**Lattice Boltzmann Method Using CUDA**

Erik Brobyn

City College of New York Department of Physics

**Abstract**

This is a brief summary of the experiment, its objectives and major conclusions. Use no more than 200 words. If someone only read this they would know what you did and why you did it. (How and details are in the main report.)

**Introduction**

Describe the importance of this experiment. Describe the relevant background theory and mention the major relations or formulae you need for data analysis. Do not derive them. At the end of the introduction state clearly and concisely the objectives and conclusions of the experiment.

**Software Investigated**

* Microsoft Visual Studio Community 2017 and 2019
* NVIDIA GPU Computing Toolkit (CUDA) v10.2.89 441.22 for Windows 10
* NVIDIA Corporation's CUDA Samples v10.2
* LATTICE BOLTZMANN SIMULATOR GPU accelerated with CUDA

by Tom Scherlis and Henry Friedlander (2017)

* NVIDIA Nsight for Visual Studio Community 2019

**About NVIDIA CUDA Samples v10.2**

The CUDA Samples is a collection of 176 projects spread across several subject areas, including Graphics, Finance, Simulation, and Imaging. The sample code is mostly written in C, with some C++ used, and many of the samples are fairly short and digestible. There is often brief commented discussion of best-practices for structure and style. Given its instructional nature, the CUDA Samples are a pretty good standard for GPU-related development best-practices for this project.

Thus, as a preliminary for this project, all the CUDA v10.2 samples were compiled and built using both 2017 and 2019 versions of Visual Studio Community Edition. 173 projects were built without errors, and there were 6 errors spread across 3 projects. Two of these projects related to missing Vulkan libraries, the other error was a heap exception.

**CUDA Errors Reported by Intellisense**

Both the 2017 and 2019 versions of the Visual Studio IDE's Intellisense found undeclared identifier errors in almost every sample for CUDA-specific objects (threadIdx, blockIdx, some CUDA functions, '<<<' and '>>>' operators, references to tex2D<T>, cooperative\_groups, etc) in both 2019 and 2017 IDEs. Short of turning off Intellisense altogether, the best you can do to fix these errors is to include of the following header files:

#include <cuda.h>

#include <cuda\_runtime.h>

#include <device\_launch\_parameters.h>

However, this does not fix all the errors Intellisense finds. The '<<<', '>>>' operators and other symbols continue to be a nuisance, and these errors have no affect on the build.

**About lbm\_cuda**

lbm\_cuda is a Visual Studio 2019 solution created with a default CUDA 10.2 project. All projects in the solution are set to Debug configuration mode. Most of the conventions used by CUDA Samples for v10.2 will be used for these projects. They include:

* additional include directories ./common/inc
* lib files location ./common/lib
* output directories for executables ./bin/win64/Debug
* to avoid run-time errors, two dlls are required in ./bin/win64/

glew64.dll

freeglut.dll

The fluidsGL CUDA Samples v10.2 project was added to the project space to provide a comparable structure. Then, the lbm project was created from another default CUDA v10.2 project. A CUDA source file (.cu) was created called lbm.cu and was initially taken whole from the following example:

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Settings for the lbm project were then configured to match conventions in the CUDA Samples v10.2 projects. glew64.lib was added to the Additional Dependencies for lbm (in Solution Explorer right-click Project, select Properties. Configuration Properties->Linker->Input->Additional Dependencies).

The original, unmodified version of Sherlis and Friedlander's code was written as a single .cu implementation file 1167 lines long. There are several global variables and definitions shared between CPU and GPU threads. For this project, this code was first refactored into multiple files with a kernel-focused file structure. In addition to providing some improved organization, these steps were also helpful in getting a better understanding of the underlying structure of the program. Some of these changes include:

* Defines and structs shared between the CPU and GPU were split into a separate header file.
* Global variables were moved into a new .cpp file and references to those variables marked extern in the .cu file.
* All CPU-related functions were then moved to the .cpp file.
* GPU entry points were declared as extern function prototypes in the .cpp file, and then defined in the .cu file.
* Two new GPU-related functions were created for handling initialization and cleanup in the new, more modular file structure.
* Original comments were edited and the code reformatted.

One of the goals of this project is to enhance the Sherlis and Friedlander code to include an additional third dimension to the simulation.

**Results**

This is the most important section. Only the final results are discussed here not the raw data which are tabulated in one of the Ap­pendices. The experimental results are pre­sented with the accompanied uncertainties. (Explanation of how the uncertainties are derived will be in a separate section on error analysis.) These results should be compared with the available theoretical predictions on the same plot. The results should be presented graph­ically in scientific plots and should also he discussed in the accompanied text.

**Conclusions**

This section contains the most important of the results, which ought to be interpreted and explained. Any statement you make here has to be well thought in advance and absolutely justified.

**List of References**

All the references cited in the report should be listed here. Reference, which is not cited in the report, should not be listed.

**Error Analysis**

This section includes a detailed analysis of all error sources for experimental measurements. Include both size of measurement errors and method of estimate. Show how errors propagate to final calculated results. Discuss both accuracy and precision of all measurements. Describe any sources of systematic errors.

**Appendix A**

This section includes tabulation of all raw data

**Appendix B**

This section includes sample calculations.

**Appendix C**

This section contains computer programs if available.