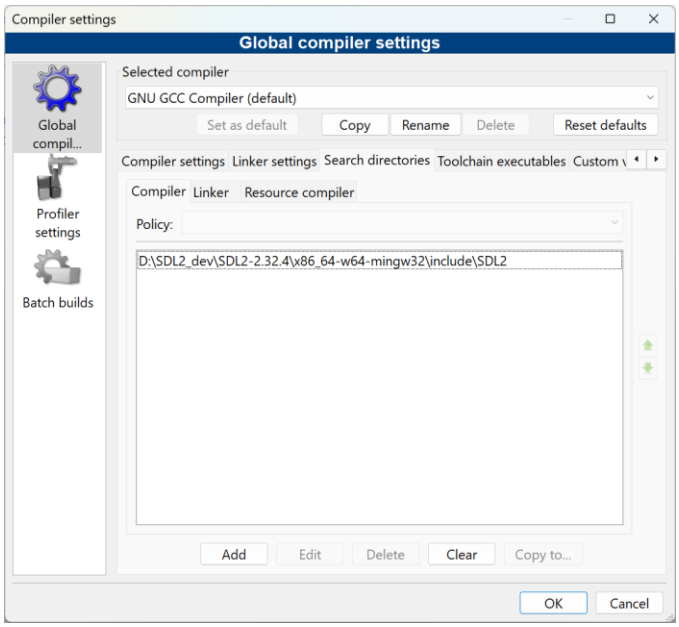
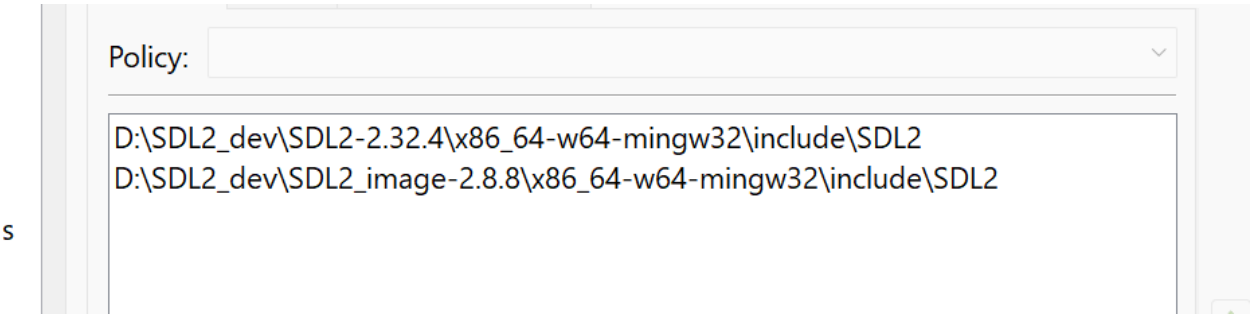


Figure 40 - Adding SDL3 include folder for the compiler

- Add the SDL2_image include as well



- Select the “Linker” sub-tab and add the location of the lib folder:

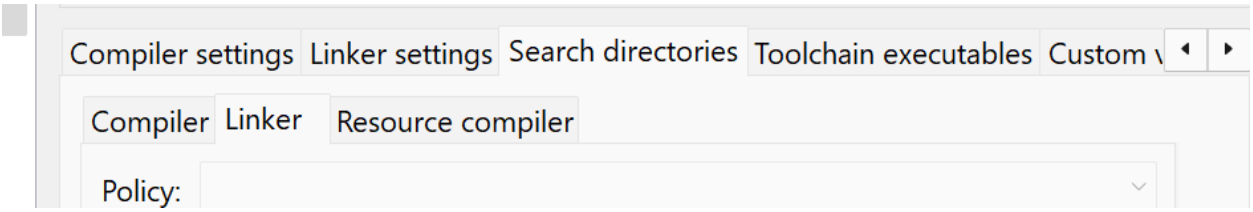
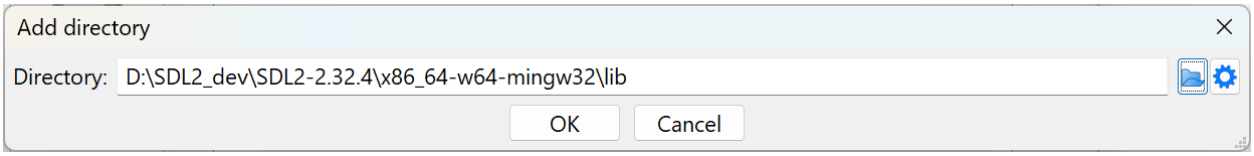


Figure 41 - Linker sub-tab

- Navigate to the SDL2 lib folder



- Click on OK
- Add lib folder under SDL_Image directory

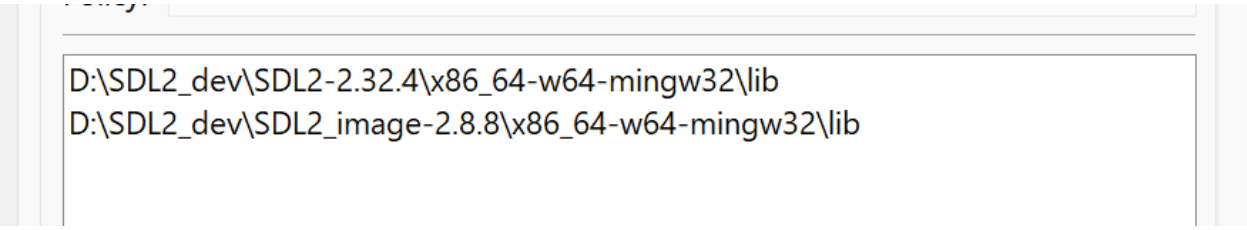


Figure 42 - SDL2 and SDL2_image lib folders for the linker

Note: If you decide to build a project with SDL_ttf and SDL_mixer it is rather cumbersome to have to add the \include and \lib folders for each SDL related library. I think a smarter way is to:

- Create D:\SDL\include and D:\SDL\lib folders and just unzip the \include and \lib folders for each SDL related library (you may find one or more overlapping include files). This way you only need to add those two folders for all SDL related libraries.

Testing the setup

- Update the code as follows:

```
1. #include <iostream>
2. #include "SDL.h"
3.
4. using namespace std;
5.
6. int main(int argc, char** argv)
7. {
8.     cout << "Hello world!" << endl;
9.     return 0;
10. }
11.
```

Note: A common error in SDL applications is to forget to update the main arguments with argc and argv!

- Click on the “Build” or “Rebuild”

You should see no errors.

The video uses SDL_INIT_EVERYTHING to initialize all the SDL subsystems at the same time. This is considered a bad practice and the flag SDL_INIT_EVERYTHING no longer exists in SDL3. We will follow the video but note that it does not exist in SDL3.

- Let's initialize SDL to make sure everything runs correctly. Update the Main.cpp:

```
1. #include <iostream>
2. #include "SDL.h"
3.
4. using namespace std;
5.
6. int main(int argc, char** argv)
7. {
8.     if (SDL_Init(SDL_INIT_EVERYTHING) == 0) {
9.         cout << "SDL_Init worked!" << endl;
10.    }
11.    SDL_Quit(); // clean up resources
12.    return 0;
13. }
```

- Try to build it again. It should build.
- Now, try to run the application. It fails:

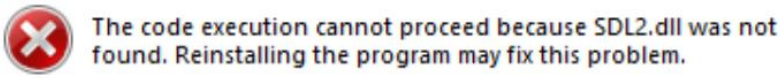


Figure 43 - Application failed to find SDL3.dll file

The problem is that the application could not find the SDL2.dll file that is located in the SDL2 \bin folder:

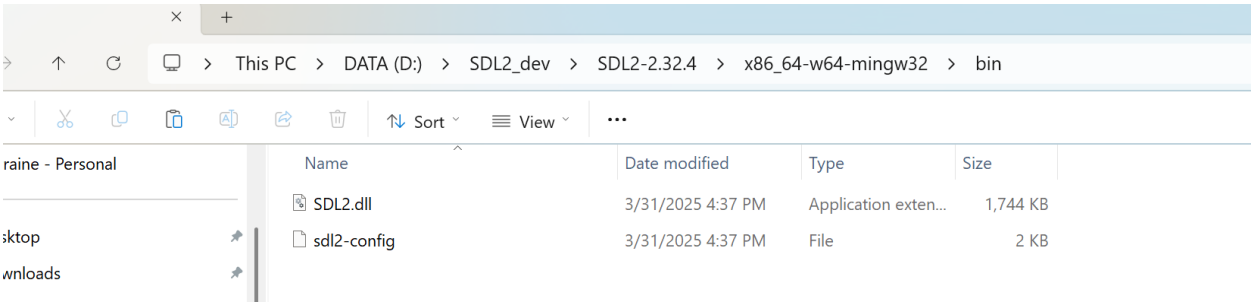
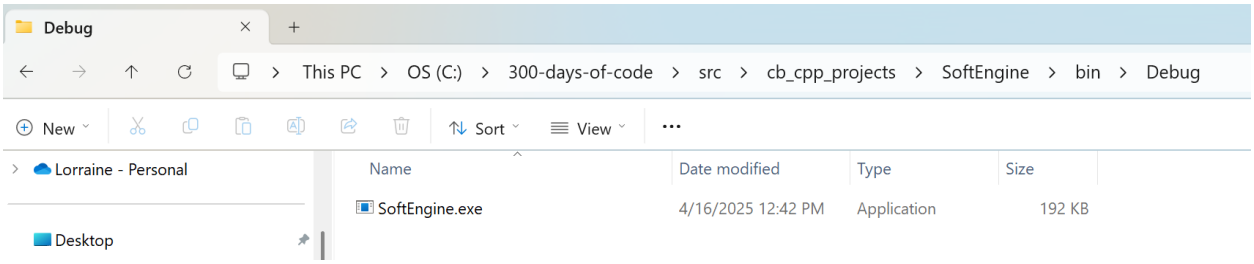
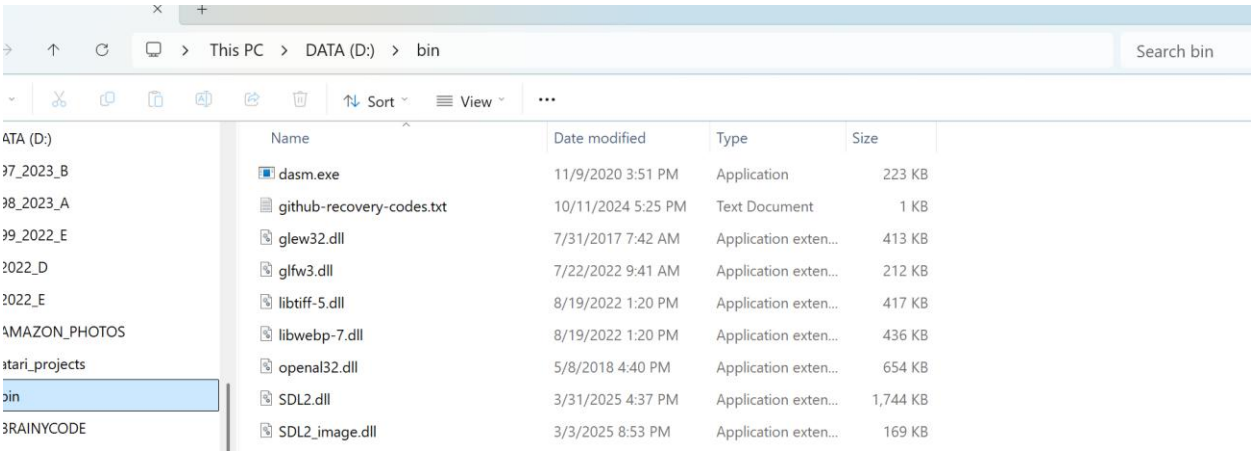


Figure 44 - The location of the SDL2.dll file

- The video presenter suggests putting the dll files for SDL2 and SDL2_image in the project debug directory:



I usually have a D:\bin or a C:\bin directory where I put in all my generic tools and common dlls that will be utilized across many projects:



I recommend[6] that a more general location be created like the above and the folder be placed in the environment path.

Whichever you choose, once the *.dll files of SDL2.dll and SDL2_image.dll are made accessible the program should now execute successfully:

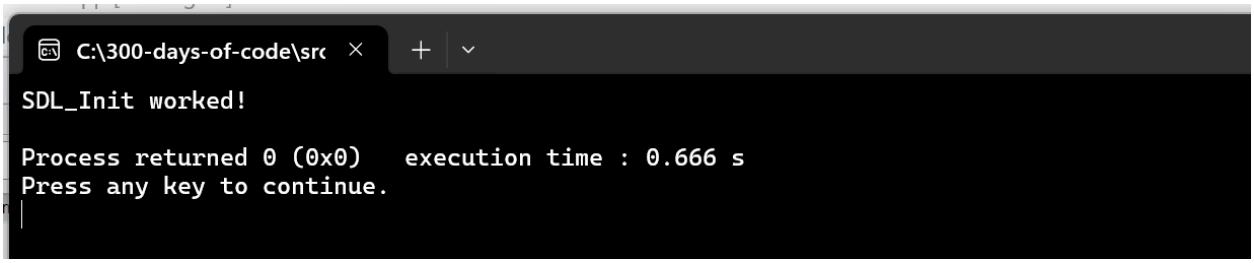


Figure 45 - Program with SDL component running ran successfully

2. Game Loop for SDL Game

In this video we implement the fundamental structure in every game and game engine – the **Game Loop**. We will add a new class – Engine.cpp (and Engine.h) that will have all the key

[6] I am not sure I would recommend this today. It seems I have multiple references to SDL2.dll in the PATH.

operations that a game loop goes through. Our Main.cpp class will be modified to invoke the key game loop functions.

Opening the Project

If you are opening the project for the next video a fast way is to select File ➔ Recent projects and select the project you are working on.

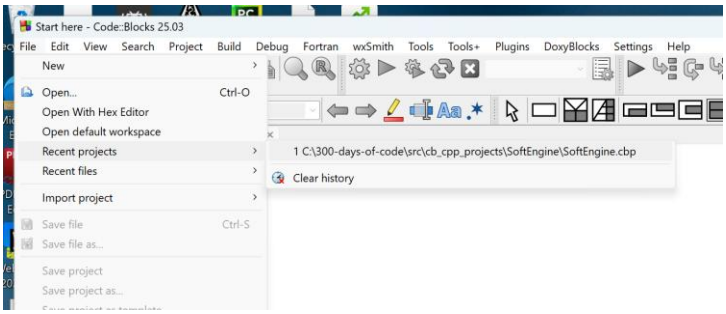


Figure 46 - Selecting a recent project

The goal of these set of videos is to create a 2D game engine that appears as follows:

Figure 47 - The final look of our 2D Game Engine

What is a game loop?

A game loop is the fundamental, repeating process that updates and renders a game's state. It's the core of how a game runs, constantly updating the game world, handling player inputs (via events) and drawing the graphics to the screen.

The core components of a Game Loop:

- Input: Processes player input from various sources like keyboard, mouse, or controller
- Update: Update the game's state, including physics, AI, and other game logic

- Render: Draws the updated game world to the screen

Initialization:

The game loop starts with an initialization phase where the game sets up its resources, including game states, graphics, and input systems.

Loop Execution:

The loop then repeatedly executes these phases:

- Process Input – The game detects player input and updates the corresponding entities.
- Update Game World – The game logic is applied, updating the state of the game world based on player input and game rules
- Render Graphics – The game renders the updated game world to the screen, creating the visual display for the player

Loop Continues:

This process continues until the game is closed or the loop's condition is no longer met.

Importance of the Game Loop:

- Smooth Gameplay: The game loop ensures the game runs smoothly and consistently, providing a fluid and responsive experience for the player
- State Management: The loop is responsible for managing the game's state, ensuring it remains consistent and up-to-date
- Foundation of Game Development: It's fundamental structure upon which most game development engines are built.

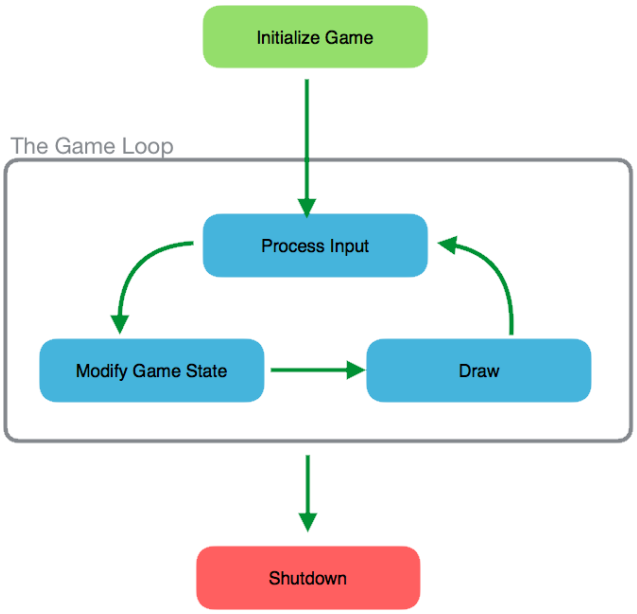


Figure 48 - A diagram of the "Game Loop"

Create an Engine class file

We will create an `Engine.cpp` and `Engine.h` C++ class that will capture the actions we want to implement a game loop.

- Select File ➔ New ➔ Class…[7]

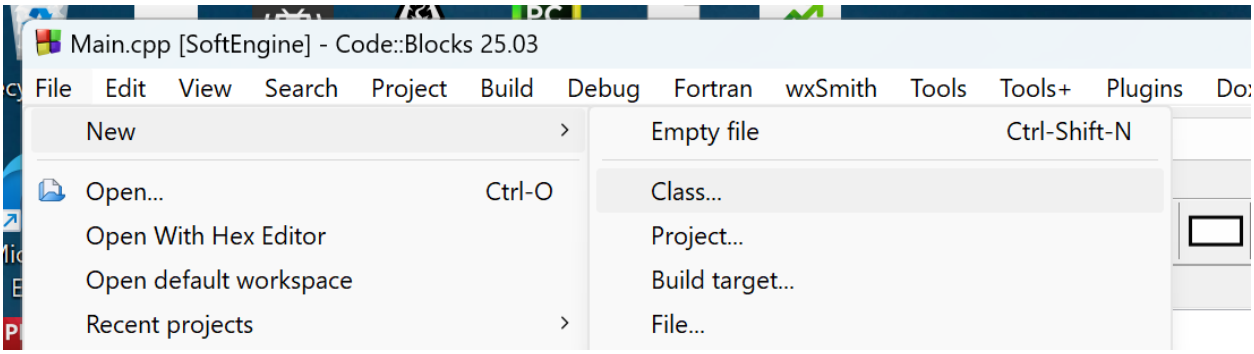


Figure 49 - Adding a new class to the project

- Fill in the “Create new class” dialog as shown:

[7] A faster way I developed in creating a new class is to just press “New File” icon.

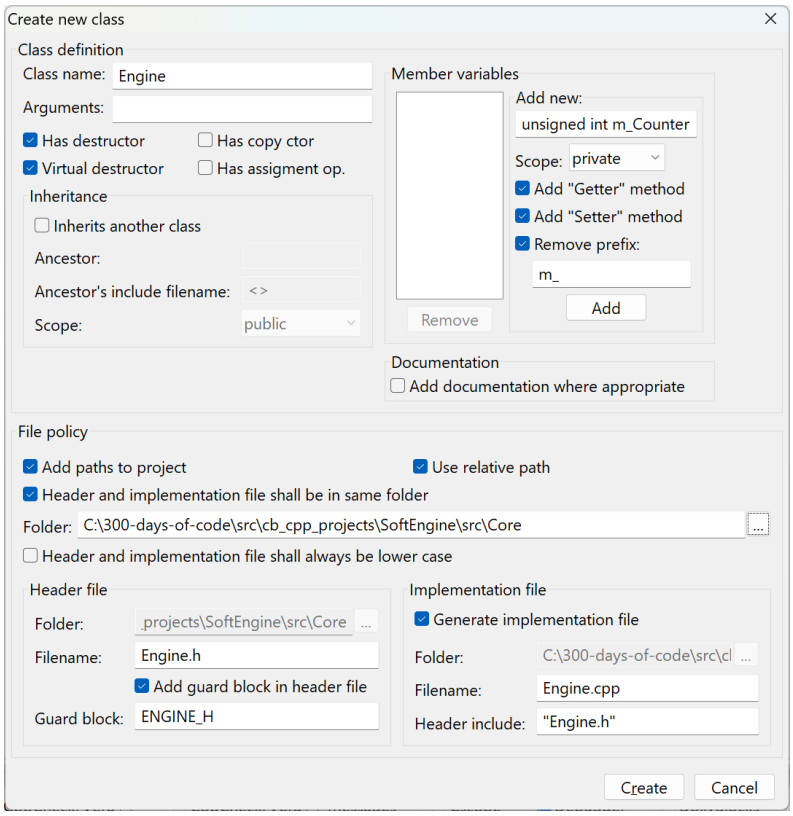


Figure 50 - Creating our Engine.cpp and Engine.h files

Note, the Folder for our new class is `\src\Core`. All the classes we will create for this project will be in their own folder under the `src` directory.

- Click on “Create”

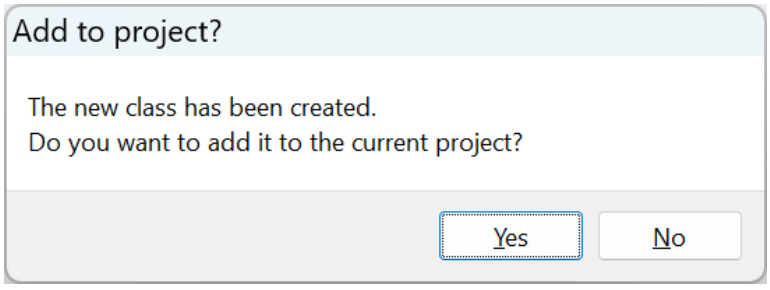


Figure 51 - Add to project prompt?

- Click “Yes” to the above prompt.

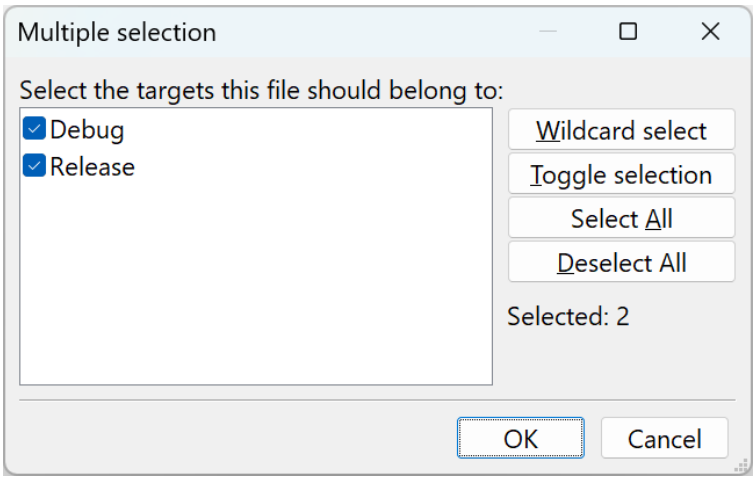


Figure 52 - Add to Debug and Release prompt

- Click “OK” to the above prompt.

The project will appear as:

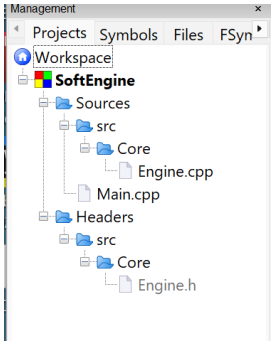
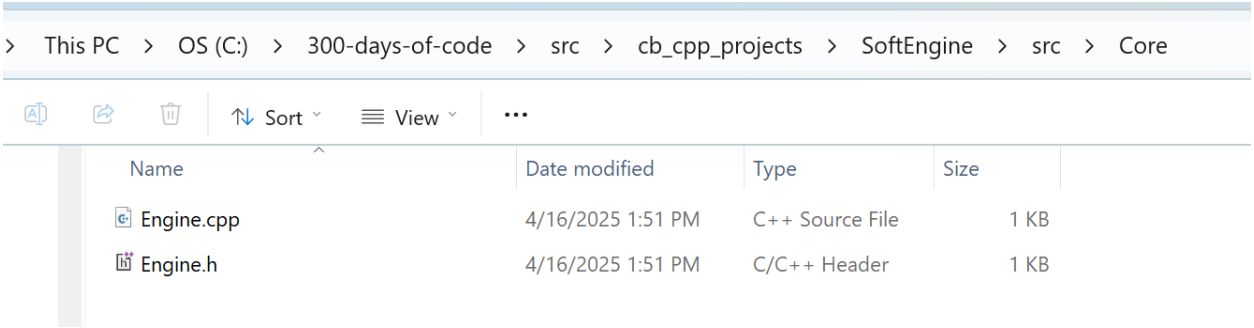


Figure 53 - Project view of the files

In fact, if you examine your folders:



You see that the `Engine.cpp` and `Engine.h` are actually in the same folder. The presenter likes to see the files together in the project view. Right-click on the `SoftEngine` project and select “Project tree” ➔ “Categorize by file types”.

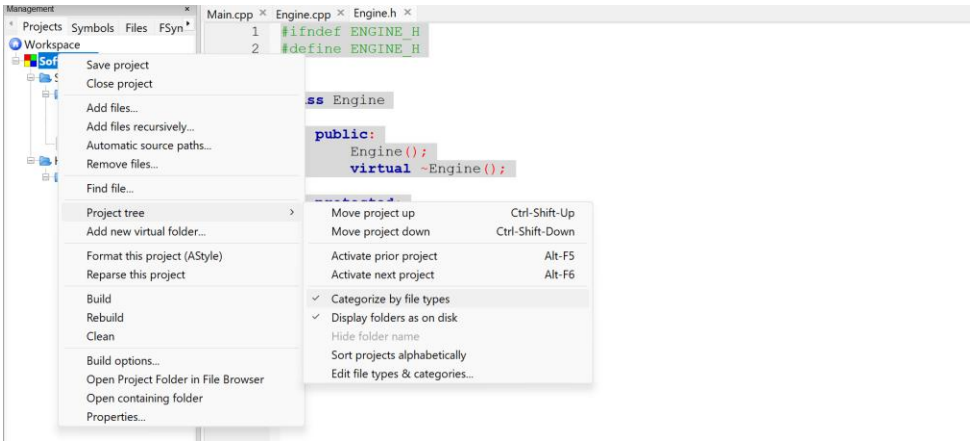
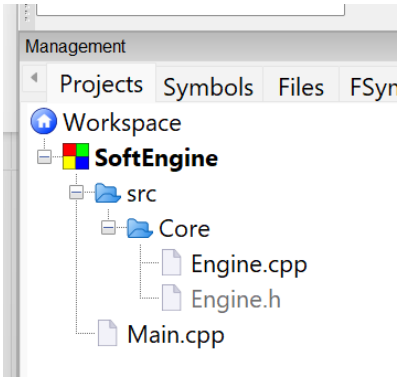


Figure 54 - Viewing the files as in actual folders

- Check “Categorize by file types” off

The result is:



Engine.cpp (initial):

```
#include "Engine.h"

Engine::Engine()
{
    //ctor
}

Engine::~Engine()
{
    //dtor
}
```

The `Engine.cpp` file created has an empty constructor and empty destructor defined. This is the implementation class.

Engine.h (initial):

```
1. Engine.h (initial):
2. #ifndef ENGINE_H
3. #define ENGINE_H
4.
5.
6. class Engine
7. {
8.     public:
9.         Engine();
10.        virtual ~Engine();
11.
12.    protected:
13.
14.    private:
15. };
16.
17. #endif // ENGINE_H
18.
```

We want our Engine class to be a Singleton class.

What is a Singleton class?

A Singleton class in C++ is a design pattern that ensures a class has only ***one instance*** throughout the program and provides a global point of access to that instance. This is useful in cases where you need centralized management of a resource, like a configuration manager or a logging system.

The Singleton pattern is typically implemented by:

1. Using a private static pointer to the single instance of the class.
2. Making the constructor private to prevent the creation of multiple instances.
3. Providing a public static method that returns the single instance (creating it if it doesn't exist).

Here's a simple example:

```
1. #include <iostream>
2. #include <memory>
3.
4. class Singleton {
5. private:
6.     static std::unique_ptr<Singleton> instance; // Static pointer to the instance
7.     Singleton() {}                              // Private constructor
8.
9. public:
10.    Singleton(const Singleton&) = delete;      // Prevent copying
11.    Singleton& operator=(const Singleton&) = delete; // Prevent assignment
12.
13.    static Singleton& getInstance() {
14.        if (!instance) {
```

```
            instance = std::make_unique<Singleton>();
        }
        return *instance;
    }

    void displayMessage() {
        std::cout << "Singleton instance accessed!\n";
    }
};

std::unique_ptr<Singleton> Singleton::instance = nullptr; // Initialize the static pointer

int main() {
    Singleton& singleton = Singleton::getInstance();
    singleton.displayMessage();

    return 0;
}

```

The example provided is compatible with **C++11** and later versions. Features like `std::unique_ptr` for memory management and the explicit use of `delete` to prevent copying were introduced in C11. If you use this code with compilers supporting C11 or newer (e.g., C14, C17, C++20), it should work seamlessly.

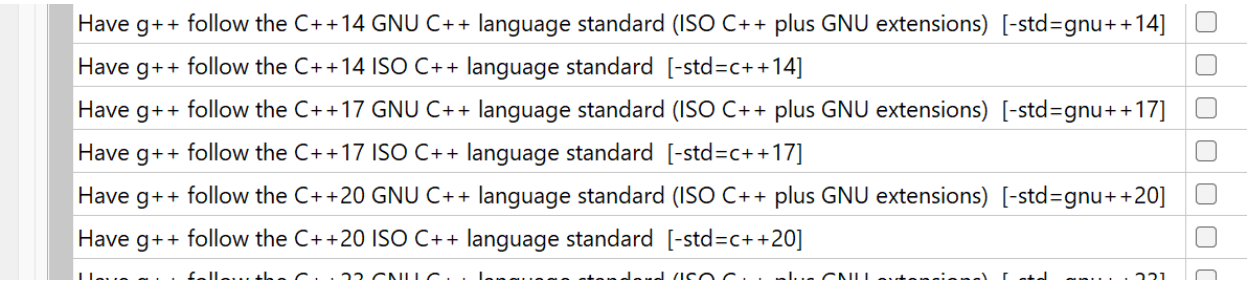
We only want to have one instance of the Engine class.

Setting the compiler to use C++ 17

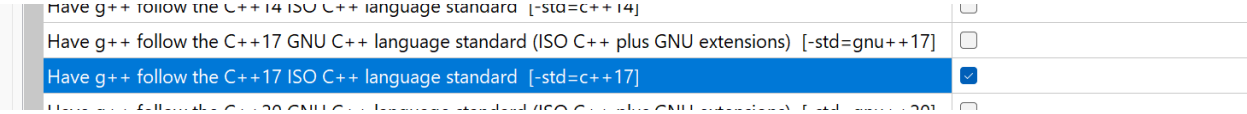
We probably should have done this earlier (in the first video) but we need to ensure that we use C++ 17 to match the presenter's version.

- Click on Settings ➔ Compiler…

We have several choices here:



The one that matches is:



Making the class Engine a Singleton

Engine.h:

```
 1. class Engine
 2. {
 3.     public:
 4.         Engine();
 5.
 6.         static Engine* GetInstance() {
 7.             return s_Instance = (s_Instance != nullpter) ? s_Instance : new Engine();
 8.         }
 9.         virtual ~Engine();
10.
11.     protected:
12.
13.     private:
14.         static Engine* s_Instance;
15.
16. };
17.
```

We create a static class method that either returns an `Engine*` or creates it. The `Engine` instance is saved as a pointer in `s_Instance`.

We will only ever have on instance of our game Engine, therefore we will move the constructor into the `private` section.

```
 1. class Engine
 2. {
 3.     public:
 4.         static Engine* GetInstance() {
 5.             return s_Instance = (s_Instance != nullpter) ? s_Instance : new Engine();
 6.         }
 7.         virtual ~Engine();
 8.
 9.     protected:
10.
11.     private:
12.         Engine() {};
13.         static Engine* s_Instance;
14.
15. };
16.
```

Note: Line 7 above should be removed.

Adding key game loop functions to our Engine

The key game loop functions are `Init()` for initialization of our game, `Events()` to obtain input events (e.g. mouse move, keyboard entry, etc.), `Update()` to update the entities according to the game logic, `Render()` to update the graphical screen. The `Clean()` function is used to clean up all resources and finally `Quit()` to terminate the game.

We will also add an inline `isRunning()` function to be used for our game loop, as long as the member variable `m_IsRunning` is true, we execute a cycle of the game loop.

Adding to Engine.h:

```
#ifndef ENGINE_H
#define ENGINE_H


class Engine
{
    public:
        static Engine* GetInstance() {
            return s_Instance = (s_Instance != nullptr) ? s_Instance : new Engine();
        }

        bool Init();
        bool Clean();
        void Quit();

        void Update();
        void Render();
        void Events();

        inline bool isRunning() {
            return m_IsRunning;
        }

    protected:

    private:
        Engine();
        static Engine* s_Instance;
        bool m_IsRunning;

};

#endif // ENGINE_H

```

There are two class methods that are defined in Engine.h:

- `GetInstance()`
- `IsRunning()`

Adding to Engine.cpp

To get `Code::Blocks` to automatically add implementation functions for all the missing functions do the following:

- Right-click on the `Engine.cpp` page
- Select Insert/Refactor
- Select “All class method without implementation…”

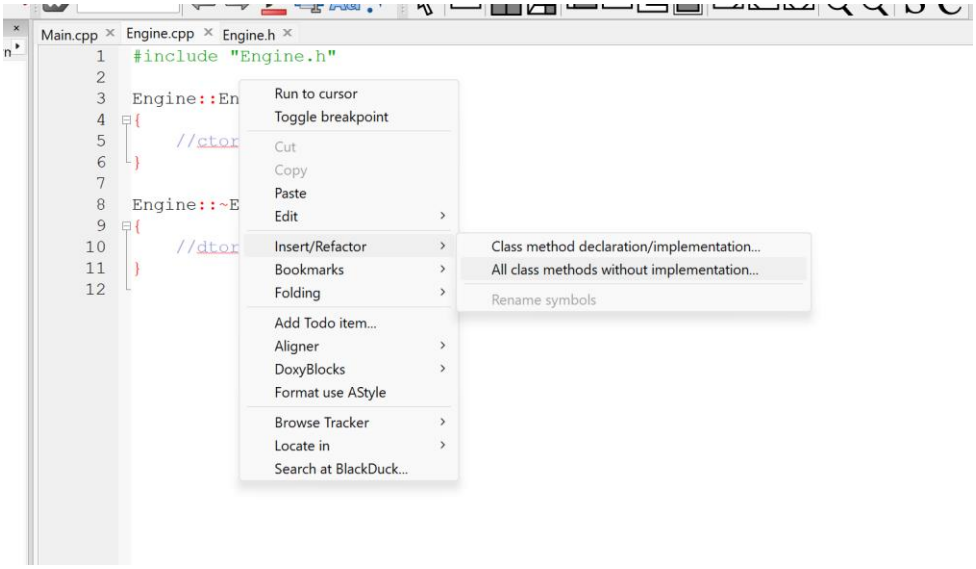


Figure 55 - Adding missing class methods

- Select all the methods you want the code to seed your class with:

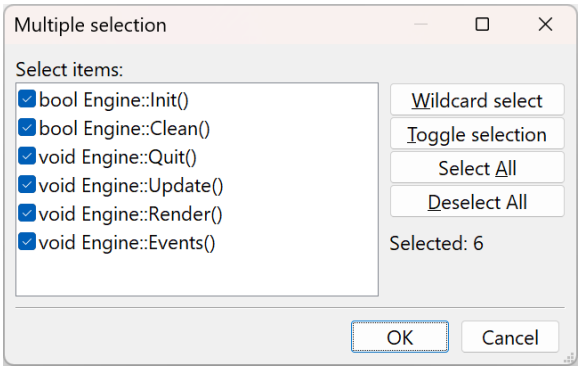


Figure 56 - Selecting the class methods to insert

- Click “OK”

Engine.cpp:

```
#include "Engine.h"

Engine::Engine()
{
    //ctor
}

bool Engine::Init()
{

}

bool Engine::Clean()
```

```
14. {
15.
16. }
17.
18. void Engine::Quit()
19. {
20.
21. }
22.
23. void Engine::Update()
24. {
25.
26. }
27.
28. void Engine::Render()
29. {
30.
31. }
32.
33. void Engine::Events()
34. {
35.
36. }
```

Now we implement the game loop in `Main.cpp` by invoking the methods in our `Engine`:

Updated Main.cpp:

```
 1. #include "Engine.h"
 2. #include <iostream>
 3. #include "Timer.h"
 4.
 5. int main(int argc, char** argv)
 6. {
 7.     if (!Engine::GetInstance()->Init()) {
 8.         std::cout << "Initialization of Engine failed." << std::endl;
 9.     }
10.
11.     // Our Game Loop
12.     while (Engine::GetInstance()->isRunning()) {
13.         // Get all current events (e.g. mouse clicks, etc.)
14.         Engine::GetInstance()->Events();
15.
16.         // Update all objects/entities
17.         Engine::GetInstance()->Update();
18.
19.         // Render/update the game graphics
20.         Engine::GetInstance()->Render();
21.
22.         // Invoke the clock
23.         Timer::GetInstance()->Tick();
24.     }
25.
26.     // Clean everything up
27.     Engine::GetInstance()->Clean();
28.
29.     return 0;
30. }
31.
```

Let's now add minimal code to ensure that the above will work.

We will:

- Set `s_Instance` to nullptr;
- Insert `std::cout` statements to each function
- Add logic to `Init()` to set `m_IsRunning`

Engine.cpp:

```
1. #include "Engine.h"
2. #include <iostream>
3.
4. Engine* Engine::s_Instance = nullptr;
5.
6. bool Engine::Init()
7. {
8.     std::cout << "Initializing..." << std::endl;
9.     m_IsRunning = true;
10.    return true;
11. }
12.
13. bool Engine::Clean()
14. {
15.    std::cout << "Clean..." << std::endl;
16.    return true;
17. }
18.
19. void Engine::Quit()
20. {
21.
22. }
23.
24. void Engine::Update()
25. {
26.    std::cout << "Updating..." << std::endl;
27. }
28.
29. void Engine::Render()
30. {
31.    std::cout << "Render..." << std::endl;
32. }
33.
34. void Engine::Events()
35. {
36.    std::cout << "Events..." << std::endl;
37. }
38.
```

The code above implements the game loop! It does not do anything right now but print over and over again the std::cout messages associated with each Engine method.

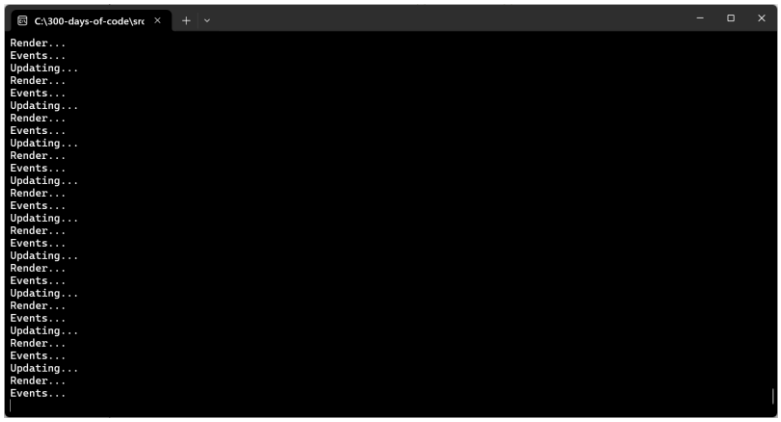


Figure 57 - Running our game loop

Note: If you followed the video you may have encountered an issue when you tried to run the program. The problem was due to the missing `bool` return values from the auto-generated methods `Init()` and `Clean()`.

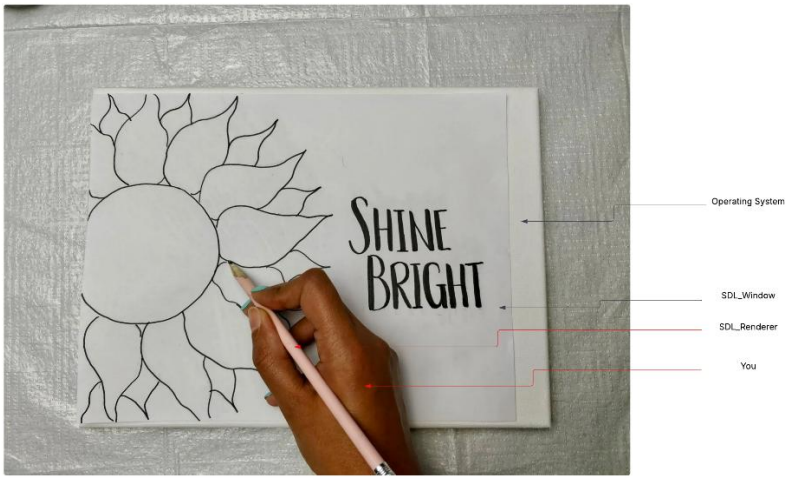
3. Create SDL Window and Renderer

This video starts the journey of filling in the components of game loop by

- Initializing SDL
- Creating our game window with SDL
- Creating the ability to draw in our window
- How to end our game

We cover/edit the key Engine.cpp methods in this video.

How I view things



The operating system (OS) is the conductor as in an orchestra – it manages and coordinates all the hardware and software to ensure harmony. SDL libraries make requests to the OS for resources. In fact, we are using SDL to hide the complexity of drawing on the screen using various operating systems.

In the figure above, the paper represents the window (`SDL_Window`) you will create to draw on. You cannot draw on it directly. You obtain permission/access to draw by requesting a pencil or in our case an `SDL_Renderer`. It is through the `SDL_Renderer` that you draw the graphics in your window. As the programmer you perform your own orchestration for your game application via the game loop.

Using SDL in our Engine

The first file we will edit is Engine.h. We will add statements to the page to allow the Engine to access SDL functions:

```
1. #ifndef ENGINE_H
2. #define ENGINE_H
3. #include "SDL.h"
4. #include "SDL_image.h"
```

The above #include will allow our Engine class to reference SDL and SDL_image elements.

In the private section we will add two new member class variables for an `SDL_Window` and an `SDL_Renderer` (detailed below).

What is an SDL_Window?

An **SDL_Window** is a structure used in the **Simple DirectMedia Layer (SDL)** library to represent a window in your application. It serves as the foundation for rendering graphics, handling events, and interacting with the display. You can create an `SDL_Window` using the `SDL_CreateWindow` function, specifying parameters like the ***title***, ***dimensions***, ***position***, and ***flags***.

The window can have various properties, such as being resizable, fullscreen, or supporting OpenGL/Vulkan contexts. It also interacts with high-DPI displays and can handle input focus, mouse grabbing, and more.

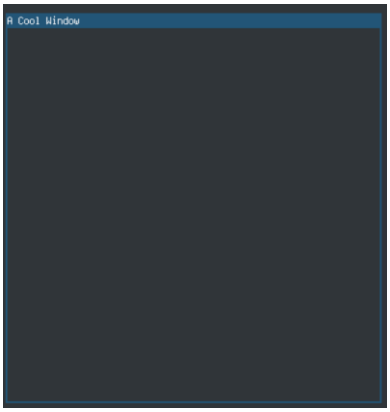


Figure 58 - An example of a Window (SDL_Window) from: https://jakob.space/blog/sdl-tutorial-part-0x00.html

Now that you have a window you want to draw or render objects on our window for that we create an `SDL_Renderer`.

What is an SDL_Renderer?

An **SDL_Renderer** is a structure in the **Simple DirectMedia Layer (SDL)** library that handles rendering operations. It is tied to an **SDL_Window** and is used to draw graphics, such as textures, shapes, and other visual elements, onto the window.

Here are some key points about `SDL_Renderer`:

- **Creation**: You can create an `SDL_Renderer` using the `SDL_CreateRenderer` function, which links it to a specific `SDL_Window`.
- **Drawing**: It provides functions like `SDL_RenderCopy` to render textures, `SDL_SetRenderDrawColor` to set drawing colors, and `SDL_RenderClear` to clear the screen.
- **Hardware Acceleration**: `SDL_Renderer` can use hardware acceleration if supported by the system, making rendering faster and more efficient.

- **Presentation**: After drawing, you use SDL_RenderPresent to update the window with the rendered content.

Adding an SDL_Window and SDL_Renderer to Engine.h

We add two new member variables:

```
1.      private:
2.          Engine() {}
3.          static Engine* s_Instance;
4.          SDL_Window* m_Window;
5.          SDL_Renderer* m_Renderer;
6.          bool m_IsRunning;
```

Since writing to the screen will be done across many other classes we will add an inline function to Engine.h to return the m_Renderer in the public section:

```
1. inline  SDL_Renderer* GetRenderer() { return m_Renderer;}
```

Adding SCREEN_WIDTH and SCREEN_HEIGHT

A major consideration is what your game screen width and height will be, that is, the aspect ratio to use for your window.

Aspect ratios for your **SDL_Window** depend on the type of application you're developing and the devices you want to support. Here are some considerations:

1. **Common Aspect Ratios**:
    - **16:9**: Widely used for modern displays, including HD and 4K screens.
    - **4:3**: Suitable for older monitors or retro-style applications.
    - **21:9**: Ideal for ultrawide monitors, often used in gaming.
    - **1:1**: Square aspect ratio, useful for specific design or artistic purposes.
2. **Maintaining Aspect Ratio**:
    - If your application allows window resizing, you can use functions like SDL_SetWindowAspectRatio to enforce a specific aspect ratio.
    - When rendering, ensure your content scales proportionally to avoid distortion.
3. **Application Context**:
    - For games, 16:9 is a safe choice as it's standard for most displays.

- For productivity tools or creative software, consider supporting multiple aspect ratios to accommodate different user setups.

The presenter decides to use 960x640:

```
1. #define SCREEN_WIDTH 960
2. #define SCREEN_HEIGHT 640
```

The resolution **960x640** corresponds to an aspect ratio of **3:2**. This aspect ratio is less common for modern displays, which often favor **16:9** or **4:3**, but it has its own merits depending on your use case:

- **Photography**: The 3:2 aspect ratio is widely used in photography, as it matches the native aspect ratio of many DSLR and mirrorless cameras.
- **Retro or Niche Applications**: If you're designing something with a retro aesthetic or targeting specific devices, 3:2 might be a good fit.
- **Content Scaling**: Keep in mind that using a less common aspect ratio might require additional effort to scale or crop content for modern screens.

If you're developing an SDL application, consider your target audience and devices. For general-purpose apps or games, **16:9** might be a safer choice for compatibility.

Editing Engine.cpp

- Remove all the `std::cout` statements in the file `Engine.cpp`
- Update the `Engine::Init()` to initialize SDL

```
1. bool Engine::Init()
2. {
3.     if (SDL_Init(SDL_INIT_VIDEO) != 0 && IMG_Init(IMG_INIT_JPG | IMG_INIT_PNG) != 0) {
4.         SDL_Log("Failed to initialize SDL: %s", SDL_GetError());
5.         return false;
6.     }
7.
8.     return m_IsRunning = true;
9. }
```

What is SDL_Init?

The `SDL_Init()` function is used to initialize the **Simple DirectMedia Layer (SDL)** library and its subsystems. It's one of the first functions you call when starting an SDL application. Here's a breakdown of its details:

Syntax:

```
1. int SDL_Init(Uint32 flags);
```

Parameters:

- **flags**: Specifies which SDL subsystems to initialize. You can combine multiple flags using the bitwise OR operator (|). Common flags include:
    - **SDL_INIT_VIDEO**: Initializes the video subsystem.
    - **SDL_INIT_AUDIO**: Initializes the audio subsystem.
    - **SDL_INIT_TIMER**: Initializes the timer subsystem.
    - **SDL_INIT_EVENTS**: Initializes the event handling subsystem.
    - **SDL_INIT_JOYSTICK**: Initializes the joystick subsystem.
    - **SDL_INIT_GAMEPAD**: Initializes the gamepad subsystem.
    - **SDL_INIT_HAPTIC**: Initializes the haptic (force feedback) subsystem.
    - **SDL_INIT_EVERYTHING**: Initializes all available subsystems.

Return Value

- Returns 0 on success.
- Returns a negative error code on failure. You can use `SDL_GetError()` to retrieve a human-readable error message.

Note: The video does not discuss the fact that for every subsystem you initialize you should also close it down in order to release resources `SDL_Quit();`

What is IMG_Init?

`IMG_Init` is a function from the **SDL_image** library, an extension of SDL that provides support for loading and handling various image formats. This function initializes the `SDL_image` library and prepares it to work with specific image formats.

Syntax

```
1. int IMG_Init(int flags);
```

Parameters

- **flags**: Specifies the image formats to initialize. You can combine multiple flags using the bitwise OR operator (|). Common flags include:
    - **IMG_INIT_JPG**: Support for JPEG images.
    - **IMG_INIT_PNG**: Support for PNG images.
    - **IMG_INIT_TIF**: Support for TIFF images.
    - **IMG_INIT_WEBP**: Support for WebP images.

Return Value

- Returns a bitmask of the successfully initialized formats.
- If the return value doesn't match the requested flags, it means some formats failed to initialize.

Notes

- You must call `IMG_Init` before using any `SDL_image` functions that depend on specific image formats.
- Always call `IMG_Quit` to clean up when you're done using `SDL_image`.

What is SDL_GetError()?

`SDL_GetError() is` a function in the SDL library that retrieves a human-readable error message describing the last error that occurred in the current thread. It's incredibly useful for debugging, as it provides insight into why an SDL function might have failed.

Syntax

```
1. const char* SDL_GetError(void);
```

Return Value

- Returns a string containing the error message.
- If no error has occurred, it returns an empty string ("").

Key Points

- **Thread-Specific**: The error message is thread-local, meaning errors in other threads won't interfere with the current thread's error state.

- **Last Error Only**: It only retrieves the most recent error. If multiple errors occur, earlier ones are overwritten.
- **Doesn't Clear Errors**: Calling `SDL_GetError()` doesn't reset the error state. To clear the error, use `SDL_ClearError()`.

Notes

- Always check the return values of SDL functions to determine when to call SDL_GetError().
- Use it alongside SDL_SetError() if you want to set custom error messages for debugging.

What is SDL_Log?

`SDL_Log()` is a function in the SDL library used for logging messages to the console or other output streams. It provides a simple way to debug and track the behavior of your application.

Syntax

```
1. void SDL_Log(const char *fmt, ...);
```

Parameters

- **fmt**: A printf()-style format string.
- **...**: Additional parameters that match the format specifiers in fmt.

Features

- **Thread-Safe**: You can safely call SDL_Log() from any thread.
- **Categories and Priorities**: SDL provides logging categories (e.g., SDL_LOG_CATEGORY_APPLICATION) and priorities (e.g., SDL_LOG_PRIORITY_INFO) for more structured logging. You can use functions like SDL_LogMessage() for categorized logging.

Notes

- By default, logs are quiet, but you can adjust the logging priority using `SDL_LogSetPriority()` or `SDL_LogSetAllPriority()`.
- On different platforms, logs are directed to different outputs (e.g., debug output stream on Windows, log output on Android, or stderr on others).

Resume Editing Engine.cpp

- Edit Engine::Update()

```
1. void Engine::Update()
2. {
3.     SDL_Log("Updating in the Game Loop...");
4. }
```

At this point we have our `Engine::Init` initializing SDL subsystems.

- Test everything by running the application

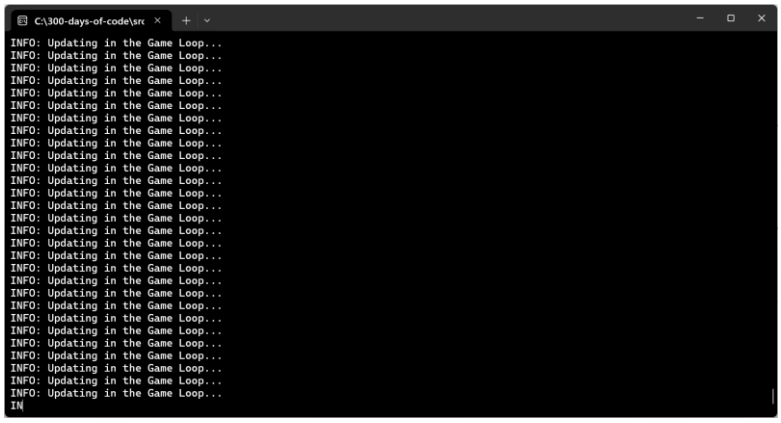


Figure 59 - Running the program with SDL Initialization

Creating SDL_Window and SDL_Renderer

We will now add the code to create our `SDL_Window` and allow ourselves to draw on it with `SDL_Renderer`.

We start to use https://wiki.libsdl.org/SDL2/FrontPage functions.

SDL_CreateWindow

The `SDL_CreateWindow` is used to create a window with specified position, dimensions, and flags.

Syntax:

```
SDL_Window * SDL_CreateWindow(const char *title,
                              int x, int y, int w,
                              int h, Uint32 flags);
```

Function Parameters:

const char *	**title**	the title of the window, in UTF-8 encoding.
int	**x**	the x position of the window, SDL_WINDOWPOS_CENTERED, or SDL_WINDOWPOS_UNDEFINED.
int	**y**	the y position of the window, SDL_WINDOWPOS_CENTERED, or SDL_WINDOWPOS_UNDEFINED.
int	**w**	the width of the window, in screen coordinates.
int	**h**	the height of the window, in screen coordinates.
Uint32	**flags**	0, or one or more SDL_WindowFlags OR'd together.

SDL_WINDOWPOS_CENTERED is a predefined constant in the SDL library that specifies the position of a window to be **centered** on the screen. When you use this flag while creating an SDL window, SDL automatically calculates the coordinates needed to place the window in the center of the display. It is used to simplify window positioning, especially when you want your application to look polished by centering the window.

Note: If you have multiple monitors, SDL_WINDOPOS_CENTERED will center the window on the **primary display**. For centering on a specific display, you can use SDL_WINDOWPOS_CENTERED_DISPLAY(n) where n is the display index.

SDL_WINDOWPOS_UNDEFINED is a predefined constant in the SDL library that indicates you don't care about the initial position of a window when creating it. When you use this flag, SDL will allow the operating system to decide where to place the window on the screen.

Note: If you want to specify the position later, you can use SDL_SetWindowPosition().

The flags parameter can be one or more SDL_WindowFlags:

```
 1. typedef enum SDL_WindowFlags
 2. {
 3.     SDL_WINDOW_FULLSCREEN = 0x00000001,         /**< fullscreen window */
 4.     SDL_WINDOW_OPENGL = 0x00000002,             /**< window usable with OpenGL context */
 5.     SDL_WINDOW_SHOWN = 0x00000004,              /**< window is visible */
 6.     SDL_WINDOW_HIDDEN = 0x00000008,             /**< window is not visible */
 7.     SDL_WINDOW_BORDERLESS = 0x00000010,         /**< no window decoration */
 8.     SDL_WINDOW_RESIZABLE = 0x00000020,          /**< window can be resized */
 9.     SDL_WINDOW_MINIMIZED = 0x00000040,          /**< window is minimized */
10.     SDL_WINDOW_MAXIMIZED = 0x00000080,          /**< window is maximized */
11.     SDL_WINDOW_MOUSE_GRABBED = 0x00000100,      /**< window has grabbed mouse input */
12.     SDL_WINDOW_INPUT_FOCUS = 0x00000200,        /**< window has input focus */
13.     SDL_WINDOW_MOUSE_FOCUS = 0x00000400,        /**< window has mouse focus */
14.     SDL_WINDOW_FULLSCREEN_DESKTOP = ( SDL_WINDOW_FULLSCREEN | 0x00001000 ),
15.     SDL_WINDOW_FOREIGN = 0x00000800,            /**< window not created by SDL */
16.     SDL_WINDOW_ALLOW_HIGHDPI = 0x00002000,      /**< window should be created in high-DPI mode
if supported.
17.                                                     On macOS NSHighResolutionCapable must be
set true in the
18.                                                     application's Info.plist for this to have
any effect. */
19.     SDL_WINDOW_MOUSE_CAPTURE    = 0x00004000,   /**< window has mouse captured (unrelated to
MOUSE_GRABBED) */
20.     SDL_WINDOW_ALWAYS_ON_TOP    = 0x00008000,   /**< window should always be above others */
```

```
21.     SDL_WINDOW_SKIP_TASKBAR     = 0x00010000,   /**< window should not be added to the taskbar
*/
22.     SDL_WINDOW_UTILITY          = 0x00020000,   /**< window should be treated as a utility
window */
23.     SDL_WINDOW_TOOLTIP          = 0x00040000,   /**< window should be treated as a tooltip */
24.     SDL_WINDOW_POPUP_MENU       = 0x00080000,   /**< window should be treated as a popup menu */
25.     SDL_WINDOW_KEYBOARD_GRABBED = 0x00100000,   /**< window has grabbed keyboard input */
26.     SDL_WINDOW_VULKAN           = 0x10000000,   /**< window usable for Vulkan surface */
27.     SDL_WINDOW_METAL            = 0x20000000,   /**< window usable for Metal view */
28.
29.     SDL_WINDOW_INPUT_GRABBED = SDL_WINDOW_MOUSE_GRABBED /**< equivalent to
SDL_WINDOW_MOUSE_GRABBED for compatibility */
30. } SDL_WindowFlags;
31.
```

Setting the **flags** parameter of SDL_CreateWindow to **0** means that no special properties or behaviors are applied to the window. The window will be created with default settings, and it won't have features like fullscreen mode, OpenGL/Vulkan support, or resizable borders.

Default Behavior

When the flags parameter is set to 0:

- The window is **visible** by default.
- It has **standard decorations** (title bar, borders, etc.).
- It is **not resizable**, unless explicitly specified later.

Notes

If you want to add specific features to the window, you can use flags like:

- **SDL_WINDOW_FULLSCREEN**: Makes the window fullscreen.
- **SDL_WINDOW_RESIZABLE**: Allows the window to be resized.
- **SDL_WINDOW_OPENGL**: Enables OpenGL rendering.

Note: You should use `SDL_DestroyWindow` to close or return resources created from a `SDL_CreateWindow`.

SDL_CreateRenderer

The `SDL_CreateRenderer` is used to create a 2D rendering context for a window.

Syntax:

```
1. SDL_Renderer * SDL_CreateRenderer(SDL_Window * window,
2.                         int index, Uint32 flags);
```

Function Parameters:

SDL_Window *	**window**	the window where rendering is displayed.
int	**index**	the index of the rendering driver to initialize, or -1 to initialize the first one supporting the requested flags.
Uint32	**flags**	0, or one or more SDL_RendererFlags OR'd together.

Return Value:

(SDL_Renderer *) Returns a valid rendering context or NULL if there was an error; call SDL_GetError() for more information.

The `SDL_RendererFlags` are used to create a rendering context. Here are the possible values:

```
 1. typedef enum SDL_RendererFlags
 2. {
 3.     SDL_RENDERER_SOFTWARE = 0x00000001,         /**< The renderer is a software fallback */
 4.     SDL_RENDERER_ACCELERATED = 0x00000002,      /**< The renderer uses hardware
 5.                                                      acceleration */
 6.     SDL_RENDERER_PRESENTVSYNC = 0x00000004,     /**< Present is synchronized
 7.                                                      with the refresh rate */
 8.     SDL_RENDERER_TARGETTEXTURE = 0x00000008     /**< The renderer supports
 9.                                                      rendering to texture */
10. } SDL_RendererFlags;
```

Note: You should return or close an `SDL_Renderer` with `SDL_DestroyRenderer()`.

Updating Engine.cpp

We now update `Engine::Init` to create our `m_Window` and `m_Renderer`.

```
 1. bool Engine::Init()
 2. {
 3.      if (SDL_Init(SDL_INIT_VIDEO) != 0 && IMG_Init(IMG_INIT_JPG | IMG_INIT_PNG) != 0) {
 4.         SDL_Log("Failed to initialize SDL: %s", SDL_GetError());
 5.         return false;
 6.     }
 7.
 8.     // Create our SDL window
 9.     m_Window = SDL_CreateWindow("Soft Engine", SDL_WINDOWPOS_CENTERED, SDL_WINDOWPOS_CENTERED,
SCREEN_WIDTH, SCREEN_HEIGHT, 0);
10.     if (m_Window == nullptr) {
11.          SDL_Log("Failed to create window: %s", SDL_GetError());
12.         return false;
13.     }
14.
15.     m_Renderer = SDL_CreateRenderer(m_Window, -1, SDL_RENDERER_ACCELERATED |
SDL_RENDERER_PRESENTVSYNC);
```

```
16.         if (m_Renderer == nullptr) {
17.          SDL_Log("Failed to create Renderer: %s", SDL_GetError());
18.         return false;
19.     }
20.
21.     return m_IsRunning = true;
22. }
23.
```

Adding a Background Color to our Application

Now that we have the “pencil” or `m_Renderer` set up. We need to update the `Engine::Render()` to make the background for the window.

```
1. void Engine::Render()
2. {
3.     SDL_SetRenderDrawColor(m_Renderer, 124, 218, 254, 255);
4.     SDL_RenderPresent(m_Renderer);
5. }
```

RGBA

One way to represent a color is to use RGBA. RGBA stands for **Red, Green, Blue, and Alpha**, which represents a color model used in graphics and digital imaging. Here's what each component means:

1. **Red (R)**: The intensity of the red color channel (typically from 0 to 255).
2. **Green (G)**: The intensity of the green color channel (also 0 to 255).
3. **Blue (B)**: The intensity of the blue color channel (again, 0 to 255).
4. **Alpha (A)**: The transparency or opacity of the color. A value of 0 means completely transparent, while 255 (or 1.0 in some systems) means completely opaque.

For example, RGBA(255, 0, 0, 0.5) would represent a semi-transparent red color.

RGBA is widely used in graphics programming, including web development (CSS), image editing, and game development, as it allows precise control over both color and transparency. Let me know if you'd like to explore it further!

Here is an example of displaying a red color using various alpha values:

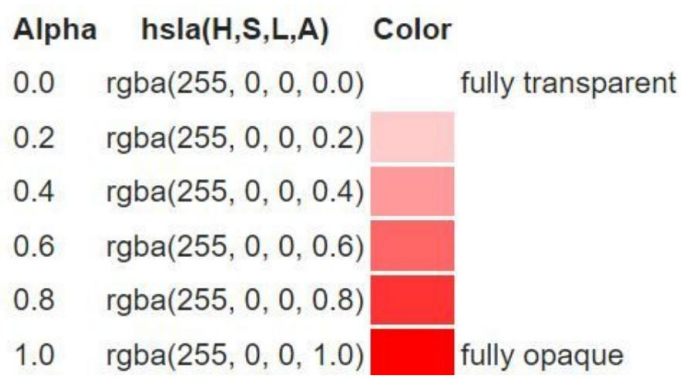


Figure 60 - Illustrating RGBA - from https://www.browserstack.com/guide/how-to-use-css-rgba

SDL_SetRenderDrawColor

This function is equivalent to setting or selecting the color of the pencil you plan on drawing with on the screen.

Syntax:

```
1. int SDL_SetRenderDrawColor(SDL_Renderer * renderer,
2.                     Uint8 r, Uint8 g, Uint8 b,
3.                     Uint8 a);
```

Function Parameters

SDL_Renderer *	**renderer**	the rendering context.
Uint8	**r**	the red value used to draw on the rendering target.
Uint8	**g**	the green value used to draw on the rendering target.
Uint8	**b**	the blue value used to draw on the rendering target.
Uint8	**a**	the alpha value used to draw on the rendering target; usually SDL_ALPHA_OPAQUE (255). Use SDL_SetRenderDrawBlendMode to specify how the alpha channel is used.

Return Value

(int) Returns 0 on success or a negative error code on failure; call SDL_GetError() for more information.

Remarks

Set the color for drawing or filling rectangles, lines, and points, and for SDL_RenderClear().

In the code we use:

```
1. SDL_SetRenderDrawColor(m_Renderer, 124, 218, 254, 255);
```

The alpha value is 255 so it will be opaque. What color is RGB=(124, 218, 254)?

The color should appear as:

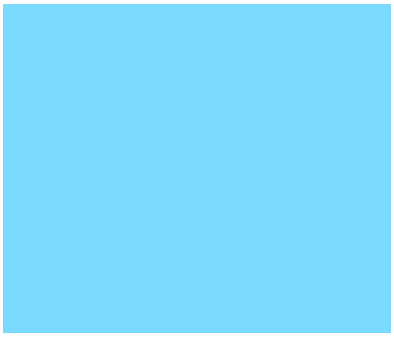


Figure 61 - The color specified to use

If you followed the steps in the video – we are not seeing this color because we have to draw something. Let's change the code to:

```
 1. void Engine::Render()
 2. {
 3.     // Set the draw color
 4.     SDL_SetRenderDrawColor(m_Renderer, 124, 218, 254, 255);
 5.
 6.     // Clear the screen with the draw color
 7.     SDL_RenderClear(m_Renderer);
 8.
 9.     // Present the renderer (update the window)
10.     SDL_RenderPresent(m_Renderer);
11. }
```

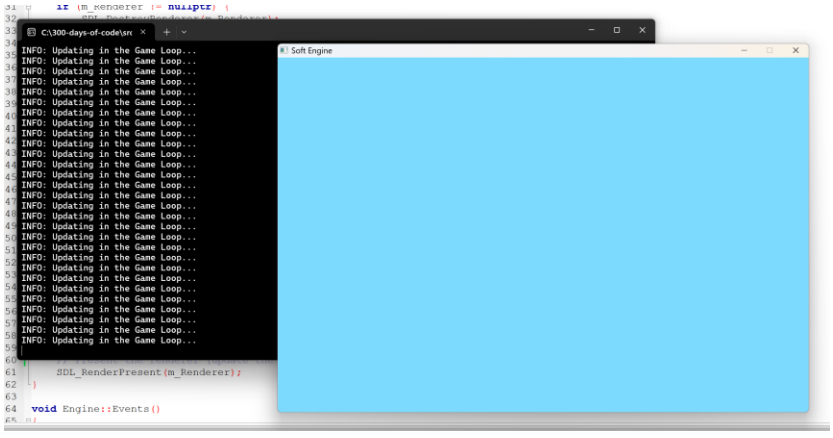


Figure 62 - Setting the screen to our draw color

SDL_RenderClear

This function is used to clear the current rendering target with the drawing color. In our case we use it to color the window background.

Syntax

```
1. int SDL_RenderClear(SDL_Renderer * renderer);
```

Function Parameters

SDL_Renderer *	**renderer**	the rendering context.

Return Value

(int) Returns 0 on success or a negative error code on failure; call SDL_GetError() for more information.

Remarks

This function clears the entire rendering target, ignoring the viewport and the clip rectangle.

SDL_RenderPresent

The `SDL_RenderPresent` update the screen with the current rendering values.

Syntax

```
1. void SDL_RenderPresent(SDL_Renderer * renderer);
```

Function Parameters

SDL_Renderer *	**renderer**	the rendering context.

Remarks

SDL's rendering functions operate on a backbuffer; that is, calling a rendering function such as SDL_RenderDrawLine() does not directly put a line on the screen, but rather updates the backbuffer. As such, you compose your entire scene and *present* the composed backbuffer to the screen as a complete picture.

Therefore, when using SDL's rendering API, one does all drawing intended for the frame, and then calls this function once per frame to present the final drawing to the user.

The backbuffer should be considered invalidated after each present; do not assume that previous contents will exist between frames. You are strongly encouraged to call SDL_RenderClear() to initialize the backbuffer before starting each new frame's drawing, even if you plan to overwrite every pixel.

Screen Buffering

This section is from: https://docs.oracle.com/javase/tutorial/extra/fullscreen/doublebuf.html

Suppose you had to draw an entire picture on the screen, pixel by pixel or line by line. If you were to draw such a thing directly to the screen, you would probably notice with much disappointment that it takes a bit of time. You will probably even notice visible artifacts of how your picture is drawn.

Figure 63 - The screen showing "tearing" [from: https://www.techspot.com/article/2192-screen-tearing-fix-pc-gaming/]

Rather than watching things being drawn in this fashion and at this pace, most programmers use a technique called *double-buffering*.

The traditional notion of double-buffering is straightforward: create an off-screen image, draw to that image using the image's graphics object, then, in one step, call SDL_RenderPresent.

The screen surface is commonly referred to as the *primary surface*, and the off-screen image used for double-buffering is commonly referred to as the *back buffer*. The act of copying the contents from one surface to another is frequently referred to as a block line transfer, or *blitting* (blt is typically pronounced "blit" and shouldn't be confused with a BLT sandwich).

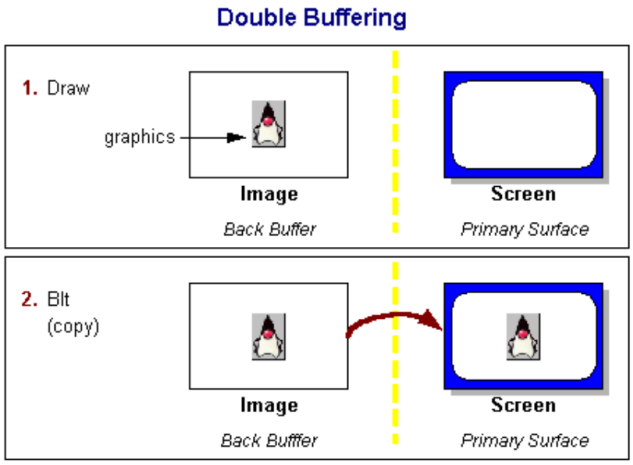


Figure 64 - Illustrating how all the drawing takes place in the backbuffer

Running and Testing the Application

If you run the application now you will notice that you cannot close the `SDL_Window`, this is because we did not add code to be responsive to users actions (via Events). So, for now close the background window.

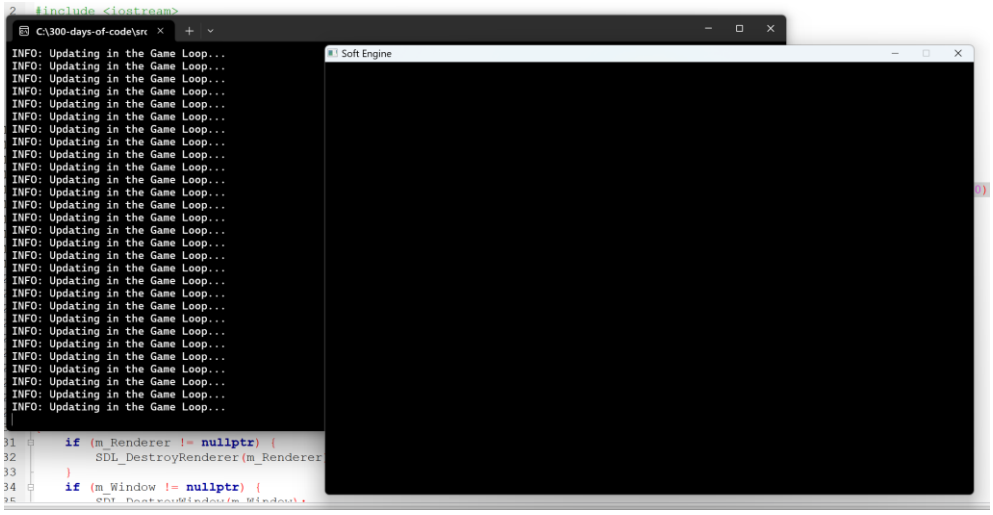


Figure 65 - Running the application at this stage of development

Note: The image above is using the original code from the video and not the update of clearing the screen with the desired color.

Handling Events

To provide user control of the SDL screen we need to be able to handle events like close window, etc. SDL manages an event queue for us. The event queue holds all the events that

have taken place like mouse move, keyboard press, mouse click, etc. Every time we do something on our SDL window an event is placed on a queue.

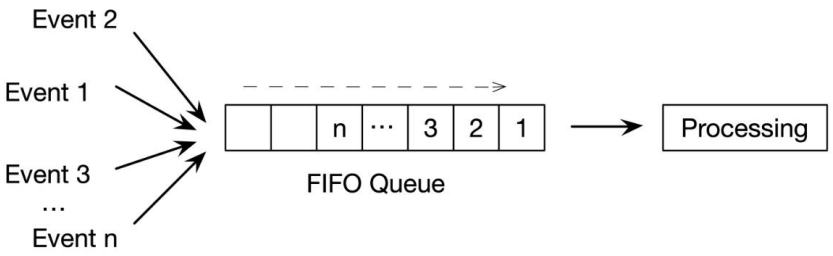


FIGURE 1. Events which occur asynchronously are posted to the FIFO queue and are processed in the order thy occur. The queue effectively decouples the processing from the events allowing for relatively complex applications to be built robustly.

Figure 66 - How an event queue works (from https://circuitcellar.com/resources/event-queues/)

What is an SDL_Event?

The data structure SDL_Event holds an event structure. An event can span various things like ***Window event*** (closing the window), ***Keyboard event*** (pressing a key), ***Mouse event*** (pressing a button). So SDL_Event is a union of many structures.

Syntax:

```
typedef union SDL_Event
{
    Uint32 type;                        /**< Event type, shared with all events */
    SDL_CommonEvent common;             /**< Common event data */
    SDL_DisplayEvent display;           /**< Display event data */
    SDL_WindowEvent window;             /**< Window event data */
    SDL_KeyboardEvent key;              /**< Keyboard event data */
    SDL_TextEditingEvent edit;          /**< Text editing event data */
    SDL_TextEditingExtEvent editExt;    /**< Extended text editing event data */
    SDL_TextInputEvent text;            /**< Text input event data */
    SDL_MouseMotionEvent motion;        /**< Mouse motion event data */
    SDL_MouseButtonEvent button;        /**< Mouse button event data */
    SDL_MouseWheelEvent wheel;          /**< Mouse wheel event data */
    SDL_JoyAxisEvent jaxis;             /**< Joystick axis event data */
    SDL_JoyBallEvent jball;             /**< Joystick ball event data */
    SDL_JoyHatEvent jhat;               /**< Joystick hat event data */
    SDL_JoyButtonEvent jbutton;         /**< Joystick button event data */
    SDL_JoyDeviceEvent jdevice;         /**< Joystick device change event data */
    SDL_JoyBatteryEvent jbattery;       /**< Joystick battery event data */
    SDL_ControllerAxisEvent caxis;      /**< Game Controller axis event data */
    SDL_ControllerButtonEvent cbutton;  /**< Game Controller button event data */
    SDL_ControllerDeviceEvent cdevice;  /**< Game Controller device event data */
    SDL_ControllerTouchpadEvent ctouchpad; /**< Game Controller touchpad event data */
    SDL_ControllerSensorEvent csensor;  /**< Game Controller sensor event data */
    SDL_AudioDeviceEvent adevice;       /**< Audio device event data */
    SDL_SensorEvent sensor;             /**< Sensor event data */
    SDL_QuitEvent quit;                 /**< Quit request event data */
    SDL_UserEvent user;                 /**< Custom event data */
    SDL_SysWMEvent syswm;               /**< System dependent window event data */
```

```
30.     SDL_TouchFingerEvent tfinger;           /**< Touch finger event data */
31.     SDL_MultiGestureEvent mgesture;         /**< Gesture event data */
32.     SDL_DollarGestureEvent dgesture;        /**< Gesture event data */
33.     SDL_DropEvent drop;                     /**< Drag and drop event data */
34.
35.     /* This is necessary for ABI compatibility between Visual C++ and GCC.
36.        Visual C++ will respect the push pack pragma and use 52 bytes (size of
37.        SDL_TextEditingEvent, the largest structure for 32-bit and 64-bit
38.        architectures) for this union, and GCC will use the alignment of the
39.        largest datatype within the union, which is 8 bytes on 64-bit
40.        architectures.
41.
42.        So... we'll add padding to force the size to be 56 bytes for both.
43.
44.        On architectures where pointers are 16 bytes, this needs rounding up to
45.        the next multiple of 16, 64, and on architectures where pointers are
46.        even larger the size of SDL_UserEvent will dominate as being 3 pointers.
47.     */
48.     Uint8 padding[sizeof(void *) <= 8 ? 56 : sizeof(void *) == 16 ? 64 : 3 * sizeof(void *)];
49. } SDL_Event;
50.
```

Using events

The SDL_Event structure has two uses:

- Reading events from the event queue
- Placing events on the event queue

Reading events from the event queue

Reading events from the event queue is done with either SDL_PollEvent or SDL_PeepEvents.

SDL_PollEvent

Poll for currently pending events.

Syntax:

```
1. int SDL_PollEvent(SDL_Event * event);
```

Function Parameters

SDL_Event *	**event**	the SDL_Event structure to be filled with the next event from the queue, or NULL.

The SDL_PollEvent function takes a pointer to an SDL_Event structure that is to be filled with event information. We know that if SDL_PollEvent removes an event from the queue then the event information will be placed in our `event` structure, but we also know that the type of

event will be placed in the **type** member of `event`. So to handle each event type separately we use a switch statement.

```
1. switch (event.type) {
```

We need to know what kind of events we're looking for and the event types of those events.

The SDL_`Event.type` field represents the type of event in SDL's event system. Here are some of the possible values:

Application Events

- **SDL_QUIT**: Indicates a user-requested quit (e.g., closing the window).
- **SDL_APP_TERMINATING**: The application is being terminated by the operating system.
- **SDL_APP_LOWMEMORY**: The application is low on memory.
- **SDL_APP_WILLENTERBACKGROUND**: The application is about to enter the background.
- **SDL_APP_DIDENTERBACKGROUND**: The application has entered the background.
- **SDL_APP_WILLENTERFOREGROUND**: The application is about to enter the foreground.
- **SDL_APP_DIDENTERFOREGROUND**: The application has entered the foreground.

Window Events

- **SDL_WINDOWEVENT**: Represents various window-related events (e.g., resizing, moving, focus changes).
- **SDL_SYSWMEVENT**: System-specific window events.

Keyboard Events

- **SDL_KEYDOWN**: A key was pressed.
- **SDL_KEYUP**: A key was released.
- **SDL_TEXTEDITING**: Text editing (composition).
- **SDL_TEXTINPUT**: Text input.

Mouse Events

- **SDL_MOUSEMOTION**: The mouse moved.
- **SDL_MOUSEBUTTONDOWN**: A mouse button was pressed.

- **SDL_MOUSEBUTTONUP**: A mouse button was released.
- **SDL_MOUSEWHEEL**: Mouse wheel motion.

Joystick Events

- **SDL_JOYAXISMOTION**: Joystick axis motion.
- **SDL_JOYBALLMOTION**: Joystick trackball motion.
- **SDL_JOYHATMOTION**: Joystick hat position change.
- **SDL_JOYBUTTONDOWN**: Joystick button pressed.
- **SDL_JOYBUTTONUP**: Joystick button released.
- **SDL_JOYDEVICEADDED**: A joystick was connected.
- **SDL_JOYDEVICEREMOVED**: A joystick was disconnected.

Controller Events

- **SDL_CONTROLLERAXISMOTION**: Game controller axis motion.
- **SDL_CONTROLLERBUTTONDOWN**: Game controller button pressed.
- **SDL_CONTROLLERBUTTONUP**: Game controller button released.
- **SDL_CONTROLLERDEVICEADDED**: A game controller was connected.
- **SDL_CONTROLLERDEVICEREMOVED**: A game controller was disconnected.

Other Events

- **SDL_AUDIODEVICEADDED**: An audio device was added.
- **SDL_AUDIODEVICEREMOVED**: An audio device was removed.
- **SDL_SENSORUPDATE**: Sensor data update.
- **SDL_DROPFILE**: A file was dropped onto the window.

This is just a subset of the possible event types. You can find a comprehensive list in the SDL documentation here. Let me know if you'd like help handling specific events!

Each event type is associated with a different union member that holds more details about the event.

SDL_Quit

The **SDL_Quit** event is triggered when the user requests to terminate the application. This typically happens when the user closes the window or selects a quit option from the operating system. The event is part of SDL's event system and is represented by the SDL_QUIT constant.

Key Details:

- **Event Type**: SDL_QUIT
- **Purpose**: Indicates that the application should shut down gracefully.
- **Usage**: You can handle this event in your main event loop to perform cleanup tasks before exiting.

Update to Engine.cpp

In this section we add code to Engine.cpp to allow the user to “quit” or “close” the window application.

Add code the Engine::Events()

```
1. void Engine::Events()
2. {
3.     SDL_Event event;
4.     SDL_PollEvent(&event);
5.     switch(event.type) {
6.     case SDL_QUIT:
7.         Quit();
8.         break;
9.     }
10. }
```

On line 3 we create an `SDL_Event` and then obtain the next item in the event queue by invoking `SDL_PollEvent` on line 4. The details of the next event is stored in the event variable.

The `switch` statement on 5 examines a value all events have `type`. If the `event.type` is `SDL_QUIT` we invoke an internal class method called `Quit()`.

Add code the Engine::Quit()

If we examine our game loop in Main.cpp:

```
1.     while (Engine::GetInstance()->isRunning()) {
2.         // Get all current events (e.g. mouse clicks, etc.)
3.         Engine::GetInstance()->Events();
4.
5.         // Update all objects/entities
6.         Engine::GetInstance()->Update();
7.
8.         // Render/update the game graphics
9.         Engine::GetInstance()->Render();
```

```
10.     }
```

The way to exit the application is to have `Engine::GetInstance()->isRunning()` to return `false`.

```
1.          inline bool isRunning() {
2.              return m_IsRunning;
3.          }
```

The value returned by `isRunning()` is just the current value of `m_IsRunning`. So, if the user closes the application we should just set the `m_IsRunning` class member variable to `false`. This should occur in `Quit()`.

```
1. void Engine::Quit()
2. {
3.     m_IsRunning = false;
4. }
```

Let's test and run the program again. You will see that you can move the window around (wondering how since we did not add an event handler for that?) and when we close the window the SDL window now closes.

Cleaning up

The video presenter does not discuss one important topic – cleanup the SDL entities you initialize or create. A general principle is close or return everything you open or create. The table below lists the corresponding cleanup functions for the SDL functions we used:

SDL function that opens or creates a resource	Corresponding close and destroy function
SDL_Init	SDL_Quit
IMG_Init	IMG_Quit
SDL_CreateWindow	SDL_DestroyWindow
SDL_CreateRenderer	SDL_DestroyRenderer

SDL_Quit()

Note: This refers to the SDL function `SDL_Quit()` not the Event type of `SDL_QUIT`.

This function cleans up all initialized subsystems.

Syntax

```
1. void SDL_Quit(void);
```

Remarks

You should call this function even if you have already shutdown each initialized subsystem with SDL_QuitSubSystem(). It is safe to call this function even in the case of errors in initialization.

If you start a subsystem using a call to that subsystem's init function (for example SDL_VideoInit()) instead of SDL_Init() or SDL_InitSubSystem(), then you must use that subsystem's quit function (SDL_VideoQuit()) to shut it down before calling SDL_Quit(). But generally, you should not be using those functions directly anyhow; use SDL_Init() instead.

You can use this function with atexit() to ensure that it is run when your application is shutdown, but it is not wise to do this from a library or other dynamically loaded code.

What is atexit()?

Explanation:

1. **atexit(cleanup);**: Registers the cleanup function to be called automatically when the program exits.
2. **cleanup()**: Ensures that SDL_Quit() is called to clean up SDL subsystems.
3. **Automatic Cleanup**: Even if the program exits early (e.g., due to an error), the cleanup function will still be executed.

This approach is useful for ensuring that resources are properly released, especially in cases where the program might terminate unexpectedly.

Example:

```
#include <SDL.h>
#include <cstdlib> // For atexit()

// Cleanup function to be called on exit
void cleanup() {
    SDL_Quit();
    SDL_Log("SDL cleaned up successfully!");
}

int main(int argc, char* argv[]) {
    // Initialize SDL
    if (SDL_Init(SDL_INIT_VIDEO) != 0) {
        SDL_Log("Unable to initialize SDL: %s", SDL_GetError());
        return 1;
    }

    // Register the cleanup function with atexit
    atexit(cleanup);

    // Create an SDL_Window
    SDL_Window* window = SDL_CreateWindow("atexit Example", SDL_WINDOWPOS_CENTERED,
SDL_WINDOWPOS_CENTERED, 800, 600, SDL_WINDOW_SHOWN);
```

```
22.     if (!window) {
23.         SDL_Log("Could not create window: %s", SDL_GetError());
24.         return 1; // Cleanup will be handled by atexit
25.     }
26.
27.     // Your program logic here...
28.
29.     // Destroy the window before exiting
30.     SDL_DestroyWindow(window);
31.
32.     return 0; // Cleanup function will be called automatically
33. }
34.
```

As you know there can be more than one reason that an application closes. So using `atexit()` ensure that cleanup will take place.

IMG_Quit()

This function deinitialize `SDL_image`.

Syntax

```
1. void IMG_Quit(void);
```

Remarks

This should be the last function you call in `SDL_image`, after freeing all other resources. This will unload any shared libraries it is using for various codecs.

After this call, a call to IMG_Init(0) will return 0 (no codecs loaded).

You can safely call IMG_Init() to reload various codec support after this call.

Unlike other SDL satellite libraries, calls to IMG_Init do not stack; a single call to IMG_Quit() will deinitialize everything and does not have to be paired with a matching IMG_Init call. For that reason, it's considered best practices to have a single IMG_Init and IMG_Quit call in your program. While this isn't required, be aware of the risks of deviating from that behavior.

SDL_DestroyWindow()

This function is used to destroy or return all resources from using `SDL_CreateWindow()`.

Syntax

```
1. void SDL_DestroyWindow(SDL_Window * window);
```

Function Parameters

SDL_Window *	**window**	the window to destroy.

Remarks

If window is NULL, this function will return immediately after setting the SDL error message to "Invalid window". See SDL_GetError().

What is the difference between NULL and nullptr?

In a C++ program, **NULL** and **nullptr** are both used to represent null pointer values, but they have significant differences:

NULL

1. **Definition**: NULL is typically defined as 0 in C and C++ via the standard library (#define NULL 0).
2. **Type**: It is essentially an integer value (0) that is implicitly converted to a pointer when needed.
3. **Issues**:
    - It can lead to ambiguity in overload resolution, especially in C++ programs where functions may be overloaded based on argument typ

`nullptr` (introduced in C++11)

1. **Definition**: `nullptr` is a keyword that represents a literal of type `std::nullptr_t`.
2. **Type**: It has a distinct type, which ensures type safety. Unlike NULL, it isn't an integer and is specifically recognized as a null pointer.
3. **Advantages**:
    - Eliminates ambiguity in function overloads.
    - Provides clearer intent when used in code, making it obvious that it represents a null pointer.

Example

Here's how NULL vs nullptr might affect function resolution

```
1. #include <iostream>
2.
```

```
3. void foo(int i) {
4.     std::cout << "Integer function called!" << std::endl;
5. }
6.
7. void foo(char* p) {
8.     std::cout << "Pointer function called!" << std::endl;
9. }
10.
11. int main() {
12.     foo(NULL);    // Ambiguous: Might call the integer version!
13.     foo(nullptr); // Clear: Calls the pointer version!
14.     return 0;
15. }
```

Key Takeaway

Always use `nullptr` in modern C++ programs, as it is type-safe, unambiguous, and more readable. NULL is considered outdated in C++ and is better suited for C programs.

SDL_DestroyRenderer()

This function is used to destroy the rendering context for a window and free associated textures.

Syntax

```
1. void SDL_DestroyRenderer(SDL_Renderer * renderer);
```

Function Parameters

SDL_Renderer *	**renderer**	the rendering context.

Remarks

If renderer is NULL, this function will return immediately after setting the SDL error message to "Invalid renderer". See SDL_GetError().

Added code to Engine::Clean()

The code that I added cleans up as follows:

```
1. bool Engine::Clean()
2. {
3.     if (m_Renderer != nullptr) {
4.         SDL_DestroyRenderer(m_Renderer);
5.     }
6.     if (m_Window != nullptr) {
```

```
 7.         SDL_DestroyWindow(m_Window);
 8.     }
 9.     IMG_Quit();
10.     SDL_Quit();
11.     return true;
12. }
```

4. Draw Texture in SDL

In this video we added a new class named `TextureManager`. The class implements everything we need to draw things on the screen. We also cover the clean up/destroy process that you should perform for every SDL resource you open or create.

While SDL2 itself does not have built-in image handling functions beyond basic surface and texture manipulation, it integrates seamlessly with an extension library called **SDL_image** for more advanced image handling capabilities.

With **SDL_image**, you can load various image formats (like PNG, JPEG, BMP, etc.) into SDL surfaces or textures, which can then be rendered in your application. Here's a high-level summary of how it works:

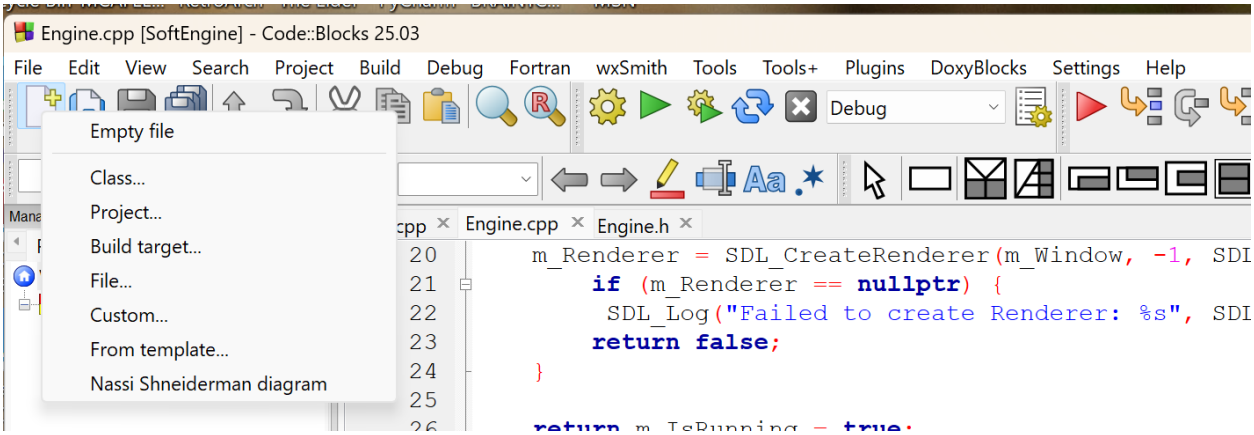
1. **Initialization**: `SDL_image` needs to be initialized alongside SDL. You can specify which image formats to support during this step.
2. **Loading Images**: It allows you to load images into an `SDL_Surface` or `SDL_Texture` using functions like `IMG_Load()` or `IMG_LoadTexture()`. These functions abstract the complexity of decoding image formats.
3. **Rendering**: Once loaded, the image can be converted into a texture and rendered using SDL's rendering API, offering efficient performance.
4. **Freeing Resources**: After you're done using an image, you'll need to free the resources using SDL functions like `SDL_DestroyTexture()` or `SDL_FreeSurface()`.

Download the Textures

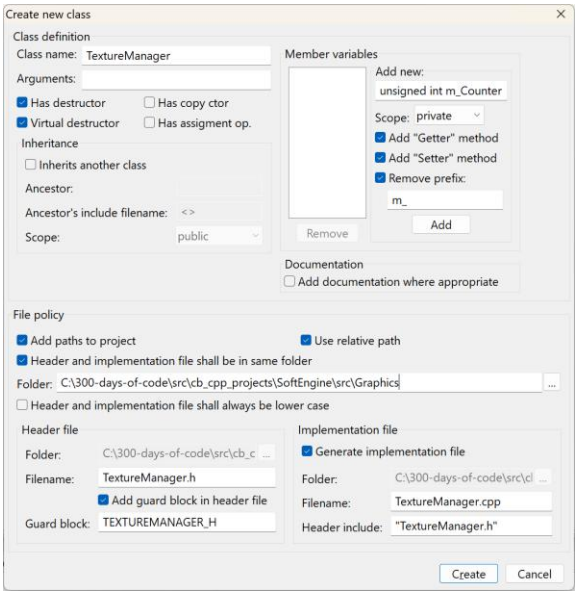
The website to obtain the texture we are using for this video are located: https://www.patreon.com/posts/33671850 or you can just access the project as I have it on GitHub, located at: https://github.com/nyguerrillagirl/300-days-of-code/tree/main/src/cb_cpp_projects/SoftEngine

Note: It appears that only few of the files and hence assets are available for free. Users have the option of paying at Patreon to obtain code and assets for the set of videos.

- Create the new class `TextureManager` in a folder `src/Graphics` by first clicking on the icon shown,  and selecting `Class`…



- Populate the “Create new class” dialog that appears as shown:



- Click on “Create” button and add to the project as before.

Like our `Engine` class we will construct the `TextureManager` as a singleton class.

- Edit the `TextureManager.h` file as shown:

```
1. #ifndef TEXTUREMANAGER_H
2. #define TEXTUREMANAGER_H
3.
4. #include <string>
5. #include <map>
```

```
 6. #include "SDL.h"
 7.
 8. class TextureManager
 9. {
10.     public:
11.         static TextureManager* GetInstance() { return s_Instance = (s_Instance != nullptr) ?
s_Instance : new TextureManager();}
12.
13.         bool Load(std::string id, std::string filename );
14.         void Drop(std::string id);
15.         void Clean();
16.
17.         void Draw(std::string id, int x, int y, int width, int height, SDL_RendererFlip
flip=SDL_FLIP_NONE);
18.
19.     protected:
20.
21.     private:
22.          TextureManager() {};
23.          std::map<std::string, SDL_Texture*> m_TextureMap;
24.          static TextureManager* s_Instance;
25. };
26.
27. #endif // TEXTUREMANAGER_H
```

<string>

Programmers include the header file to access the functionality of the `std::string` class in the Standard Template Library (STL). The `std::string` class provides a convenient way to work with strings in C++, offering a variety of features that simplify string manipulation compared to traditional C-style strings (char[]).

Here are some key reasons why the file is commonly used:

1. **Dynamic Size Management**: Unlike C-style strings, `std::string` automatically handles memory allocation and resizing, making it more flexible and less error-prone.
2. **Rich String Manipulation Functions**: It provides methods for concatenation, searching, substring extraction, comparison, and more, all built-in.
3. **Ease of Use**: With `std::string`, you don't have to worry about managing null terminators ('\0') or buffer sizes manually.
4. **Integration with Other STL Components**: `std::string` works seamlessly with other STL classes like `std::vector` and `std::map`, making it essential for modern C++ programming.

Including ensures access to these features, making string handling in C++ far more robust and efficient.

Note to the reader: While I am writing these notes, I am acquainting myself with the new features added to the standard library (yes, I am that old). The <string> header and class was added as part of the C++ Standard Library with the first official C++ standard C++98 which was finalized in 1998. I am accustomed to using C-style strings and in fact you will find that libraries like SDL2 expect C-style strings as arguments so we will often convert a string to a C-style string using the function `c_str()` of the string object.

<map>

The `std::map` provides an efficient way to store and manage key-value pairs, where keys are unique and values can be accessed using the keys. Here are some reasons why is commonly used:

1. **Associative Container**: `std::map` allows for fast retrieval of values based on their keys, making it ideal for scenarios like lookup tables or dictionaries.
2. **Automatic Sorting**: The keys in `std::map` are always sorted in ascending order by default, based on their comparison operator. This makes it useful for ordered data.
3. **Flexible Key Types**: You can use any type that supports comparison operators as keys, providing great versatility.
4. **Efficient Performance**: Internally, `std::map` uses a balanced binary search tree (like a red-black tree) for storing data, ensuring efficient time complexity for operations like insertion, deletion, and lookup.
5. **Built-in Functions**: It provides numerous member functions for manipulating and accessing data, like `insert()`, `find()`, `erase()`, and iteration support with iterators.

Creating the GetInstance()

We have a static GetInstance() method similar to what we created in our Engine class:

```
1. static TextureManager* GetInstance() { return s_Instance = (s_Instance != nullptr) ? s_Instance : new TextureManager();}
```

Adding the key class methods for TextureManager

We then define our key public methods:

- **Load()** – Load a new texture or image
- **Drop()** – drop a texture or image (this usually occurs when we move from one level to the next in our game)

- **Clean()** – return all resources
- **Draw()** – Draw to the screen a particular texture or image

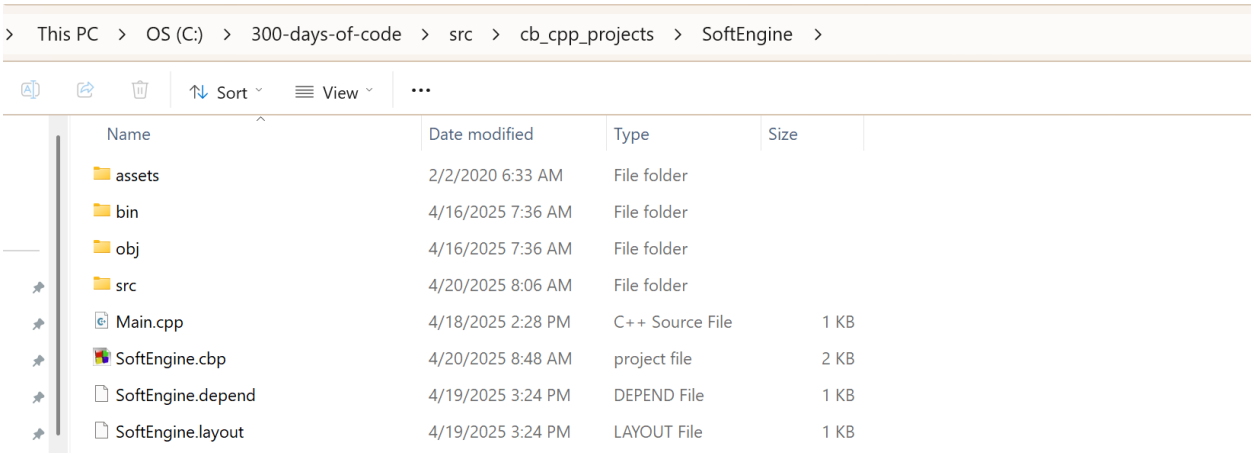
The key data structure used by this class is a map defined as:

```
1. std::map<std::string, SDL_Texture*> m_TextureMap;
```

The program will create many textures to display (the monsters, the background trees, sky, etc.) When you `Load()` a texture, you will provide a unique id to identify the texture/image and the `SDL_Texture` that stores the texture information will be saved to the map.

Edit TextureManager.cpp

- Delete the default provided methods
- First add template code for all unimplemented methods
    - Right-click on file
    - Select Insert/Refactor
    - Select "All class methods without implementation…"
- Create a folder for you project – called assets



- Copy or move the image tree.png into the assets folder

Edit TextureManager.cpp

Add reference to Engine.h

- Add header for `Engine.h`

```
1. #include "Engine.h"
```

Why do we need `Engine.h`? We added the ability to draw on the window in the `Engine` class via the `m_Renderer`. Any piece of code in `SoftEngine` that needs to draw on the window needs to obtain the renderer:

```
1. Engine::GetInstance()->GetRenderer()
```

Since one of the key functions in `TextureManager` is `Draw()`, this is where we will need to access and utilize the `SDL_Renderer`. The philosophy being used is that we will only utilize one `SDL_Renderer` in the program rather than trying to manage one in every class that needs to draw.

Initialize the TextureManager::s_Instance

- Initialize the TextureManager::s_Instance

```
1. // Initialize our singleton to nullptr
2. TextureManager* TextureManager::s_Instance = nullptr;
```

Implement the Load() class method

- Implement the Load() class method:

```
 1. bool TextureManager::Load(std::string id, std::string filename)
 2. {
 3.     SDL_Surface* surface = IMG_Load(filename.c_str());
 4.     if (surface == nullptr) {
 5.         SDL_Log("Failed to load texture: %s, %s", filename.c_str(), SDL_GetError());
 6.         return false;
 7.     }
 8.
 9.     SDL_Texture* texture = SDL_CreateTextureFromSurface(Engine::GetInstance()->GetRenderer(),
surface);
10.     if (texture == nullptr) {
11.         SDL_Log("Failed to create texture from surface: %s",  SDL_GetError());
12.         return false;
13.     }
14.
15.     m_TextureMap[id] = texture;
16.
17.     return true;
18. }
```

In order to create an SDL_Texture we will need to first create an SDL_Surface:

The relationship between `SDL_Surface` and SDL_Texture in SDL2 involves how image data is managed and displayed on the screen:

1. **Definition**:
    - `SDL_Surface`: Represents a block of pixel data stored in system memory. It's mainly used for software rendering or manipulation of images and does not interact directly with the GPU.
    - `SDL_Texture`: Represents a block of pixel data stored in GPU memory. It's optimized for rendering and is used to interact directly with the graphics hardware.
2. **Conversion**:
    - If you load an image into an `SDL_Surface`, you can then convert it into an `SDL_Texture` to render it efficiently using GPU acceleration. This is achieved using the `SDL_CreateTextureFromSurface()` function.
3. **Usage**:
    - `SDL_Surface` is suitable for operations like editing pixel data or performing software-based transformations. However, it's not ideal for rendering because it relies on the CPU.
    - `SDL_Texture` is optimized for rendering on the screen and is used with SDL's rendering API (e.g., `SDL_RenderCopy()`).
4. **Performance**:
    - While `SDL_Surface` is easier to manipulate, `SDL_Texture` offers significantly better performance for rendering since it uses hardware acceleration.

So, you might load your image into an `SDL_Surface` for initial handling, then convert it to an `SDL_Texture` for efficient display.

A good illustration[8] is the following:

[8] Inspired by image at: https://www.freepascal-meets-sdl.net/surfaces-and-textures/

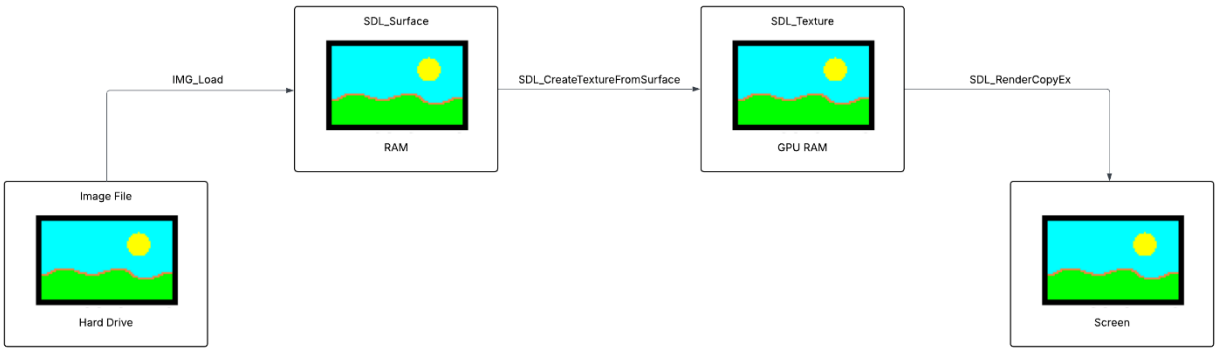


Figure 67 - How we draw an image to the screen

After we successfully create the `SDL_Texture` we place it into the data structure map - `m_TextureMap`.

SDL_Surface

`SDL_Surface` is a structure in SDL2 that represents an area of pixel data stored in system memory.

Syntax

```
typedef struct SDL_Surface
{
    Uint32 flags;               /**< Read-only */
    SDL_PixelFormat *format;    /**< Read-only */
    int w, h;                   /**< Read-only */
    int pitch;                  /**< Read-only */
    void *pixels;               /**< Read-write */

    /** Application data associated with the surface */
    void *userdata;             /**< Read-write */

    /** information needed for surfaces requiring locks */
    int locked;                 /**< Read-only */

    /** list of BlitMap that hold a reference to this surface */
    void *list_blitmap;         /**< Private */

    /** clipping information */
    SDL_Rect clip_rect;         /**< Read-only */

    /** info for fast blit mapping to other surfaces */
    SDL_BlitMap *map;           /**< Private */

    /** Reference count -- used when freeing surface */
    int refcount;               /**< Read-mostly */
} SDL_Surface;
```

Remarks

This structure should be treated as read-only, except for pixels, which, if not NULL, contains the raw pixel data for the surface.

IMG_Load()

Load an image from a filesystem path into a software surface.

Syntax

```
1. SDL_Surface * IMG_Load(const char *file);
```

Function Parameters

const char *	**file**	a path on the filesystem to load an image from.

Return Value

(SDL_Surface *) Returns a new SDL surface, or NULL on error.

Remarks

An SDL_Surface is a buffer of pixels in memory accessible by the CPU. Use this if you plan to hand the data to something else or manipulate it further in code.

There are no guarantees about what format the new SDL_Surface data will be; in many cases, SDL_image will attempt to supply a surface that exactly matches the provided image, but in others it might have to convert (either because the image is in a format that SDL doesn't directly support or because it's compressed data that could reasonably uncompress to various formats and SDL_image had to pick one). You can inspect an SDL_Surface for its specifics, and use SDL_ConvertSurface to then migrate to any supported format.

If the image format supports a transparent pixel, SDL will set the colorkey for the surface. You can enable RLE acceleration on the surface afterwards by calling: SDL_SetColorKey(image, SDL_RLEACCEL, image->format->colorkey);

There is a separate function to read files from an SDL_RWops, if you need an i/o abstraction to provide data from anywhere instead of a simple filesystem read; that function is IMG_Load_RW().

If you are using SDL's 2D rendering API, there is an equivalent call to load images directly into an SDL_Texture for use by the GPU without using a software surface: call IMG_LoadTexture() instead.

When done with the returned surface, the app should dispose of it with a call to SDL_FreeSurface().

SDL_Texture

An efficient driver-specific representation of pixel data

Syntax

```
struct SDL_Texture;
```

SDL_Texture is a structure in SDL2 that represents a block of pixel data stored in GPU memory. It is specifically designed for efficient rendering using hardware acceleration, making it the preferred choice for displaying images, sprites, and other graphical elements in modern applications or games

Key Features of SDL_Texture:

- **GPU-Based**: Unlike SDL_Surface, which works in system memory, SDL_Texture utilizes the graphics hardware (GPU) for fast rendering.
- **Rendering Optimization**: It allows for operations like scaling, rotation, and blending to be performed efficiently during rendering.
- **Immutable Pixel Data**: Once created, you can't directly modify the pixel data in an SDL_Texture. Instead, any changes need to be made at the SDL_Surface level before converting it into a texture.

Common Workflow:

1. **Create a Texture**: You typically create an SDL_Texture using SDL_CreateTexture() or SDL_CreateTextureFromSurface().
2. **Render the Texture**: Use SDL's rendering functions (e.g., SDL_RenderCopy()) to draw the texture on the screen.
3. **Destroy Texture**: Once you're done with the texture, free up its resources using SDL_DestroyTexture().

SDL_CreateTextureFromSurface

Create a texture from an existing surface.

Syntax

```
1. SDL_Texture * SDL_CreateTextureFromSurface(SDL_Renderer * renderer, SDL_Surface * surface);
```

Function Parameters

SDL_Renderer *	**renderer**	the rendering context.
SDL_Surface *	**surface**	the SDL_Surface structure containing pixel data used to fill the texture.

Return Value

(SDL_Texture *) Returns the created texture or NULL on failure; call SDL_GetError() for more information.

Remarks

The surface is not modified or freed by this function.

The SDL_TextureAccess hint for the created texture is SDL_TEXTUREACCESS_STATIC.

The pixel format of the created texture may be different from the pixel format of the surface. Use SDL_QueryTexture() to query the pixel format of the texture.

Implement Draw class method

This method is used to draw the texture to the screen

```
 1. void TextureManager::Draw(std::string id, int x, int y, int width, int height, SDL_RendererFlip
flip)
 2. {
 3.     // Defines the part of the image we plan on drawing
 4.     SDL_Rect srcRect = {0, 0, width, height};
 5.
 6.     // Defines where on the screen we will draw our image
 7.     SDL_Rect dstRect = {x, y, width, height};
 8.
 9.     // Draw our texture to the screen
10.     SDL_RenderCopyEx(Engine::GetInstance()->GetRenderer(), m_TextureMap[id], &srcRect, &dstRect,
0, nullptr, flip);
11.
12. }
```

Your game uses this function to draw a texture to the screen using SDL_RenderCopyEx. We could use SDL_RenderCopy but there are more features and capabilities in SDL_RenderCopyEx.

SDL_Rect

A rectangle, with the origin at the upper left (integer). This is an essential data structure since any graphics element you want to draw on the screen must fit within a rectangular space – yes that goes for game paddle, image of monsters and even balls!

Syntax

```
1. typedef struct SDL_Rect
2. {
3.     int x, y;
4.     int w, h;
5. } SDL_Rect;
6.
```

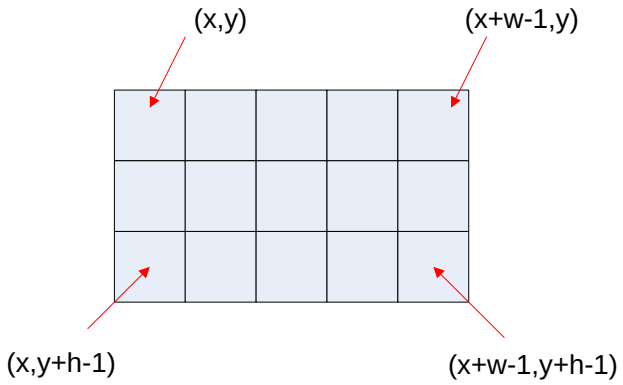


Figure 68 - The pixel coordinates part of the SDL_Rect

SDL_RendererFlip

Flip constants for SDL_RenderCopyEx

Syntax

```
1. typedef enum SDL_RendererFlip
2. {
3.     SDL_FLIP_NONE = 0x00000000,     /**< Do not flip */
4.     SDL_FLIP_HORIZONTAL = 0x00000001,    /**< flip horizontally */
5.     SDL_FLIP_VERTICAL = 0x00000002     /**< flip vertically */
6. } SDL_RendererFlip;
```

What is the difference between SDL_RenderCopy and SDL_RenderCopyEx?

The primary difference between SDL_RenderCopy and SDL_RenderCopyEx lies in the additional rendering options provided by SDL_RenderCopyEx, which are not available in the simpler SDL_RenderCopy function.

1. **SDL_RenderCopy**

This function is used to copy (render) a texture to the rendering target without any transformations. It simply places the texture on the screen.

Key Features:

- Renders the texture at the specified position and size.
- Supports clipping source and destination rectangles.
- No rotation or flipping is available.

Syntax:

```
1. int SDL_RenderCopy(SDL_Renderer* renderer,
2.                    SDL_Texture* texture,
3.                    const SDL_Rect* srcRect,
4.                    const SDL_Rect* dstRect);
```

2. **SDL_RenderCopyEx**

This function is an extended version of SDL_RenderCopy. It includes options for rotating, flipping, and specifying a center point for the rotation.

Key Features:

- Allows rotation by specifying an angle in degrees.
- Supports flipping the texture horizontally, vertically, or both.
- Let's you define the rotation center point.

Syntax:

```
1. int SDL_RenderCopyEx(SDL_Renderer* renderer,
2.                      SDL_Texture* texture,
3.                      const SDL_Rect* srcRect,
4.                      const SDL_Rect* dstRect,
5.                      const double angle,
6.                      const SDL_Point* center,
7.                      const SDL_RendererFlip flip);
```

3. **Key Parameters in SDL_RenderCopyEx**:

- **angle**: The rotation angle (in degrees).
- **center**: The point around which the texture is rotated (can be nullptr to default to the texture's center).
- **flip**: Controls whether the texture is flipped horizontally (SDL_FLIP_HORIZONTAL), vertically (SDL_FLIP_VERTICAL), or not flipped (SDL_FLIP_NONE).

In summary, use `SDL_RenderCopy` for simple, straightforward rendering, and turn to `SDL_RenderCopyEx` when you need to apply transformations like rotation or flipping.

Implement Drop()

There may be occasions where you want to remove/drop a texture from the map. One example is when you move from one level to another level where different textures are being used at the new level so you want to remove textures that you will no longer use.

```
1. void TextureManager::Drop(std::string id)
2. {
3.     SDL_DestroyTexture(m_TextureMap[id]);
4.     m_TextureMap.erase(id);
5. }
```

To use the `Drop()` method you will just need to provide the unique id used to create the texture.

SDL_DestroyTexture

The SDL function `SDL_DestroyTexture` destroys the specified texture.

Syntax

```
1. void SDL_DestroyTexture(SDL_Texture * texture);
```

Function Parameters

SDL_Texture *	**texture**	the texture to destroy.

Remarks

Passing NULL or an otherwise invalid texture will set the SDL error message to "Invalid texture".

Implement Clean()

This method is invoked when the application closes, and all the SDL_Textures need to be returned.

```
// Removes everything from the map
void TextureManager::Clean()
{
    std::map<std::string, SDL_Texture*>::iterator it;
    for(it = m_TextureMap.begin(); it != m_TextureMap.end(); it++)
        SDL_DestroyTexture(it->second);

    m_TextureMap.clear();

    SDL_Log("texture map cleaned!");

}
```

Update Engine to invoke Clean()

Add TextureManager.h

```
#include "TextureManager.h"
```

Add code to cleanup Textures

We add code to invoke the TextureManager Clean() class method.

```
bool Engine::Clean()
{
    TextureManager::GetInstance()->Clean();

    if (m_Renderer != nullptr) {
        SDL_DestroyRenderer(m_Renderer);
    }
    if (m_Window != nullptr) {
        SDL_DestroyWindow(m_Window);
    }
    IMG_Quit();
    SDL_Quit();
    return true;
}
```

The results

The compilation and execution of the application for this video produces the following:

Figure 69 - Displaying a Texture to the Screen

5. Transform and Vector SDL Game

The start of this video gave us a peek into how the final product will look like. We will have a character that will have an interesting background with our game character being able to move, swing his sword and jump around our game.

Figure 70 - A peek into our game

Overview

In this video we add two header files (only the header files no corresponding cpp classes) that we will use to move objects around.

Coordinate System

The first thing we must establish is a coordinate system. What is a coordinate system?[9]

- A set of points used to identify the position of an object in space
- 2D coordinate system has an (x,y) location
- 3D coordinate system has (x,y,z)

Since we are building a 2D game we will only concern ourselves with the 2D coordinate system.

Visualizing the Coordinate System

We recall learning that the coordinate system looks like:

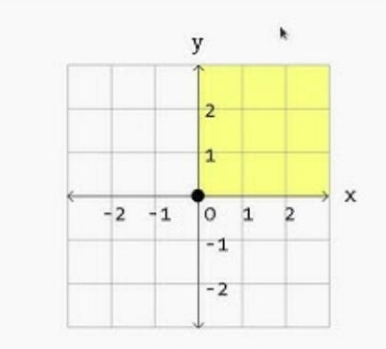


Figure 71 - Coordinate System in our math class

The X-axis is on the horizonal and the Y-axis on the vertical.

We specify the location using (x,y) values as shown when the point (3,5) is shown.

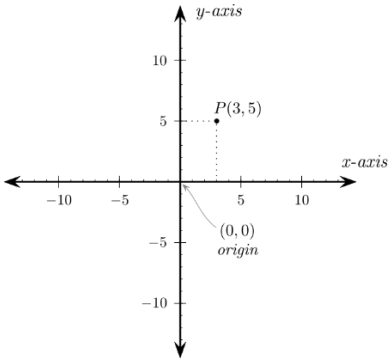


Figure 72 - Locating a point (from: http://programarcadegames.com/index.php?chapter=introduction_to_graphics&lang=en#section_5)

Going up the vertical Y-axis was going in the positive direction (0, 1, 2 …) going down the Y-axis was going in the negative direction (0, -1, -2, …)

[9] https://www.youtube.com/watch?v=M0RVM0-TuH4&ab_channel=BayoCode

When programmers gained the ability to draw graphics/images on the computer screen the Y-axis was changed so that going down the screen was going in the positive direction as shown below:

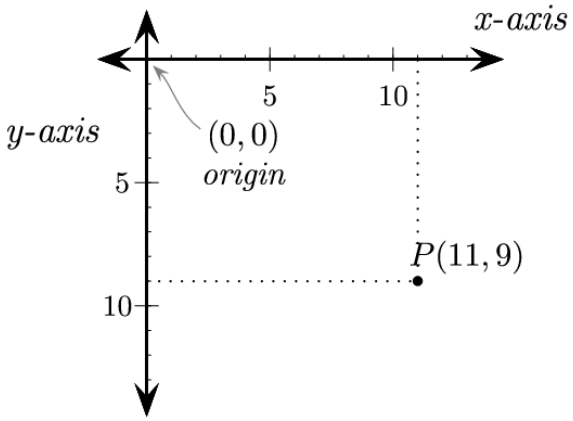


Figure 73 - How to visualize the coordinate system on the screen (from: http://programarcadegames.com/index.php?chapter=introduction_to_graphics&lang=en#section_5)

Physics

In a simple 2D game program, "Physics" refers to the simulation of real-world physical behaviors to make the game feel more natural and interactive. It's essentially a set of rules that define how objects in the game world behave when interacting with each other or the environment. Here's what it typically includes:

1. **Motion and Gravity**: Governs how objects move, fall, or accelerate (like a character jumping or an object dropping).
2. **Collisions**: Ensures that objects don't pass through each other and react realistically when they collide (e.g., bouncing off a wall).
3. **Forces**: Simulates forces like pushing, pulling, or friction that impact the object's movement.
4. **Constraints**: Defines limits on how objects can move, such as keeping a character within the screen boundaries.
5. **Elasticity**: Determines how objects respond after impact, like whether they bounce back or stop.

For example, in a game like "Pong," physics ensures the ball bounces off paddles and walls at the correct angles and speeds.

If you're creating a 2D game, most game engines (like Unity or Godot) have built-in physics engines to handle these elements for you, saving time on complex calculations.

We will implement the code to define the position of an object in our game – `Vector2D.h` and then how to move the object on the screen – `Transform.h`.

Vector2D.h

What is a vector?

A vector is an entity that has a direction and magnitude. What we are defining in this video is a `Point` not a vector.

In game programming, a ***vector*** is a mathematical concept used to represent quantities that have both ***magnitude*** and ***direction***. Vectors are fundamental in game development for tasks like positioning, movement, rotation, and scaling objects within a game world. They can be two-dimensional (for 2D games) or three-dimensional (for 3D games), depending on the game's requirements.

For example:

- **Positioning**: A vector can indicate the location of an object in the game world, such as (x, y) for 2D or (x, y, z) for 3D.
- **Movement**: Vectors can represent the direction and speed of an object's movement.
- **Rotation**: They help define the orientation of objects.
- **Scaling**: Vectors can be used to adjust the size of objects proportionally.

Vectors are also used in physics calculations, such as determining collision responses or simulating forces like gravity. Game engines like Unity and Unreal Engine have built-in support for vector operations, making it easier for developers to implement complex mechanics.

Note: We will be changing this header in some future video.

- Create only a header file named `Vector2D` in a new folder named `Physics`
    - We Create it in a new folder – `Physics`
    - We will not be generating the implementation file
    - Accept the prompts after the “Create” button is clicked to add the file to the project

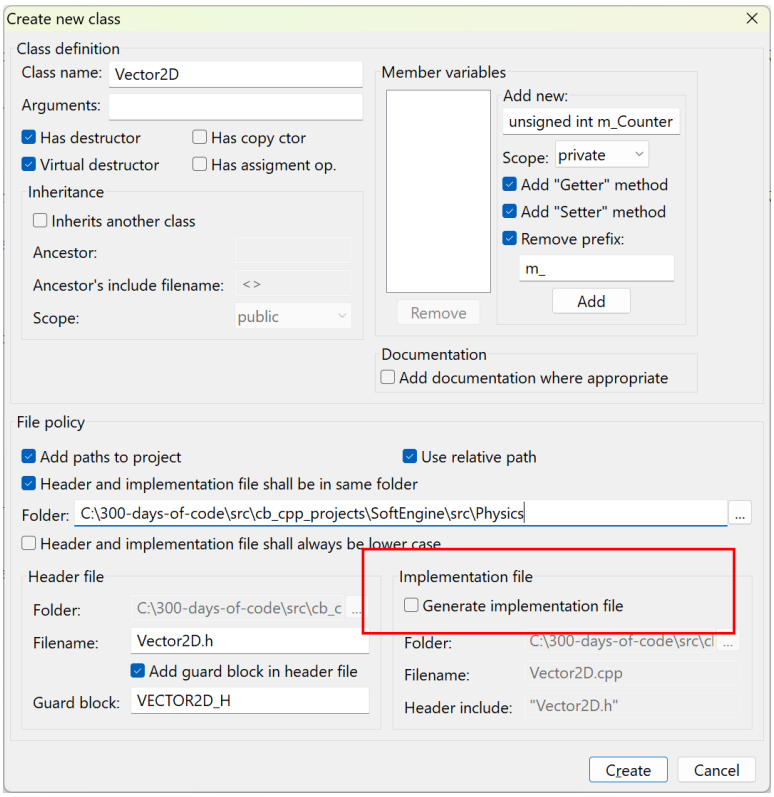


Figure 74 - Creating our new Vector2D.h file (only)

We will see a new folder added to the project:

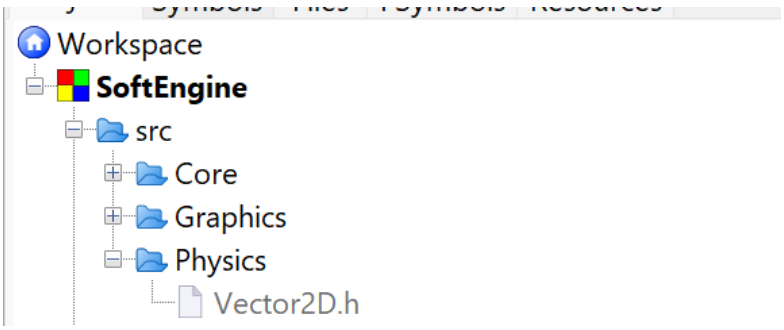


Figure 75 - New Vector2D.h file in Physics folder

```
1. #ifndef VECTOR2D_H
2. #define VECTOR2D_H
3.
4. #include <iostream>
5.
6. class Vector2D
7. {
8.     public:
9.         float X, Y;
10.
11.     public:
```

```
12.         Vector2D(float x=0, float y=0): X(x), Y(y) {}
13.
14.     public:
15.         inline Vector2D operator+(const Vector2D& v2) const {
16.             return Vector2D(X + v2.X, Y + v2.Y);
17.         }
18.          inline Vector2D operator-(const Vector2D& v2) const {
19.             return Vector2D(X - v2.X, Y - v2.Y);
20.         }
21.
22.        void Log(std::string msg="") {
23.             std::cout << msg << "(X,Y)= (" << X << " " << Y << ")" << std::endl;
24.        }
25. };
26.
27. #endif // VECTOR2D_H
```

As you can see from the file the Vector2D makes public the position X, Y. Initializing something like:

```
Vector2D  v1;
```

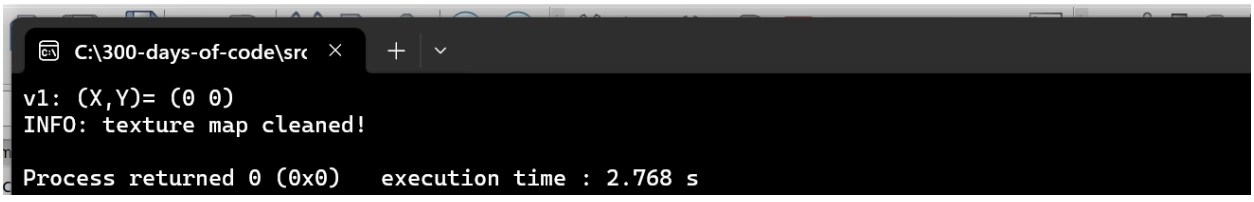
The above will automatically set v1 to X=0 and Y=0. Let's test this out by:

- Open for edit Engine.cpp
- Include Vector2D.h

- Add code in Engine::Init() to create and print out a new vector:

```
1.      TextureManager::GetInstance()->Load("tree", "assets/tree.png");
2.
3.      Vector2D v1;
4.      v1.Log("v1: ");
5.      return m_IsRunning = true;
6.
```

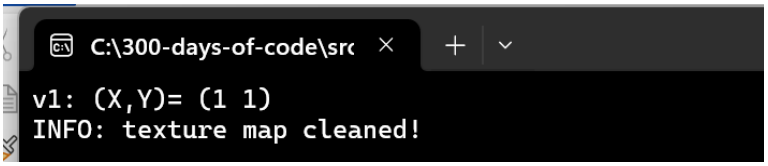
- Run and examine the console log



- Let's change the code to initialize the vector to a specific value:

```
1.      Vector2D v1(1,1);
2.      v1.Log("v1: ");
```

We see the following printed out:



Vector operations

There are several key operations we need to implement:

- Adding vectors and Subtracting vectors
- Multiplying and Dividing vector

Performing the operations above to vectors just means applying the operations to the individual components of a vector:

$$\boxed{v_3 = v_1 + v_2 = (x_1, y_1) + (x_2, y_2) = (x_1 + x_2, y_1 + y_2)}$$

Let $\vec{u} = \langle u_1, u_2 \rangle$ and $\vec{v} = \langle v_1, v_2 \rangle$ be two vectors.

Then, the sum of $\vec{u}$ and $\vec{v}$ is the vector

$$\vec{u} + \vec{v} = \langle u_1 + v_1, u_2 + v_2 \rangle$$

The difference of $\vec{u}$ and $\vec{v}$ is

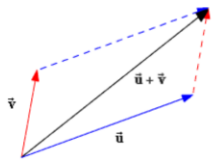
$$\vec{u} - \vec{v} = \vec{u} + \left(-\vec{v}\right)$$
$$= \langle u_1 - v_1, u_2 - v_2 \rangle$$

The sum of two or more vectors is called the resultant. The resultant of two vectors can be found using either the *parallelogram method* or the *triangle method*.

Figure 76 - From https://www.varsitytutors.com/hotmath/hotmath_help/topics/adding-and-subtracting-vectors

Parallelogram Method:

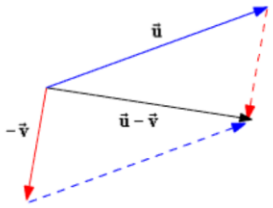
Draw the vectors so that their initial points coincide. Then draw lines to form a complete parallelogram. The diagonal from the initial point to the opposite vertex of the parallelogram is the resultant.



Vector Addition:

1. Place both vectors $\vec{u}$ and $\vec{v}$ at the same initial point.
2. Complete the parallelogram. The resultant vector $\vec{u}+\vec{v}$ is the diagonal of the parallelogram.

Figure 77 - From https://www.varsitytutors.com/hotmath/hotmath_help/topics/adding-and-subtracting-vectors



Vector Subtraction:

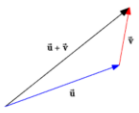
1. Complete the parallelogram.
2. Draw the diagonals of the parallelogram from the initial point.

Alternative method for visualizing how to add and subtract vectors:

Triangle Method:

Draw the vectors one after another, placing the initial point of each successive vector at the terminal point of the previous vector. Then draw the resultant from the initial point of the first vector to the terminal point of the last vector. This method is also called the *head-to-tail method*.

Vector Addition:



Vector Subtraction:

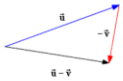


Figure 78 - From https://www.varsitytutors.com/hotmath/hotmath_help/topics/adding-and-subtracting-vectors

Add Code for Vector Addition and Subtraction

```
class Vector2D
{
    public:
        float X, Y;

    public:
        Vector2D(float x=0, float y=0): X(x), Y(y) {}

    public:
        inline Vector2D operator+(const Vector2D& v2) const {
            return Vector2D(X + v2.X, Y + v2.Y);
        }
         inline Vector2D operator-(const Vector2D& v2) const {
            return Vector2D(X - v2.X, Y - v2.Y);
        }

       void Log(std::string msg="") {
            std::cout << msg << "(X,Y)= (" << X << " " << Y << ")" << std::endl;
        }
};
```

- Test the above in Engine.cpp again:

```
    Vector2D v1(1,1), v2(2,2);
    Vector2D v3 = v1 + v2;

    v3.Log("v3: ");
```

We expect to see the sum (3,3) in the console:

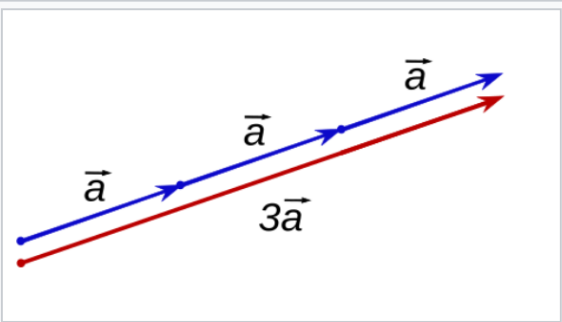
```
v3: (X,Y)= (3 3)
INFO: texture map cleaned!
```

Adding the multiplication operation

The next operation we will add to the `Vector2D.h` file is the multiplication:

```
        inline Vector2D operator*(const float scaler) const {
            return Vector2D(X * scaler, Y * scaler);
        }
```

What is the visualization on how multiplying a scaler to a vector does to it:



Scalar multiplication of a vector by a factor of 3 stretches the vector out.

The scaler increases or scales up the original vector. You can imagine it can be used to stretch or shrink the vector.

Transform.h

What does it mean to Transform an object?

In game programming, a **Transform** typically refers to an object's position, rotation, and scale in a game world. Vectors play a crucial role in defining and manipulating these properties. Here's how they work together:

1. **Position**: A vector represents the object's location in the game world. For example, in a 3D game, a position vector like (x, y, z) specifies where the object is located relative to the origin.
2. **Rotation**: Vectors are used to define the direction an object is facing. For instance, a forward vector might indicate the direction an object is moving or looking. Rotations can also be represented using quaternions or Euler angles, but vectors are often involved in calculations.
3. **Scale**: A vector can define how much an object is scaled along each axis. For example, a scale vector (1,2) would stretch the object twice as much along the y-axis while x-axis unchanged
4. **Transformations**: Vectors are manipulated to apply transformations like translation (moving an object), rotation, or scaling. For example:
    - **Translation**: Adding a vector to an object's position moves it in the specified direction.

- **Rotation**: Multiplying a vector by a rotation matrix or quaternion rotates the object
- **Scaling**: Multiplying a vector by a scaler value or a scale matrix adjust's the object's size

So Transform is used to change an object's position, rotate it, or scale it.

- Create the `Transform.h` file
  - Make sure you do not implement to cpp file
  - After pressing "Create" add the file to the project as before

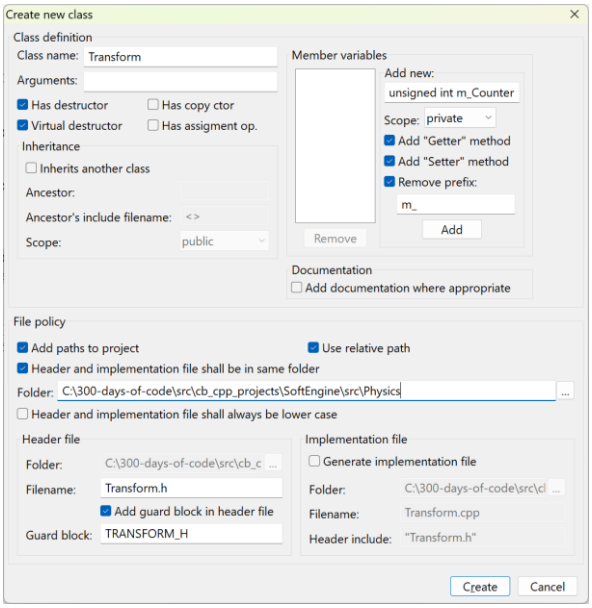


Figure 79 - Creating the Transform.h file

- Populate the `Transform.h` with the following code:

```
1. #ifndef TRANSFORM_H
2. #define TRANSFORM_H
3.
4. #include "Vector2D.h"
5.
6. class Transform
7. {
8.     public:
9.         float X, Y;
10.
11.    public:
12.        Transform(float x=0, float y=0):X(x), Y(y) {}
13.
14.    public:
15.        // Move in the X-axis direction
16.        inline void TranslateX(float x) { X += x; }
17.
```

```
18.         // Move in the Y-axis direction
19.         inline void TranslateY(float y) { Y += y; }
20.
21.         // Move in the game world using a vector
22.         inline void Translate(Vector2D v) { X += v.X; Y += v.Y; }
23. };
24.
25. #endif // TRANSFORM_H
26.
```

Note: In the video the TranslateX, TranslateY and Translate are all private but this needs to be made public in order to be able to utilize the function.

We define a constructor and three class methods that allow us to move an object in the game world.

- Add a public Log class method to the `Transform.h` file:

```
1.         void Log(std::string msg="") {
2.             std::cout << msg << "(X,Y)= (" << X << " " << Y << ")" << std::endl;
3.         }
```

We added this method so we can test things out.

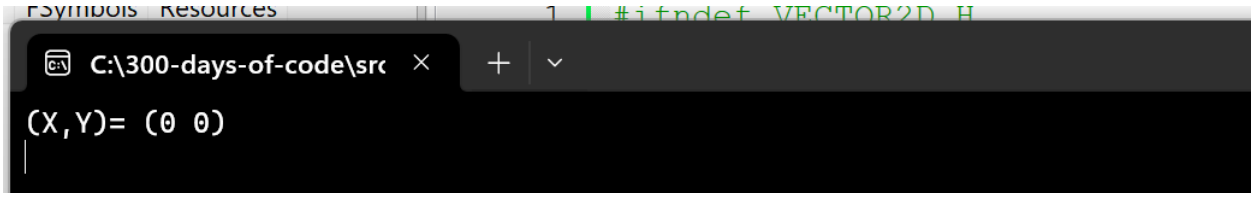
- Edit the file `Engine.cpp` again
    - Remove the include line for `Vector2D.h`
    - Add an include line for `Transform.h`

```
1. #include "Transform.h"
```

    - Remove the `Vector2D` variable and log and replace with:

```
1.     Transform tf;
2.     tf.Log();
```

    - Test run the program again



Is there a better way to Unit test our code?

The unit testing for the classes we are creating seems to be an old style way to test. I have been a Java developer for the last two decades and was wondering what it would take to do unit testing in a C++ development environment. This is what Copilot tells me:

Unit testing in C++ is a crucial step in ensuring that individual components of a program work correctly. Developers typically use unit testing frameworks to automate and streamline the process. Here's how they go about it:

1. **Choose a Testing Framework:** Popular options for C++ include:
    - **Google Test (GTest):** Widely used due to its rich feature set and simplicity.
    - **Catch2:** A lightweight, single-header alternative.
    - **Boost.Test:** Part of the Boost C++ libraries, offering comprehensive testing capabilities.
    - **CppUnit:** Inspired by JUnit for testing C++ code.
2. **Write Test Cases:** Developers create small, isolated test functions to validate specific parts of the code. Each test function checks a particular scenario using assertions like EXPECT_EQ or ASSERT_TRUE in Google Test.
3. **Organize Tests:** Tests are usually grouped into suites based on related functionality, making it easier to run and debug them.
4. **Run Tests Automatically:** The testing framework executes all test cases, reporting failures and errors. Many developers integrate unit tests into **continuous integration (CI)** pipelines to ensure issues are caught early.
5. **Mock Dependencies:** If a function relies on external modules (like databases or network calls), mocking frameworks like **Google Mock** help simulate expected behavior.
6. **Analyze Code Coverage:** Tools like **gcov**, **LCOV**, or **Clang Sanitizers** provide insights into how much of the code is covered by tests, helping identify gaps.
7. **Refactor and Maintain Tests:** As the code evolves, developers regularly update tests to reflect changes, ensuring they remain useful.

I will pursue a new area (outside these notes and the video) to learn how one would unit test a C++ program, I would like to see how we can add testing to a game as it is being built.

6. Game Object SDL Game

Overview

We will need to represent various “video game objects” in our game. An object is a fundamental building block within a game scene. It’s essentially a container that holds components, which determine the object’s visual appearance, behavior, and functionality.

An object can be the player, an enemy, or something we interact with in our game. We will start the video by creating an interface class – `IObject`. This interface defines what all objects (e.g. the sneaky monster out to get the player) must all implement, the functions:

- `Update()` – to update the object’s position in the game world
- `Draw()` – draw the object to the screen
- `Clean()` – draws the object

Within the game loop, we will invoke the functions within each object.

Create the interface IObject

- Create a new class in a new folder for our project named `src\Object`
    - The name of the class is `IObject`
    - This is only a header file (turn off implementation generation)
    - Add the file to the current project
    - Accept both Debug and Release targets

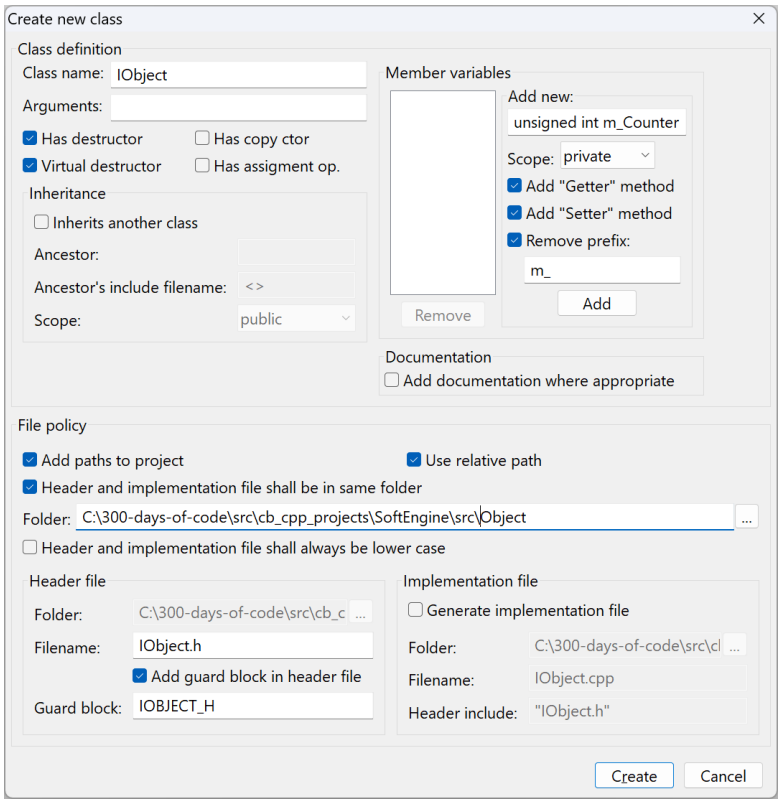


Figure 80 - Creating IObject header file

The contents of the `IObject` interface is:

```
 1. #ifndef IOBJECT_H
 2. #define IOBJECT_H
 3.
 4.
 5. class IObject
 6. {
 7.
 8.     public:
 9.         virtual void Draw() = 0;
10.         virtual void Update(float dt) = 0;
11.         virtual void Clean() = 0;
12.
13. };
14.
15. #endif // IOBJECT_H
16.
```

The interface defines the three actions or functions that every object should implement:

- ***Draw*** – draw the image that represents the object
- ***Update*** – move or transform the position of the object
- ***Clean*** – clean up all resources associated with the object

Create GameObject class

This class will also be just a header file:

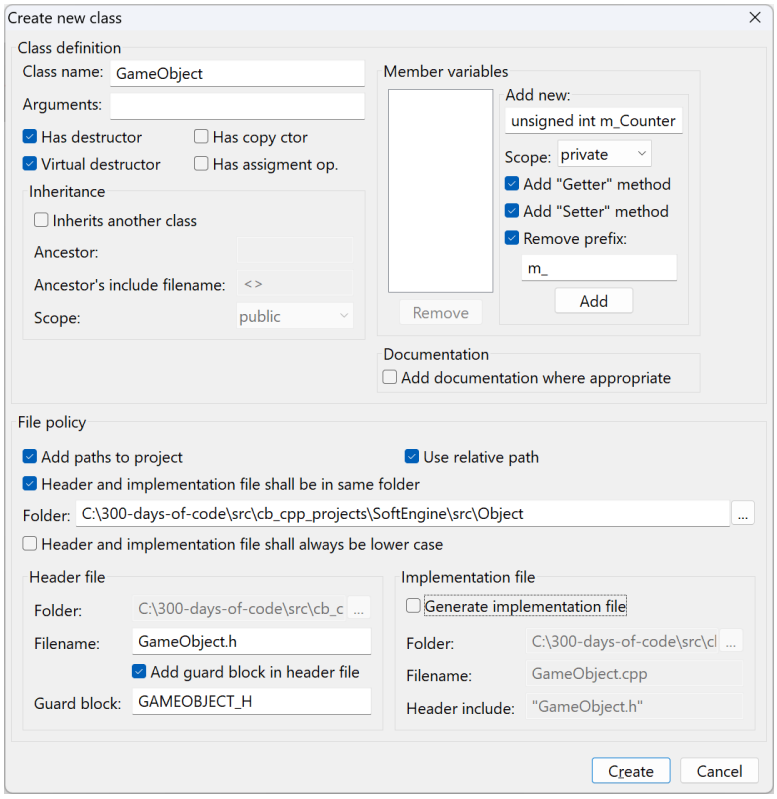


Figure 81 - Creating the GameObject header file

`GameObject` is also only a header file that inherits from `IObject`.

The `GameObject` tracks several key properties of an object:

- **Transform** – which is the point in the game world our object is in and how it is moving
- **Width and Height** – since every object defines a rectangular space in the game world this holds the width and height of the GameObject
- **textureID** – this holds the texture/image id of the current object (see TextureManager class)
- **flip** – this holds the orientation of the object

Figure 82 - From https://blenderartists.org/t/2d-character-sprites/436586

The initial code we will add to GameObject:

```
 1. #ifndef GAMEOBJECT_H
 2. #define GAMEOBJECT_H
 3.
 4. #include "IObject.h"
 5. #include "Transform.h"
 6.
 7. class GameObject : public IObject
 8. {
 9.     public:
10.         GameObject() {}
11.
12.         virtual void Draw() = 0;
13.         virtual void Update(float dt) = 0;
14.         virtual void Clean() = 0;
15.
16.     protected:
17.        std::string m_TextureID;
18.        int m_Width, m_Height;
19.        SDL_RendererFlip m_Flip;
20.        Transform* m_Transform;
21.
22. };
23.
24. #endif // GAMEOBJECT_H
25.
```

Lines 4-5 are the include for the interface and transform header files, respectively.

Lines 12-14 are placeholders for the functions `Draw`, `Update` and `Clean` defined by the interface `IObject`.

Lines 17-20 define the key properties of all objects.

We need to fill out the `GameObject` constructor but there are many properties that need to be provided by any client code. The list of arguments can potentially grow too long. A common

practice used is to create a `struct` that captures all the attributes that need to be provided in the constructor.

- In the same `GameObject.h` file add a new struct `Properties`:

```
 1. struct Properties {
 2.
 3.     public:
 4.         Properties(std::string textureID, int x, int y, int width, int height, SDL_RendererFlip
flip = SDL_FLIP_NONE) {
 5.             X = x;
 6.             Y = y;
 7.             Flip = flip;
 8.             Width = width;
 9.             Height = height;
10.             TextureID = textureID;
11.         }
12.
13.         std::string TextureID;
14.         int Width, Height;
15.         float X, Y;
16.         SDL_RendererFlip Flip;
17. };
18.
```

- Update the `GameObject` constructor to expect a Properties* argument:

```
1.         GameObject(Properties* props) :
2.             m_TextureID(props->TextureID),
3.             m_Width(props->Width),
4.             m_Height(props->Height),
5.             m_Flip(props->Flip) {
6.                 m_Transform = new Transform(props->X, props->Y);
7.             };
8.
```

Test Things out

I added:

`#include "GameObject.h"` to my GameEngine.cpp file to make sure everything compiled with no issues. I removed the header once I found all typos.

7. Sprite Sheet Animation for SDL Game – Part 1

In this video tutorial we add code to animate a warrior character from a sprite sheet. When all is said and done, we should see the following image on the screen:

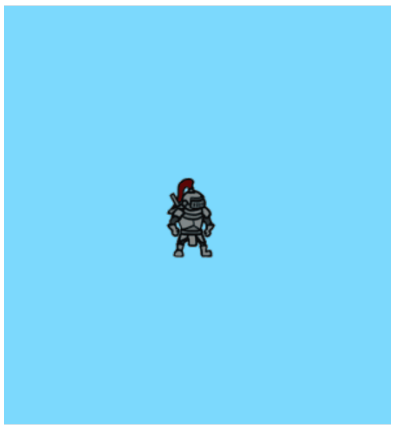


Figure 83 - Our animated Warrior/player

To display the Warrior/player we will need to iterate through several images of the player as he stands in *idle* mode. This video series starts the discussion on animation of our game characters.

What is a sprite sheet?

We start with what we call a sprite sheet – an image file consisting of many images with the intent that we utilize the images to display characters in our game walking, idling, running, or dying.

A **sprite sheet** is a single image file that contains multiple smaller images, called **sprites**, arranged in a grid or sequence. These sprites are used in **video games, animations, and UI design** to create characters, objects, and effects efficiently.

Why Use Sprite Sheets?

- **Performance Optimization**: Reduces the number of image loads, improving rendering speed.
- **Animation Efficiency**: Stores multiple frames of an animation in one file.
- **Memory Management**: Helps reduce memory usage by keeping assets compact.

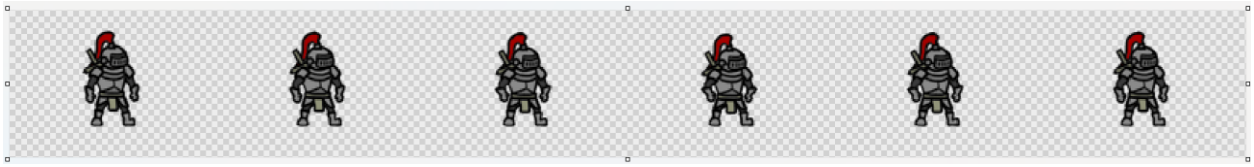
How Sprite Sheets Work

Each sprite in the sheet is mapped using **coordinates**, allowing game engines or software to extract and display specific frames when needed. This technique is commonly used in **2D games** for character movements, explosions, and UI elements.

If you're looking to create your own sprite sheet, you can check out tools like Piskel or Final Parsec's Sprite Sheet Maker.

For this video we use the image file `Idle.png`:

The file contains six images of a warrior as he stands idle. It is hard to tell from the above image that the warrior position changes slightly from frame to frame. It may be easier to see in the image below:



We want the code to input the sheet/file and display each “frame” or portion of the warrior to give us the illusion of the warrior moving up and down as he idles waiting for the next user commands.

How do we ensure the sprite animates in a timely manner?

One of the things we must do is know how to partition the sprite sheet into frames and set how fast to display every frame on the sheet to give the illusion of walking, fighting, or just standing there waiting.

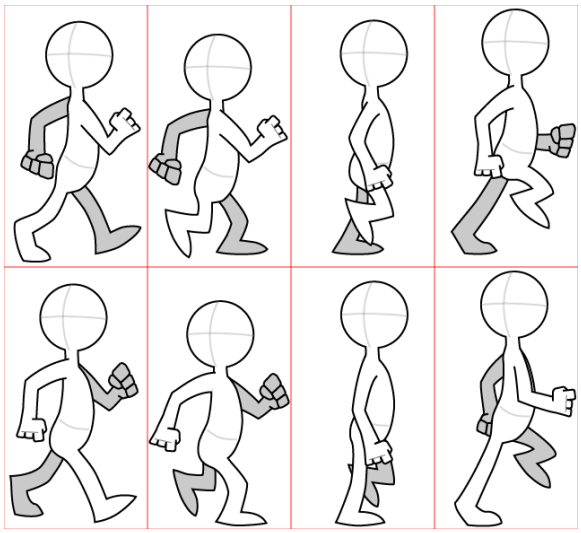


Figure 84 - Working with an animation sheet (from: https://www.cs.cornell.edu/courses/cs5152/2025sp/labs/design1/#task-2-the-sprite-sheet)

We know that as part of the game loop the repeated call to update the entities on the screen, with respect to a sprite it means moving to the next frame on the sheet – but not so fast! We don't want every call to the Update for our warrior to move to the next frame but we need to wait sometime between every frame. We will discuss how to do that later.

Updating TextureManager to handle a spritesheet

We add a new method to the `TextureManager` class to handle a sprite sheet. Normally, a sprite sheet may contain several rows of images where each row has one or more frames to display of characters in various modes:

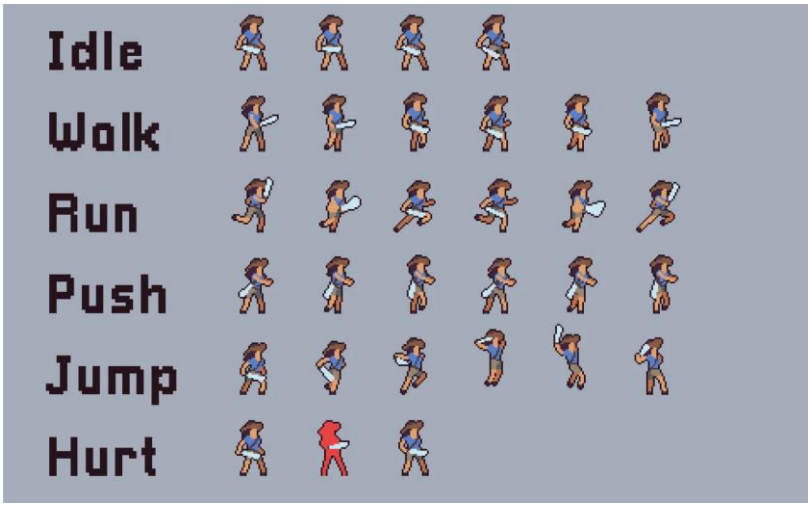


Figure 85 - A sprite sheet (from: https://craftpix.net/freebies/free-3-character-sprite-sheets-pixel-art/)

The sprite sheet for this video is rather simple, having only one row.

- Edit `TextureManager.h` adding a new `DrawFrame` method:

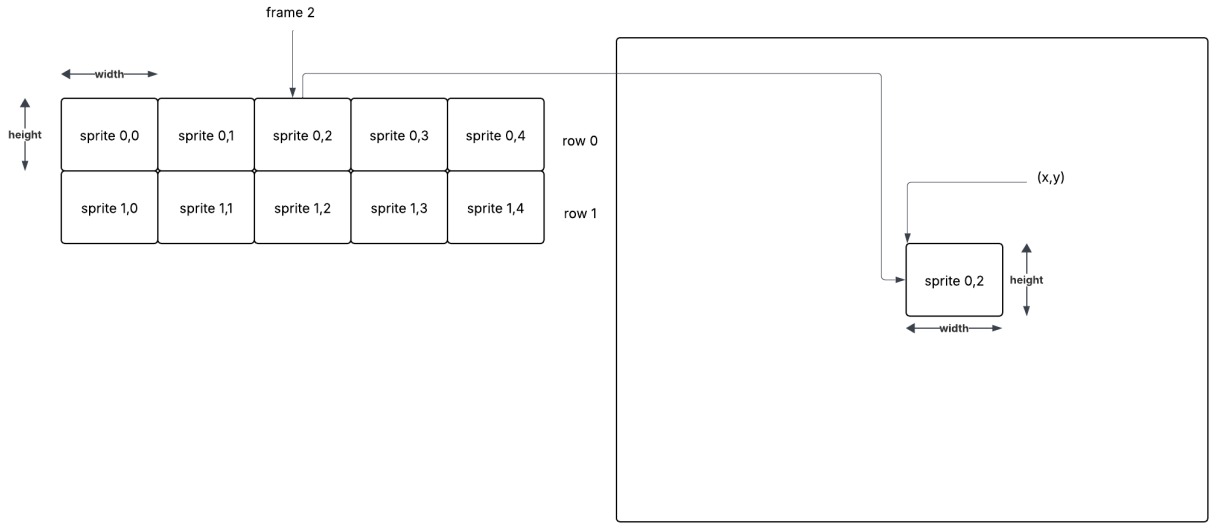
```
1.        void DrawFrame(std::string id, int x, int y, int width, int height, int row, int frame,
SDL_RendererFlip flip);
```

- Edit `TextureManager.cpp` to add the implementation:

```
1. void TextureManager::DrawFrame(std::string id, int x, int y, int width, int height, int row, int
frame, SDL_RendererFlip flip)
2. {
3.     SDL_Rect srcRect = {width*frame, height*row, width, height};
4.     SDL_Rect dstRect = {x, y, width, height};
5.
6.     SDL_RenderCopyEx(Engine::GetInstance()->GetRenderer(), m_TextureMap[id], &srcRect, &dstRect,
0, nullptr, flip);
7.
8. }
9.
```

The method `DrawFrame` has two more arguments (row and frame) to allow us to calculate which image on the sprite sheet we want to draw to the screen.

The `srcRect` represents the part of the texture/sprite sheet you want to extract and draw to the screen. The dstRect defines the location on the screen you want to draw that frame.



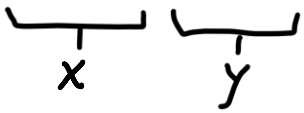
The above represents a sprite sheet with two rows, where each row has 5 frames[10].

If we invoke `DrawFrame` with the following arguments to draw sprite 0,2 (row 0, frame 2) to the screen at location (x,y).

- id – the sprite sheet texture
- x,y – the location on the screen to draw the frame we are interested in
- width – the width of the sprite
- height – the height of the sprite
- row – the row in the sprite sheet we want to draw from
- frame – the sprite in the row we want to draw
- flip – orientation of our sprite

We need to define the `srcRect` to be the location on the sprite sheet of the desired frame on the desired row:

```
SDL_Rect srcRect = {width*frame, height*row, width, height};
```



[10] We will maintain using our counts that start at 0 (for row 1).

The first two arguments define the x and y location in the sprite sheet we want to start the extraction of the source frame. When frame=0 and row = 0 we are going to extract sprite 0,0 (do the math). When we want to extract sprite 0,2 we calculate the x as width*2 and y=0 to determine the top left corner.

Create the Character.h file

- Create a new class (with no implementation) called `Character` in a new folder `src/Characters`
    - The class will inherit from `GameObject`

```
#ifndef CHARACTER_H
#define CHARACTER_H

#include <GameObject.h>


class Character : public GameObject
{
    public:
        Character() {}
        virtual ~Character() {}

    protected:

    private:
};

#endif // CHARACTER_H
```

- Update the constructor to invoke the `GameObject` constructor:

```
Character(Properties props): GameObject(props) {}
```

- Remove the destructor class method
- We need to define or implement the methods defined in the interface `IObject`

```
#ifndef CHARACTER_H
#define CHARACTER_H

#include <GameObject.h>


class Character : public GameObject
{
    public:
        Character(Properties* props): GameObject(props) {}

        virtual void Draw() = 0;
        virtual void Update(float dt) = 0;
        virtual void Clean() = 0;
```

```
15.
16.     protected:
17.
18.
19. };
20.
21. #endif // CHARACTER_H
```

- Add an include for string:

```
1. #include <string>
```

- Add a protected member for the `m_Name` member variable:

```
1.     protected:
2.         std::string m_Name;
```

Creating the Warrior class

- Create a new class named `Warrior`
  - Save into the `\src\Characters` folder
  - Inherit from the `Character` class
  - Implement the `Warrior.cpp` file

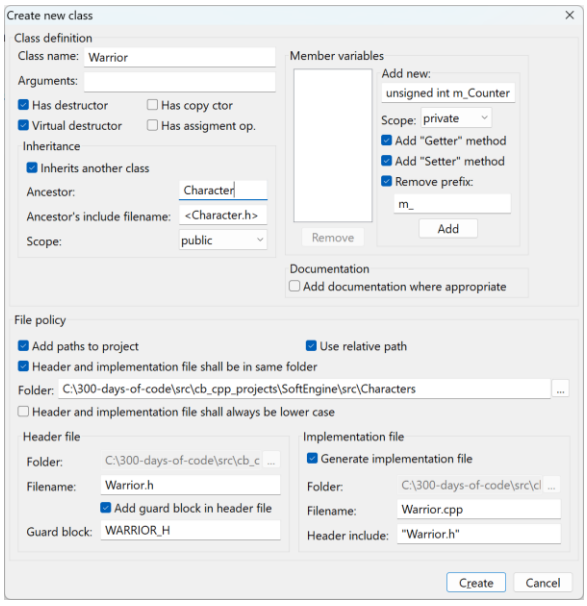


Figure 86 - Creating the Warrior.h and Warrior.cpp

UML Diagram of our current classes

Let's keep in mind the relationship between classes:

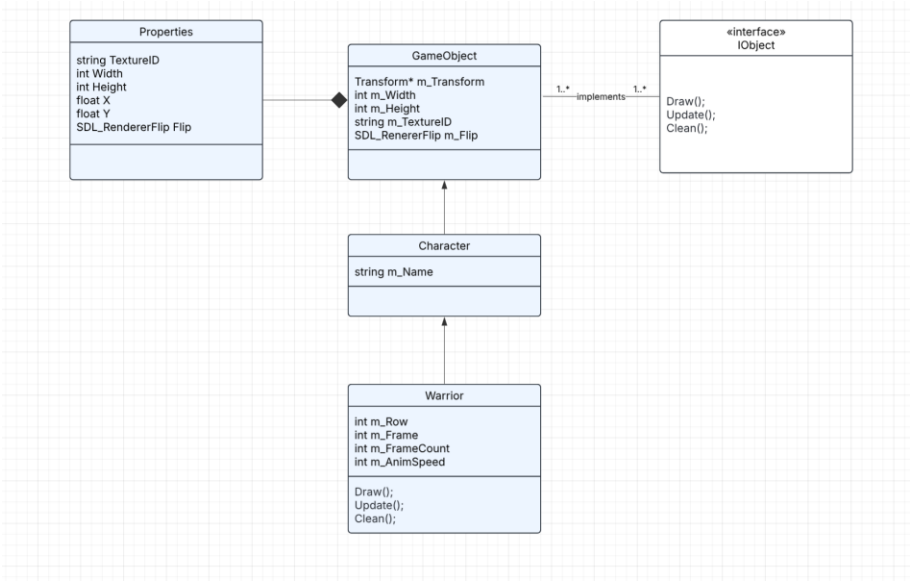


Figure 87 - UML Diagram our classes

When we instantiate a Warrior class we also have an m_Name from the Character class and m_Transform, m_Width, m_Heigh, m_TextureID and m_Flip from the GameObject class.

Add Code for Update

- Remove the destructor in the Warrior.h
- Add the Draw, Update, Clean virtual methods to the Warrior.h:

```
#ifndef WARRIOR_H
#define WARRIOR_H

#include <Character.h>


class Warrior : public Character
{
    public:
        Warrior(Properties* props);

        virtual void Draw() = 0;
        virtual void Update(float dt) = 0;
        virtual void Clean() = 0;

    protected:

    private:
};

#endif // WARRIOR_H
```

```
22.
```

- Open the Warrior.cpp file
- Remove the destructor place holder
- Right-click on the file and select Insert/Rector and select All class methods without implementation

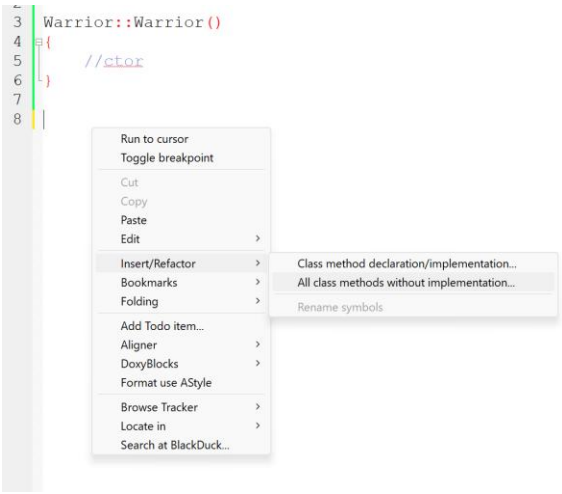


Figure 88 - Using IDE to add class method placeholders

- Edit the Warrior.h to add three private member variable to manage/track the frame animation that is being displayed for the Warrior:

```
1.     private:
2.         int m_Row, m_Frame, m_FrameCount;
```

Another important member variable is the animation speed – how fast should we be going through our frames:

```
1.     private:
2.         int m_Row, m_Frame, m_FrameCount;
3.         int m_AnimSpeed;
```

Add complete implementation methods for Draw, Update and Clean

Warrior::Warrior constructor

We add the following code to initialize our Warrior player:

```
1. #include "Warrior.h"
2. #include "SDL.h"
```

```
 3. #include "TextureManager.h"
 4.
 5.
 6. Warrior::Warrior(Properties* props): Character(props)
 7. {
 8.     m_Row = 0;
 9.     m_FrameCount = 6;
10.     m_AnimSpeed = 80;
11. }
12.
```

The sprite sheet we are working with only has one row with six frames or images. The animation speed will be examined in the Update().

Warrior::Draw()

This class method utilizes the `DrawFrame` method in the `TextureManager`:

```
1. void Warrior::Draw()
2. {
3.     TextureManager::GetInstance()->DrawFrame(m_TextureID, m_Transform->X, m_Transform->Y,
m_Width, m_Height, m_Row, m_Frame, m_Flip);
4. }
```

Note, how we access and utilize member variables defined in classes we inherited, we can see the members that are accessible via the UML diagram (see Figure 87).

Warrior::Update()

The `Warrior` class must handle what occurs when its `Update()`, `Draw()` and `Clean()` functions are invoked. In this example, we want the object to display the right frame, and after a bit of time move to the next frame. When it reaches the last frame we want it to wrap around back to frame #0. It is in this function that we determine how long to spend on frame x before we move to frame x+1.

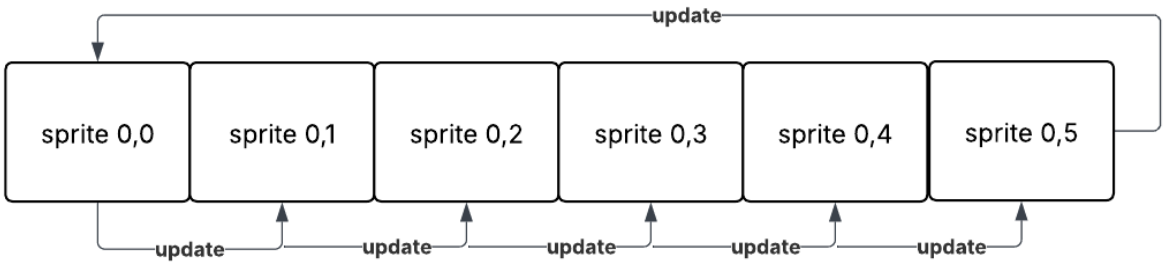


Figure 89 - Updating the frame to display

The figure illustrates the fact that we move from one frame in the sprite sheet to another until we reach the end and go back to the first frame. The ideal operation for cycling is the mod operator (%). Suppose we want to cycle from frames 0..5 and then back to 0. Imagine using the algorithm:

```
1. count = 0
2. repeat
3.        draw frame(count % 6)
4.        ++count;
5. until object_is_removed;
```

We see that because of % operator we will cycle from `0, 1, 2, 3, 4, 5`, back to `0, 1, 2, 3, 4, 5` as the count increases. The mod operator limits the frame number to a number from `0..5`.

The above is easy to understand but what if the count was increasing every millisecond? We don't want to iterate to a new frame every millisecond! It will just appear as one big blur rather than a Warrior idling waiting for a key press.

Suppose the loop was running every millisecond but we only wanted to move up to the next frame every `80` milliseconds. How can we do that?

When we divide x by y (x/y) we get the quotient of the division. Suppose x = 100 and y = 10.

At first `x / y => 100/ 10 = 10`.

Increase x by 1. (this is our counter)

`x / y  => 101 / 10 = 10`

Increase x by 1 again.

`x / y => 102 / 10 = 10`

This continues to be 10 until x = 110. Then we get

`x / y => 110 / 10 = 11`.

We use this fact to "wait" `m_AminSpeed` before moving to the next frame. We divide the counter by `m_AminSpeed`.

But what is our counter?

What is SDL_GetTicks()?

`SDL_GetTicks()` is a function in the Simple DirectMedia Layer (SDL) library that returns the number of milliseconds that have elapsed since the SDL library was initialized. This function is useful for timing operations, measuring frame rates, and handling animations in games and multimedia applications.

Syntax

```
Uint32 SDL_GetTicks(void);
```

Function Parameters

NA

Returns

(Uint32) Returns an unsigned 32-bit value representing the number of milliseconds since the SDL library initialized.

Remarks

This value wraps if the program runs for more than ~49 days.

This function is not recommended as of SDL 2.0.18; use SDL_GetTicks64() instead, where the value doesn't wrap every ~49 days. There are places in SDL where we provide a 32-bit timestamp that cannot change without breaking binary compatibility, though, so this function isn't officially deprecated.

The `SDL_GetTicks` will be our “counter”.

Using the AnimSpeed to control the frame rate

The implementation of Update():

```
1. void Warrior::Update(float dt)
2. {
3.     m_Frame = (SDL_GetTicks() / m_AnimSpeed) % m_FrameCount;
4. }
```

The `(SDL_GetTicks() / m_AnimSpeed)`[11] changes to a new quotient value every `m_AnimSpeed` time which in turn maps to a new frame in our sprite sheet.

Warrior::Clean()

This function just calls the TextureManager Clean() function.

```
1. void Warrior::Clean()
2. {
3.     TextureManager::GetInstance()->Clean();
4. }
```

Testing our Warrior class

We will now add code to our Engine.cpp class to test out our Warrior class.

- Open the Engine.cpp class file
- Add an include for the Warrior.h file:

```
1. #include "Warrior.h"
```

- Initialize a Warrior object (the player):

```
1. Engine* Engine::s_Instance = nullptr;
2. Warrior* player = nullptr;
```

- Change code to load the Idle.png rather than tree.png and initialize the player

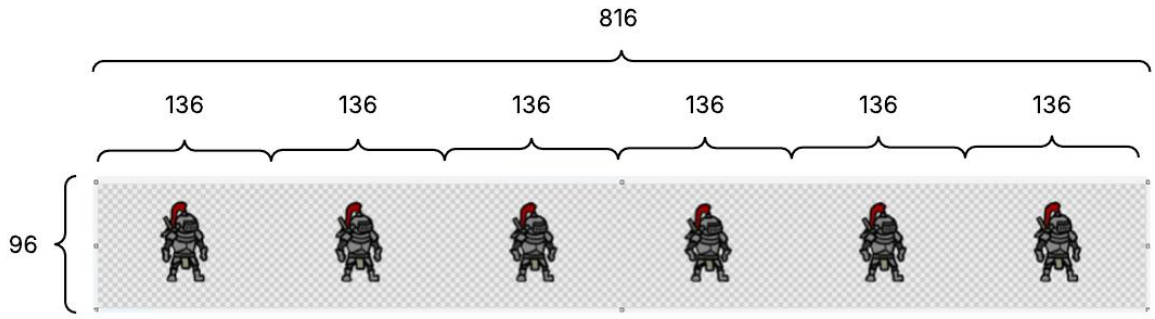
```
1.     TextureManager::GetInstance()->Load("player", "assets/Idle.png");
2.     player = new Warrior(new Properties("player", 100, 200, 136, 96));
```

You may be wondering how to figure out the width and height to provide as the properties values. We need to provide the width and height of the individual sprite.

The entire sprite sheet is 816 x 96 pixels. We know it has 6 sprite images therefore we want to partition the sprite sheet into 816 / 6 or 136 pixels wide and 96 pixels in height.

We can imagine the following:

[11] The first time, going from frame 0 to frame 1 the timing may be off since we don't know the starting value of the counter - SDL_GetTicks() is the number of milliseconds from the start of initial call to SDL_Init().



Things can get more complicated if the sprite sheet consisted of many rows where the sprites had different widths on every row. You would probably need to use another file to specify the width and height more accurately. In the case of our Warrior things are rather straightforward.

- Add code to the Engine::Update() to invoke the player's Update() function

```
1. void Engine::Update()
2. {
3.     player->Update(0);
4. }
```

- Add code to the Engine::Render to draw our player

```
 1. void Engine::Render()
 2. {
 3.     // Set the draw color
 4.     SDL_SetRenderDrawColor(m_Renderer, 124, 218, 254, 255);
 5.
 6.     // Clear the screen with the draw color
 7.     SDL_RenderClear(m_Renderer);
 8.
 9.     //TextureManager::GetInstance()->Draw("tree", 100, 100, 347, 465);
10.
11.     // Draw our Warrior
12.     player->Draw();
13.
14.     // Present the renderer (update the window)
15.     SDL_RenderPresent(m_Renderer);
16. }
17.
```

Note: We do not have to explicitly invoke the player->Clean() function, it will be invoked when we invoke:

`TextureManager::GetInstance()->Clean();`

- Compile and run the program

At this point you should see the figure animated in Figure 83.

8. Sprite Sheet Animation for SDL Game – Part 2

In this video, we cleanup/change the code to make it more convenient to create and manage objects that have animation in our game. The Warrior class should *only* be managing details pertaining to the Warrior character and not handling the Animation details shown below:

```
1.      private:
2.          int m_Row, m_Frame, m_FrameCount;
3.          int m_AnimSpeed;
```

Composition vs. Inheritance

In object-oriented programming, inheritance establishes an "***is-a***" relationship between classes, where a subclass inherits properties and behaviors from its parent class. Composition, on the other hand, creates a "***has-a***" relationship, where one object contains or uses another object's functionality. Composition is generally favored for its greater flexibility and loose coupling, especially in complex, evolving systems, whereas inheritance can lead to rigid designs and tight coupling.

Elaboration:

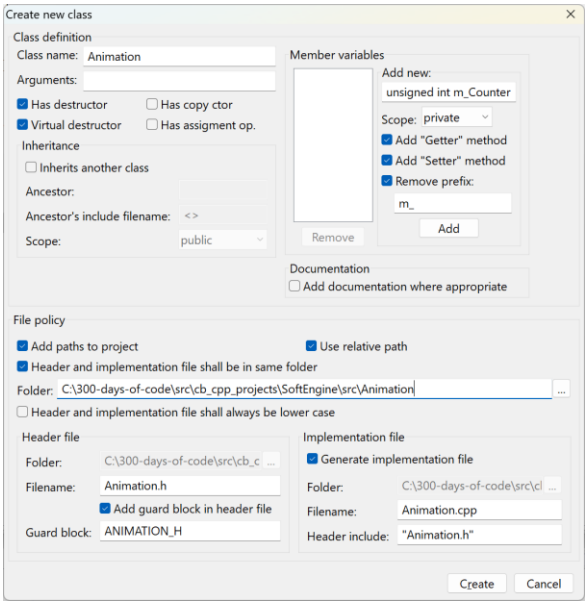
- **Inheritance:**
    - A class can inherit properties and methods from a parent class, creating a hierarchy of classes.
    - This can lead to code reuse and a more organized structure.
    - However, inheritance can create rigid designs and make it difficult to modify the code if changes are needed in the parent class.
- **Composition:**
    - A class contains instances of other classes, allowing it to use their functionality.
    - This approach provides greater flexibility and modularity, as objects can be swapped or modified without affecting the entire system.
    - Composition promotes loose coupling, making it easier to maintain and evolve the code.

- **Key Differences:**
    - **Relationship:** Inheritance establishes an "is-a" relationship, while composition establishes a "has-a" relationship.
    - **Coupling:** Inheritance can lead to tight coupling between classes, whereas composition promotes loose coupling.
    - **Flexibility:** Composition offers greater flexibility and adaptability to changes in the system.
    - **Maintainability:** Loose coupling in composition makes it easier to maintain and evolve the code.

In this video we see the presenter chooses to use composition since a Warrior class is not an Animation but has an animation component to it.

Create Animation class

- Create a new Animation class (with .cpp) in a new folder src/Animation.
    - Add to the project when prompted
    - Add to Debug and Release targets



- Update Animation.h to capture all the elements required to animate a sprite.

```
1. #ifndef ANIMATION_H
2. #define ANIMATION_H
3.
4. #include <string>
```

```
 5. #include "SDL.h"
 6.
 7. class Animation
 8. {
 9.     public:
10.         Animation();
11.
12.         void Update();
13.         void Draw(float x, float y, int spriteWidth, int spriteHeight);
14.         void SetProps(std::string textureID, int spriteRow, int frameCount, int animSpeed,
SDL_RendererFlip flip=SDL_FLIP_NONE);
15.
16.     private:
17.         int m_SpriteRow;            // holds the sprite sheet row we are processing
18.         int m_SpriteFrame;          // holds the sprite or frame in the row we will draw next
19.         int m_AnimSpeed;            // holds the number of milliseconds we will display a frame
20.         int m_FrameCount;           // holds the total number of frames per row
21.         std::string m_TextureID;    // holds the sprite sheet texture/image ID
22.         SDL_RendererFlip m_Flip;    // holds the orientation of the image to display
23. };
24.
25. #endif // ANIMATION_H
```

Notice we moved all the member variables in Warrior to manage the sprites on a sprite sheet to the Animation class.

- Update Animation.cpp

```
 1. #include "Animation.h"
 2. #include "TextureManager.h"
 3.
 4. Animation::Animation()
 5. {
 6.     //ctor
 7. }
 8.
 9. void Animation::Update()
10. {
11.    m_SpriteFrame = (SDL_GetTicks() / m_AnimSpeed) % m_FrameCount;
12. }
13.
14. void Animation::Draw(float x, float y, int spriteWidth, int spriteHeight)
15. {
16.     TextureManager::GetInstance()->DrawFrame(m_TextureID, x, y, spriteWidth, spriteHeight,
m_SpriteRow, m_SpriteFrame, m_Flip);
17. }
18.
19. void Animation::SetProps(std::string textureID, int spriteRow, int frameCount, int animSpeed,
SDL_RendererFlip flip)
20. {
21.    m_TextureID = textureID;
22.    m_SpriteRow = spriteRow;
23.    m_FrameCount = frameCount;
24.    m_AnimSpeed = animSpeed;
25.    m_Flip = flip;
26. }
```

Update Warrior to utilize the new Animation class

- Edit the Warrior.h file
    - Comment out the m_Row, m_Frame, m_FrameCount and m_AnimSpeed
    - Add include for Animation.h
    - Create a new private member variable m_Animation

```
#ifndef WARRIOR_H
#define WARRIOR_H

#include <Character.h>
#include <Animation.h>

class Warrior : public Character
{
    public:
        Warrior(Properties* props);

        virtual void Draw();
        virtual void Update(float dt);
        virtual void Clean();


    private:
        //int m_Row, m_Frame, m_FrameCount;
        //int m_AnimSpeed;
        Animation* m_Animation;
};

#endif // WARRIOR_H
```

- Change the Warrior.cpp to match the changes:

```
#include "Warrior.h"
#include "SDL.h"
#include "TextureManager.h"


Warrior::Warrior(Properties* props): Character(props)
{
    m_Animation = new Animation();
    m_Animation->SetProps(m_TextureID, 0, 6, 80, SDL_FLIP_HORIZONTAL);
}

void Warrior::Draw()
{
    m_Animation->Draw(m_Transform->X, m_Transform->Y, m_Width, m_Height);
}

void Warrior::Update(float dt)
{
    m_Animation->Update();
}

void Warrior::Clean()
{
    TextureManager::GetInstance()->Clean();
```

```
25. }
```

The Warrior class relies on the m_Animation to manage the frame being displayed on the sprite sheet.

Note: We maintained the fact that our sprite row starts on the count of 0 and did not adjust for starting the count at 1. This is important if you don't "see" anything come up on the screen – you may be on the wrong row!

Test the program

- Compile and run the program you should see the same animation for the Warrior player as before

Figure 90 - Our Warrior class making use of the Animation class

9. Rigid Body and Game Physics in SDL Game

The concept of **RigidBody** in a 2D platformer game is crucial for handling physics-based movement and interactions. In game development, a **RigidBody** represents an object that follows the rules of physics, meaning it can move, collide, and be influenced by forces like gravity or impulse.

Here's why **RigidBody** is useful in a **2D platformer**:

1. **Realistic Movement:** It allows characters and objects to move naturally, with proper acceleration and deceleration, rather than just teleporting between positions.
2. **Collision Handling:** A RigidBody ensures that the character or object properly interacts with the game world, preventing unwanted clipping through walls or falling through platforms.

3. **Gravity Effects:** In a platformer, gravity plays a big role. By using a **RigidBody**, developers can control how characters fall, jump, or bounce off surfaces.
4. **Force-based Interactions:** RigidBody lets developers apply forces like jumps, pushes, or explosions that feel dynamic and believable.
5. **Platform Behavior:** Moving platforms, spring-like surfaces, or rotating objects can behave naturally using physics-based movement.

Most game engines, like **Unity**, allow developers to set up **RigidBody2D** components, where you can tweak properties like mass, drag, constraints, and collision layers to fine-tune the physics behavior.

We must start with our Vector2D class we created in video #5.

- The ***Vector2D*** class represents a 2D vector for position, velocity, and acceleration.
- The ***RigidBody*** class handles movement, force application, and gravity simulation
- ***Physics Update*** where acceleration affects velocity, which then updates the position
- ***Gravity Simulation***, where gravity continuously pulls the player downward
- ***Force Application***, where jump forces and external influences modify acceleration

An example to demonstrate physics

We will examine a simple example that demonstrates the physics around jumping and gravity. This example is intentionally simple, so you get a feel for what we are trying to do in this video.

- Create a new project “physics_example”
- Replace the contents of the main.cpp with the following code:

```
#include <SDL.h>
#include <iostream>

// Screen dimensions
const int SCREEN_WIDTH = 800;
const int SCREEN_HEIGHT = 600;

// Gravity constant
const float GRAVITY = 0.2f;

// Player structure with physics properties
struct Player {
    SDL_Rect rect;  // Position and size
    float velocityY;  // Vertical velocity
    bool isOnGround; // Ground check
```

```
16.
17.     Player(int x, int y, int w, int h) {
18.         rect = { x, y, w, h };
19.         velocityY = 0.0f;
20.         isOnGround = false;
21.     }
22.
23.     void applyGravity() {
24.         if (!isOnGround) {
25.             velocityY += GRAVITY;
26.         }
27.     }
28.
29.     void jump() {
30.         if (isOnGround) {
31.             velocityY = -12.0f; // Jump force
32.             isOnGround = false;
33.         }
34.     }
35.
36.     void update() {
37.         applyGravity();
38.         rect.y += static_cast<int>(velocityY);
39.
40.         // Simulate ground collision (simple floor check)
41.         if (rect.y + rect.h >= SCREEN_HEIGHT) {
42.             rect.y = SCREEN_HEIGHT - rect.h;
43.             velocityY = 0;
44.             isOnGround = true;
45.         }
46.     }
47. };
48.
49. // Main SDL application loop
50. int main(int argc, char* argv[]) {
51.     if (SDL_Init(SDL_INIT_VIDEO) < 0) {
52.         std::cerr << "SDL Initialization Failed: " << SDL_GetError() << std::endl;
53.         return -1;
54.     }
55.
56.     SDL_Window* window = SDL_CreateWindow("2D Platformer Physics",
57.                                           SDL_WINDOWPOS_CENTERED, SDL_WINDOWPOS_CENTERED,
58.                                           SCREEN_WIDTH, SCREEN_HEIGHT, SDL_WINDOW_SHOWN);
59.
60.     SDL_Renderer* renderer = SDL_CreateRenderer(window, -1, SDL_RENDERER_ACCELERATED);
61.
62.     Player player(50, 50, 50, 50); // Initialize player position
63.
64.     bool running = true;
65.     SDL_Event event;
66.
67.     while (running) {
68.         while (SDL_PollEvent(&event)) {
69.             if (event.type == SDL_QUIT) {
70.                 running = false;
71.             }
72.             if (event.type == SDL_KEYDOWN) {
73.                 if (event.key.keysym.sym == SDLK_SPACE) {
74.                     player.jump();  // Jump when Space is pressed
75.                 }
76.             }
77.         }
78.
79.         player.update(); // Update physics
80.
```

```
81.         // Rendering
82.         SDL_SetRenderDrawColor(renderer, 0, 0, 0, 255); // Clear screen (black)
83.         SDL_RenderClear(renderer);
84.
85.         SDL_SetRenderDrawColor(renderer, 255, 255, 255, 255); // Draw player (white)
86.         SDL_RenderFillRect(renderer, &player.rect);
87.
88.         SDL_RenderPresent(renderer); // Display frame
89.
90.         SDL_Delay(16); // Simulate ~60 FPS
91.     }
92.
93.     SDL_DestroyRenderer(renderer);
94.     SDL_DestroyWindow(window);
95.     SDL_Quit();
96.
97.     return 0;
98. }
99.
```

```
1. #include <SDL.h>
```

Line #1 adds the use of SDL functions to the program. I did not have to do the same setup we did for the current video project (adding SDL header and lib folders configuration) since I saved that configuration so that all my projects will start with same set of libraries.

```
 8. // Gravity constant
 9. const float GRAVITY = 0.2f;
```

One of the forces defined in the game is gravity and the other is the one initiated on the “player” or block representing the player when they click on the “jump” key (space bar). If you want gravity to have a stronger effect just increase the const value.

We need to remember that GRAVITY is in the down direction of y on the screen. The next figure illustrates how this works:

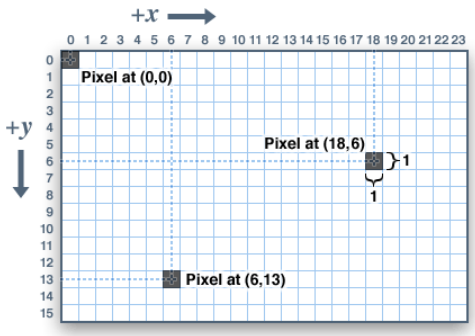


Figure 91 - The screen coordinates (from: https://learn.adafruit.com/adafruit-gfx-graphics-library/coordinate-system-and-units)

So to pull an object down we add +y value to it, this is why GRAVITY is set to 0.2f.

We start to define the Player (a rectangular block for us) at line 12:

```
12. struct Player {
```

```
13.     SDL_Rect rect;  // Position and size
14.     float velocityY;  // Vertical velocity
15.     bool isOnGround; // Ground check
```

The player will be represented on the screen by a rectangular block. The player will track two key values: current velocity (velocityY) and a boolean to indicate if the player is on the ground or not (isOnGround). The player can only have velocity in the Y direction and can only jump if it is on the ground.

Lines 17-21 initializes the player.

```
17.     Player(int x, int y, int w, int h) {
18.         rect = { x, y, w, h };
19.         velocityY = 0.0f;
20.         isOnGround = false;
21.     }
```

The (x,y) defines the top-left pixel location. We initialize the SDL_Rect. The player starts with 0 velocity and is not on the ground. We will start the program with the player falling down until it hits the ground.

The game loop start on line 67:

```
67.     while (running) {
```

In the game loop we do the following:

- Check for any keyboard events
    - If player closes the window => we stop running the game
    - If the player presses on SPACE BAR we invoke the jump command if the player is on the ground

```
29.     void jump() {
30.         if (isOnGround) {
31.             velocityY = -12.0f; // Jump force
32.             isOnGround = false;
33.         }
34.     }
```

Simulating a player jumping is the player moving up or in the -Y direction.

- Update the player location

```
36.     void update() {
37.         applyGravity();
38.         rect.y += static_cast<int>(velocityY);
39.
```

```
40.         // Simulate ground collision (simple floor check)
41.         if (rect.y + rect.h >= SCREEN_HEIGHT) {
42.             rect.y = SCREEN_HEIGHT - rect.h;
43.             velocityY = 0;
44.             isOnGround = true;
45.         }
46.     }
```

We first applyGravity, that is we modify the current velocity of the player moving up by the value of GRAVITY pulling the player down:

```
23.     void applyGravity() {
24.         if (!isOnGround) {
25.             velocityY += GRAVITY;
26.         }
27.     }
```

We really don't have time in this example but the game loop has a 15 ms delay:

```
90.         SDL_Delay(16); // Simulate ~60 FPS
```

Since 1000 ms / 60 = 16ms an SDL_Delay(16) ensures the game loop runs at 60 frames or updates per second.

- Draw the player on the screen.

Figure 92 - animated gif of gravity and jumping physics

Every time through the loop the player's velocity is adjusted by applying GRAVITY value to it, until the player hits the bottom of the screen.

This example is quite simple (only two possible forces) and we only move in one direction (up or down).

Incorporating Physics in our SDL2 game

The topic of how to handle physics can fill a book and in fact there are many good books that cover the topic. The example program above hopefully gave you an intuitive feeling for what we are trying to do by adding physics to the game.

In a 2D platform game, physics plays a crucial role in creating a smooth, responsive, and realistic experience. Let's break it down:

1. Velocity – This refers to the speed and direction of your character's movement. In a platformer, velocity often determines how fast a character moves horizontally across the level or falls vertically due to gravity. If a character has a positive velocity moving right, they will continue in that direction until acted upon by another force (such as friction or acceleration).

2. Acceleration – Acceleration is the rate at which velocity changes over time. When a player holds the movement key, the character accelerates to its top speed rather than instantly reaching it. Similarly, when a character jumps, an initial burst of acceleration propels them upward, until gravity slows them down.

3. Gravity – Gravity constantly pulls objects down toward the ground. In most platformers, gravity ensures that characters fall back to the ground after jumping. The strength of gravity can be adjusted—higher gravity makes jumps feel heavier and shorter, while lower gravity allows for floatier movements.

4. Friction – Friction slows down movement when an object is in contact with a surface. In a platformer, friction affects how quickly a character stops when the player releases the movement key. Low friction results in sliding effects, while high friction allows for quick stops.

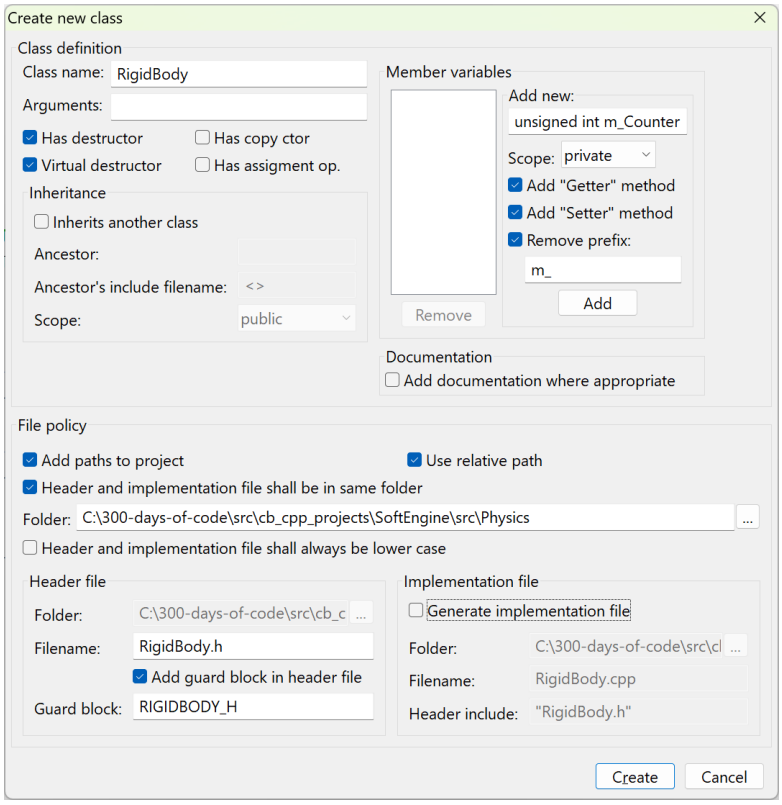
Putting It Together in Gameplay:

When a character jumps:

- **Upward velocity** is initially high.
- **Gravity** reduces velocity gradually until it reaches zero (the peak of the jump).
- As the character falls, **gravity accelerates them downward** until they land on the ground.
- If they land on a slippery surface, **low friction** could cause them to slide rather than stop immediately.
- If they are running, **acceleration** determines how quickly they reach top speed.

Creating a RigidBody.h file

- Create a RigidBody class (no implementation) in the Physics folder:



- We will be using Vector2D

```
#include "Vector2D.h"
```

- We will add the private member variables that define the elements that pertain to a rigid body:

```
 1.     private:
 2.         float m_Mass;
 3.         float m_Gravity;
 4.
 5.         Vector2D m_Force;
 6.         Vector2D m_Friction;
 7.
 8.         Vector2D m_Position;
 9.         Vector2D m_Velocity;
10.         Vector2D m_Acceleration;
11.
```

- Add #define for default values of mass and gravity:

```
1. // The default unit mass of a rigid body entity
```

```
2. #define UNIT_MASS 1.0f
3.
4. // The default gravity to use for any rigid body
5. #define GRAVITY 9.8f
```

- Remove the destructor
- Edit the constructor to set mass and gravity member variables to the default:

```
1.     public:
2.         RigidBody() {
3.             m_Mass = UNIT_MASS;
4.             m_Gravity = GRAVITY;
5.         }
6.
```

- Add setters for gravity and mass

```
1.     public:
2.         RigidBody() {
3.             m_Mass = UNIT_MASS;
4.             m_Gravity = GRAVITY;
5.         }
6.
7.     inline void SetMass(float mass) { m_Mass = mass;}
8.     inline void SetGravity(float gravity) { m_Gravity = gravity;}
9.
```

- Add similar functions for Force and Friction

```
 1.     // Force
 2.     inline void ApplyForce(Vector2D F) { m_Force = F;}
 3.     inline void ApplyForceX(float Fx) { m_Force.X = Fx; }
 4.     inline void ApplyForceY(float Fy) { m_Force.Y = Fy; }
 5.     inline void UnSetForce() { m_Force = Vector2D(0,0);}
 6.
 7.     // Friction
 8.     inline void ApplyFriction(Vector2D Fr) { m_Friction = Fr;}
 9.     inline void UnSetFriction() { m_Friction = Vector2D(0,0);}
10.
```

- Add getters for key attributes:

```
1.     // Add Getters
2.     inline float GetMass() { return m_Mass; }
3.     inline Vector2D Position() { return m_Position; }
4.     inline Vector2D Velocity() { return m_Velocity; }
5.     inline Vector 2D Acceleration() { return m_Acceleration;}
```

- Add code to update the key parameters for the rigid body

```
1.     // Update methods
```

```
2.      void Update(float dt) {
3.          m_Acceleration.X = (m_Force.X + m_Friction.X) / m_Mass;
4.          m_Acceleration.Y = m_Gravity + m_Force.Y/m_Mass;
5.          m_Velocity = m_Acceleration * dt;
6.          m_Position = m_Velocity * dt;
7.      }
8.
```

The entire RigidBody.h file:

```
 1. #ifndef RIGIDBODY_H
 2. #define RIGIDBODY_H
 3.
 4. #include "Vector2D.h"
 5.
 6. // The default unit mass of a rigid body entity
 7. #define UNIT_MASS 1.0f
 8.
 9. // The default gravity to use for any rigid body
10. #define GRAVITY 9.8f
11.
12. class RigidBody
13. {
14.     public:
15.         RigidBody() {
16.             m_Mass = UNIT_MASS;
17.             m_Gravity = GRAVITY;
18.         }
19.
20.     inline void SetMass(float mass) { m_Mass = mass;}
21.     inline void SetGravity(float gravity) { m_Gravity = gravity;}
22.
23.     // Force
24.     inline void ApplyForce(Vector2D F) { m_Force = F;}
25.     inline void ApplyForceX(float Fx) { m_Force.X = Fx; }
26.     inline void ApplyForceY(float Fy) { m_Force.Y = Fy; }
27.     inline void UnSetForce() { m_Force = Vector2D(0,0);}
28.
29.     // Friction
30.     inline void ApplyFriction(Vector2D Fr) { m_Friction = Fr;}
31.     inline void UnSetFriction() { m_Friction = Vector2D(0,0);}
32.
33.
34.     // Add Getters
35.     inline float GetMass() { return m_Mass; }
36.     inline Vector2D Position() { return m_Position; }
37.     inline Vector2D Velocity() { return m_Velocity; }
38.     inline Vector2D Acceleration() { return m_Acceleration;}
39.
40.     // Update methods
41.     void Update(float dt) {
42.         m_Acceleration.X = (m_Force.X + m_Friction.X) / m_Mass;
43.         m_Acceleration.Y = m_Gravity + m_Force.Y/m_Mass;
44.         m_Velocity = m_Acceleration * dt;
45.         m_Position = m_Velocity * dt;
46.     }
47.
48.     private:
49.         float m_Mass;
50.         float m_Gravity;
51.
52.         Vector2D m_Force;
```

```
53.         Vector2D m_Friction;
54.
55.         Vector2D m_Position;
56.         Vector2D m_Velocity;
57.         Vector2D m_Acceleration;
58.
59. };
60.
61. #endif // RIGIDBODY_H
62.
```

Update Our Warrior class

We will now add code to our `Warrior` class to utilize the `RigidBody` class to see the effects of gravity on our warrior.

- Add a new `RigidBody` member variable to `Warrior.h`:

```
 1. #ifndef WARRIOR_H
 2. #define WARRIOR_H
 3.
 4. #include "Character.h"
 5. #include "Animation.h"
 6. #include "RigidBody.h"
 7.
 8. class Warrior : public Character
 9. {
10.     public:
11.         Warrior(Properties* props);
12.
13.         virtual void Draw();
14.         virtual void Update(float dt);
15.         virtual void Clean();
16.
17.
18.     private:
19.         Animation* m_Animation;
20.         RigidBody* m_RigidBody;
21. };
22.
23. #endif // WARRIOR_H
24.
```

- Initialize our m_RigidBody in Warrior constructor:

```
1. Warrior::Warrior(Properties* props): Character(props)
2. {
3.     m_RigidBody = new RigidBody();
4.     m_Animation = new Animation();
5.     m_Animation->SetProps(m_TextureID, 0, 6, 80, SDL_FLIP_HORIZONTAL);
6. }
```

- Add code in the Warrior.cpp Update function to Update our RigidBody and apply to the Warrior:

```
1. void Warrior::Update(float dt)
2. {
3.     m_RigidBody->Update(0.2);
4.     m_Transform->TranslateX(m_RigidBody->Position().X);
5.     m_Transform->TranslateY(m_RigidBody->Position().Y);
6.
7.     m_Animation->Update();
8. }
```

Figure 93 - Our Warrior moving down due to gravity

We only expect to see movement in the Y direction due to gravity.

Let's add a force in the X direction to see what happens:

```
1. void Warrior::Update(float dt)
2. {
3.     m_RigidBody->Update(0.2);
4.     m_RigidBody->ApplyForceX(5.0);
5.     m_Transform->TranslateX(m_RigidBody->Position().X);
6.     m_Transform->TranslateY(m_RigidBody->Position().Y);
7.
8.     m_Animation->Update();
9. }
```

The player now moves in two directions – down due to gravity and right due to some force:

Figure 94 - Our Warrior moving down and to the right

As you can see from the animated gif above adding a positive force in the X direction moves our fearless warrior down (due to gravity) and to the right.

10. Event Handler in SDL Game

In a game loop, an **event** refers to an action or occurrence that the game detects and responds to. Events can be triggered by player interactions (like pressing a key, clicking a mouse, or touching the screen), system updates (such as a timer expiring or a collision happening), or external inputs (like network messages).

Game loops typically follow these steps:

1. **Event Handling:** The game checks for user input or system events.
2. **Update:** The game state is modified based on events, physics calculations, AI behavior, etc.
3. **Render:** The visuals are updated to reflect the new game state.

Events help make games interactive and dynamic!

We handle events in the Main.cpp file:

```
1.      while (Engine::GetInstance()->isRunning()) {
2.          // Get all current events (e.g. mouse clicks, etc.)
3.          Engine::GetInstance()->Events();
4.
5.          // Update all objects/entities
6.          Engine::GetInstance()->Update();
7.
8.          // Render/update the game graphics
9.          Engine::GetInstance()->Render();
```

```
    }

```

We can see that the events or inputs are handled in the Engine::Events() function:

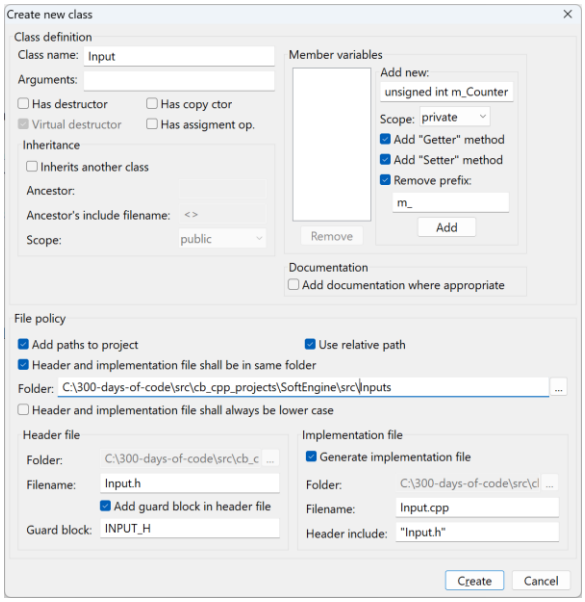
```
void Engine::Events()
{
    SDL_Event event;
    SDL_PollEvent(&event);
    switch(event.type) {
    case SDL_QUIT:
        Quit();
        break;
    }
}
```

At this point in the game the only event we handle is SDL_QUIT which is issued when the user closes the application.

The objective of this video is to move all the event handling into a specific class named Input. This new Input class will be constructed as a singleton similar to Engine and TextureManager.

Create the Input Class

- Select the “New File” icon and create the Input class (with implementation) in a new folder src/Inputs:



Note: I checked off the “Has destructor check box above, since we usually delete the virtual destructor.

- Make the file into a singleton using a similar method we employed for Engine and TextureManager class:
    - First move the constructor into the private section and add the s_Instance member:

```
 1. class Input
 2. {
 3.     public:
 4.
 5.
 6.     protected:
 7.
 8.     private:
 9.       Input();
10.       static Input* s_Instance;
11. };
```

    - So we don't forget initialize the s_Instance to the nullptr in the associated cpp file:

```
1. #include "Input.h"
2.
3. Input* Input::s_Instance = nullptr;
4.
5. Input::Input()
6. {
7.     //ctor
8. }
9.
```

- Add the public GetInstance() method to Input.h:

```
1.     public:
2.         static Input* GetInstance() {
3.             return s_Instance = (s_Instance != nullptr) ? s_Instance : new Input();
4.         }
5.
```

A **Singleton** is a design pattern used in software development to ensure that a class has only **one** instance and provides a global access point to it. Here are some key reasons to use a Singleton:

1. Controlling Access to Resources

- When managing shared resources like **database connections, logging systems, or configuration settings**, a Singleton ensures consistent access and prevents multiple instances from consuming unnecessary memory.

2. Reducing Memory Usage

- Since Singleton objects are created only **once**, they help minimize memory footprint, especially when objects are expensive to create and maintain.

3. Enforcing Global State

- Certain components, such as **caching systems or thread pools**, require a single point of control to maintain uniform behavior across the application.

4. Preventing Multiple Instances

- If you need a class to have **strictly one instance** throughout the execution of the program (like a game manager or a settings manager), a Singleton guarantees this constraint.

5. Improving Performance

- Rather than creating multiple instances and incurring additional processing costs, a Singleton allows reuse, enhancing efficiency.

However, **overusing Singletons** can lead to issues such as **hidden dependencies**, **difficulty in unit testing**, and **potential bottlenecks in multi-threaded applications**. They should be used thoughtfully where **global access and single instance control are truly necessary**.

What are SDL_Scancodes?

In the context of SDL (Simple DirectMedia Layer), **scancodes** represent the physical position of a key on the keyboard, independent of the current keyboard layout. They are used to ensure game controls and other applications respond consistently to the same key on different keyboard layouts (e.g., US QWERTY, French AZERTY).

Here's a more detailed explanation:

- **Layout-Independent:**

Scancodes are designed to represent the key's physical location on the keyboard, regardless of the active layout.

- **Example:**

If a player presses the "W" key (for movement) on a French AZERTY keyboard, the scancode will still be the same as if they pressed the "W" key on a US QWERTY keyboard.

- **Contrast with Keycodes:**

Keycodes, on the other hand, are based on the current keyboard layout and can change depending on the active language/layout.

- **Usage in Games:**

Scancodes are commonly used in games, especially for movement controls, as they ensure consistency regardless of the player's keyboard layout.

- **SDL Implementation:**

SDL uses SDL_Scancode values to represent these physical key locations.

- **Key Constants:**

Scancode values are defined as constants, such as SDL_SCANCODE_A, SDL_SCANCODE_B, etc., as shown in the provided resources.

The list of scancode can be found here: https://wiki.libsdl.org/SDL3/SDL_Scancode

Adding functions to Input.h

We will add private and public functions to Input.h.

```
#ifndef INPUT_H
#define INPUT_H

#include "SDL.h"

class Input
{
    public:
        // Only ever have one instance of Input in our program
        static Input* GetInstance() {
            return s_Instance = (s_Instance != nullptr) ? s_Instance : new Input();
        }

        void Listen();

        // Used to let the client know if a specific key has been pressed
        bool GetKeyDown(SDL_Scancode key);

    private:
      Input();
      void KeyUp();
      void KeyDown();

      // An array that tracks all the keys that are currently being pushed
      const Uint8* m_KeyStates;
      static Input* s_Instance;
};

#endif // INPUT_H
```

The Listen() function will replace the logic we had in the Engine::Events to handle the incoming keyboard functions, it will obtain the incoming events and process them. The GetKeyDown() is

utilized by clients to determine if the key of interest (e.g. did the user press the right-arrow?) has been pressed.

The m_KeyStates will utilize an SDL function `SDL_KeyboardState` to obtain the set of key states.

SDL_GetKeyboardState

Get a snapshot of the current state of the keyboard.

Syntax

```
const Uint8* SDL_GetKeyboardState(int *numkeys);
```

Function Parameters

int *	**numkeys**	if non-NULL, receives the length of the returned array.

Returns

(const Uint8 *) Returns a pointer to an array of key states.

Remarks

The pointer returned is a pointer to an internal SDL array. It will be valid for the whole lifetime of the application and should not be freed by the caller.

An array element with a value of 1 means that the key is pressed and a value of 0 means that it is not. Indexes into this array are obtained by using SDL_Scancode values.

Use SDL_PumpEvents() to update the state array.

This function gives you the current state after all events have been processed, so if a key or button has been pressed and released before you process events, then the pressed state will never show up in the SDL_GetKeyboardState() calls.

Note: This function doesn't take into account whether shift has been pressed or not.

We will utilize this array to determine if a key has been pressed (or released).

Implement the functions in Input.cpp

- Open Input.cpp for editing
- Add all the unimplemented functions

```cpp
#include "Input.h"
#include "Engine.h"

Input* Input::s_Instance = nullptr;

Input::Input()
{
    // Obtain the initial state of the keyboard
    m_KeyStates = SDL_GetKeyboardState(nullptr);
}

void Input::Listen()
{
    SDL_Event event;

    while(SDL_PollEvent(&event)) {
        switch(event.type) {
            case SDL_QUIT:
                // User requested application close
                Engine::GetInstance()->Quit();
                break;
            case SDL_KEYDOWN:
                KeyDown();
                break;
            case SDL_KEYUP:
                KeyUp();
                break;
            default:
                break;
        }
    }
}

bool Input::GetKeyDown(SDL_Scancode key)
{
    if (m_KeyStates[key] == 1) {
        return true;
    } else {
        return false;
    }
}

void Input::KeyUp()
{
    // Update our keyboard array
    m_KeyStates = SDL_GetKeyboardState(nullptr);
}

void Input::KeyDown()
{
    // Update the keyboard array
    m_KeyStates = SDL_GetKeyboardState(nullptr);
}
```

Update Engine::Events

We need to change the logic in Engine::Events to utilize the Input::Listen() function.

- First add the include Input.h header to Engine.cpp
- Modify the Engine::Events to:

```
1. void Engine::Events()
2. {
3.     Input::GetInstance()->Listen();
4. }
```

Test things out

Let's update the Engine::Update to check if the key "A" is press and print out a message using SDL_log

- Add code to Engine::Update():

```
1. void Engine::Update()
2. {
3.     if (Input::GetInstance()->GetKeyDown(SDL_SCANCODE_A)) {
4.         SDL_Log("Key A pushed!");
5.     }
6.     player->Update(0);
7. }
8.
```

- Run the application and press the key "A" on your keyboard:

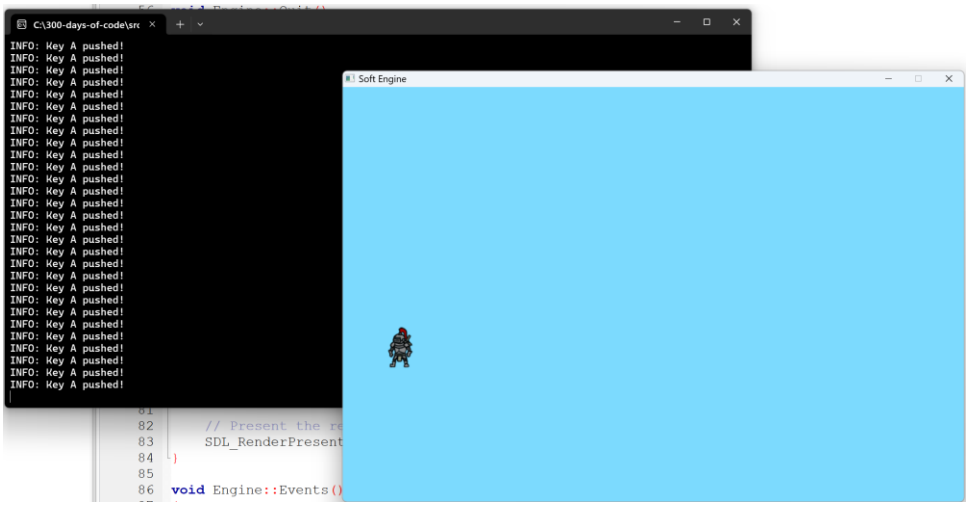


Figure 95 - Testing the Input class!

Note: In my current version of the code I am applying a forceX in the negative direction. This is set here:

```
1. void Warrior::Update(float dt)
2. {
3.     m_RigidBody->Update(0.2);
4.     m_RigidBody->ApplyForceX(-5.0);
5.     m_Transform->TranslateX(m_RigidBody->Position().X);
6.     m_Transform->TranslateY(m_RigidBody->Position().Y);
7.
8.     m_Animation->Update();
```

```
9. }
```

To get it to match the video movement just restore back to 5.0.

11. Player Animation

In this video we do not introduce new concepts or classes but utilize the existing code to get our warrior player to run left or right in response to key presses and idle in place when no keys are being pressed.

Introducing the Run Sprite Sheet

We will add a new sprite sheet named Run.png:

Figure 96 - The running sprite sheet

This sprite sheet has one row with eight frames to depict the warrior running. This is different than our previous sprite sheet with one row and six frames.

Let's review how our current Idle sprite works

We know when we start our application that the sprite moves down and to the right because of the force of gravity (pulling it down) and a positive force in the X direction.

1. The Idle texture gets loaded in the Engine::Init()

```
TextureManager::GetInstance()->Load("player", "assets/Idle.png");
```

The above finds the sprite image on your PC and converts it into an `SDL_Texture`. The sprite sheet is saved on a map structure named `m_TextureMap` so we can access it when needed using the `TextureManager::Draw()` or `TextureManager::DrawFrame()` functions.

2. We initialize our warrior player with the properties of location (x,y) and width and height.

```
player = new Warrior(new Properties("player", 100, 200, 136, 96));
```

A good question is - what will be the width and height of the warrior "running" frames? The sprite properties are 1088 x 96. The height is the same 96 pixels. The width of each frame is

1088 / 8 = 136 pixels. This matches our Idle sprite sheet properties – so this will stay invariant between the two sheets.

3. During the `Update()` phase of the game loop is when we get the warrior player updated for the next position (if running) and frame. The player Update() is invoked in the Engine::Update function:

```
player->Update(0);
```

At this time, we are not using time so we set the dt value to 0. Currently the Warrior::Update() is doing several things:

```
1. void Warrior::Update(float dt)
2. {
3.     m_RigidBody->Update(0.2);
4.     m_RigidBody->ApplyForceX(5.0);
5.     m_Transform->TranslateX(m_RigidBody->Position().X);
6.     m_Transform->TranslateY(m_RigidBody->Position().Y);
7.
8.     m_Animation->Update();
9. }
```

Line 3 invokes the RigidBody Update with 0.2. We are hardcoding the dt value in the RigidBody to update the Velocity (using gravity as the only thing impacting velocity) and hence the position of the warrior player on our screen. We will change this hardcoding in the future.

Line 4 is where we are moving the player to the right as it falls.

Line 5 and 6 update the X and Y position of the player

Line 8 is used to invoke the Animation logic to display the right frame.

```
5  void Animation::Update()
6  {
7      m_SpriteFrame = (SDL_GetTicks() / m_AnimSpeed) % m_FrameCount;
8  }
```

After an Update() the next phase in our game loop is to Render() the player on the screen.

4. Render/Draw the player on the screen

In `Engine::Render` we invoke:

```
78
79      // Draw our Warrior
80      player->Draw();
81
```

to draw the current player.

```
12
13  void Warrior::Draw()
14  {
15      m_Animation->Draw(m_Transform->X, m_Transform->Y, m_Width, m_Height);
16  }
17
```

In this video the above will not need to be changed since it uses the (x,y) location of the object and both frames are using the same width and height.

Loading the Run sprite sheet

- Update the Engine::Init to also load the Run.png sprite sheet:

```
1.      // Load sprite sheet of the playing in idle state
2.      TextureManager::GetInstance()->Load("player", "assets/Idle.png");
3.      // Load sprite sheet of the player running
4.      TextureManager::GetInstance()->Load("player_run", "assets/Run.png");
5.      // Set the player's initial position on the screen and the size of each frame
6.      player = new Warrior(new Properties("player", 100, 200, 136, 96));
// Load sprite sheet of the playing in idle state
```

Line 4 above loads our new sprite of the player running.

Testing our new sprite

- Change Line #6 above in Engine::Init so that it invokes our Warrior running first

```
player = new Warrior(new Properties("player_run", 100, 200, 136, 96));
```

- Update the Warrior constructor to start with our 8 frame animation:

```
1. Warrior::Warrior(Properties* props): Character(props)
2. {
3.      m_RigidBody = new RigidBody();
4.      m_Animation = new Animation();
5.      m_Animation->SetProps(m_TextureID, 0, 8, 100);
6. }
```

Note: That we dropped the last parameter so the image does not get flipped and changed the animation speed from 80 to 100 to slow things down a bit.

- Let's drop gravity from affecting our player by commenting out the transformation of Y

```
1. void Warrior::Update(float dt)
2. {
3.      m_RigidBody->Update(0.2);
4.      // This moves the player to the right on positive value
5.      m_RigidBody->ApplyForceX(20.0);
```

```
 6.      m_Transform->TranslateX(m_RigidBody->Position().X);
 7.      //m_Transform->TranslateY(m_RigidBody->Position().Y);
 8.
 9.      m_Animation->Update();
10. }
11.
```

I found I had to increase the value of ApplyForceX from 5 to 20 in order to make the running images/frames match how far the player was getting across the screen (otherwise it looked like he was running so fast and not getting far at all!).

Notice line 7 is commented out to dismiss the change due to gravity.

If you compile and run you should see the player running across your screen.

Another Option

I found I missed the fact that the video increased the speed of the player by increasing the Update in the RigidBody. So there is the video's option:

```
 1. void Warrior::Update(float dt)
 2. {
 3.      m_RigidBody->Update(0.8);
 4.      // This moves the player to the right on positive value
 5.      m_RigidBody->ApplyForceX(5);
 6.      m_Transform->TranslateX(m_RigidBody->Position().X);
 7.      //m_Transform->TranslateY(m_RigidBody->Position().Y);
 8.
 9.      m_Animation->Update();
10. }
```

Process A and D keys

We will now add logic to the game to either:

- Idle if no keys are being pressed – this is the default
- If A key is pressed the player runs to the left
    - This will require changing the orientation of the player
- If D key is pressed the player runs to the right

Clean up Engine::Update

Remove the code that Logged the A key press from the previous video:

```
1. void Engine::Update()
2. {
3.     player->Update(0);
4. }
```

Add code in Warrior::Update to move left and right (or backwards and forwards)

```
1. void Warrior::Update(float dt)
2. {
3.     if (Input::GetInstance()->GetKeyDown(SDL_SCANCODE_A)) {
4.         // player is moving left/backwards
5.     }
6.
7.     if (Input::GetInstance()->GetKeyDown(SDL_SCANCODE_D)) {
8.         // player is moving right/forwards
9.     }
10.                :
11.                :
12. }
```

First we add the infrastructure code to respond to the the A and D keys ..

If neither are being pressed what should occur? We should display the player idle texture frames and not apply any force at all.

- Enter the following and compile and execute (do not press any keys yet):

```
1. void Warrior::Update(float dt)
2. {
3.     // Default to player being idle
4.     m_Animation->SetProps("player", 0, 6, 100);
5.     // Unset any and all forces by default
6.     m_RigidBody->UnSetForce();
7.
8.     if (Input::GetInstance()->GetKeyDown(SDL_SCANCODE_A)) {
9.         // player is moving left/backwards
10.    }
11.
12.    if (Input::GetInstance()->GetKeyDown(SDL_SCANCODE_D)) {
13.        // player is moving right/forwards
14.    }
15.
16.    m_RigidBody->Update(0.8);
17.    m_Transform->TranslateX(m_RigidBody->Position().X);
18.    //m_Transform->TranslateY(m_RigidBody->Position().Y);
19.
20.    m_Animation->Update();
21. }
```

When you compile and run you should see the warrior player by default idling on the screen.

Add some constants

What does it mean to move left or backwards? It means the X value is negative. To move right or forwards is the X value is positive. Similarly for moving up and down in the Y direction. We will define the following constants in the RigidBody.h file:

```
#define FORWARD 1
#define BACKWARD -1

#define UPWARD -1
#define DOWNWARD 1
```

When the player hits the A key we want to:

- Change over to the player_run texture
- Apply our force in the negative X direction

When the player hits the D key we want to:

- Change over to the player_run texture
- Apply our force in the positive X direction

The code is:

```
void Warrior::Update(float dt)
{
    // Default to player being idle
    m_Animation->SetProps("player", 0, 6, 100);
    // Unset any and all forces by default
    m_RigidBody->UnSetForce();

    if (Input::GetInstance()->GetKeyDown(SDL_SCANCODE_A)) {
        // player is moving left/backwards
        m_RigidBody->ApplyForceX(5*BACKWARD);
        // need to reset the animation to player_run and flip on horizontal
        m_Animation->SetProps("player_run", 0, 8, 100, SDL_FLIP_HORIZONTAL);
    }

    if (Input::GetInstance()->GetKeyDown(SDL_SCANCODE_D)) {
        // player is moving right/forwards
        m_RigidBody->ApplyForceX(5*FORWARD);
        // need to reset the animation to player_run
        m_Animation->SetProps("player_run", 0, 8, 100);
    }

    m_RigidBody->Update(0.8);
    m_Transform->TranslateX(m_RigidBody->Position().X);
    //m_Transform->TranslateY(m_RigidBody->Position().Y);

    m_Animation->Update();
}
```

The following figure illustrates our warrior responding to A and D key presses and no key press.

Figure 97 - Warrior player responding to A and D key presses

That's it for this video. We animated our warrior player to respond to input, more importantly we transitioned from idle to running left or right.

12. Delta Time

This video will add the concept of time to the game. The goal is to display or render the screen at ideally at 60 frames[12] per second (FPS).

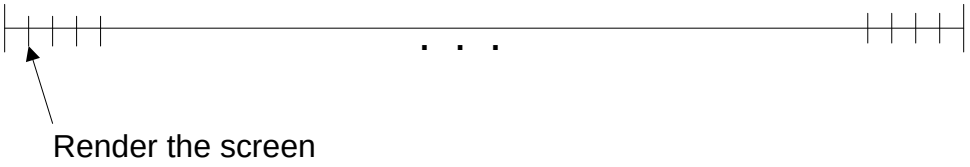


Figure 98 - We want to render the screen every 1/60 seconds.

The above illustrates the ticks on a line where ideally the game completes the game loop within each tick. Imagine you have a game character moving across the screen at 5 pixels per frame. Inside the game loop we would do the following:

1. Process inputs
2. Update all entities
3. Render the screen
4. Go back to 1

[12] The use of the word "frames" refers to the painting of the screen not sprite sheet images.

We would like to hit the "render the screen" part of the code at ideally 1000ms/ 60 or every 16.6 milliseconds. The problem is that some machines are faster than others and don't necessarily complete the game loop in exactly 16.6 ms. If we render too quickly our game character moves across the screen too quickly but if our machine is too slow the game character appears to be moving across the screen too slowly. The goal is for the gamer player to experience the same movement regardless of their machine.

The goal is to achieve as close to 60 FPS. Why 60? Most computer monitors refresh the screen at 60 times per second so anything faster probably will not provide a visible benefit.

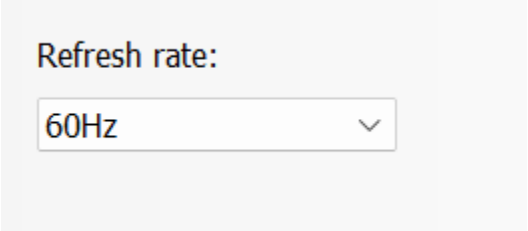


Figure 99 - From my NVIDIA panel

SDL provides a perfect monotonic counter `SDL_GetTicks`[13]. We have used this function to help us determine how fast to go through each animation frame.

The video discusses the need to have a "clock" or timer because of the different monitor refresh rates. In fact, the reason we want a timer is so that the action on the screen moves the same way regardless of how fast or slow a game player's CPU runs. For example, in older games that did not time things because it was written for an IBM 486 model computer the game on a modern machine would just run too fast – everything would whiz around too fast because the game designers did not time how long a game loop tick should take. So the main reason for a timer or clock is so we can manage the entities on the screen to the same rate of change regardless of CPU power.

Create Timer class

Create a new Timer class (with *.cpp and *.h files). The class will be created in a new folder src/Timer. The option to create destructor should be removed.

- Remove the Timer::Timer() constructor in the *.cpp
- Add an empty constructor in the Timer.h file

```
1. #ifndef TIMER_H
```

[13] SDL provides a high-resolution performance API that improves on SDL_GetTicks – SDL_GetPerformanceCounter() and SDL_GetPerformanceFrequency().

```
 2. #define TIMER_H
 3.
 4.
 5. class Timer
 6. {
 7.     public:
 8.         Timer() {};
 9.
10.     private:
11. };
12.
13. #endif // TIMER_H
```

This class will be constructed as a singleton.

- Move the constructor to private since we plan on making this class a singleton

```
 1. #ifndef TIMER_H
 2. #define TIMER_H
 3.
 4.
 5. class Timer
 6. {
 7.     public:
 8.         inline static Timer* GetInstance() { return s_Instance = (s_Instance != nullptr) ?
s_Instance : new Timer();}
 9.     private:
10.         Timer() {};
11.         static Timer* s_Instance;
12.
13. };
14.
15. #endif // TIMER_H
16.
```

- Make sure to initialize s_instance in the *.cpp file to nullptr:

```
1. #include "Timer.h"
2.
3. Timer* Timer::s_Instance = nullptr;
4.
```

- Add key functions and member variables to Timer.h

```
 1. #ifndef TIMER_H
 2. #define TIMER_H
 3.
 4. const int TARGET_FPS = 60;
 5. const float TARGET_DELTATIME = 1.5f; // 1.5 milliseconds
 6.
 7. class Timer
 8. {
 9.     public:
10.         inline static Timer* GetInstance() { return s_Instance = (s_Instance != nullptr) ?
s_Instance : new Timer();}
11.
```

```
12.         void Tick();
13.         inline float GetDeltaTime() { return m_DeltaTime; }
14.     private:
15.         Timer() {};
16.         static Timer* s_Instance;
17.         float m_DeltaTime;  // The difference between now and last time of a tick
18.         float m_LastTime;   // holds the last time we recorded a tick()
19. };
20.
21. #endif // TIMER_H
22.
```

- Implement the Timer::Tick() in Timer.cpp file:

```
 1. #include "Timer.h"
 2. #include "SDL.h"
 3.
 4. Timer* Timer::s_Instance = nullptr;
 5.
 6. void Timer::Tick() {
 7.     m_DeltaTime = (SDL_GetTicks() - m_LastTime) * (TARGET_FPS/1000.0f);
 8.
 9.     if (m_DeltaTime > TARGET_DELTATIME) {
10.         m_DeltaTime = TARGET_DELTATIME;
11.     }
12.
13.     m_LastTime = SDL_GetTicks();
14. }
15.
```

- Call the Tick() function in Main.cpp:

```
 1. #include "Engine.h"
 2. #include <iostream>
 3. #include "Timer.h"
 4.
 5. int main(int argc, char** argv)
 6. {
 7.     if (!Engine::GetInstance()->Init()) {
 8.         std::cout << "Initialization of Engine failed." << std::endl;
 9.     }
10.
11.
12.     while (Engine::GetInstance()->isRunning()) {
13.         // Get all current events (e.g. mouse clicks, etc.)
14.         Engine::GetInstance()->Events();
15.
16.         // Update all objects/entities
17.         Engine::GetInstance()->Update();
18.
19.         // Render/update the game graphics
20.         Engine::GetInstance()->Render();
21.
22.         // Invoke the clock
23.         Timer::GetInstance()->Tick();
24.     }
25.
26.     // Clean everything up
27.     Engine::GetInstance()->Clean();
```

```
28.
29.     return 0;
30. }
```

- Edit The Engine::Update() to update the player using the Timer.
    - Add “Timer.h” to Engine.cpp
    - Edit the Engine::Update()

```
1. void Engine::Update()
2. {
3.     float dt = Timer::GetInstance()->GetDeltaTime();
4.     player->Update(dt);
5. }
```

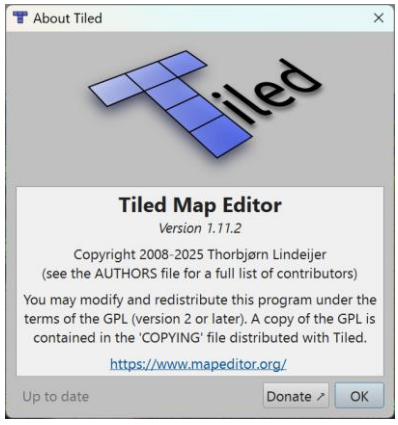
- Edit the Warrior Update to utilize the dt value being sent in:

```
 1. void Warrior::Update(float dt)
 2. {
 3.     // Default to player being idle
 4.     m_Animation->SetProps("player", 0, 6, 100);
 5.     // Unset any and all forces by default
 6.     m_RigidBody->UnSetForce();
 7.
 8.     if (Input::GetInstance()->GetKeyDown(SDL_SCANCODE_A)) {
 9.         // player is moving left/backwards
10.         m_RigidBody->ApplyForceX(5*BACKWARD);
11.         // need to reset the animation to player_run and flip on horizontal
12.         m_Animation->SetProps("player_run", 0, 8, 100, SDL_FLIP_HORIZONTAL);
13.     }
14.
15.     if (Input::GetInstance()->GetKeyDown(SDL_SCANCODE_D)) {
16.         // player is moving right/forwards
17.         m_RigidBody->ApplyForceX(5*FORWARD);
18.         // need to reset the animation to player_run
19.         m_Animation->SetProps("player_run", 0, 8, 100);
20.     }
21.
22.     m_RigidBody->Update(dt);
23.     m_Transform->TranslateX(m_RigidBody->Position().X);
24.     //m_Transform->TranslateY(m_RigidBody->Position().Y);
25.
26.     m_Animation->Update();
27. }
28.
```

- Compile and Test the program. It should work the same as before.

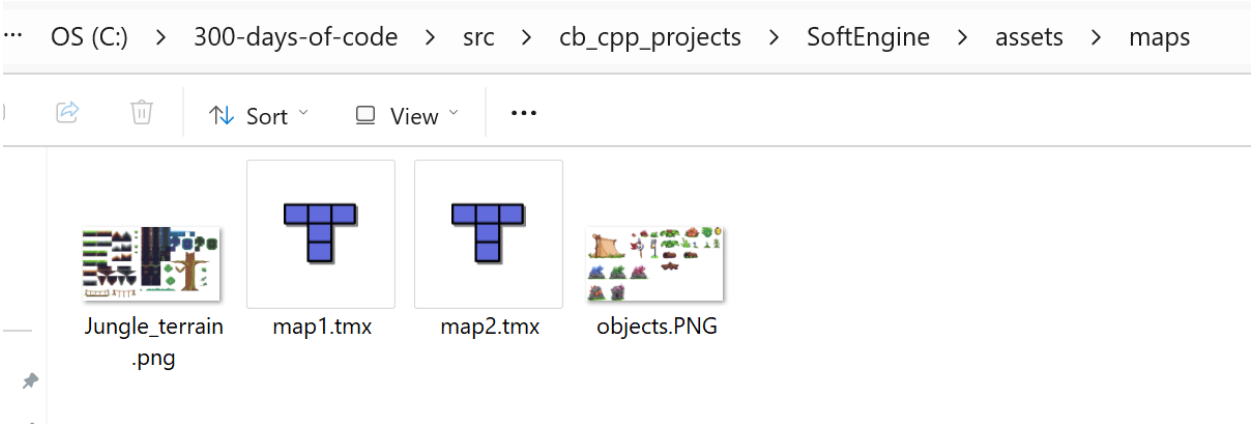
13. Render TileMap

This video prepares the files to process maps we create with the application Tiled Map Editor.



For the code in this video to make sense it is probably a good idea to spend some time learning to build tiled maps using the Tiled Map Editor. For those that want to skip learning the tool you can just:

1. Install The Tiled Map Editor[14] for your platform (https://www.mapeditor.org/)
2. Download and install the maps and images used to the assets/maps folder



3. Open the map1.tmx in Tiled Map Editor application

[14] The application is free to use but I highly recommend that you make a donation.

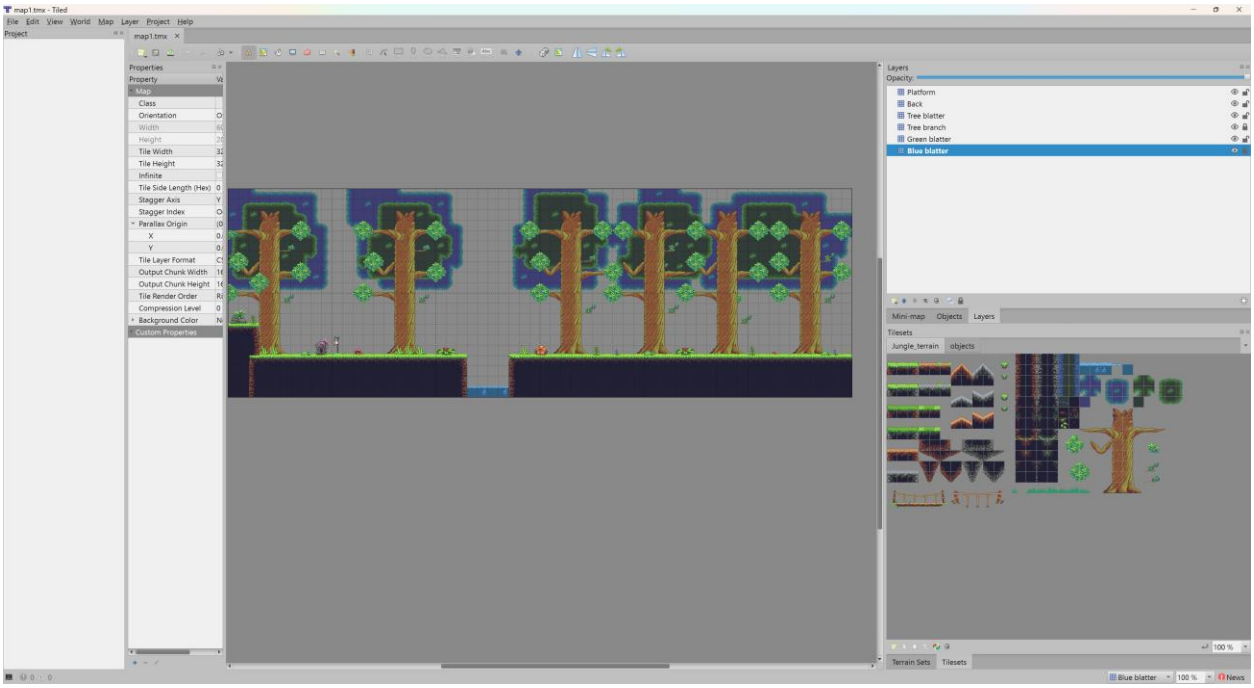


Figure 100 - Working in Tiled Map Editor

If you are watching the video to learn how to build your own game then it makes sense to take some time to learn how to use the Tiled Map Editor.

Using A Tile Set to create a Level

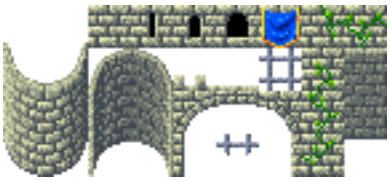
A ***tileset*** is a collection of small, reusable images (tiles) used to create game environments. These tiles are arranged in a grid to form maps, levels, or backgrounds in 2D games. Tilesets are commonly used in platformers, RPGs, and strategy games to efficiently build large worlds while maintaining a consistent visual style.

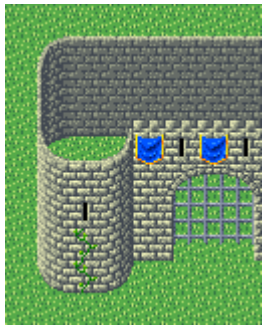
Key Features of Tilesets:

- **Grid-Based Design** – Each tile fits into a predefined grid, making it easy to assemble maps.
- **Reusable Assets** – Developers can use the same tiles multiple times to create varied environments.
- **Layering** – Some tilesets support multiple layers for backgrounds, foregrounds, and interactive elements.
- **Collision Data** – Tiles can include metadata for collision detection, defining walkable and non-walkable areas.

If you're looking for free tilesets, you can find some on itch.io, OpenGameArt, and Sprite Fusion.

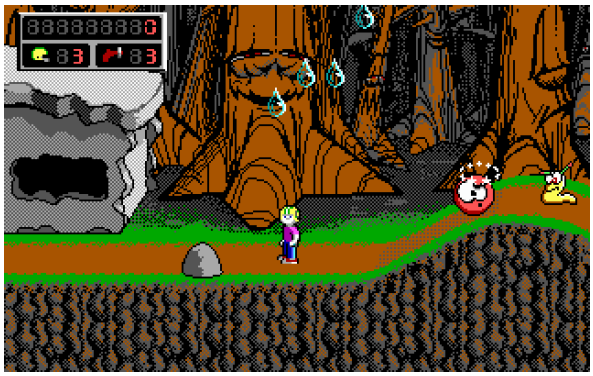
Here are some tilesets and example maps created using them:





The idea behind using a Tile Map Editor is that someone creates a tile set, usually with a particular theme in mind and you create the map or level using the tiles in the tile set. The tile set usually consists of many tiles of the same size 16x16 or 32x32. You use a tool like Tile Map Editor to read in the tileset image file. You inform Tile Map Editor what the size each tile map is so it can identify each tile in the image.

A good illustration of how tile map development evolved is to compare the game Commander Keen 1 with Commander Keen 4.



The original version was clearly created by programmers where the tiles were rectangular and rather blocky in nature. Whereas the Keen games after that were created by artists who knew

how to draw tiles to create the perception of depth. I recommend the website https://opengameart.org/ for free and well done tilesets.

I also recommend taking the time to follow another tutorial at https://gamefromscratch.com/tiled-map-editor-tutorial-series/ to learn how to use Tiled Map Editor.

The Key Components of a Tiled Map

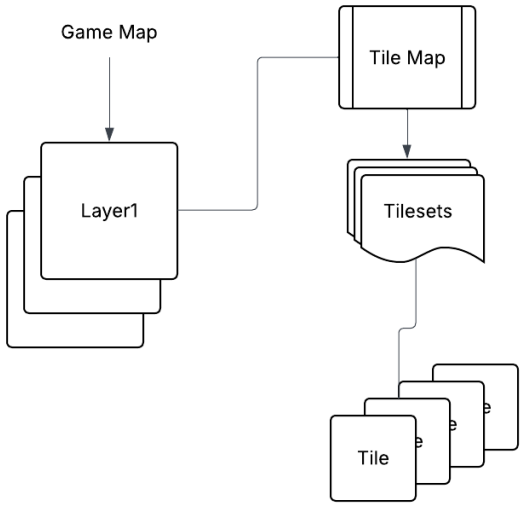


Figure 101 - Tile Map Components

At the very top is our Game Map. The Game Map consists of one or more Layers. We will create a `GameMap` class that captures the following facts about the Game Map:

- Manages a list (via a <vector>) of Layers
- The elements of a Layer
    - Each Layer is rendered on a Tile Map
    - Each Tile Map is constructed from one or more Tile sets
    - Each tileset is composed of one of more tiles
- Renders the Map
- Updates the Map Layers
- Cleans up the Layers

The *.tmx file records all the details about our Game Map. We are building the infrastructure to read, process and render the game map.

The `TileLayer` class is used to detail every Tileset a Layer is using. We need to track the `TileMap` associated with a Layer in addition to the Tile set being used in construction of the

Layer. The class TileLayer will manage the details required to manage a Layer. In later videos we will discuss how to parse the *.tmx file to build out the classes we are constructing in this video.

All of these terms and the reason for the classes we are creating can be quite perplexing without some knowledge of the Tiled Map Editor.

The bottom line is that we want an easy way to construct and layout our game map. The application Tiled Map Editor is an excellent tool for that and that is why many indie game developers use it. Tiled can be used to create visually stunning 2D maps.

There is a nice webpage (https://discourse.mapeditor.org/t/showcase-of-maps-made-in-tiled/5487) that show cases many of the maps created with Tiled.

Figure 102 - From https://discourse.mapeditor.org/t/showcase-of-maps-made-in-tiled/5487

The creator of the map selects the tile(s) from any of the tileset and objects. Every tile has a unique id and that unique id is stored in the data associated with the Layer's tiled map. The Tiled designer slowly creates a wonderful 2D landscape for their game.

Working with the *.tmx file

Our game engine shall use the output file generated by the Tiled Map Editor. The Tiled Map Editor generates a *.tmx that has all the information about the map that the user created with the tool.

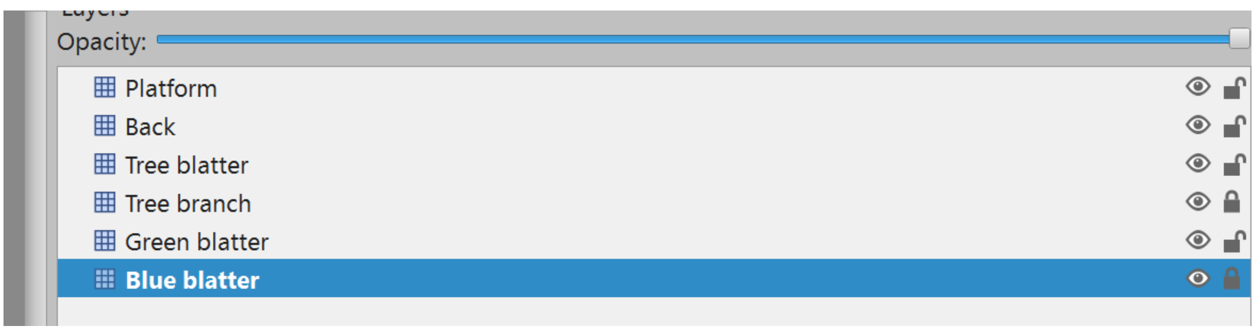
The files provided in this tutorial is map1.tmx and map2.tmx. A *partial* representation of the contents of the map1.tmx is:

```
<?xml version="1.0" encoding="UTF-8"?>
<map version="1.2" tiledversion="1.3.2" orientation="orthogonal" renderorder="right-down"
compressionlevel="0" width="60" height="20" tilewidth="32" tileheight="32" infinite="0" nextlayerid="10"
nextobjectid="1">
 <tileset firstgid="1" name="Jungle_terrain" tilewidth="32" tileheight="32" tilecount="420" columns="28">
  <image source="Jungle_terrain.png" width="896" height="480"/>
 </tileset>
 <tileset firstgid="421" name="objects" tilewidth="32" tileheight="32" tilecount="91" columns="13">
  <image source="objects.PNG" width="416" height="224"/>
 </tileset>
 <layer id="4" name="Blue blatter" width="60" height="20" locked="1">
  <data encoding="csv">
131,131,76,78,78,78,78,78,79,0,0,105,131,131,131,131,76,78,78,78,78,79,0,0,0,0,0,0,105,131,131,131,131,131
,76,78,79,0,0,105,131,106,131,76,78,79,0,0,77,78,78,78,78,78,78,78,79,0,0,
131,131,131,131,131,106,131,106,107,0,0,105,131,106,131,131,131,131,106,131,106,107,0,0,0,0,0,0,105,131,13
1,131,131,106,131,131,107,77,78,75,131,131,106,131,131,107,77,78,75,131,131,106,131,131,131,106,131,107,0,
0,
106,131,131,131,131,131,131,131,107,0,0,105,131,131,131,131,131,131,131,131,131,107,0,0,0,0,0,0,105,131,13
1,131,131,131,131,131,107,105,131,131,131,131,131,131,131,107,105,131,131,131,131,131,131,131,131,131,131,
76,78,78,
131,131,131,131,131,131,131,131,76,79,0,133,103,131,131,131,131,131,131,131,131,76,79,0,0,0,0,77,75,131,13
1,131,131,131,131,131,76,75,131,131,131,131,131,131,131,76,75,131,131,131,131,131,131,131,131,131,131,131,
131,131,
131,131,131,131,131,131,131,131,131,107,0,0,105,131,131,131,131,131,131,131,131,131,107,0,0,0,0,105,131,13
1,131,131,131,131,131,131,131,131,131,131,131,131,131,131,131,131,131,131,131,131,131,131,131,131,131,131,
131,131,131,104,
131,106,131,131,131,131,106,131,131,107,0,0,105,131,106,131,131,131,131,106,131,131,107,0,0,0,0,105,131,10
6,131,131,131,131,106,131,104,103,106,131,131,131,131,106,131,131,131,106,131,131,131,131,106,131,131,131,
131,106,131,107,
131,131,131,131,131,131,131,131,131,107,0,0,105,131,131,131,131,131,131,131,131,131,107,0,0,0,0,105,131,13
1,131,131,131,131,131,131,107,105,131,131,131,131,131,131,104,103,131,131,131,131,131,131,131,131,131,107,
131,131,104,135,
131,131,131,131,131,131,131,131,131,107,0,0,105,131,131,131,131,131,131,131,131,104,135,0,0,0,0,105,131,13
1,131,131,131,131,131,104,135,105,131,131,131,131,131,131,107,105,131,131,131,131,131,131,131,131,131,107,
131,131,107,0,
131,131,131,131,131,131,131,131,106,107,0,0,133,134,103,131,131,131,131,131,131,107,0,0,0,0,0,105,106,131,
131,131,131,131,131,107,0,105,131,131,131,131,131,131,107,105,106,131,131,131,131,131,131,131,106,107,131,
131,107,0,
134,134,134,134,134,134,134,134,134,135,0,0,0,0,133,134,134,134,134,134,134,135,0,0,0,0,0,133,134,134,134,
134,134,134,134,135,0,133,134,134,134,134,134,134,135,133,134,134,134,134,134,134,134,134,134,135,134,134,
135,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
```

```
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,51,0,0,0,0,51,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,51,0,0,0,0,51,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,51,47,48,47,48,51,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0
</data>
 </layer>
```

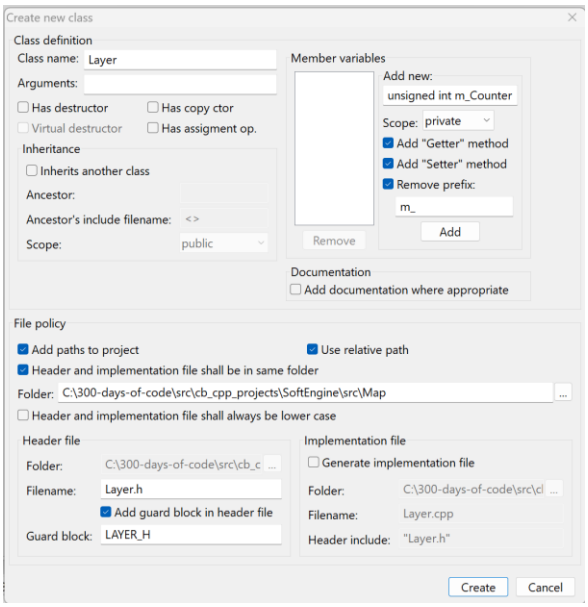
The details of the tmx file format are available here: https://doc.mapeditor.org/en/stable/reference/tmx-map-format/ .

In this video we prepare to use a tile map for our game. We will use the free tool Tiled Map Editor. One key element in building a Tiled Map is the creation of layers. If you examine map1.tmx inside of Tiled Map Editor you will see that the map we will be working with has 5 layers:



The first class we will create is the Layer class:

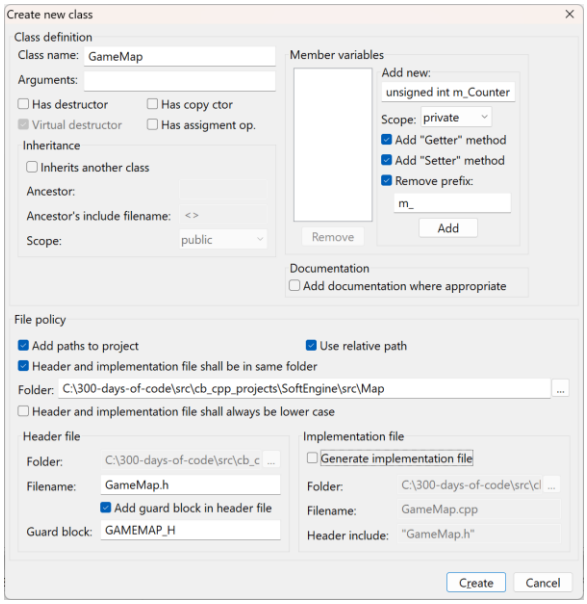
- Create New abstract class (header only) named `Layer` in a new folder `src\Map`



- Edit the Layer.h to the following:

```
#ifndef LAYER_H
#define LAYER_H


class Layer
{
    public:
        virtual void Render()=0;
        virtual void Update()=0;

};

#endif // LAYER_H
```

- Create another class (header only) named GameMap:



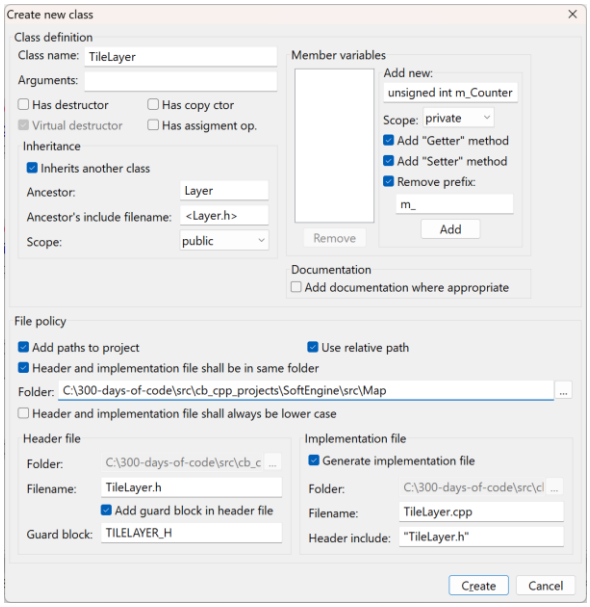
- Populate with the following code:

```
#ifndef GAMEMAP_H
#define GAMEMAP_H

#include <vector>
#include "Layer.h"

class GameMap
{
    public:
        void Render() {
            for(unsigned int i=0; i < m_MapLayers.size(); i++){
                m_MapLayers[i]->Render();
            }
        }

        void Update() {
             for(unsigned int i=0; i < m_MapLayers.size(); i++){
                m_MapLayers[i]->Update();
            }
        }

        std::vector<Layer*> GetMapLayers() {
            return m_MapLayers;
        }

    private:
        std::vector<Layer*> m_MapLayers;
};

#endif // GAMEMAP_H

```

The purpose of the GameMap class is to manage a <vector> of Layer pointers. This class will be used to draw our game map – layer by layer. The Render() method handles drawing of each

Layer. In addition, it also implements an Update method that in turn invokes the Update() method for each Layer.

- Create a new class named TileLayer that inherits from Layer:
  - Inherits Layer
  - In the same folder src/Map
  - Generates *.h and *.cpp



This class is used to hold the information about the layer.

- Add to TileLayer.h:

```
#ifndef TILELAYER_H
#define TILELAYER_H

#include <Layer.h>
#include <string>
#include <vector>

struct Tileset {
    int FirstID, LastID;
    int RowCount, ColCount;
    int TileCount, TileSize;
    std::string Name;           // The name of the tileset
    std::string Source;         // The filename for the tileset
};

using TilesetList = std::vector<Tileset> ;
using TileMap = std::vector<std::vector<int> >;

class TileLayer : public Layer
{
    public:
```

```
22.         TileLayer(int tilesize, int rowcount, int colcount, TileMap tilemap, TilesetList
tilesets);
23.
24.         virtual void Render();
25.         virtual void Update();
26.
27.         inline TileMap GetTilemap() {
28.             return m_Tilemap;
29.         }
30.     private:
31.         int m_TileSize;
32.         int m_RowCount, m_ColCount;
33.
34.         TileMap m_Tilemap;
35.         TilesetList m_Tilesets;
36. };
37.
38. #endif // TILELAYER_H
39.
```

The class contains a struct Tileset that captures the details of a tileset. We also know that we usually have one or more Tilesets that we will save in a TilesetList. In addition, we also define the TileMap (composed of a two-dimensional array) that defines our Layer's TileMap.

- Populate the TileLayer constructor:

```
 1. #include "TileLayer.h"
 2.
 3. TileLayer::TileLayer(int tilesize, int rowcount, int colcount, TileMap tilemap, TilesetList
tilesets)
 4. {
 5.     m_TileSize = tilesize;
 6.     m_RowCount = rowcount;
 7.     m_ColCount = colcount;
 8.     m_Tilemap = tilemap;
 9.     m_Tilesets = tilesets;
10. }
11.
12. void TileLayer::Render()
13. {
14.
15. }
16.
17. void TileLayer::Update()
18. {
19.
20. }
21.
```

A Note

This video required a bit of time to complete because I had to learn what the Tiled Map Editor was all about. The terminology used (e.g. Layer) was a bit foreign and unless you go through a tutorial it is difficult to comprehend why we are building the classes in this video. I highly

recommend the tutorial available at https://gamefromscratch.com/tiled-map-editor-tutorial-series/.

As you know I do not like just following a video series blindly without putting in the time to understand things better. If anyone is reading this ..then you are probably the same.

The next item I would like to address is my unhappiness with the inconsistent and unconventional coding style being used. I mentioned before that I have been away from C++ coding for many years and when following the videos I did not understand the coding style. I decided to look up a C++ coding style guide to check if my intuition was correct that the style being used in this video is, to put it mildly – awful.

I found a nice guide at https://isocpp.github.io/CppCoreGuidelines/CppCoreGuidelines. The guide appears to be recently updated. It may be my age but I feel an important element of coding is to adhere to a style. It may not be a style I like but a conventional style is very important.

I will follow the coding style being used in the videos.

14. Tile Map Editor – Creating Maps

The title of the last video should have probably been "Building the Infrastructure for rendering the Game Map" since we did not actually render anything. We created the basic components for representing the GameMap, which consists of one or more Layers. Each `Layer` consists of a `TileMap` constructed from one or more `Tilesets`. Each `Tileset` is made of one or more `Tiles`. Each Tile is determined by the contents of an image file.

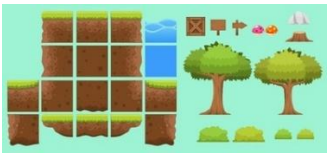


Figure 103 - Image file of tiles

The tiles in a tileset is used to construct a game map:

Figure 104 - Game map consisting of many layers

The Game map in Figure 104 is composed of several layers. The one all the way to the back consists of the clouds and sky. The next level is the mountains. After that, the next layer is composed of trees. The top-most layer consists of our platform components. Why so many layers? Each layer can be constructed on its own and when playing the game can move at different speeds to give the illusion of depth. When we lay out the game map, we have a specific order in which we draw the layers on the game map.

The version of Tiled used in the video was 1.3.2. The current version I am using is 1.11.2. I did not have any issues opening the map1.tmx file that is provided as part of this video series.

- Open Tiled Map Editor (note: close any opened Tiled Project)

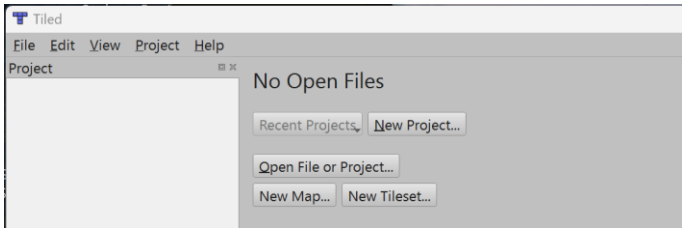


Figure 105 - Creating a new map

- Click on “New Map…”
- Fill out the New Map dialog as shown:

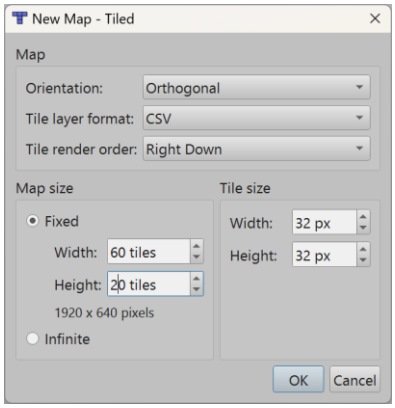


Figure 106 - Options for a new Tiled map

We will select the “Orientation” of Orthogonal which is a straightforward grid-based layout, where tiles are aligned in a rectangular fashion, making them ideal for top-down or side-scrolling game. The camera views the scene directly from above or the side, ensuring that all tiles are aligned at right angles.

The tile layer format we want to select is CSV (comma-separated values). It is a simple format used to store tabular data:

```
<data encoding="csv">
131,131,76,78,78,78,78,78,79,0,0,105,131,131,131,131,76,78,78,78,78,79,0,0,0,0,0,0,105,131,131,131,131,131,76,78,79,0,0,105,131,106,131,76,78,79,0,0,77,78,78,78,78,
131,131,131,131,131,106,131,106,107,0,0,105,131,106,131,131,131,131,106,131,106,107,0,0,0,0,0,0,105,131,131,131,131,106,131,131,107,77,78,75,131,131,106,131,131,107
106,131,131,131,131,131,131,131,107,0,0,105,131,131,131,131,131,131,131,131,131,107,0,0,0,0,0,0,105,131,131,131,131,131,131,131,107,105,131,131,131,131,131,131,131,
131,131,131,131,131,131,131,131,76,79,0,133,103,131,131,131,131,131,131,131,131,76,79,0,0,0,0,77,75,131,131,131,131,131,131,131,76,75,131,131,131,131,131,131,131,76
131,131,131,131,131,131,131,131,131,107,0,0,105,131,131,131,131,131,131,131,131,131,107,0,0,0,0,105,131,131,131,131,131,131,131,131,131,131,131,131,131,131,131,131,
131,106,131,131,131,131,106,131,131,107,0,0,105,131,106,131,131,131,131,106,131,131,107,0,0,0,0,105,131,106,131,131,131,131,106,131,104,103,106,131,131,131,131,106,
131,131,131,131,131,131,131,131,131,107,0,0,105,131,131,131,131,131,131,131,131,131,107,0,0,0,0,105,131,131,131,131,131,131,131,131,107,105,131,131,131,131,131,131,
131,131,131,131,131,131,131,131,131,107,0,0,105,131,131,131,131,131,131,131,131,104,135,0,0,0,0,105,131,131,131,131,131,131,131,104,135,105,131,131,131,131,131,131,
131,131,131,131,131,131,131,131,106,107,0,0,133,134,103,131,131,131,131,131,131,107,0,0,0,0,0,105,106,131,131,131,131,131,131,107,0,105,131,131,131,131,131,131,107,
134,134,134,134,134,134,134,134,134,135,0,0,0,0,133,134,134,134,134,134,134,135,0,0,0,0,0,133,134,134,134,134,134,134,134,135,0,133,134,134,134,134,134,134,135,133,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,51,0,0,0,0,51,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,51,0,0,0,0,51,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,51,47,48,47,48,51,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
</data>
```

The above represents the tiles ids used in our layer tile map.

- Click on “OK”
- Select File ➔ Save As , I am saving into the code assets folder under a new directory named maps (note: I already have map1.tmx and map2.tmx which is from the video series assets).

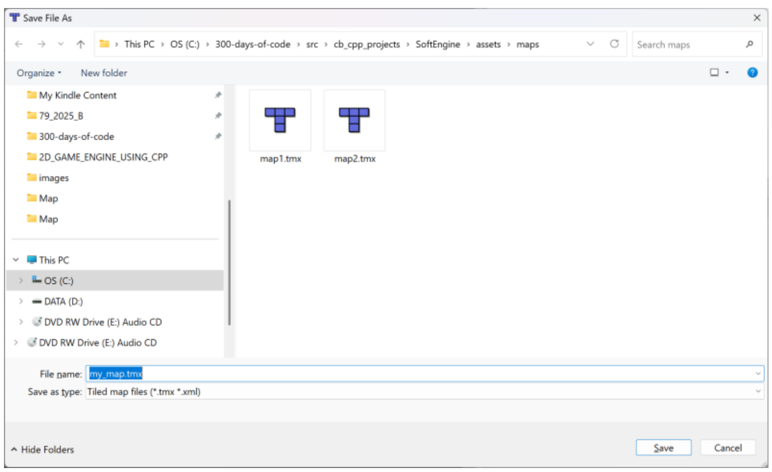


Figure 107 - Saving my_map.tmx in assets/maps folder

You will see the following in Tiled:

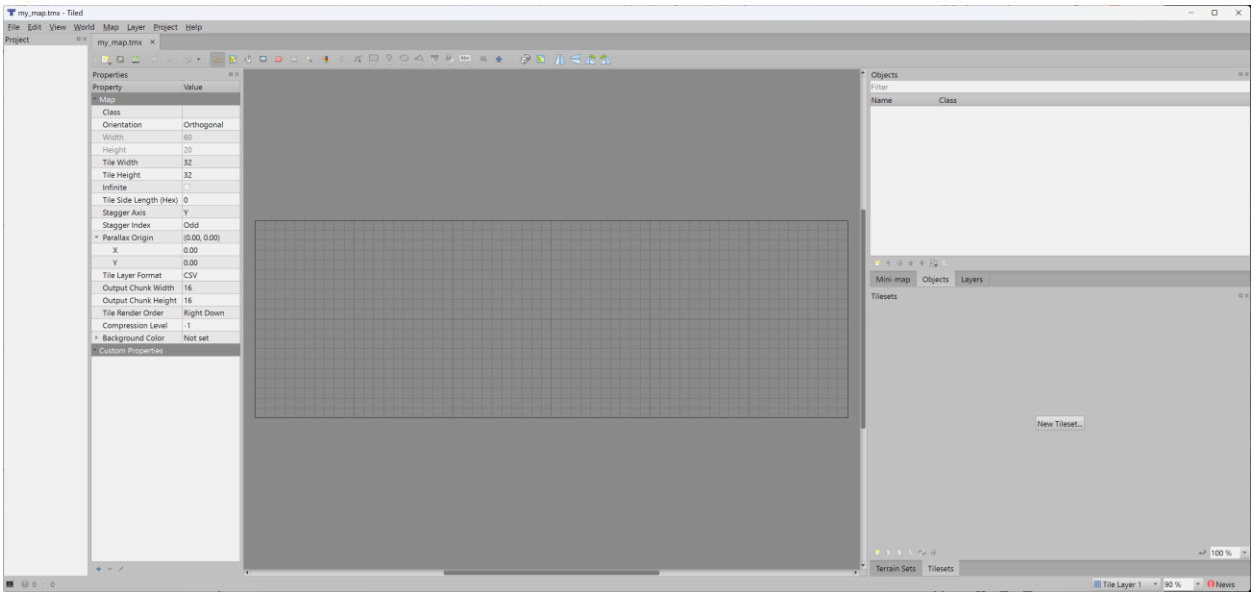


Figure 108 - Our map in Tiled

Note: My default layout appears different than what is in the video.

Click the “Layers” tab (bottom right panel):

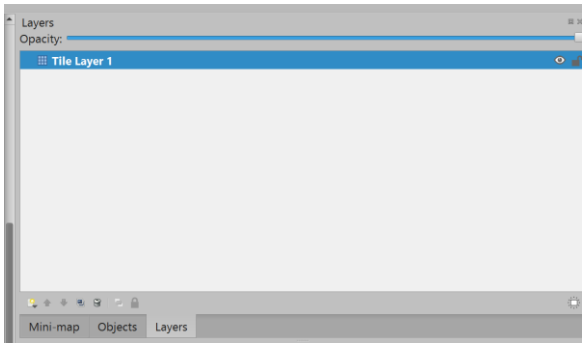


Figure 109 - Selecting the "Layers" panel tab

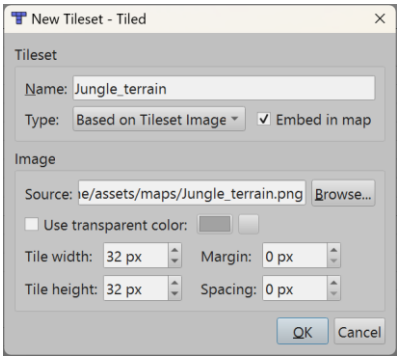
- Add the tile set image file to the same assets/maps folder. The name of the tile set it Jungle_terrain.png:

Figure 110 - jungle_terrian.png tile set

- Add the tile set file named objects.PNG to the same directory:

Figure 111 - The objects.PNG file

- Create/Add the tile set jungle_terrian.png to Tiled
  - Click on “New Tileset…”
  - Navigate to the jungle_terrian.png file you added in assets/maps folder



Make sure you click on the check box “Embed in map” to ensure that the tile map details are added into the *.tmx file that will be created and not placed in a separate file.

- Click on “OK” and you will now see your tile map file incorporated into the Tiled application:

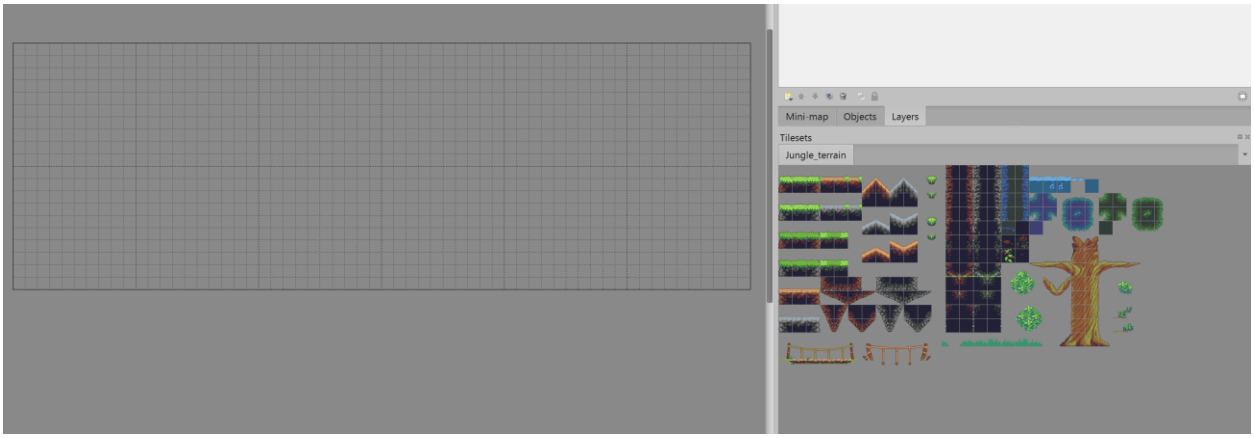
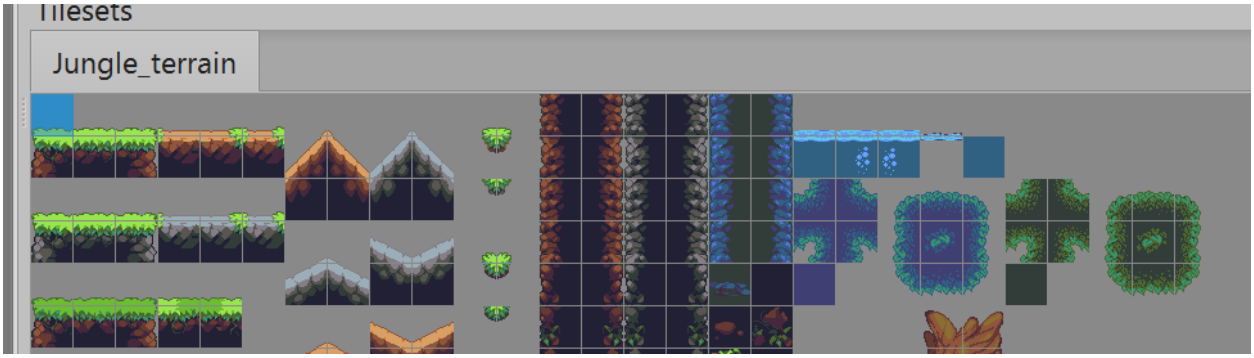
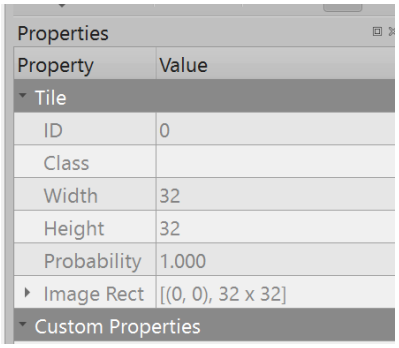


Figure 112 - Tiled with our Jungle_terrain.png tileset

If you highlight the first tile in the Tileset:



You will see from the property panel that is has a unique id of 0.



If you highlight the last tile in the Tileset:

You will see it has the id of 419:

Properties

Property	Value
Tile	
ID	419
Class	
Width	32
Height	32
Probability	1.000
Image Rect	[(864, 448), 32 x 32]
Custom Properties	

Note: The presenter was not on the last tile.

- Click on “Save”
- Navigate to the location of your map and open in vs code or some other editor:

```
<?xml version="1.0" encoding="UTF-8"?>
<map version="1.10" tiledversion="1.11.2" orientation="orthogonal" renderorder="right-down" width="60"
height="20" tilewidth="32" tileheight="32" infinite="0" nextlayerid="2" nextobjectid="1">
 <tileset firstgid="1" name="Jungle_terrain" tilewidth="32" tileheight="32" tilecount="420" columns="28">
  <image source="Jungle_terrain.png" width="896" height="480"/>
 </tileset>
 <layer id="1" name="Tile Layer 1" width="60" height="20">
  <data encoding="csv">
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
```

```
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0
</data>
 </layer>
</map>
```

The interesting information we find is the tilecount="420" (hence the IDs from 0..419). The width and height we specified (which corresponds to the number of columns and rows of tiles). By default, we start with a layer named "Tile Layer 1" (this will be changed). The <data> consists of all 0's <TBD>.

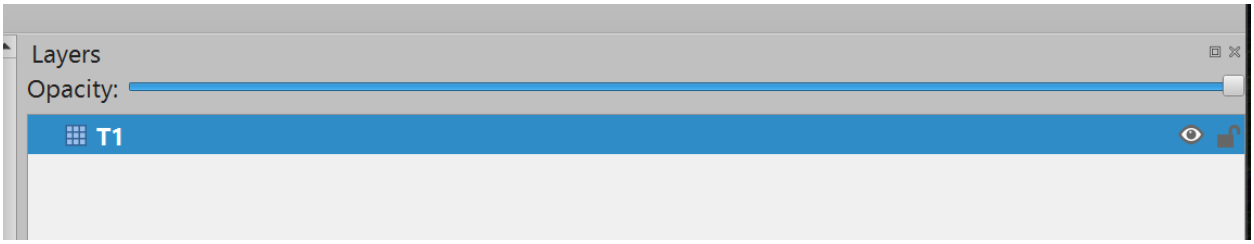
Why does the csv in the *.tmx file use 0 for any empty layer map? Isn't this the ID of the first tile

Great observation! In a **TMX file**, when using **CSV encoding**, empty tiles in a layer are represented by **0**. This does not necessarily mean that **0** is the ID of the first tile in the tileset—it actually signifies that **no tile is present** in that position.
Here's why:

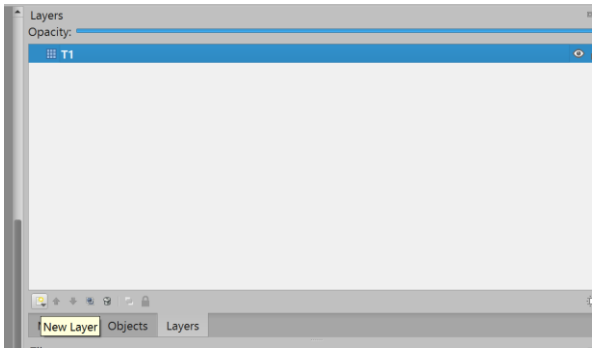
- **0 means "no tile"**: In Tiled Map Editor, a tile layer consists of a grid of tile references. If a cell contains **0**, it means that the cell is empty and does not reference any tile from the tileset.
- **Tile IDs start from 1**: The first tile in a tileset typically has an ID of **1**, because **0 is reserved for empty spaces**.
- **CSV format is simple**: Unlike Base64 or XML encoding, CSV is a straightforward way to store tile data, making it easy to read and parse.

So, while **0 might seem like the first tile ID**, it's actually just a placeholder for an **empty tile**. If you need to check the actual tile IDs, you can look at the **firstgid** attribute in the tileset definition within the TMX file.

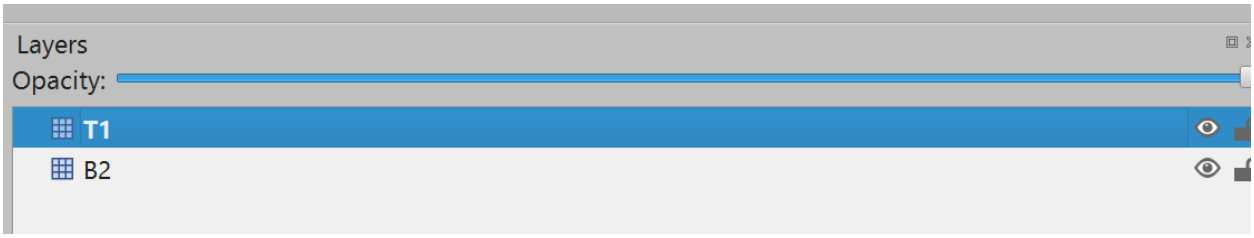
- Rename the first Layer to T1:



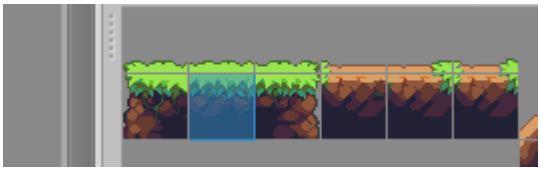
- Rename the first Layer to T1:



- Click on “New Layer” icon to create a new Layer named B2. Move it down so it is below T1.



- Select T1 as the current Layer
- Select the tile with ID 29:



- Start drawing on the map

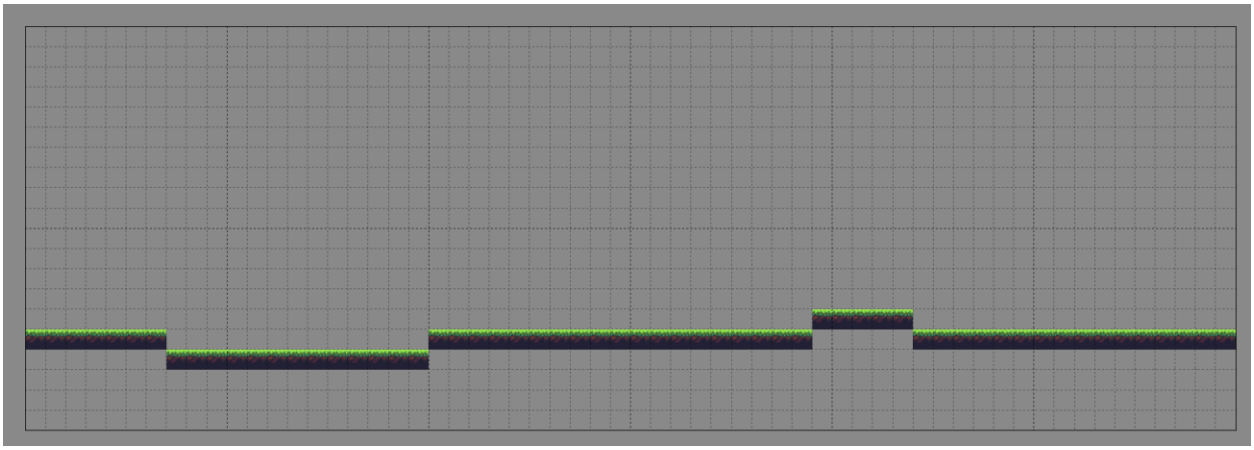
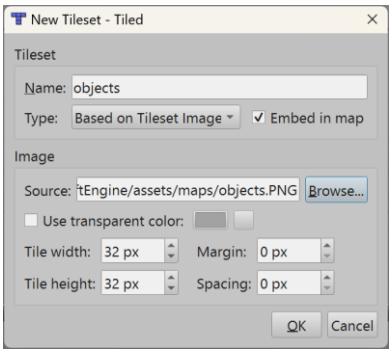


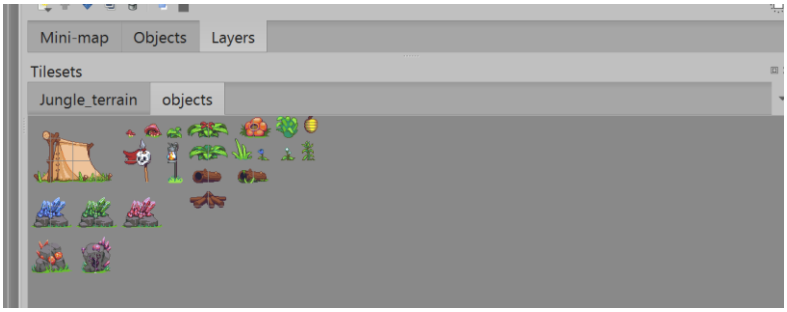
Figure 113 - Drawing with tile ID:29

- Click on the “New Tileset” icon:

- Add the other tileset image file “object.PNG”

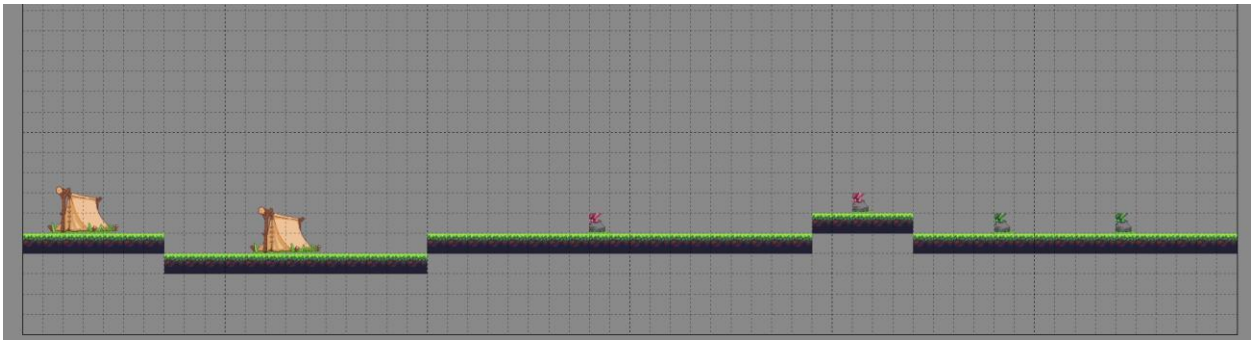


- Click “OK”. You will see a second tileset added to your project:



- Select all the tiles associated with the tent image:

- Click the B2 layer
- Place the tent and other objects into the B2 layer:



The reader should familiarize themselves with the basic features of Tiled, such as the eraser, fill or selection tools. I should note that before using a tool like eraser make sure the correct Layer is selected.

- Save the map.

The next three videos covers parsing tmx files. I did look up if there were existing libraries for parsing TMX files, here is a brief overview:

- **tmxlite:**

A lightweight C++14 library specifically designed for parsing TMX files. It is header-only, meaning it does not require external linking and includes all dependencies.

- **tmxparser:**

A C++11 library that relies on the TinyXML2 library for parsing TMX files. It can handle map files stored in memory and supports base64 encoded data.

- **cocos2d-x:**

While primarily a game engine, cocos2d-x includes the CCTMXTiledMap class, which can be used to parse TMX files independently of the engine's other features.

- **Tileson:**

A C++ library for parsing Tiled maps in JSON format. If the TMX file is exported to JSON, Tileson can be used to parse it.

- **irrTiled:**

A third-party library for the Irrlicht engine that enables loading TMX files.

The choice of library depends on specific needs and project requirements, such as C++ version compatibility, dependencies, and desired features.

15. Tile Map Parser – Part I

In the previous video we got acquainted with the Tiled Map Editor application. We learned about creating/adding a map, layers, associating a tileset with the map and starting to draw or place one or more tiles on a map layer.

We need to now create a parser for the *.tmx file that Tiled outputs. The *.tmx represents all the information we need to render the map we created in Tiled in out Game Engine.

- Create a new class named MapParser

- Create both *.h and *.cpp files
- Place the class in the project folder src\Map
- Do not generate the destructor

```
#ifndef MAPPARSER_H
#define MAPPARSER_H


class MapParser
{
    public:
        MapParser();

    protected:

    private:
};

#endif // MAPPARSER_H

```

And

```
#include "MapParser.h"

MapParser::MapParser()
{
    //ctor
}

```

The goal of this and the next set of videos is to add code to our project that will process the *.tmx file that represents our game map. The first issue to address about building our parser is that the file is written in XML format.

This is the contents of the practice map we created in the previous video:

```
<?xml version="1.0" encoding="UTF-8"?>
<map version="1.10" tiledversion="1.11.2" orientation="orthogonal" renderorder="right-down" width="60"
height="20" tilewidth="32" tileheight="32" infinite="0" nextlayerid="3" nextobjectid="1">
 <tileset firstgid="1" name="Jungle_terrain" tilewidth="32" tileheight="32" tilecount="420" columns="28">
  <image source="Jungle_terrain.png" width="896" height="480"/>
 </tileset>
 <tileset firstgid="421" name="objects" tilewidth="32" tileheight="32" tilecount="91" columns="13">
  <image source="objects.PNG" width="416" height="224"/>
 </tileset>
 <layer id="2" name="B2" width="60" height="20">
  <data encoding="csv">
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
```

```
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,421,422,423,424,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,
0,434,435,436,437,0,0,0,0,0,0,421,422,423,424,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,478,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,447,448,449,450,0,0,0,0,0,0,434,435,436,437,0,0,0,0,0,0,0,0,0,0,0,0,0,478,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,476,0,0,0,0,0,476,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,447,448,449,450,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0
</data>
 </layer>
 <layer id="1" name="T1" width="60" height="20">
  <data encoding="csv">
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
```

```
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,30,30,30,30,30,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,
30,30,30,30,30,30,30,0,0,0,0,0,0,0,0,0,0,0,0,0,30,30,30,30,30,30,30,30,30,30,30,30,30,30,30,30,30,30,30,0,
0,0,0,0,30,30,30,30,30,30,30,30,30,30,30,30,30,30,30,30,
0,0,0,0,0,0,0,30,30,30,30,30,30,30,30,30,30,30,30,30,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0
</data>
 </layer>
</map>
```

The file contains the details of the map we created.

We first need an XML parser so we can parse the XML into our Game classes. We need to add a library to parse the XML. The library we will be using is TinyXML. The code for the library can be found at https://github.com/vmayoral/tinyxml.

- Download the zip file of the tinyxml repo from the URL
- Unzip the zip file and place the following files into a new folder in your project: src/Vendor/TinyXML

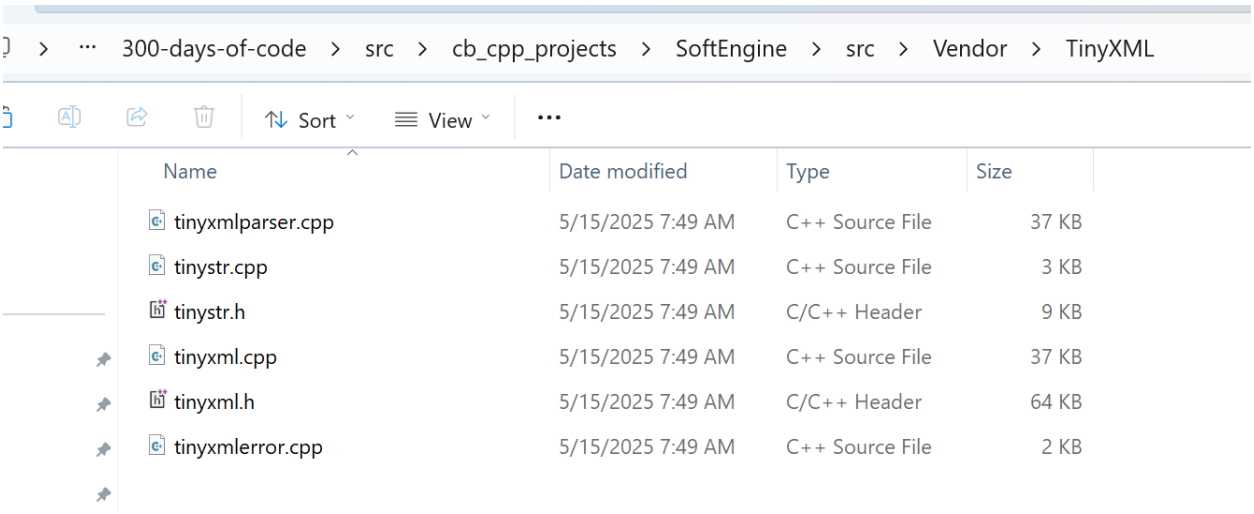


Figure 114 - TinyXML files

The Vendor folder will contain all 3rd party code that we add to our project.

If you take a look at your Code::Blocks project you will not see our Vendor folder!

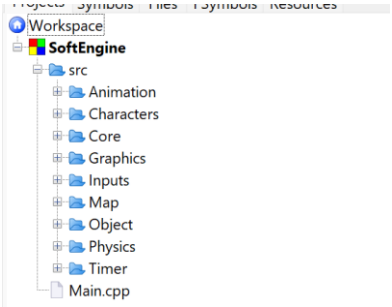


Figure 115 - Missing Vendor folder from our project

- Right-click on the SoftEngine project in the Workspace

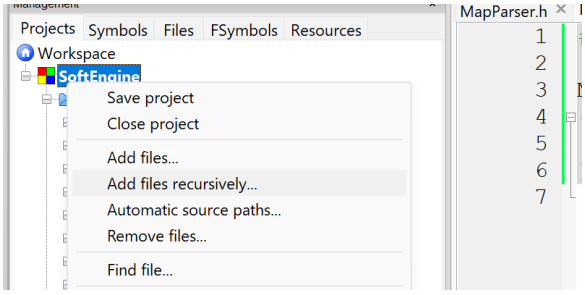


Figure 116 - Adding a new folder to our project

- Select “Add files recursively…”
- Navigate to the Vendor folder and click on “Select Folder”
    - Make sure all the filed in TinyXML are selected and added

Our project now has Vendor folder:

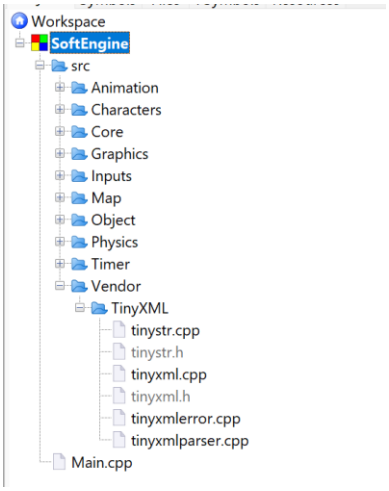
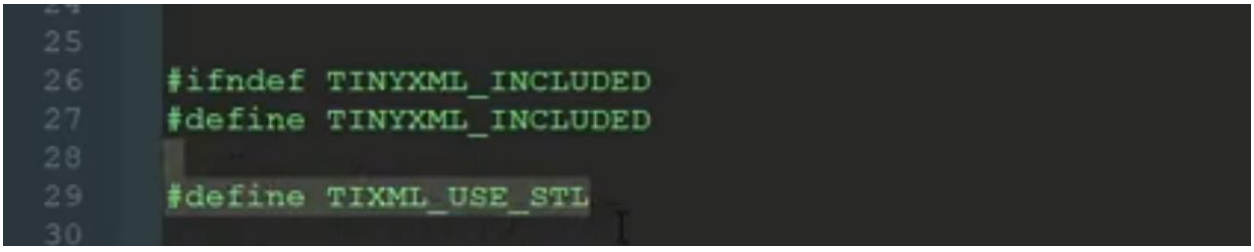


Figure 117 - Our updated project folders

- Open the file tinyxml.h and edit to have the highlighted line below:



Note: I found in the current version of tinyxml.h I do not have to add this line.

- The next step is to add or include a search for the include files. The video presenter at first suggests doing this globally but he changes it for this specific project since most of us will have other Code::Blocks projects.

- Select Project ➔ Build options…
- Click on the "Search directories" tab and make sure the Compiler sub-tab is selected:

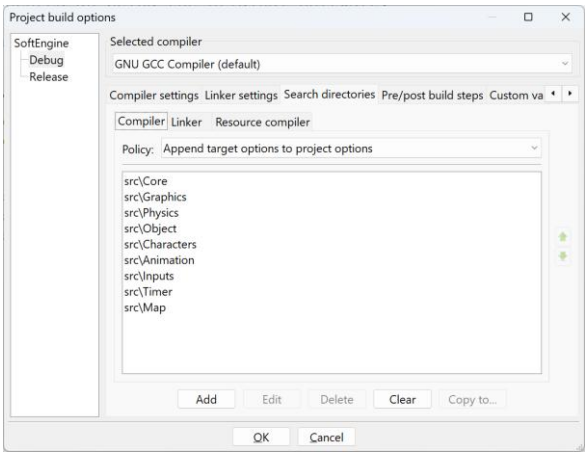
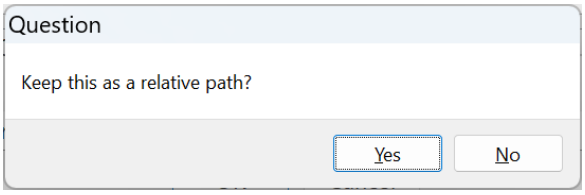
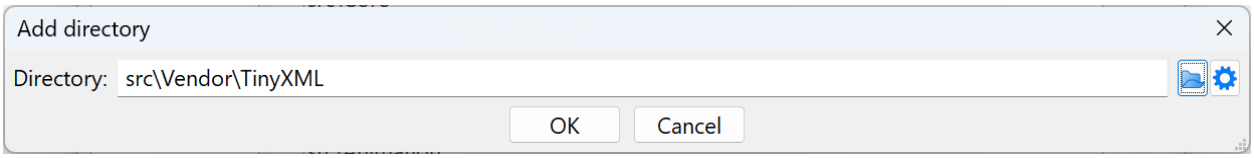


Figure 118 - Project build options to add TinyXML

- Click on "Add" and navigate to the TinyXML folder, when prompted about keeping the relative path, click on "Yes".



- When prompted to add "src/Vendor/TinyXML" click on "OK"



You may be wondering why you needed this step when you did not have to add the other directories in the search path – they were automatically added. The problem is that the `TinyXML` is under the `Vendor` folder and we did not want to muck up the `#include` for `TinyXML` header files.

- Open the MapParser.h for editing
- Add the required #include files:

```
1. #include <map>
2. #include <string>
3. #include "GameMap.h"
4. #include "TileLayer.h"
5. #include "tinyxml.h"
```

- The MapParser is a singleton class:

```
class MapParser
{
    public:
        inline static MapParser* GetInstance() {
            return s_Instance = (s_Instance != nullptr ? s_Instance : new MapParser());
        }


    private:
        MapParser() {};
        static MapParser* s_Instance;
};

```

- Don't forget to remove the constructor in MapParser.cpp
- Don't forget to initialize s_Instance in MapParser.cpp

```
#include "MapParser.h"

MapParser* s_Instance = nullptr;

```

The idea behind the MapParser is to process the *.tmx file. The two main elements we want are:

- Tilesets

```
<tileset firstgid="1" name="Jungle_terrain" tilewidth="32" tileheight="32" tilecount="420" columns="28">
 <image source="Jungle_terrain.png" width="896" height="480"/>
</tileset>
<tileset firstgid="421" name="objects" tilewidth="32" tileheight="32" tilecount="91" columns="13">
 <image source="objects.PNG" width="416" height="224"/>
</tileset>
```

- Layer information

```
<layer id="2" name="B2" width="60" height="20">
 <data encoding="csv">
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
```

```
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,421,422,423,424,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,
0,434,435,436,437,0,0,0,0,0,0,421,422,423,424,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,478,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,447,448,449,450,0,0,0,0,0,0,434,435,436,437,0,0,0,0,0,0,0,0,0,0,0,0,0,478,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,476,0,0,0,0,0,476,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,447,448,449,450,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0
</data>
 </layer>
```

- Populate MapParser.h with the required methods to process the TMX file:

```
#ifndef MAPPARSER_H
#define MAPPARSER_H
```

```
 3.
 4. #include <map>
 5. #include <string>
 6. #include "GameMap.h"
 7. #include "TileLayer.h"
 8. #include "tinyxml.h"
 9.
10. class MapParser
11. {
12.     public:
13.         // Returns true if the map was successfully loaded, otherwise false
14.         bool Load();
15.
16.         // Cleans the map
17.         void Clean();
18.
19.         inline GameMap* GameMaps() {};
20.
21.         // Returns the current instance of the MapParser
22.         inline static MapParser* GetInstance() {
23.             return s_Instance = (s_Instance != nullptr ? s_Instance : new MapParser());
24.         }
25.
26.     private:
27.         bool Parse(std::string id, std::string source);
28.         Tileset ParseTileset(TiXmlElement* xmlTileset);
29.         TileLayer* ParseTileLayer(TiXmlElement* xmlLayer, TilesetList tilesets, int tilesize,
int rowcount, int colcount);
30.
31.     private:
32.         MapParser() {};
33.         static MapParser* s_Instance;
34.         std::map<std::string, GameMap*> m_MapDictionary;
35. };
36.
37. #endif // MAPPARSER_H
38.
```

Line 14: The Load function returns true if the *.tmx file was successfully processed.

Line 17: Is invoked to clean up any and all objects

Line 22: Is used by client code to invoke any of the MapParser function

There are several private methods:

Line 27: Is invoked internally to parse the tmx file

Line 28: Is directly invoked to parse a <tileset> element in the file. We should note that there may be one or more tilesets, one or more layers and one or more gamemaps (for the various levels).

Line 29: Is invoked to parse a <layer> element

The class MapParser maintains a hash map named m_MapDictionary. Every GameMap is given a unique string name.

- Populate the MapParser.cpp
    - We only provide the code for MapParser::Load() and MapParser::ParseTileset()
    - We provide placeholder return values for the other methods that are supposed to return some value:

```
#include "MapParser.h"

MapParser* MapParser::s_Instance = nullptr;

bool MapParser::Load()
{
   return Parse("level1", "assets/maps/my_map.tmx");

}

void MapParser::Clean()
{

}

GameMap* MapParser::GameMaps()
{
    return nullptr;
}

bool MapParser::Parse(std::string id, std::string source)
{
    return true;
}


/*  Processes something like:
    <tileset firstgid="1" name="Jungle_terrain" tilewidth="32" tileheight="32" tilecount="420" columns="28">
        <image source="Jungle_terrain.png" width="896" height="480"/>
    </tileset>
*/
Tileset MapParser::ParseTileset(TiXmlElement* xmlTileset)
{
    Tileset tileset;
    // Extract the name (string value)
    tileset.Name = xmlTileset->Attribute("name");

    // Extract the firstgid (int value)
    xmlTileset->Attribute("firstgid", &tileset.FirstID);

    xmlTileset->Attribute("tilecount", &tileset.TileCount);

    // Calculate the LastID (makes sense if there is more than one tileset...
    tileset.LastID = (tileset.FirstID + tileset.TileCount) - 1;

    xmlTileset->Attribute("columns", &tileset.ColCount);
    tileset.RowCount = tileset.TileCount / tileset.ColCount;


    xmlTileset->Attribute("tilewidth", &tileset.TileSize);

    // Extract the first/only child element under <tileset>
    TiXmlElement* image = xmlTileset->FirstChildElement();
    tileset.Source = image->Attribute("source");

    return tileset;
```

```
57. }
58.
59. TileLayer* MapParser::ParseTileLayer(TiXmlElement* xmlLayer, TilesetList tilesets, int tilesize,
int rowcount, int colcount)
60. {
61.     return nullptr;
62. }
63.
```

We continue working on the MapParser in the next video.

16. Tile Map Parser – Part II

- Make a correction to the code we added to the TileLayer::TileLayer constructor.
- First make the following changes to TileLayer.h:

```
 1. #ifndef TILELAYER_H
 2. #define TILELAYER_H
 3.
 4. #include <string>
 5. #include <vector>
 6. #include "Layer.h"
 7. #include "Vector2D.h"
 8.
 9. struct Tileset{
10.     int FirstID, LastID;
11.     int Height, Width;
12.     int TileCount, TileSize;
13.     std::string Name, Source;
14. };
15.
16. using TilesetsList = std::vector<Tileset> ;
17. using TileMap = std::vector<std::vector<int> >;
18.
19. class TileLayer : public Layer {
20.
21.     public:
22.         TileLayer(int tilesize, int width, int height, TileMap tilemap, TilesetsList tilesets);
23.
24.         virtual void Render();
25.         virtual void Update();
26.
27.         inline int GetWidth(){return m_Width;}
28.         inline int GetHeight(){return m_Height;}
29.         inline int GetTileSize(){return m_TileSize;}
30.         inline TileMap GetTileMap(){return m_Tilemap;}
31.
32.     private:
33.         TileMap m_Tilemap;
34.         TilesetsList m_Tilesets;
35.         int m_TileSize, m_Width, m_Height;
36. };
37.
38. #endif // TILELAYER_H
39.
```

Updating to the above may impact already existing code.

- Update the TileLayer constructor:

```
1. TileLayer::TileLayer(int tilesize, int width, int rowcount, TileMap tilemap, TilesetsList
tilesets):
2.     m_TileSize(tilesize),
3.     m_Width(width),
4.     m_Height(rowcount),
5.     m_Tilemap(tilemap),
6.     m_Tilesets(tilesets)
7. {}
8.
```

- You may need to fix the code in MapParser as well:

```
1.         TileLayer* ParseTileLayer(TiXmlElement* xmlLayer, TilesetsList tilesets, int tilesize,
int rowcount, int colcount);
2.
```

- Make all required code changes to rename TilesetList to TilesetsList

- You may need to fix the code in MapParser as well:

Since ColCount and RowCount was changed to, TileCount and TileSize:

```
1. struct Tileset{
2.     int FirstID, LastID;
3.     int Height, Width;
4.     int TileCount, TileSize;
5.     std::string Name, Source;
6. };
```

MapParser.cpp:

```
 1. #include "MapParser.h"
 2.
 3. MapParser* MapParser::s_Instance = nullptr;
 4.
 5. bool MapParser::Load()
 6. {
 7.    return Parse("level1", "assets/maps/my_map.tmx");
 8.
 9. }
10.
11. void MapParser::Clean()
12. {
13.
14. }
15.
16. GameMap* MapParser::GameMaps()
17. {
18.     return nullptr;
19. }
```

```
20.
21. bool MapParser::Parse(std::string id, std::string source)
22. {
23.     return true;
24. }
25.
26.
27. /*  Processes something like:
28.     <tileset firstgid="1" name="Jungle_terrain" tilewidth="32" tileheight="32" tilecount="420"
columns="28">
29.         <image source="Jungle_terrain.png" width="896" height="480"/>
30.     </tileset>
31. */
32. Tileset MapParser::ParseTileset(TiXmlElement* xmlTileset)
33. {
34.     Tileset tileset;    // We will extract one tileset from the parser
35.
36.     // Extract the name (string value)
37.     tileset.Name = xmlTileset->Attribute("name");
38.
39.     // Extract the firstgid (int value)
40.     xmlTileset->Attribute("firstgid", &tileset.FirstID);
41.
42.     xmlTileset->Attribute("tilecount", &tileset.TileCount);
43.
44.     // Calculate the LastID (makes sense if there is more than one tileset...
45.     tileset.LastID = (tileset.FirstID + tileset.TileCount) - 1;
46.
47.     // Extract the number of tile columns
48.     xmlTileset->Attribute("columns", &tileset.Width);
49.
50.     // Calculate the height or number of rows of tiles
51.     tileset.Height = tileset.TileCount / tileset.Width;
52.
53.
54.     xmlTileset->Attribute("tilewidth", &tileset.TileSize);
55.
56.     // Extract the first/only child element under <tileset>
57.     TiXmlElement* image = xmlTileset->FirstChildElement();
58.     tileset.Source = image->Attribute("source");
59.
60.     return tileset;
61. }
62.
63. TileLayer* MapParser::ParseTileLayer(TiXmlElement* xmlLayer, TilesetsList tilesets, int
tilesize, int rowcount, int colcount)
64. {
65.     return nullptr;
66. }
67.
```

You know you have made all the changes required if the project builds with no complaints.

In this video we will be working on the ParseTileLayer code:

- Add the code for the methods MapParser::ParseTileLayer

```
1. /* This method parses the <layer> section of the tmx file
2.     <layer id="2" name="B2" width="60" height="20">
3.       <properties>
4.         <property> ... </property>
```

```
            :
            :
        <property> ... </property>
      </properties>
      <data encoding="csv">
            :
            :
      </data>
    </layer>
*/
TileLayer* MapParser::ParseTileLayer(TiXmlElement* xmlLayer, TilesetsList tilesets, int
tilesize, int rowcount, int colcount)
{
    // Holds the <data> part of the <layer>
    TiXmlElement* data;

    // Need to find the child element that is a <data>, so we iterate through the children
    for(TiXmlElement* e=xmlLayer->FirstChildElement(); e!= nullptr; e=e->NextSiblingElement()){
        if(e->Value() == std::string("data")){
            data = e;
            break;
        }
    }

    // Parse Layer tile map
    std::string matrix(data->GetText());    // just a string
    std::istringstream iss(matrix);
    std::string id;

    // convert or transform the string of data into a 2D matrix
    TileMap tilemap(rowcount, std::vector<int> (colcount, 0));  // this is our 2D array holding
the game map tile IDs
    for(int row = 0; row < rowcount; row++){
        for (int col = 0; col < colcount; col++){
            getline(iss, id, ',');
            std::stringstream convertor(id);
            convertor >> tilemap[row][col];

            if(!iss.good())
                break;
        }
    }

    return (new TileLayer(tilesize, colcount, rowcount, tilemap, tilesets));
}

```

Note: I reversed colcount and rowcount. This is corrected later.

I will create another set of notes to cover std::stringstream. The above takes the <data>…</data> values and populates a tilemap which we know consists of rows and columns.

- Edit the GameMap class to make the MapParser a friend class:

```
    private:
        friend class MapParser;
        std::vector<Layer*> m_MapLayers;
```

- Populate the method MapParser::Parse():

```
bool MapParser::Parse(std::string id, std::string source)
{
    TiXmlDocument xml;

    // Read in the *.tmx file
    xml.LoadFile(source);

    // Check if all went well
    if (xml.Error()) {
        std::cerr << "Failed to load: " << source << std::endl;
        return false;
    }

    // get the root element <map>
    TiXmlElement* root = xml.RootElement();
    int rowcount, colcount, tilesize = 0;    // extract these attributes from <map>

    root->Attribute("width", &colcount);
    root->Attribute("height", &rowcount);
    root->Attribute("tilewidth", &tilesize); // This assumes all tiles are N x N

    // Iterate through all the <tileset> elements
    TilesetsList tilesets;
    for(TiXmlElement* e = root->FirstChildElement(); e != nullptr; e = e->NextSiblingElement())
{
        if (e->Value() == std::string("tileset")) {
            tilesets.push_back(ParseTileset(e));
        }
    }

    // Populate with Game Map layers
    GameMap* gamemap = new GameMap();

    // iterate through all the <layer> elements
    for(TiXmlElement* e=root->FirstChildElement(); e!= nullptr; e=e->NextSiblingElement()){
        if(e->Value() == std::string("layer")){
            TileLayer* tilelayer = ParseTileLayer(e, tilesets, tilesize, rowcount, colcount);
            gamemap->m_MapLayers.push_back(tilelayer);
        }
    }

    m_MapDictionary[id] = gamemap;

    return true;

}

```

17. Tile Map Parser – Part III

At this point in the video series, it appears the presenter was getting a lot of feedback that things were not working. I agree with the statement he makes at the start of this video that if you don't have the patience to figure things out or hang in there until everything works – you probably don't have what it takes to complete the series. I think this is generally true for programming.

The trick I use to catch as many errors as possible is to a) compile often b) look up errors I don't understand on the Internet or Copilot, c) keep working on it.

My code is available at https://github.com/nyguerrillagirl/300-days-of-code/tree/main/src/cb_cpp_projects/SoftEngine.

- Edit TileLayer.cpp

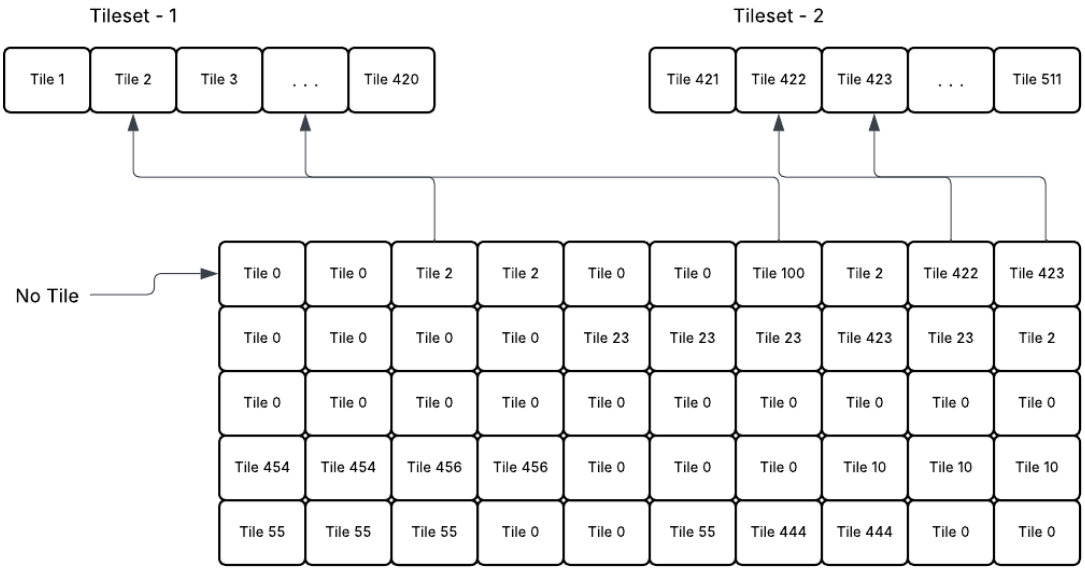
```
1. void TileLayer::Render()
2. {
3.     for(unsigned int i=0; i < m_Height; i++)
4.     for (unsigned int j=0; j < m_Width; j++) {
5.         // layout a tile
6.     }
7. }
```

Note: The video uses m_RowCount and m_ColCount but this is changed to m_Height and m_Width later in the video series.

The thing to note is every tileID is unique but we must determine what tileset it is from since a game map layer may be associated with one or more tilesets.

An important algorithm we must construct is to

- map the tileID to the tileset it comes from
- the "real" tileID or offset in the tileset



If there is only one tileset then things are trivial, either the ID represents “no tile” or it must be from the sole tileset. If there are one or more tilesets (as above) we will need to calculate what tileset holds the image for this tile.

We will utilize three properties we track in a TileSet struct:

```
1. struct Tileset{
2.     int FirstID, LastID;
3.     int Height, Width;
4.     int TileCount, TileSize;
5.     std::string Name, Source;
6. };
```

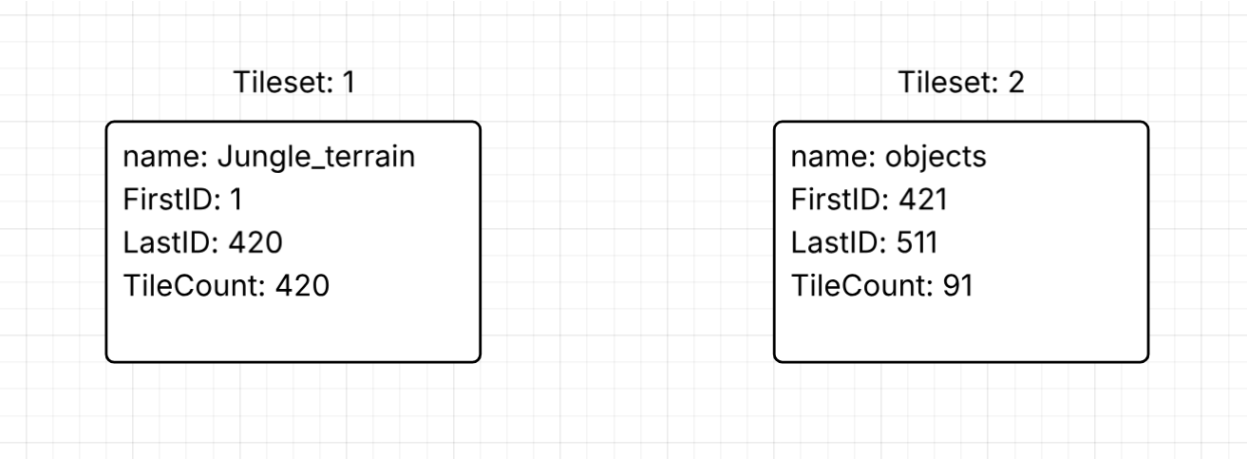
Using the information in the <tileset> element in the tmx file:

```
 <tileset firstgid="1" name="Jungle_terrain" tilewidth="32" tileheight="32"
tilecount="420" columns="28">
  <image source="Jungle_terrain.png" width="896" height="480"/>
 </tileset>
 <tileset firstgid="421" name="objects" tilewidth="32" tileheight="32"
tilecount="91" columns="13">
  <image source="objects.PNG" width="416" height="224"/>
 </tileset>
```

FirstID: is the value in firstgid attribute in the <tileset>

LastID: is calculated as tilecount + firstgid – 1 (should be the last TileID)

TileCount – the number of tiles in the tile set We will have the following values for these three:



The way to determine what tileset a specific TileID falls in is to just see if the TileID falls into the range FirstID..LastID.

Once we know what tileset it falls into we then want the “real” TileID or offset within that tile set. For example, suppose the TileID is 425. We know it falls into the second tile set since its range of TileID values is between 421:511.

Now within that tile set where does the tile fall. That is easily calculated as:

tileID + tilecount – lastId

So, for TileID that is, 425 – 91 – 511 = 5 (this is the location of TileID 425 in the second Tileset!)

So far we have the following code:

```
1. void TileLayer::Render() {
2.
3.     for(unsigned int i=0; i < m_Height; i++) {
4.         int tileset_index = 0;
5.         for (unsigned int j=0; j < m_Width; j++) {
6.             // layout a tile
7.             int tileID = m_Tilemap[i][j];
8.             if (tileID == 0) {
9.                 continue; // no tile specified
10.            } else {
11.                if (m_Tilesets.size() > 1) {
12.                    for (unsigned int k=1; k < m_Tilesets.size(); k++) {
13.                        if (tileID > m_Tilesets[k].FirstID && tileID < m_Tilesets[k]. LastID) {
14.                            // This determines the "real" TileID or offset inside the tileset
15.                            // tileID will be tile offset within tileset (not required for first
tileset)
16.                            tileID = tileID + m_Tilesets[k].TileCount - m_Tilesets[k].LastID;
17.                            tileset_index = k;
18.                        }
19.                    }
20.                }
21.            }
22.        }
23.    }
24. }
```

Now that we have the adjusted tileID we then must find that tile in the associated tilemap, that is the exact row and column of the tile in the associated tileset.

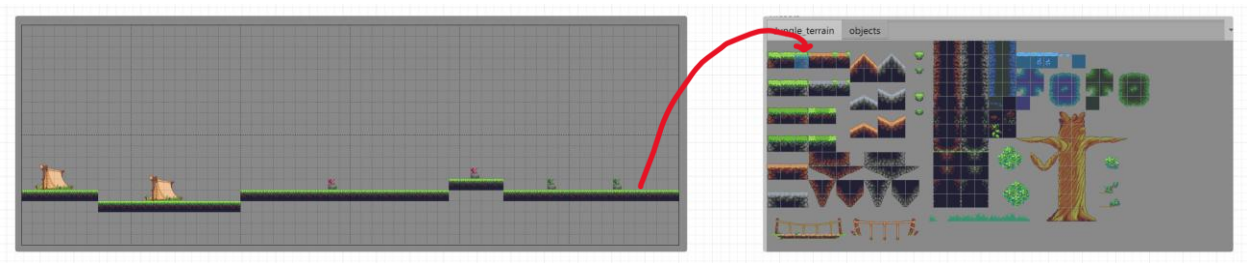


Figure 119 - game map/screen tile maps to a tileset/tileID.

In our data the source tile in the tile map has the TileID of 30. We need to map this TileID with the exact location in the tile map so we can extract that 32x32 tile image and draw it in the correct position on the screen.

- Add code to calculate the row and col this tile resides on

Imagine our tile map was 4x5, that is four rows and 5 columns.

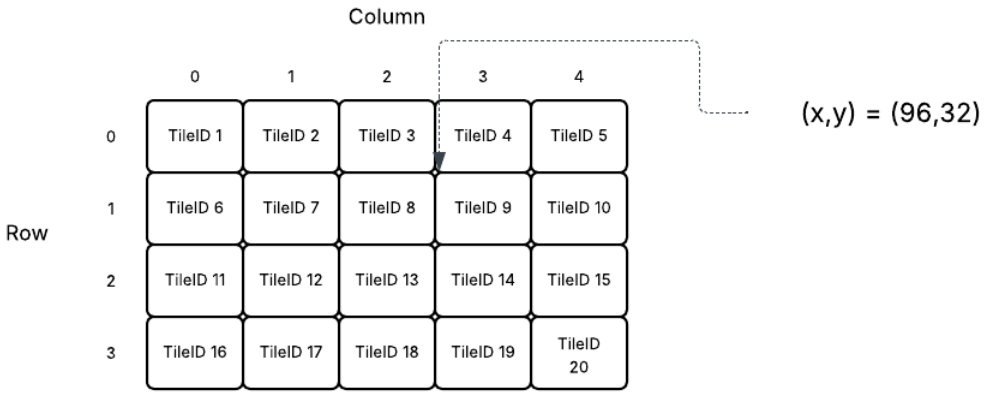


Figure 120 - Calculating the row and col, given TileID

We would like a formula where given the "real" TileID we can determine the row and column that tile falls on. Why do we need the row and col information?

From Figure 119 we need to find the (x,y) location of the tile within the tileset to draw it to the screen! We know the tile size[15] is saved in

In the figure above let's say we want to calculate the row and col for TileID 9.

The row is easily calculated as (TileID-1) / ts.Width, width is the number of columns (extracted from the <tileset> element attribute of columns. The column calculation is TileID – (row * ts.width) – 1.

Let's see if we get the correct row and col for TileID 9:

```
Row = (9-1) / 5 = 8 / 5 = 1
```

```
Col = 9 – (1*5) – 1 = 9 – 5 – 1 = 3
```

Note: This is slightly different than what the video presenter provided. I hated the kludge of:

```
1.          // fix in case tile is on the last column
```

[15] The video presenter made the assumption that the width and height of the tile will always be the same. In our case it is 32x32 pixels

```
2.          //if (tileID % ts.Width == 0) {
3.          //    tileRow--;
4.          //    tileCol = ts.Width - 1
5.          //}
```

Now it is easy to figure out what the (x,y) value for TileID should be it is (TileSize * col, TileSize * row)

So for TileID 9 we have (32 * 3, 32 * 1) or (96, 32).

Let's look at the code provided.

- Add a new DrawTile method to TextureManager.h

```
1.        void DrawTile(std::string tilesetID, int tileSize, int x, int y, int row, int col,
SDL_RendererFlip flip=SDL_FLIP_NONE);
```

- Add implementation of the method into the TextureManager.cpp

```
 1. void TextureManager::DrawTile(std::string tilesetID, int tileSize, int x, int y, int row, int
col, SDL_RendererFlip flip) {
 2.     // Defines the part of the image we plan on drawing in the tileset
 3.     SDL_Rect srcRect = {tileSize * col, tileSize * row, tileSize, tileSize};
 4.
 5.     // Defines where on the screen we will draw our image
 6.     SDL_Rect dstRect = {x, y, tileSize, tileSize};
 7.
 8.     // Draw our texture to the screen
 9.     SDL_RenderCopyEx(Engine::GetInstance()->GetRenderer(), m_TextureMap[tilesetID], &srcRect,
&dstRect, 0, nullptr, flip);
10. }
```

Note: I like my counting to start at 0! I find maintaining the understanding that counting starts at 0 is consistent with everything else in programming.

- Implement MapParser::Clean() in MapParser.cpp

```
 1. void MapParser::Clean()
 2. {
 3.     std::map<std::string, GameMap*>::iterator it;
 4.     for(it = m_MapDictionary.begin(); it != m_MapDictionary.end(); it++) {
 5.         it->second = nullptr;
 6.     }
 7.
 8.     m_MapDictionary.clear();
 9. }
10.
```

- Edit the MapParser::Load in MapParser.cpp

```
1. bool MapParser::Load()
2. {
3.     return Parse("MAP", "assets/maps/my_map.tmx");
4.
5. }
```

- Edit MapParser.h to change GameMaps to GameMap

```
    1. inline GameMap* GetMap(std::string id) { return m_MapDictionary[id];};
```

- Edit the TileLayer constructor:

```
 1. TileLayer::TileLayer(int tilesize, int width, int rowcount, TileMap tilemap, TilesetsList
tilesets):
 2.     m_TileSize(tilesize),
 3.     m_Width(width),
 4.     m_Height(rowcount),
 5.     m_Tilemap(tilemap),
 6.     m_Tilesets(tilesets)
 7. {
 8.     // Read in the texture/image of the tileset
 9.     for(int i = 0; i < m_Tilesets.size(); i++) {
10.         TextureManager::GetInstance()->Load(m_Tilesets[i].Name, "assets/maps/" +
m_Tilesets[i].Source);
11.     }
12. }
```

The above loads the tileset image files.

Engine.h:

```
 1. #ifndef ENGINE_H
 2. #define ENGINE_H
 3. #include "SDL.h"
 4. #include "SDL_image.h"
 5. #include "GameMap.h"
 6.
 7. #define SCREEN_WIDTH 960
 8. #define SCREEN_HEIGHT 640
 9.
10. class Engine {
11.     public:
12.         static Engine* GetInstance() {
13.             return s_Instance = (s_Instance != nullptr) ? s_Instance : new Engine();
14.         }
15.
16.         bool Init();
17.         bool Clean();
18.         void Quit();
19.
20.         void Update();
21.         void Render();
22.         void Events();
```

```
23.
24.         inline bool isRunning() {
25.             return m_IsRunning;
26.         }
27.
28.         inline  SDL_Renderer* GetRenderer() {
29.             return m_Renderer;
30.         }
31.
32.     protected:
33.
34.     private:
35.         Engine() {}
36.         bool m_IsRunning;
37.
38.         GameMap* m_LevelMap;
39.
40.         SDL_Window* m_Window;
41.         SDL_Renderer* m_Renderer;
42.
43.         static Engine* s_Instance;
44.
45. };
46.
47. #endif // ENGINE_H
48.
```

Engine.cpp:

```
 1. #include "Engine.h"
 2. #include "TextureManager.h"
 3. #include "Transform.h"
 4. #include "Warrior.h"
 5. #include "Input.h"
 6. #include "Timer.h"
 7. #include "MapParser.h"
 8.
 9. #include <iostream>
10.
11. Engine* Engine::s_Instance = nullptr;
12. Warrior* player = nullptr;
13.
14. bool Engine::Init()
15. {
16.      if (SDL_Init(SDL_INIT_VIDEO) != 0 && IMG_Init(IMG_INIT_JPG | IMG_INIT_PNG) != 0) {
17.         SDL_Log("Failed to initialize SDL: %s", SDL_GetError());
18.         return false;
19.     }
20.
21.     // Create our SDL window
22.     m_Window = SDL_CreateWindow("Soft Engine", SDL_WINDOWPOS_CENTERED, SDL_WINDOWPOS_CENTERED,
SCREEN_WIDTH, SCREEN_HEIGHT, 0);
23.     if (m_Window == nullptr) {
24.          SDL_Log("Failed to create window: %s", SDL_GetError());
25.         return false;
26.     }
27.
28.     m_Renderer = SDL_CreateRenderer(m_Window, -1, SDL_RENDERER_ACCELERATED |
SDL_RENDERER_PRESENTVSYNC);
29.         if (m_Renderer == nullptr) {
30.          SDL_Log("Failed to create Renderer: %s", SDL_GetError());
31.         return false;
```

```
32.     }
33.
34.     if (!MapParser::GetInstance()->Load()) {
35.         std::cout << "Failed to load map" << std::endl;
36.         return false;
37.     }
38.     // Get our game map
39.     m_LevelMap = MapParser::GetInstance()->GetMap("MAP");
40.
41.     // Load sprite sheet of the playing in idle state
42.     TextureManager::GetInstance()->Load("player", "assets/Idle.png");
43.
44.     // Load sprite sheet of the player running
45.     TextureManager::GetInstance()->Load("player_run", "assets/Run.png");
46.
47.     // Set the player's initial position on the screen and the size of each frame
48.     player = new Warrior(new Properties("player", 100, 200, 136, 96));
49.
50.     Transform tf;
51.     tf.Log();
52.
53.     return m_IsRunning = true;
54. }
55.
56. bool Engine::Clean()
57. {
58.     TextureManager::GetInstance()->Clean();
59.
60.     if (m_Renderer != nullptr) {
61.         SDL_DestroyRenderer(m_Renderer);
62.     }
63.     if (m_Window != nullptr) {
64.         SDL_DestroyWindow(m_Window);
65.     }
66.     IMG_Quit();
67.     SDL_Quit();
68.     return true;
69. }
70.
71. void Engine::Quit()
72. {
73.     m_IsRunning = false;
74. }
75.
76. void Engine::Update()
77. {
78.     float dt = Timer::GetInstance()->GetDeltaTime();
79.     m_LevelMap->Update();
80.     player->Update(dt);
81. }
82.
83. void Engine::Render()
84. {
85.     // Set the draw color
86.     SDL_SetRenderDrawColor(m_Renderer, 124, 218, 254, 255);
87.
88.     // Clear the screen with the draw color
89.     SDL_RenderClear(m_Renderer);
90.
91.     // Draw our map
92.     m_LevelMap->Render();
93.
94.     // Draw our Warrior
95.     player->Draw();
96.
```

```
 97.     // Present the renderer (update the window)
 98.     SDL_RenderPresent(m_Renderer);
 99. }
100.
101. void Engine::Events()
102. {
103.     Input::GetInstance()->Listen();
104. }
105.
```

When you run the program using the map we created with the Tiled Map Editor we should see:

Figure 121 - SoftEngine displaying the game level

- Change the map to the one provided map1.tmx:

```
1. bool MapParser::Load()
2. {
3.     return Parse("MAP", "assets/maps/map1.tmx");
4.
5. }
6.
```

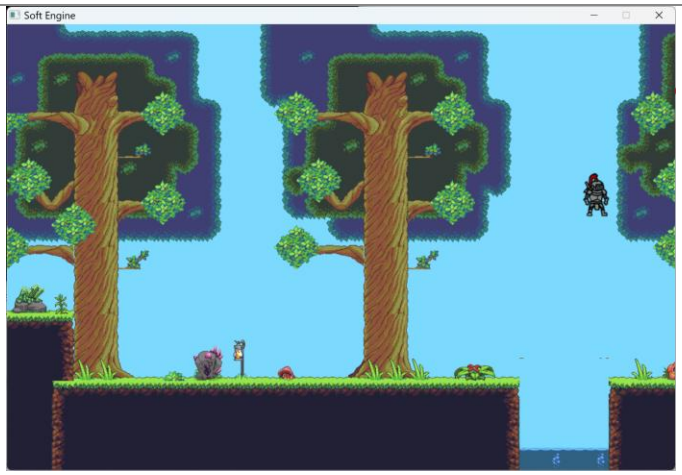


Figure 122 - Our game map using the project's map1.tmx

You may have noticed that there is a difference between the game map we created and the game map we actually displayed on the screen:

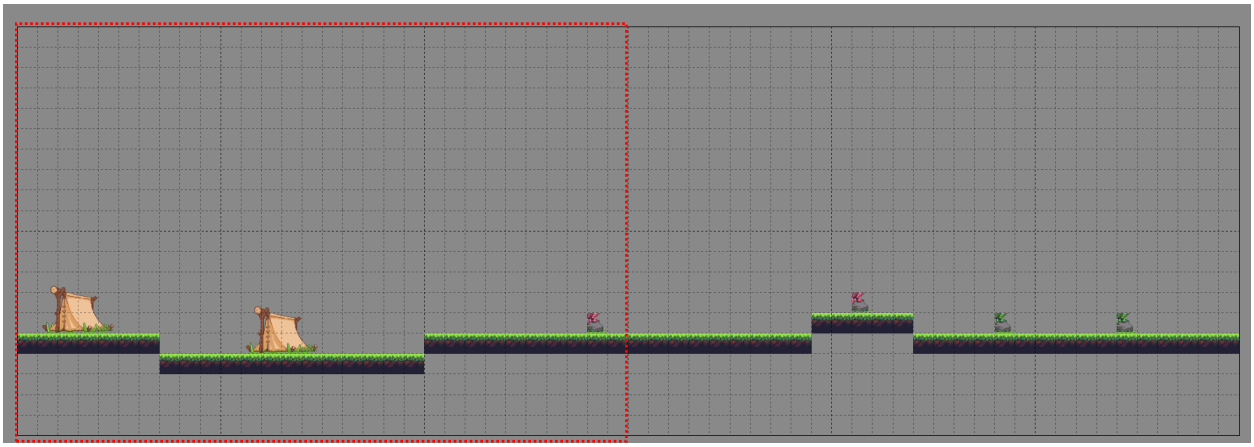


Figure 123 - The game map we created

The above makes sense since the screen is 960x640, the map is 60 tiles wide or 1920 pixels wide. The 960 pixels for our screen will only cover half the map or 30 tiles. That explains why we only see half our map.

An exercise

An interesting observation – if we only can "see" half the screen, do we try drawing the entire screen or just the part we can see? From the code it appears we draw the entire game map even if only half of it gets displayed. How can I tell?

The place to start is in our Engine::Render() method:

```
 85
 86  void Engine::Render()
 87  {
 88      // Set the draw color
 89      SDL_SetRenderDrawColor(m_Renderer, 124, 218, 254, 255);
 90
 91      // Clear the screen with the draw color
 92      SDL_RenderClear(m_Renderer);
 93
 94      // Draw our map
 95      m_LevelMap->Render();
 96
 97      // Draw our Warrior
 98      player->Draw();
 99
100      // Present the renderer (update the window)
101      SDL_RenderPresent(m_Renderer);
102  }
```

You can see that at the time we start to draw or render our screen we have the m_LevelMap, it holds our game map.

The m_LevelMap is a map containing all our maps (probably each one representing a level. We have only one such map. The Engine::Render() invokes the map's Render() method.

```
class GameMap
{
    public:
        void Render() {
            for(unsigned int i=0; i < m_MapLayers.size(); i++){
                m_MapLayers[i]->Render();
            }
        }
```

The game map Render invokes the TileLayer Render for each map. The TileLayer::Render() iterates through each tile in the tile map. Therefore, the answer is – we draw everything, even though we can only see half of it on the screen.

The next video starts to introduce a Camera class which will allow us to fix this issue.

18. Camera View Port

In a 2D game, the "camera" isn't a physical object like in real life—it's a virtual mechanism that dictates what portion of the game world is visible to the player at any given time. Here's what it does:

- **Controls Viewport**: Since many 2D games have larger worlds than can fit on the screen, the camera determines which part of the world the player sees.
- **Follows the Action**: Often, the camera moves to follow the player's character, keeping them centered or positioned optimally within the frame.
- **Enhances Gameplay**: Strategic camera movement can make exploration feel smoother, add dynamism to the game, and even create a sense of urgency or tension.
- **Controls Parallax Effects**: Some cameras manipulate different layers of the scene to create depth, making background elements move slower than foreground ones.

Even though 2D games don't have a fully dynamic 3D perspective, the camera still plays a huge role in making the experience feel immersive and engaging.

An interesting discussion about the camera is available at: https://bymuno.com/post/camera. I saved it as PROGRAMMING_A_2D CAMERA.

- Create a new class named Class in a new folder named src/Camera

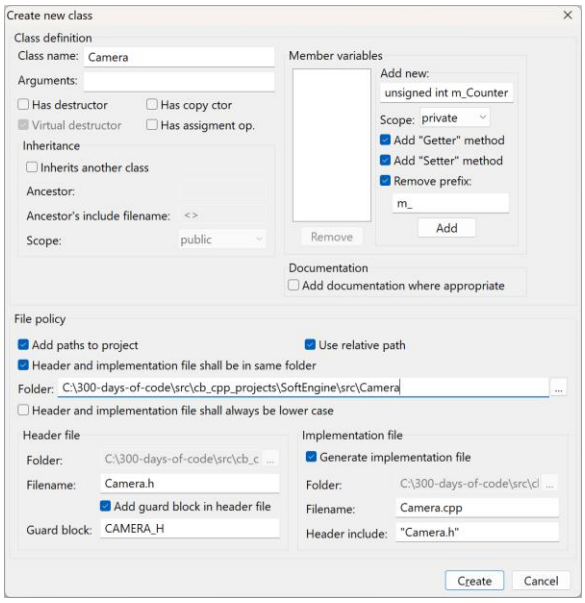


Figure 124 - Creating our new Camera class

- Make the changes in Camera.h to make the Camera class a singleton

```
 1. #ifndef CAMERA_H
 2. #define CAMERA_H
 3.
 4.
 5. class Camera
 6. {
 7.     public:
 8.         static Camera* GetInstance() { return s_Instance = (s_Instance != nullptr) ? s_Instance
: new Camera();};
 9.
10.     protected:
11.
12.     private:
13.         Camera(){};
14.
15.         static Camera* s_Instance;
16.
17. };
18.
19. #endif // CAMERA_H
```

- Initialize the Camera::s_Instance in the Camera.cpp file:

```
1. #include "Camera.h"
2.
3. Camera* Camera::s_Instance = nullptr;
```

- Create a new class named Point. The class will be placed in the src/Physics folder and there will be only a Point.h file created.

```
#ifndef POINT_H
#define POINT_H
#include <iostream>

class Point
{
    public:
        Point() {}

    protected:

    private:
};

#endif // POINT_H

```

- Edit Point.h to match Vector2D.h … with additional methods:

```
#ifndef POINT_H
#define POINT_H


class Point {
    public:
        float X, Y;

    public:
        Point(float x=0, float y=0): X(x), Y(y) {}

    public:
        // addition +
        inline Point operator+(const Point& p2) const {
            return Point(X + p2.X, Y + p2.Y);
        }

        // addition +=
        inline friend Point operator+=(Point& p1, const Point& p2){
            p1.X += p2.X;
            p1.Y += p2.Y;
            return p1;
        }

        // subtraction -
        inline Point operator-(const Point& p2) const {
            return Point(X - p2.X, Y - p2.Y);
        }

        // subtraction -=
        inline friend Point operator-=(Point& p1, const Point& p2) {
            p1.X -= p2.X;
            p1.Y -= p2.Y;
            return p1;
        }

        // multipication
        inline Point operator*(const float scaler) const {
```

```
39.             return Point(X * scaler, Y * scaler);
40.         }
41.
42.         void Log(std::string msg="") {
43.             std::cout << msg << "(X,Y)= (" << X << " " << Y << ")" << std::endl;
44.         }
45. };
46.
47. #endif // POINT_H
48.
```

- Complete the Camera.h:

```
 1. #ifndef CAMERA_H
 2. #define CAMERA_H
 3.
 4. #include "SDL.h"
 5. #include "Point.h"
 6. #include "Vector2D.h"
 7. #include "Engine.h"
 8.
 9. class Camera
10. {
11.     public:
12.         static Camera* GetInstance() { return s_Instance = (s_Instance != nullptr) ? s_Instance
: new Camera(); };
13.
14.         void Update(float dt);
15.         inline SDL_Rect GetViewBox() { return m_ViewBox; }
16.         inline Vector2D GetPosition() { return m_Position; }
17.         inline void SetTarget(Point* target) { m_Target = target; }
18.
19.     private:
20.         Camera(){ m_ViewBox = {0, 0, SCREEN_WIDTH, SCREEN_HEIGHT}; }
21.         Point* m_Target;        // This will be associated with the center of the player
22.         Vector2D m_Position;    // THe current position of the camera
23.
24.         SDL_Rect m_ViewBox;
25.         static Camera* s_Instance;
26.
27.
28. };
29.
30. #endif // CAMERA_H
31.
```

- Complete the Camera.cpp

```
 1. #include "Camera.h"
 2.
 3. Camera* Camera::s_Instance = nullptr;
 4.
 5.
 6. void Camera::Update(float dt) {
 7.     if(m_Target != nullptr) {
 8.
 9.         // We adjust the camera's view box
10.         m_ViewBox.x = m_Target->X - SCREEN_WIDTH / 2;
11.         m_ViewBox.y = m_Target->Y - SCREEN_HEIGHT / 2;
```

```
12.
13.         if(m_ViewBox.x < 0) {
14.             m_ViewBox.x = 0;
15.         }
16.
17.         if(m_ViewBox.y < 0) {
18.             m_ViewBox.y = 0;
19.         }
20.
21.         if(m_ViewBox.x > (2*SCREEN_WIDTH - m_ViewBox.w)) {
22.             m_ViewBox.x = (2*SCREEN_WIDTH - m_ViewBox.w);
23.         }
24.
25.         if(m_ViewBox.y > (SCREEN_HEIGHT - m_ViewBox.h)) {
26.             m_ViewBox.y = (SCREEN_HEIGHT - m_ViewBox.h);
27.         }
28.
29.         m_Position = Vector2D(m_ViewBox.x, m_ViewBox.y);
30.     }
31. }
32.
```

Since the need to track the center point of our player (or any object for that matter), we will update GameObject:

```
 1. #ifndef GAMEOBJECT_H
 2. #define GAMEOBJECT_H
 3.
 4. #include "IObject.h"
 5. #include "Transform.h"
 6. #include "SDL.h"
 7. #include "Point.h"
 8.
 9. struct Properties {
10.
11.     public:
12.         Properties(std::string textureID, int x, int y, int width, int height, SDL_RendererFlip
flip = SDL_FLIP_NONE) {
13.             X = x;
14.             Y = y;
15.             Flip = flip;
16.             Width = width;
17.             Height = height;
18.             TextureID = textureID;
19.         }
20.
21.         std::string TextureID;
22.         int Width, Height;
23.         float X, Y;
24.         SDL_RendererFlip Flip;
25. };
26.
27. class GameObject : public IObject
28. {
29.     public:
30.         GameObject(Properties* props) :
31.             m_TextureID(props->TextureID),
32.             m_Width(props->Width),
33.             m_Height(props->Height),
34.             m_Flip(props->Flip) {
35.                 m_Transform = new Transform(props->X, props->Y);
```

```
36.                 // Find the object's center
37.                 float px = props->X + props->Width / 2;
38.                 float py = props->Y + props->Height / 2;
39.                 m_Origin = new Point(px,py);
40.             }
41.         inline Point* GetOrigin() { return m_Origin; }
42.
43.         virtual void Draw() = 0;
44.         virtual void Update(float dt) = 0;
45.         virtual void Clean() = 0;
46.
47.     protected:
48.         Point* m_Origin;
49.         std::string m_TextureID;
50.         int m_Width, m_Height;
51.         SDL_RendererFlip m_Flip;
52.         Transform* m_Transform;
53.
54. };
55.
56. #endif // GAMEOBJECT_H
57.
```

- Update The Warrior::Update method to set the object's m_Origin:

```
 1. void Warrior::Update(float dt)
 2. {
 3.     // Default to player being idle
 4.     m_Animation->SetProps("player", 0, 6, 100);
 5.     // Unset any and all forces by default
 6.     m_RigidBody->UnSetForce();
 7.
 8.     if (Input::GetInstance()->GetKeyDown(SDL_SCANCODE_A)) {
 9.         // player is moving left/backwards
10.         m_RigidBody->ApplyForceX(5*BACKWARD);
11.         // need to reset the animation to player_run and flip on horizontal
12.         m_Animation->SetProps("player_run", 0, 8, 100, SDL_FLIP_HORIZONTAL);
13.     }
14.
15.     if (Input::GetInstance()->GetKeyDown(SDL_SCANCODE_D)) {
16.         // player is moving right/forwards
17.         m_RigidBody->ApplyForceX(5*FORWARD);
18.         // need to reset the animation to player_run
19.         m_Animation->SetProps("player_run", 0, 8, 100);
20.     }
21.
22.     m_RigidBody->Update(dt);
23.     m_Transform->TranslateX(m_RigidBody->Position().X);
24.     //m_Transform->TranslateY(m_RigidBody->Position().Y);
25.
26.     // Update the Origin
27.     m_Origin->X = m_Transform->X + m_Width / 2;
28.     m_Origin->Y = m_Transform->Y + m_Height / 2;
29.
30.     m_Animation->Update();
31. }
32.
```

- Edit the Engine.cpp file:
    - Add include for the Camera.h

```
1. #include "Camera.h"
```

- Add reference to the Camera in the Engine::Init:

```
 1. bool Engine::Init()
 2.                                                 :
 3.                                                 :
 4.     // Set the player's initial position on the screen and the size of each frame
 5.     player = new Warrior(new Properties("player", 100, 200, 136, 96));
 6.
 7.     Camera::GetInstance()->SetTarget(player->GetOrigin());
 8.
 9.
10.     return m_IsRunning = true;
11. }
```

- Edit the Engine::Update to refer to the Camera:

```
1. void Engine::Update()
2. {
3.     float dt = Timer::GetInstance()->GetDeltaTime();
4.     m_LevelMap->Update();
5.     player->Update(dt);
6.     Camera::GetInstance()->Update(dt);
7. }
```

- At this point make sure everything compiles.
- Edit MapParser::Init() so that is loads the map you created with the Tiled Map Editor:

```
1. bool MapParser::Load()
2. {
3.     return Parse("MAP", "assets/maps/my_map.tmx");
4.
5. }
```

- Let's use the camera position information in TextureManager::DrawTile() and TextureManager::DrawFrame():

```
 1. void TextureManager::Draw(std::string id, int x, int y, int width, int height, SDL_RendererFlip
flip) {
 2.     // Defines the part of the image we plan on drawing
 3.     SDL_Rect srcRect = {0, 0, width, height};
 4.
 5.     // Get current camera position
 6.     Vector2D cam = Camera::GetInstance()->GetPosition();
 7.
 8.     // Defines where on the screen we will draw our image
 9.     SDL_Rect dstRect = {x-cam.X, y-cam.Y, width, height};
10.
11.     // Draw our texture to the screen
```

```
12.     SDL_RenderCopyEx(Engine::GetInstance()->GetRenderer(), m_TextureMap[id], &srcRect, &dstRect,
0, nullptr, flip);
13.
14. }
15. void TextureManager::DrawTile(std::string tilesetID, int tileSize, int x, int y, int row, int
col, SDL_RendererFlip flip) {
16.     // Defines the part of the image we plan on drawing in the tileset
17.     SDL_Rect srcRect = {tileSize * col, tileSize * row, tileSize, tileSize};
18.
19.     // Get current camera position
20.     Vector2D cam = Camera::GetInstance()->GetPosition();
21.
22.     // Defines where on the screen we will draw our image
23.     SDL_Rect dstRect = {x - cam.X, y - cam.Y, tileSize, tileSize};
24.
25.     // Draw our texture to the screen
26.     SDL_RenderCopyEx(Engine::GetInstance()->GetRenderer(), m_TextureMap[tilesetID], &srcRect,
&dstRect, 0, nullptr, flip);
27. }
28.
29. void TextureManager::DrawFrame(std::string id, int x, int y, int width, int height, int row, int
frame, SDL_RendererFlip flip) {
30.     SDL_Rect srcRect = {width*frame, height*row, width, height};
31.
32.         // Get current camera position
33.     Vector2D cam = Camera::GetInstance()->GetPosition();
34.
35.     SDL_Rect dstRect = {x - cam.X, y - cam.Y, width, height};
36.
37.     SDL_RenderCopyEx(Engine::GetInstance()->GetRenderer(), m_TextureMap[id], &srcRect, &dstRect,
0, nullptr, flip);
38.
39. }
40.
```

- Run the program. The figure below is an animated gif of running the program now:

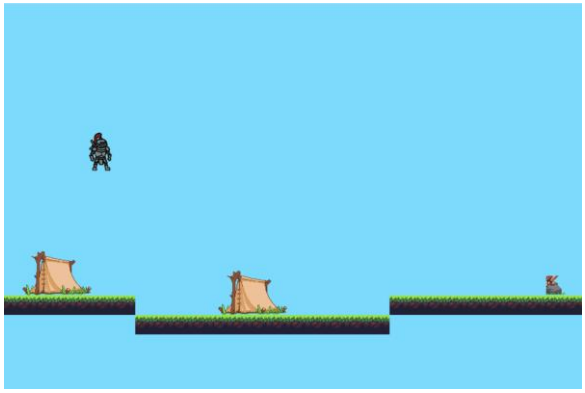


Figure 125 - The Warrior running across the screen

The camera is moving but the Warrior is spilling off the screen to the left and right. We will address this shortly.

A new folder was added assets/images. The folder contains the following image bg.png:

Figure 126 - background image

- Load the bg.png image in the Engine::Init() method:

```
1.      // Load sprite sheet of the playing in idle state
2.      TextureManager::GetInstance()->Load("player", "assets/Idle.png");
3.
4.      // Load sprite sheet of the player running
5.      TextureManager::GetInstance()->Load("player_run", "assets/Run.png");
6.
7.      // Load a background image
8.      TextureManager::GetInstance()->Load("bg", "assets/images/bg.png");
```

- Now let's draw the "bg" in Engine::Render():

```
 1. void Engine::Render()
 2. {
 3.     // Set the draw color
 4.     SDL_SetRenderDrawColor(m_Renderer, 124, 218, 254, 255);
 5.
 6.     // Clear the screen with the draw color
 7.     SDL_RenderClear(m_Renderer);
 8.
 9.     // Draw our background
10.     TextureManager::GetInstance()->Draw("bg", 0, 0, 2100, 1050);
11.     // Draw our map
12.     m_LevelMap->Render();
13.
14.     // Draw our Warrior
15.     player->Draw();
16.
17.     // Present the renderer (update the window)
18.     SDL_RenderPresent(m_Renderer);
19. }
```

```
20.
```

- Compile and Execute

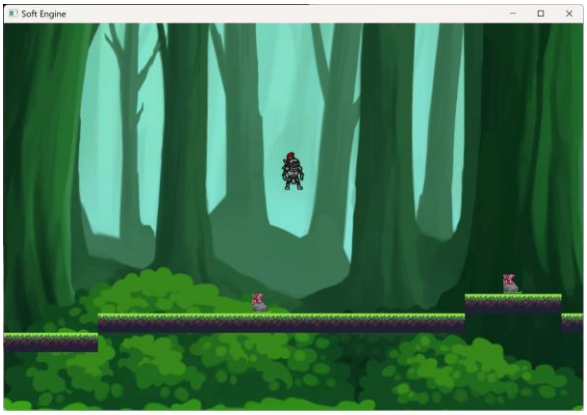


Figure 127 - The background is moving at the same rate as the gamemap!

We really want the background image to move slower since it is further away.

For now the solution is hokey…feels more like a kludge:

- Update TextureManager::Draw

```
 1. void TextureManager::Draw(std::string id, int x, int y, int width, int height, SDL_RendererFlip
flip) {
 2.     // Defines the part of the image we plan on drawing
 3.     SDL_Rect srcRect = {0, 0, width, height};
 4.
 5.     // Get current camera position
 6.     Vector2D cam = Camera::GetInstance()->GetPosition()*0.5;
 7.
 8.     // Defines where on the screen we will draw our image
 9.     SDL_Rect dstRect = {x-cam.X, y-cam.Y, width, height};
10.
11.     // Draw our texture to the screen
12.     SDL_RenderCopyEx(Engine::GetInstance()->GetRenderer(), m_TextureMap[id], &srcRect, &dstRect,
0, nullptr, flip);
13.
14. }
15.
```

We will slow the movement of the background by half.

Figure 128 - The background moves slower than the game map

I rest of the video series is covered in
TUTORIAL_CREATE_2D_GAME_ENGING_USING_CPP_PART_2

Web sites to Learn SDL2

- https://lazyfoo.net/tutorials/SDL/index.php
- https://wiki.libsdl.org/SDL2/FrontPage
- https://wiki.libsdl.org/SDL2_image
- https://www.ferzkopp.net/wordpress/2016/01/02/sdl_gfx-sdl2_gfx/
- https://www.freepik.com/
- http://programarcadegames.com/
- https://giphy.com/
- https://github.com/nsklaus/SoftEngine
- https://forum.gdevelop.io/t/solved-how-do-i-slice-a-sprite-sheet/37755
- https://box2d.org/
- https://www.gameart2d.com/ - Tile sets