Getting Started with OpenGL ES 3+ Programming

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Introduction

Welcome to this tutorial series, and congratulations for taking this first step. Maybe you're interested in creating a game from scratch, and/or want to understand the code. Maybe you're dreaming of writing your own game engine, or becoming a developer at a game studio. Or maybe you want to learn graphics programming for some other reason entirely. Whatever the case, you're here.

These tutorials will give you an accelerated path from zero through to rendering stuff in 3D. You will learn modern OpenGL that's usable on both desktop and mobile devices. No, it won't meget you to AAA game engine level as that's a huge task. However, it will give you the fundamentals you need before you can build more complicated stuff.

IMPORTANT: If your sole goal is to write a computer game and you don't care about the code, then you may wish to look for a ready-made game engine instead. There are many game engines out there that can get your project underway faster. These tutorials are for those who want to learn how to do graphics programming which will help you build custom graphics engines or tailor existing ones to your needs.

Who is this For?

These tutorials are intended for people with almost zero OpenGL programming experience. Having some C/C++ coding experience is helpful, but not required. The tutorials will explain the code at a fairly basic level.

That said, if you have no programming experience, then I recommend learning the basics of programming in C as well (e.g., follow this free online course: http://www.learn-c.org/).

Why OpenGL ES 3+ and SDL2?

There are a mind-boggling array of options out there: OpenGL, Direct-X, Vulkan, Metal, GLUT, GLFW, etc. Which is best? How to choose?

I've chosen to teach OpenGL ES 3+ (GLES3) because it's modern and available on all major mobile devices and is usable on desktops too. This maximises your options. Systems like Direct-X and Metal are restricted to specific platforms, and Vulkan is very complicated to use (definitely not good for beginners).

SDL2 (or Simple Direct-media Layer 2) takes care of low-level stuff like opening windows/screens, handling user input from joysticks, keyboards, touch, etc.. These tasks are normally platform dependent, and SDL2 gives you a common way of using them. There are other options like GLFW and GLUT, but I prefer SDL2. It has good support for both desktop and mobile devices, and provides a wide range of features, including multi-touch support, image loading (via SDL_image), etc. SDL2 also provides access to OS native objects should you want to use platform-specific features.

Don't worry about whether SDL2 really is the best choice for you because it can always be replaced later if you wish. The key right now is to get started.

How to Get the Most Out of These Tutorials

Simply owning a copy of these tutorials won't magically give you expertise. It takes work, or to put it another way: "you still have to do your own push-ups." Here are a few tips on how to get the most out of these tutorials.

First, follow the tutorials step-by-step. They've been written in a specific order for a reason; it's what works best.

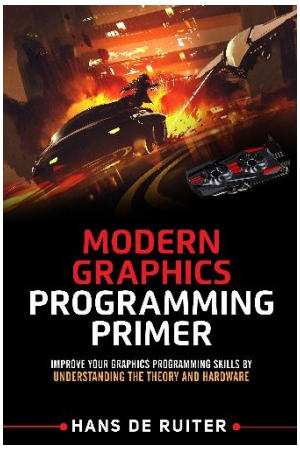
Write code by hand. It's very tempting to copy and paste the code from this book to save time. Resist that urge, because you'll learn and remember more by typing out the code manually.

Next, try to go through the tutorials on a regular schedule, e.g., one per day or maybe one every few days. You'll learn and remember more with regular practise then trying to cram everything in a few sessions (e.g., 1 hour a day beats 7 hour marathons once a week)

Third, do the exercises and perform your own experiments. Try changing the code to do something else, e.g., draw a square instead of a triangle, change the texture or the colour, etc.

Finally, I've written a "Modern Graphics Programming Primer" to accompany these tutorials. While the tutorials teach you *how* to code graphics, you'll be more capable if you understand *what* the hardware is doing (at least at a high level). The primer covers things such as: how modern GPUs work, 3D coordinate systems, and the underlying theory.

Get the primer at: https://keasigmadelta.com/graphics-primer



What if I Get Stuck?

There's a lot to learn, and you're likely to get stuck at some point. Here's what to do:

1. Try to figure it out yourself first
2. If you're still stuck, search the internet for a solution. Chances are high that someone else has experienced your problem already, and published a solution
3. Ask for help. Send me a message (https://keasigmadelta.com/support/)

Follow this process; resist the urge to jump to step 3 immediately. This isn't for purely selfish reasons (I can't respond to huge numbers of queries); it's also better for you. By following this process you're training yourself for developing software the real world. It's how professional software developers solve problems.

That said, don't be afraid to reach out for help if you need it. I'm happy to help, and knowing what people get stuck on will help me improve these tutorials.

Tutorial 1: Getting Started

This tutorial we'll be setting up our development environment, and creating a basic GLES3 app. It won't do much; just open a window and clear it to black. The goal is simply to get something basic working.

Setting Up the Development Environment

To write GLES3 + SDL2 apps we need a suitable development environment (dev-environment) that allows us to write code and compile it. There are two parts to this. First, we need to install the code editor and compiler. Second, most dev-environments don't come with GLES3 and SDL2 support out of the box. Their dev-files need to be installed before we can use them.

NOTE: This tutorial currently only covers using Visual Studio on Windows. Don't worry about developing for mobile devices yet; just get the basics working on your desktop computers. If you're using MacOS X or some other platform then search the internet for how you set up a compiler (e.g., here's one for SDL2 on MacOS X: http://lazyfoo.net/tutorials/SDL/01_hello_SDL/mac/index.php).

Setup on Windows

Microsoft provide a comprehensive dev-environment called Visual Studio. So download that now from: https://www.visualstudio.com/downloads/

IMPORTANT: Download the free *Visual Studio Community* edition. The free version provides all that you need.

Start the Visual Studio installer, and select the "Custom," (Figure 1).

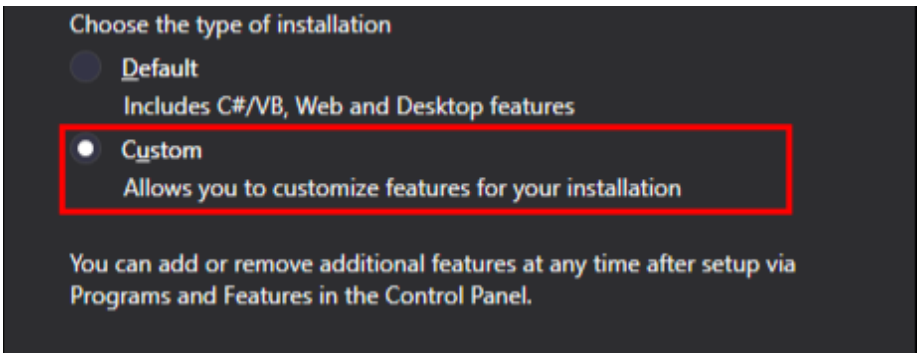


Figure 1: Choose the custom installation type.

Click the "Next" button. Next, make sure that you're installing Visual C++ (see Figure 2).

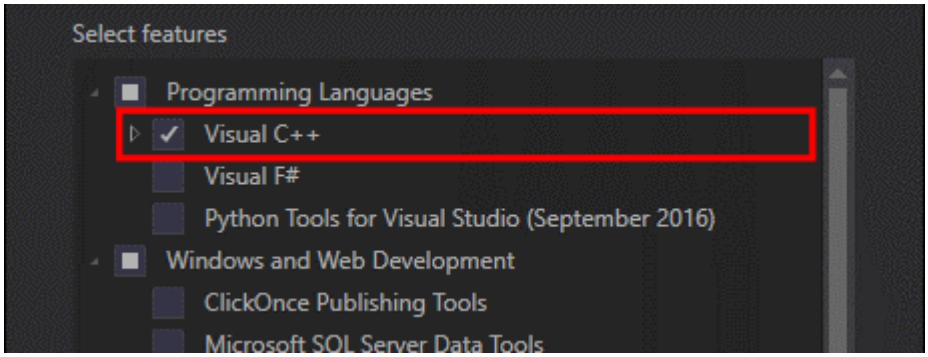


Figure 2: Select the features to install.

With this done, click "Next," then "Install," and wait for the installer to complete.

Installing the GLES3 & SDL2 Development Files

On Windows you need two sets of dev-files:

- Angle (for GLES3 support) - https://github.com/google/angle
- SDL2 - https://www.libsdl.org/download-2.0.php

The setup process is currently rather tedious, so I've created a template that does it all for you. Download the template from: https://keasigmadelta.com/assets/GLTutorials/GLES3SDL2-Application.zip

To install the template, copy the downloaded file to: "<My Documents folder>\Visual Studio 2015\Templates\ProjectTemplates\Visual C++ Project" (see Figure 3).

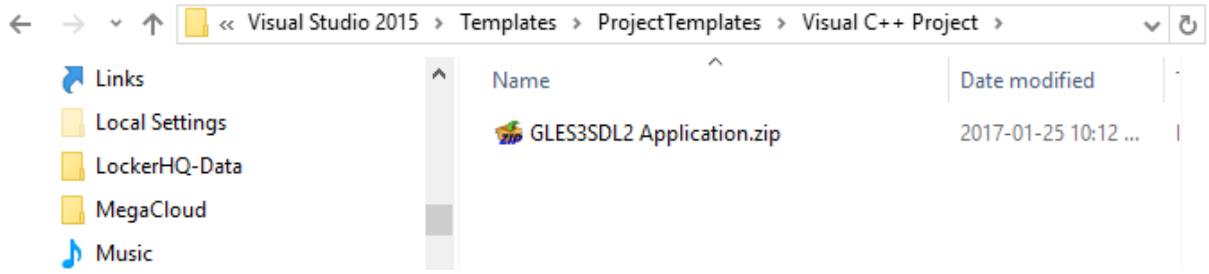


Figure 3: The template is installed by copying it to the project templates folder.

Create a New Project

Now we can create our project. In Visual Studio, select File => New => Project from the menu. Select the "GLES3SDL2 Application" template, and call the project something like "GLTutorial1" (Figure 4). After clicking "OK" it'll create the new project.

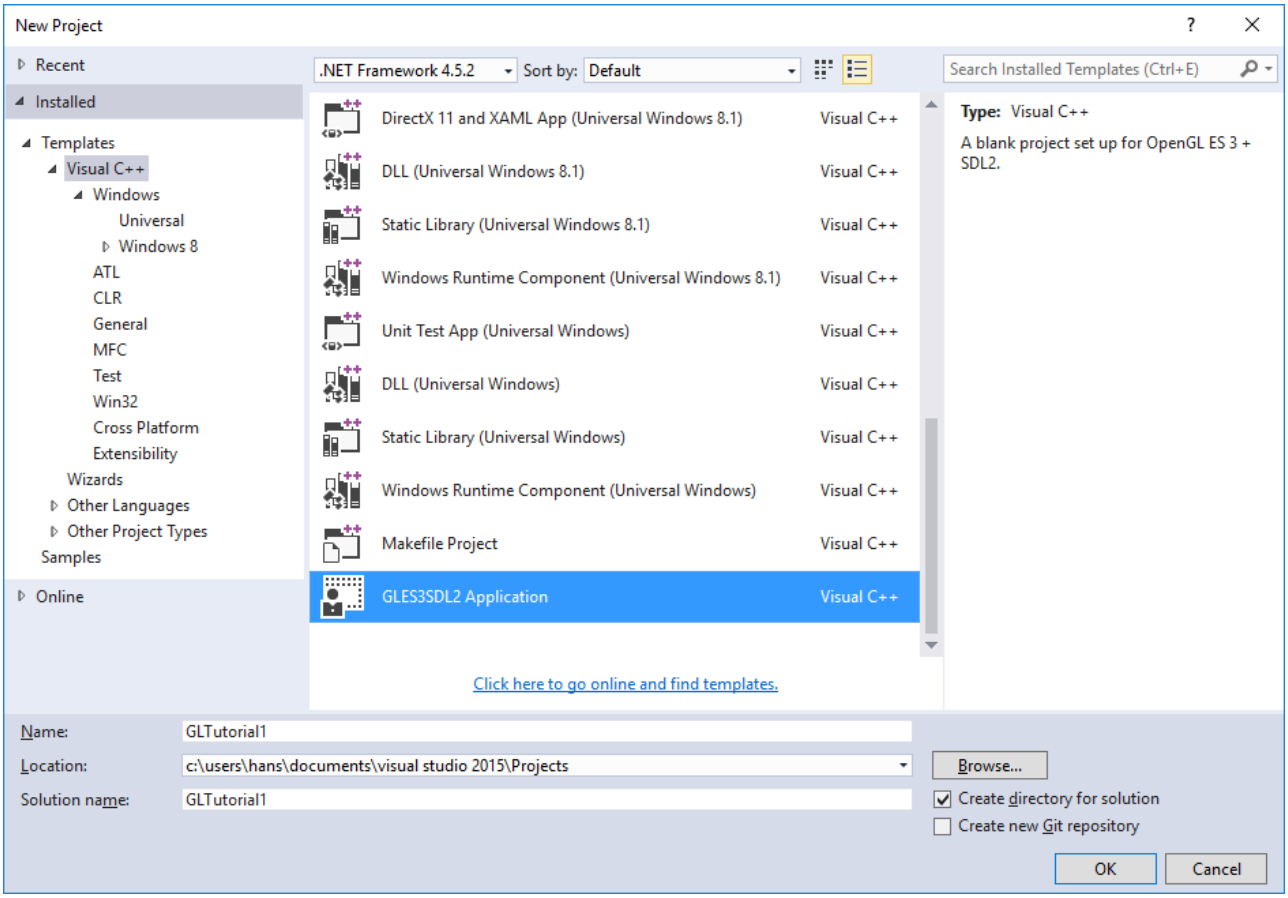


Figure 4: Create a new project using the GLES2SDL2 Application template.

Next, right-click on the new "GLTutorial1" project in the Solution Explorer (on the left) and select build. With the first build it'll set up SDL2 and Angle within the project. The Angle files are in a self-extracting archive. It'll pop up a window asking you where to put it (Figure 5). Simply click the Extract button.

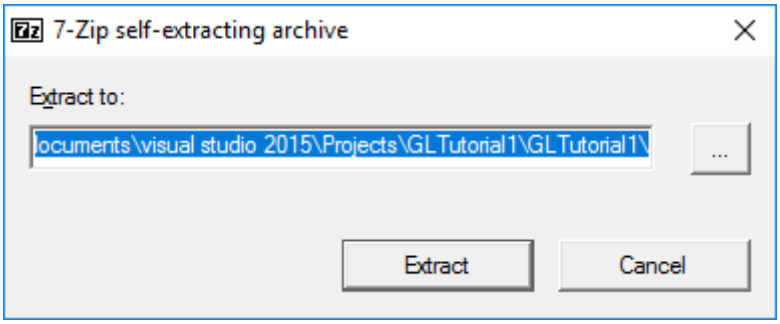


Figure 5: Click Extract to unpack the Angle files.

NOTE: Visual Studio's editor may claim it can't find "SDL.h" despite having installed the SDL2 package during the initial build. Simply close and reopen the project/solution (File => Close Solution, followed by File => Recent Projects and Solutions => GLTutorial1.sln).

Our First GLES3 & SDL2 Program

Right! Let's get into actual coding, and write our first GLES3 + SDL program. In the solution explorer (left column), open Main.cpp. You'll find it under GLTutorial1 => Source Files. Delete the existing code, and start writing.

IMPORTANT: As mentioned in the How to Get the Most Out of These Tutorials section (on page 6), it's highly recommended that you type out the code by hand instead of copying and pasting. You'll learn/remember more if you do it that way.

Headers and Definitions

We'll start by including the header files for libraries we're using (SDL2 & OpenGL). Here's the code:

```
// Basic OpenGL ES 3 + SDL2 template code


#include <SDL.h>
#include <SDL_opengles2.h>
#include <GLES3/gl3.h>
#include <cstdio>
#include <cstdlib>
```

Next, comes a few constants for the window's dimensions:

```
const unsigned int DISP_WIDTH = 640;
const unsigned int DISP_HEIGHT = 480;
```

SDL and OpenGL Initialization

Its time to set up SDL and create a window with an OpenGL ES 3 context. This is the start of your program. With SDL, the main entry point is *SDL_main()*. This is optional, but worth using because it hides the difference between main() & WinMain() (or whatever special main entry point an OS may have). Anyway, SDL is initialized as follows (put this directly below the headers and definitions):

```
int SDL_main(int argc, char *args[]) {

  // The window
  SDL_Window *window = NULL;


  // The OpenGL context
  SDL_GLContext context = NULL;


  // Init SDL
```

```
if (SDL_Init(SDL_INIT_VIDEO) < 0) {
  SDL_Log("SDL could not initialize! SDL_Error: %s\n", SDL_GetError());
  return EXIT_FAILURE;
}

// Setup the exit hook
atexit(SDL_Quit);
```

Notice that we're only initializing SDL's video subsystem in the SDL_Init() call:

```
if (SDL_Init(SDL_INIT_VIDEO) < 0) {
```

SDL has other sub-systems such as audio and joystick input, but we're not using any of them.

Next, we request OpenGL ES 3.0, and double-buffering:

```
// Request OpenGL ES 3.0

SDL_GL_SetAttribute(SDL_GL_CONTEXT_PROFILE_MASK, SDL_GL_CONTEXT_PROFILE_ES);
SDL_GL_SetAttribute(SDL_GL_CONTEXT_MAJOR_VERSION, 3);
SDL_GL_SetAttribute(SDL_GL_CONTEXT_MINOR_VERSION, 0);

// Want double-buffering
SDL_GL_SetAttribute(SDL_GL_DOUBLEBUFFER, 1);
```

Double-buffering is a technique whereby we render to an invisible back-buffer and then flip the buffers round to show it. Rendering directly to the screen runs the risk that partially rendered images are shown. We definitely don't want that because it's ugly.

Opening the Window

With base initialization done, we can now open the window and set up the OpenGL context:

```
// Create the window

window = SDL_CreateWindow("GLES3+SDL2 Tutorial", SDL_WINDOWPOS_UNDEFINED,
      SDL_WINDOWPOS_UNDEFINED, DISP_WIDTH, DISP_HEIGHT,
      SDL_WINDOW_OPENGL | SDL_WINDOW_SHOWN);
if (!window) {
  SDL_ShowSimpleMessageBox(SDL_MESSAGEBOX_ERROR, "Error",
      "Couldn't create the main window.", NULL);
  return EXIT_FAILURE;
}
```

```
context = SDL_GL_CreateContext(window);
if (!context) {
  SDL_ShowSimpleMessageBox(SDL_MESSAGEBOX_ERROR, "Error",
      "Couldn't create an OpenGL context.", NULL);
  return EXIT_FAILURE;
}
```

The code above has two steps; create the window (*SDL_CreateWindow()*), and create the OpenGL context (*SDL_GL_CreateContext()*). Everything else is error handling. If you wish to use OpenGL then it's very important to pass SDL_CreateWindow() the ***SDL_WINDOW_OPENGL*** flag. Otherwise the SDL_GL_CreateContext() call will fail.

Draw Something

Yes, it's finally time to draw something! Okay, all we're going to do this tutorial is clear the screen, but it'll still be an OpenGL draw operation nonetheless. Clearing to black is done as follows:

```
// Clear to black
glClearColor(0.0f, 0.0f, 0.0f, 1.0f);
glClear(GL_COLOR_BUFFER_BIT);

// Update the window
SDL_GL_SwapWindow(window);
```

GL_COLOR_BUFFER_BIT tells *glClear()* to only clear the screen/image (a.k.a., colour buffer). A context may also have depth/z and stencil buffers, and you may wish to clear one or more of them. The clear colour is, unsurprisingly, set by *glClearColor()*. Finally, *SDL_GL_SwapWindow()* swaps the buffers so that our new image is displayed. We enabled double-buffering (by passing *SDL_GL_DOUBLEBUFFER* to *SDL_GL_SetAttribute()*) so rendering is performed on an invisible back buffer. So the front and back buffers need to be swapped.

Wait Until the User Wants to Quit

Normally a "real" OpenGL program would have a main loop that does things like respond to events and render animated graphics. Since this is a really basic program, all that's needed is to wait for the user to click the window's close button. SDL makes this relatively easy with its event handling functions:

```
// Wait for the user to quit
bool quit = false;
while (!quit) {
  SDL_Event event;
```

```
    if (SDL_WaitEvent(&event) != 0) {
      if (event.type == SDL_QUIT) {
        // User wants to quit
        quit = true;
      }
    }
  }

  return EXIT_SUCCESS;
}
```

SDL_WaitEvent() stops the program until an event comes in. If the incoming event is an *SDL_QUIT*, then the code above exits the while loop, and quits.

The Code in Full

Putting it all together, Main.cpp is:

```
// Basic OpenGL ES 3 + SDL2 template code


#include <SDL.h>
#include <SDL_opengles2.h>
#include <GLES3/gl3.h>
#include <cstdio>
#include <cstdlib>

const unsigned int DISP_WIDTH = 640;
const unsigned int DISP_HEIGHT = 480;

int SDL_main(int argc, char *args[]) {
  // The window
  SDL_Window *window = NULL;

  // The OpenGL context
  SDL_GLContext context = NULL;

  // Init SDL
  if (SDL_Init(SDL_INIT_VIDEO) < 0) {
    fprintf(stderr, "SDL could not initialize! SDL_Error: %s\n", SDL_GetError());
    return 10;
  }

  // Setup the exit hook
```

```
atexit(SDL_Quit);

// Request OpenGL ES 3.0
SDL_GL_SetAttribute(SDL_GL_CONTEXT_PROFILE_MASK, SDL_GL_CONTEXT_PROFILE_ES);
SDL_GL_SetAttribute(SDL_GL_CONTEXT_MAJOR_VERSION, 3);
SDL_GL_SetAttribute(SDL_GL_CONTEXT_MINOR_VERSION, 0);

// Want double-buffering
SDL_GL_SetAttribute(SDL_GL_DOUBLEBUFFER, 1);


// Create the window
window = SDL_CreateWindow("GLES3+SDL2 Tutorial", SDL_WINDOWPOS_UNDEFINED,
       SDL_WINDOWPOS_UNDEFINED, DISP_WIDTH, DISP_HEIGHT,
      SDL_WINDOW_OPENGL | SDL_WINDOW_SHOWN);
if (!window) {
  SDL_ShowSimpleMessageBox(SDL_MESSAGEBOX_ERROR, "Error",
      "Couldn't create the main window.", NULL);
  return EXIT_FAILURE;
}

context = SDL_GL_CreateContext(window);
if (!context) {
  SDL_ShowSimpleMessageBox(SDL_MESSAGEBOX_ERROR, "Error",
      "Couldn't create an OpenGL context.", NULL);
  return EXIT_FAILURE;
}

// Clear to black
glClearColor(0.0f, 0.0f, 0.0f, 1.0f);
glClear(GL_COLOR_BUFFER_BIT);

// Update the window
SDL_GL_SwapWindow(window);

// Wait for the user to quit
bool quit = false;
while (!quit) {
  SDL_Event event;
  if (SDL_WaitEvent(&event) != 0) {
```

```
      if (event.type == SDL_QUIT) {
        // User wants to quit
        quit = true;
      }
    }
  }

  return EXIT_SUCCESS;
}
```

Running the Program

Save Main.cpp, then push F5 to build and run GLTutorial1 (or right-click on the project and select Debug => Start new instance). Visual Studio will compile the program and run it. If you typed out everything correctly, you'll be greeted with the following (Figure 6).

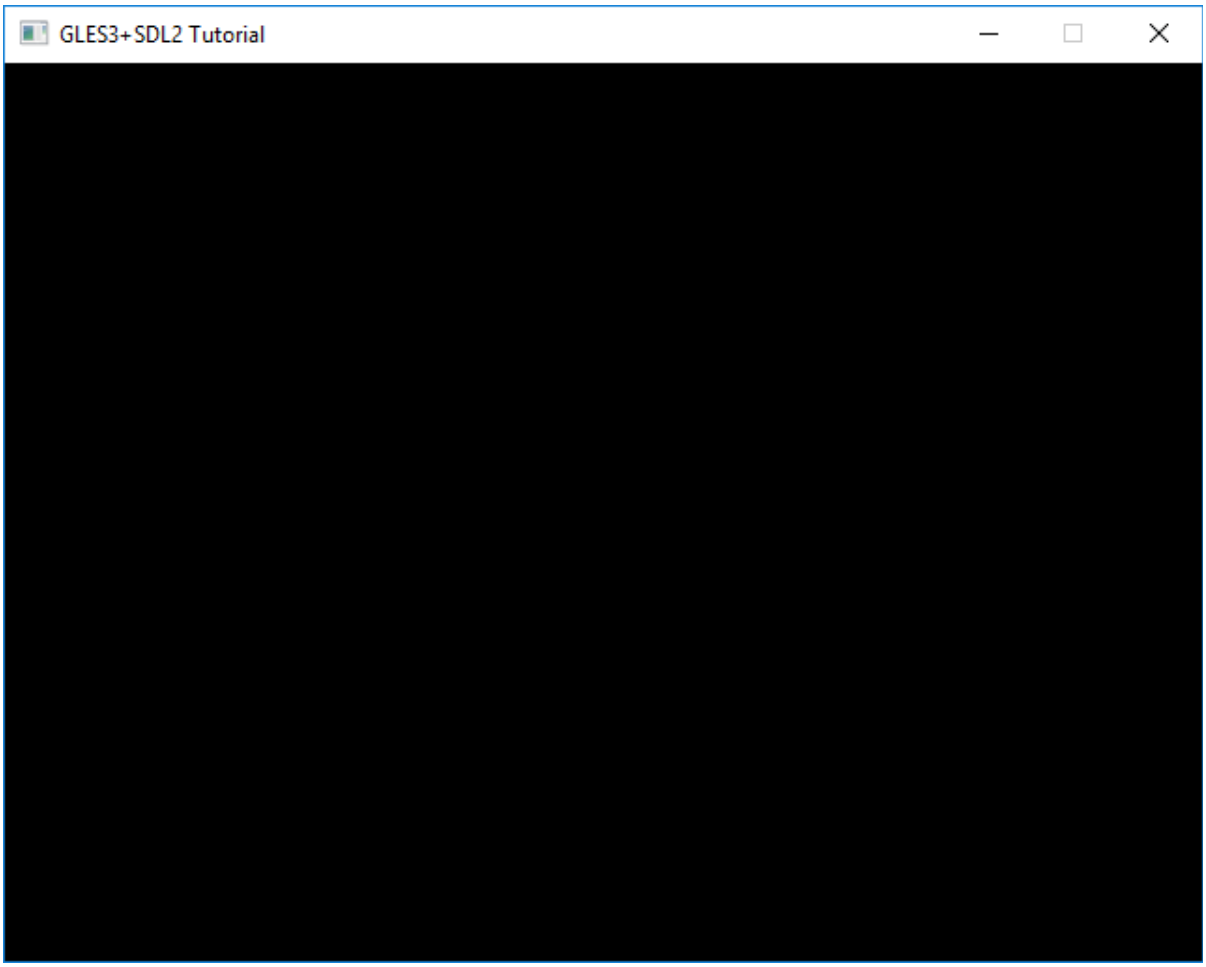


Figure 6: GLTutorial1 running in all its minimalist glory.

Congratulations! You just wrote your first GLES3 + SDL2 program. Yes, it's really boring, but it covers the basics you'll need to build more interesting stuff. The next tutorial covers rendering something (a single triangle).

Exercises

You've learnt the basics by example, now it's time to write some code on your own. Experimentation is a great way to learn. So, see if you can modify the code to do the following:

1. Change the window's size to 800x600
2. Change the clear colour to red, then green, blue, & yellow