Geometric Tools Engine Version 3.5 Installation Manual and Release Notes

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1 Introduction

You are about to install Geometric Tools Engine 3.5. Version 1.0 source code was the companion to the book GPGPU Programming for Games and Science and was developed on Microsoft Windows 8.1 using Microsoft Visual Studio 2013, C++ 11, and Direct3D 11.1. Version 3.x is close enough to what is in the book that you should have no problem navigating the code as you read the book. The source code has been reorganized using subfolders of Source and Include, and the header includes are now slightly different.

Version 3.x has a graphics engine that requires minimally OpenGL 4.3 (or later) and GLSL 4.3 (or later) in order to support compute shaders and GLSL introspection, and it runs on both Microsoft Windows (WGL) and Linux (GLX). Please observe that the engine and sample applications require OpenGL 4.3 (or later) and GLSL 4.3 (or later). If your graphics driver does not support this, the applications will gracefully terminate with a message to the console window: *OpenGL 4.3 is required.* In particular, the Nouveau Open Source graphics drivers that ship with the various flavors of Linux do not currently support OpenGL 4.3 (or later) or GLSL 4.3 (or later). You must install the graphics card manufacturer's proprietary driver.

A Direct3D 12 engine is in development, but given that the programming model is significantly different from Direct3D 11, the graphics subsystem of GTEngine needs to be redesigned. The plan is to factor GTEngine into smaller projects, each graphics API having its own project and corresponding application support. The mathematics library will also be factored into a stand-alone project to allow developers to use the code without having to depend on all other parts of the library.

Visit the Geometric Tools website for updates, bug fixes, known problems, new features, and other materials.

1.1 License

The Geometric Tools Engine uses the Boost License, listed next.

```
Boost Software License - Version 1.0 - August 17th, 2003

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```

1.2 Copying the Distribution to Your Machine

You may unzip the distribution to a folder of your choice. The top-level folder of the distribution is GeometricTools and the subfolder for the distribution is named GTEngine. Some of the folder hierarchy is shown next. The Include and Source folders contain all the code for the engine.

```
GeometricTools
  GTEngine                      // Root folder for Geometric Tools Engine, set GTE_PATH to here.
    Include                     // Location for *.h files.
      Applications              // Platform-independent classes.
        GLX                     // Support for Linux GLX applications.
        MSW                     // Support for Microsoft Windows applications.
          DX11                  // Support for Direct3D 11 applications.
          WGL                   // Support for WGL applications.
      Graphics                  // Platform-independent graphics files.
        DX11                    // DX11-specific graphics files.
        GL4                     // Platform-independent OpenGL-specific graphics files.
          GLX                   // Linux GLX graphics files.
          WGL                   // WGL graphics files.
      Imagics                   // Image processing files.
      LowLevel                  // Several low-level utility files.
        MSW                     // Microsoft Windows-specific files.
      Mathematics               // The bulk of the engine consists of mathematics support.
        MSW                     // Microsoft Windows-specific files.
      Physics                   // Some physics support, not all WM5 physics code has been ported.
    Source                      // Location for *.cpp files.
      Applications              // Platform-independent classes.
        GLX                     // Support for Linux GLX applications.
        MSW                     // Support for Microsoft Windows applications.
          DX11                  // Support for Direct3D 11 applications.
          WGL                   // Support for WGL applications.
      Graphics                  // Platform-independent graphics files.
        DX11                    // DX11-specific graphics files.
        GL4                     // Platform-independent OpenGL-specific graphics files.
          GLX                   // Linux GLX graphics files.
          WGL                   // WGL graphics files.
      Imagics                   // Image processing files.
      LowLevel                  // Several low-level utility files.
        MSW                     // Microsoft Windows-specific files.
      Mathematics               // The bulk of the engine consists of mathematics support.
        MSW                     // Microsoft Windows-specific files.
      Physics                   // Some physics support, not all WM5 physics code has been ported.
    Samples                     // Sample applications, many discussed in the GPGPU book.
      Data                      // A small number of data files for the samples.
      Basics                    // Basic tutorials for several HLSL concepts.
      Geometrics                // Samples for computational geometry.
      Graphics                  // Samples for graphics and video streams (parallel copy).
      Imagics                   // Samples for 2D and 3D image processing.
      Mathematics               // Samples for mathematical algorithms and numerical methods.
      Physics                   // Samples for 2D and 3D physics.
      DX11                      // Samples specifically for Direct3D 11.
    Shaders                     // HLSL/GLSL shader files (embedded versions are in the engine source).
    Tools                       // Several convenient tools.
      BitmapFontCreator         // Generate .h/.cpp file to represent a graphics font.
      GenerateApproximations    // Used to generate the minimax approximations for common functions.
      GenerateOpenGLWrapper     // Source-code generator for gl* wrappers driven by glcorearb.h.
      GenerateProject           // Generate MSVS 2013/2015 vcxproj, sln, h, and cpp for applications.
      PrecisionCalculator       // Determine bits of precision needed exact-arithmetic algorithms.
```

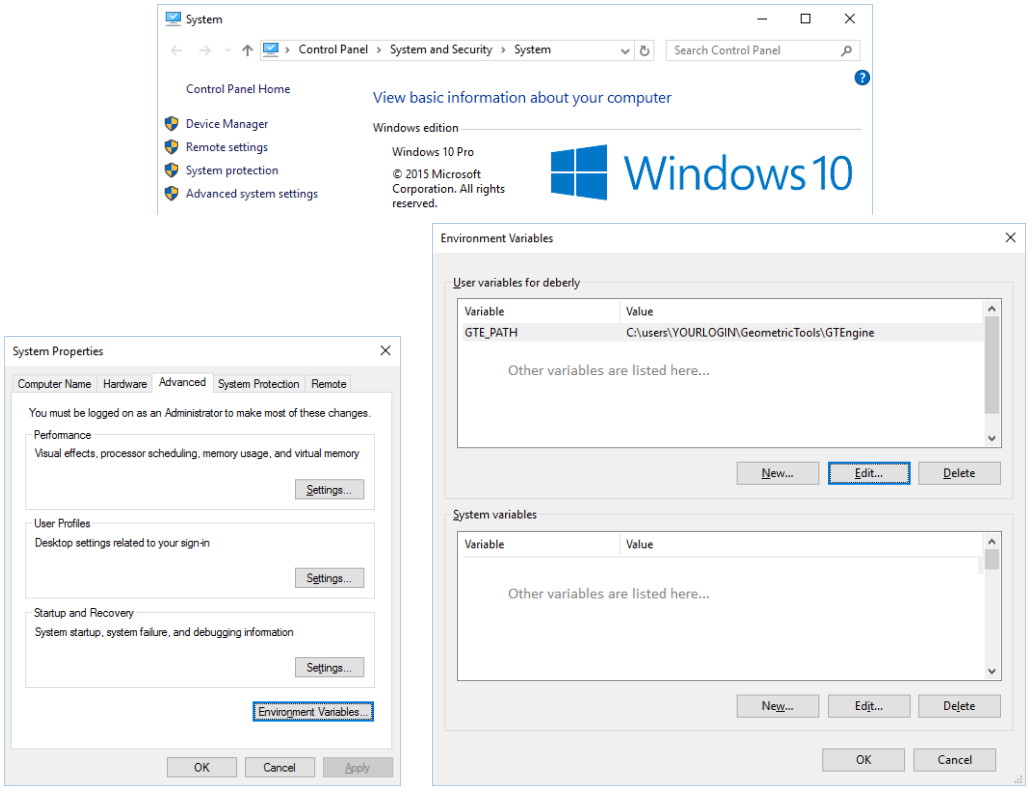
The Samples subfolders are many. Listing them here would make the displayed hierarchy difficult to read. The projects all use paths relative to GTEngine and they do not rely on the top-level directory being located at the root of a hard drive. An environment variable GTE_PATH is used to locate data files required by the application. How you set an environment variable depends on the operating system and/or shell you are using.

2 Development on Microsoft Windows

The code is maintained currently on an Intel-based computer with Microsoft Windows 10, Version 1607 (OS Build 14393.447). If you develop on Microsoft Windows 7 or 8.x and encounter problems with the code, contact us via the email address listed at the Geometric Tools website.

2.1 Environment Variables

Create an environment variable named GTE_PATH that stores the absolute directory path to the folder GeometricTools/GTEngine. For example, if you unzipped the distribution to the root of the C drive, you would set GTE_PATH to C:/GeometricTools/GTEngine. You can set environment variables via System | Advanced system settings, which launches the System Properties dialog with a button for Environment Variables.



2.2 Compiling the Source Code

Microsoft Visual Studion 2013 uses Version 12 of the compiler and Microsoft Visual Studio 2015 uses Version 14 of the compiler. The project and solution names have embedded in them v12 or v14; that is, both versions of the compiler are supported. The engine solutions are GeometricTools/GTEngine/GTEngine.v12.sln and GeometricTools/GTEngine/GTEngine.v14.sln. Each sample application or tool has its own solution with all dependencies listed, so it is possible to open a sample application and compile and run it without

explicitly building the engine solution first. The folder GTEngine contains the solutions GTBuildAll.v12.sln and GTBuildAll.v14.sln if you want to build the engine, samples, and tools at the same time rather than building the projects separately.

2.3 Support for OpenGL

All the Microsoft Visual Studio projects have configurations Debug and Release that include compiling the Direct3D 11 source code. The configurations DebugGL4 and ReleaseGL4 include compiling the OpenGL source code. Although it is possible to have an application that creates both a Direct3D 11 engine and an OpenGL engine, the current project design does not allow this. If you have such a need, you must create your own GTEngine project that enables both sets of graphics code. For example, you might have an application that uses OpenGL for rendering but uses Direct3D 11 for compute shaders (for GPGPU).

2.4 Automatic Generation of Project and Solution Files

Creating a new Microsoft Visual Studio project and manually setting its properties to match those of the current sample applications is tedious. A tool is provided to generate a skeleton project, solution, and source files, GeometricTools/GTEngine/Tools/GenerateProject. As an example of how to use the tool, suppose you want to create a new project in the folder, GeometricTools/GTEngine/Samples/Graphics/MySample for a sample application. Copy GenerateProject.exe to that folder, and in a command window opened in that folder, execute

```
GenerateProject 3 MySample
```

The number 3 indicates the nesting of the MySample folder relative to the GTEngine folder. The tool creates the files MySample.v12.sln, MySample.v12.vcxproj, MySample.v12.vcxproj.filters, MySample.v14.sln, MySample.v14.vcxproj, MySample.v14.vcxproj.filters, MySampleWindow.h, and MySampleWindow.cpp. You can open the solution, build, and run to see a blank window of size 512×512. The copyright notice generated as the preamble of the files MySampleWindow.* is for our convenience—you may delete those notices.

If you want the generated files to live in a folder outside the GTEngine hierarchy, you will need to modify the include path in the projects to $(GTE_PATH)/Include. You will also need to delete the GTEngine project from the Required folder of the solution and re-add it so that the correct path occurs. This is necessary because the Microsoft Visual Studio reference system is used to link in the GTEngine library.

Also, it is not necessary to copy GenerateProject.exe to the project folder. If the executable can be found via the PATH statement, just execute it in any folder of your choosing and then copy the generated files to your project folder.

2.5 Running the Samples

You can run the samples from within the Microsoft Visual Studio development environment. Samples that access data files use the GTE_PATH environment variable to locate those files; code is in place to assert when the environment variable is not set. If you run from Microsoft Windows, presumably double-clicking an executable via Windows Explorer, the environment variable is still necessary.

Many of the samples compile HLSL shaders at run time. This requires having D3Dcompiler_*.dll in your path, where * is the version number of the shader compiler. You might have to modify your PATH environment variable to include the path. With latest Windows, the DLL should be in a Windows Kit bin folder.

2.6 Microsoft Visual Studio Custom Visualizers

A new file has been added, GeometricTools/GTEngine/gtengine.natvis, that provides a native visualizer for the Vector and Matrix classes. Copy this to C:/Users/YOURLOGIN/Documents/Visual Studio 2015/Visualizers. More visualizers will be added over time. Feel free to suggest GTEngine classes for which you want specialized visualization during debugging.

2.7 Falling Back to Direct3D 10

For Microsoft Windows machines, the default settings for GTEngine are to use Direct3D 11.0 or later for rendering and to compile the shaders for the built-in effects (such as Texture2Effect and VertexColorEffect) using Shader Model 5. These settings are also used when compiling shaders that are part of the sample application or those you write yourself. If you do not have graphics hardware recent enough to support the default configuration, it is possible to modify the start-up code in the sample applications to fall back to Direct3D 10.0 (Shader Model 4.0) or Direct3D 10.1 (Shader Model 4.1).

Open the graphics sample named VertexColoring. The main function has the block of code

```
Window::Parameters parameters(L"VertexColoringWindow", 0, 0, 512, 512);
auto window = TheWindowSystem.Create<VertexColoringWindow>(parameters);
TheWindowSystem.MessagePump(window, TheWindowSystem.DEFAULT_ACTION);
TheWindowSystem.Destroy<VertexColoringWindow>(window);
```

All the 2D and 3D windowed applications have similar blocks of code. The Window::Parameters structure has a member named featureLevel that defaults to D3D_FEATURE_LEVEL_11_0. The general list of values from which you can choose is

```
enum D3D_FEATURE_LEVEL
{
    D3D_FEATURE_LEVEL_9_1   = 0x9100,   // 4_0_level_9_1
    D3D_FEATURE_LEVEL_9_2   = 0x9200,   // 4_0_level_9_1
    D3D_FEATURE_LEVEL_9_3   = 0x9300,   // 4_0_level_9_3
    D3D_FEATURE_LEVEL_10_0  = 0xa000,   // 4_0
    D3D_FEATURE_LEVEL_10_1  = 0xa100,   // 4_1
    D3D_FEATURE_LEVEL_11_0  = 0xb000,   // 5_0
    D3D_FEATURE_LEVEL_11_1  = 0xb100    // 5_1
}
D3D_FEATURE_LEVEL;
```

The enumeration is found in d3dcommon.h. If you have a graphics card that supports at most Direct3D 10.0, then modify the main code to

```
    Window::Parameters parameters(L"VertexColoringWindow", 0, 0, 512, 512);
#if !defined(GTE_DEV_OPENGL)
    parameters.featureLevel = D3D_FEATURE_LEVEL_10_0;
    HLSLProgramFactory::defaultVersion = "4_0";
#endif
    auto window = TheWindowSystem.Create<VertexColoringWindow>(parameters);
    TheWindowSystem.MessagePump(window, TheWindowSystem.DEFAULT_ACTION);
    TheWindowSystem.Destroy<VertexColoringWindow>(window);
```

Comments were added after the enumerates to indicate what to assign to HLSLProgramFactory::defaultVersion.

For non-windowed applications, the DX11Engine constructors allow you to specify directly the feature level.

2.8 Falling Back to Direct3D 9

This is not really possible, because GTEngine uses constant buffers and other concepts without equivalent DX9 representations. The best you can do is specify one of the feature levels mentioned in the previous section for which LEVEL_9 is part of the name. Note that there is no shader profile with name 4_0_level_9_2. If you set the version string to "3_0", the D3DReflect call will fail with HRESULT 0x8876086C, which is not listed in winerror.h. This is the code for the obsolete D3DERR_INVALIDCALL. The HLSL assembly instructions for Shader Model 3 do not contain constant buffer register assignments (because they did not exist then).

2.9 No Support Yet for Dynamic Libraries for GTEngine

Currently, the engine solution generates static libraries. The hooks are in place for dynamic libraries, but the build configurations have not yet been added to the projects.

3 Development on Linux

The GTEngine source code and sample applications have been tested on four flavors of Linux: Fedora 24, Debian 8.5.0, Ubuntu 16.04, and Linux Mint 18 (MATE). As mentioned previously, your graphics driver must be capable of OpenGL 4.3 (or later) and GLSL 4.3 (or later).

If you have obtained GTEngine 3.2 as a package already part of the Linux distribution, all you need do is set an environment variable and compile the sample applications. The GTEngine libraries should already be built, and the headers and libraries should be installed in the default locations. The other directions provided here are for those obtaining the package from the Geometric Tools website.

3.1 Environment Variables

Create an environment variable named GTE_PATH that stores the absolute directory path to the folder GeometricTools/GTEngine. For example, if you use a bash shell, you would define the environment variable in the file .bashrc by adding the line

```
GTE_PATH=/home/YOURLOGIN/GeometricTools/GTEngine ; export GTE_PATH
```

The actual path depends on YOURLOGIN and where you copied the GTEngine distribution. The .bashrc file is processed when you login; however, if you modify it after logging in, you may process it by executing

```
source .bashrc
```

from a terminal window whose active directory is your home folder. For other versions of Linux or other shells, consult your user's guide on how to create an environment variable.

3.2 Dependencies on Other Packages

Each of the three supported flavors of Linux was installed from Live distributions. GTEngine depends on development packages for X11, OpenGL, GLX, and libpng. The latter package is used for a simple reader/writer of PNG files for the sample applications. The package manager for Fedora 24 is dnf and the package manager for Debian 8.5.0, Ubuntu 16.04, and Linux Mint 18 is apt. The names of the dependent packages vary with Linux distribution.

3.3 Compiling the Source Code

The makefile to build the GTEngine library is GeometricTools/GTEngine/makeengine.gte where both static and shared library builds are supported. From a terminal window execute

```
make CFG=configuration -f makeengine.gte
```

where configuration is Debug or Release for static libraries abd is DebugDynamic or ReleaseDynamic for shared libraries.

You can build all samples by changing directory to GeometricTools/GTEngine/Samples and executing

```
make CFG=configuration -f makeallsamples.gte
```

If you want to build a single sample application, change directory to the sample folder. For example, change directory to GeometricTools/GTEngine/Samples/Graphics/VertexColoring and execute

```
make CFG=configuration APP=VertexColoring -f ../../makesample.gte
```

3.4 Support for OpenGL via Proprietary Drivers

On Fedora 24, Ubuntu 16.04, and Linux Mint 18, glxinfo showed that the Nouveau drivers are OpenGL 4.1. On Debian 8.5.0, the Nouveau driver is OpenGL 3.3. In all cases, you cannot run the sample applications with the Nouveau drivers—you need the proprietary drivers.

Installing the NVIDIA proprietary driver (version 367.27) was challenging. This version of the driver supports OpenGL 4.5. The installation directions varied for each Linux OS. After searching the Internet, the following links led to successful installation. The directions are not for the most recent versions of the operating systems, but the directions still apply.

- Install on Fedora 24
- Install on Debian 8.5.0
- Install on Ubuntu 16.04

The Ubuntu directions are via a search using Google, and there is a simple summary of steps listed at the top of the search page. The installation of NVIDIA proprietary driver on Linux Mint was trivial (via the Hardware Drivers menu).

The bare minimum of GLX functions is used to create windows that allow OpenGL accelerated rendering. All functions are included in the GLX packages for Linux, so there is no need for GLX extensions.

3.5 Running the Samples

For the static library builds, you can simply open a terminal window and change directory to the project directory. For example, if you built the static release library and the Graphics/BlendedTerrain sample application, the application can be launched by executing ./BlendedTerrain.Release

For shared library builds, the libraries are stored in GeometricTools/GTEngine/lib. Once GTEngine 3.2 becomes part of the Linux distributions, you will find these libraries in the standard locations. Before then, a simple way to launch the application is the following. Suppose you have a terminal window open and you have changed directory to Samples/Graphics/BlendedTerrain and that you have built the shared release versions of the engine and application. Execute the following

```
LD_LIBRARY_PATH=$GTE_PATH/lib/ReleaseDynamic ./BlendedTerrain.Release
```

4 Development on Macintosh OS X

Support for graphics on the Macintosh has been discontinued because compute shaders and GLSL introspection require OpenGL 4.3 (or later) but Apple has not updated their OpenGL support from version 4.1. However, the nongraphics and nonapplication code compiles. An Xcode project (actually a folder and subfolders) is provided, GeometricTools/GTEngine/GTEngine.xcodeproj, that allows you to build any of four configurations. The Debug and Release configurations generate static libraries. The Debug Dynamic and Release Dynamic configurations generate shared libraries.

With the introduction of Mac OS X 10.7, access to environment variables via the library function getenv appears to have been disabled. A plist mechanism used to work with earlier versions of the operating system, but no longer. The Wild Magic 5 distribution had a workaround for this, but the sample applications in GTEngine are not supported on the Macintosh, so there is no need for the workaround.

5 Accessing the OpenGL Driver Information

This section is applicable both to Microsoft Windows and to Linux.

The GL4Engine code is designed to allow you to write to disk information about the OpenGL driver. Extending the example for VertexColoring described in the previous sections, modify the main code

```
    Window::Parameters parameters(L"VertexColoringWindow", 0, 0, 512, 512);
#if defined(GTE_DEV_OPENGL)
    parameters.deviceCreationFlags = 1;
#endif
    auto window = TheWindowSystem.Create<VertexColoringWindow>(parameters);
    TheWindowSystem.MessagePump(window, TheWindowSystem.DEFAULT_ACTION);
    TheWindowSystem.Destroy<VertexColoringWindow>(window);
```

For now the only device creation flags for OpenGL are the default 0 or 1, the latter causing the OpenGL driver information to be written to a file named OpenGLDriverInfo.txt. The first several lines of the file show the vendor, the renderer (graphics card model and related), and the OpenGL version supported by the driver. The remaining lines list supported OpenGL extensions.

6 Automatic Generation of a Wrapper for OpenGL

Several packages may be found online that provide wrappers that query for OpenGL function pointers and that encapsulate many of the gory details in using the OpenGL API. As an alternative, GTEngine ships with a tool to build a wrapper, GeometricTools/GTEngine/Tools/GenerateOpenGLWrapper. The file GteOpenGL.h was written manually—do not modify it. The file GteOpenGL.cpp is generated by parsing glcorearb.h, a file that is available from the OpenGL Registry. This file is introduced in the OpenGL 4.3 Specification.

If the file is updated, or if you want to use a previous version, you can copy your file to the tool's project folder and then use the wrapper tool to regenerate GteOpenGL.cpp and copy it to

GeometricTools/GTEngine/Source/Graphics/GL4/GteOpenGL.cpp

You must also copy your version of glcorearb.h to

GeometricTools/GTEngine/Include/Graphics/GL4/GL/glcorearb.h

The extension files from the OpenGL Registry were also copied to the same folder as glcorearb.h. These include glext.h, glxext.h, and wglext.h. The first three are not used by the engine, but the last one is used by the WGL OpenGL engine.

The GenerateOpenGLWrapper tool has projects for Microsoft Visual Studio. To build this on Linux,

```
g++ -std=c++14 -c GenerateOpenGLWrapper.c -o GenerateOpenGLWrapper.o
g++ GenerateOpenGLWrapper.o -o GenerateOpenGLWrapper
```

and then execute the program in the project folder.