Porting the HPC-Lab Snow Simulator to OpenCL

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SPECIALIZATION PROJECT

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Problem Description

OpenCL is a recently defined and widespread open standard that will make the massive parallelism power now available in GPUs, but also newer CPUs (like the Cell B.E.) , more easily accessible to programmers.

This project involves porting an existing OpenCL snow simulation application to Open CL and comparing the implementation and benchmarks to those implemented in CUDA.

Trondheim, 2015-01-04

Supervisor: Dr. Anne C. Elster

Acknowledgment

I would like to thank Dr. Anne C. Elster for heading the HPC-Lab and letting me work there. The lab provides a unique opportunity for students to work together and learn from each other, all in a great work environment.

I.K.

Summary and Conclusions

Here you give a summary of your your work and your results. This is like a management summary and should be written in a clear and easy language, without many difficult terms and without abbreviations. Everything you present here must be treated in more detail in the main report. You should not give any references to the report in the summary – just explain what you have done and what you have found out. The Summary and Conclusions should be no more than two pages.

You may assume that you have got three minutes to present to the Rector of NTNU what you have done and what you have found out as part of your thesis. (He is an intelligent person, but does not know much about your field of expertise.)

Contents

Chapter 1

Introduction

1.1 Background

1.1.1 Graphics Hardware

Graphics processing units (GPUs) are special-purpose processors designed with graphics in mind. Computer graphics require large amounts of calculations, typically the same calculations done over and over. This type of workload is very different from the mostly serial workloads typically done by CPUs. Hence, large performance benefits can be gotten by using specialized hardware with a large number of execution units in a single-instruction/multiple-data (SIMD) setup.

1.1.2 General-Purpose GPU Computing

As it happens, there is another field where SIMD hardware is widely used: scientific computing. A typical physics simulation (e.g. a weather report) can involve solving systems of equations with thousands of unknowns. Historically, vector processors were used for this purpose. However, these processors were little used outside of scientific computing, leading to high cost due to the nature of semiconductor manufacturing. Designing a processor, making photolithography masks and buying fabrication equipment are all extremely expensive. Once these are done, though, processors can be made at next to no cost, leading to economies of scale.

GPUs, on the other hand, are sold in vast quantities to the consumer market, due in no

small part to computer games. If one could use graphics hardware to compute other things than graphics, one could potentially do scientific computing at much lower cost.

Experiments in general-purpose GPU (GPGPU for short) computing began with Larsen and McAllister (2001), which presents a routine for matrix multiplication using graphics

1.2 Goals

The main goal for this project can be stated simply as "Port the HPC-Lab Snow Simulator to OpenCL". However, there are a few secondary goals that should be considered as well.

Firstly, this is not the first time the snow simulator has been ported to OpenCL. Previous ports have been obsolete pretty much out of the gate, which is why the most current version has always been CUDA only. I can see two possible reasons for this. One is simply that working with two APIs is more work than working with one, and people are likely to just take the path of least resistance. To mitigate this, an OpenCL port should have the API specific code isolated from the rest of the code, separated by a clean abstraction layer. This will ensure that making changes to the host-side code will be just as easy in the cross-platform version as in the CUDA only version. One should also take steps to make the OpenCL and CUDA code both as readable and as similar to each other as possible. This will minimize the work required to make changes to the device-side code, and hopefully encourage people to keep both versions of this code up to date.

Additionally, other students are also doing projects involving the snow simulator this semester. If their work and mine are not kept in sync with frequent merging, we might end up with separate versions, and future projects will need to choose between these when choosing what code base to work on.

Finally, the snow simulator is a very computationally intensive program. Producing correct code should of course be priority number one, but one should not neglect performance. Therefore I will analyze the performance of the simulator using whatever tools I can, and explore options for using OpenCL-specific tricks to improve this performance.

1.3 Limitations

In this section you describe the limitations of your study. These may be related to the study object (physical limitations, operational limitations), to the environmental and operational conditions, to the thoroughness of the analysis, and so on.

1.4 Approach

Here you should describe the (scientific) approach that you will use to solve the problem and meet your objectives. You should specify the approach for each objective.

If there are any ethical problems related to your approach, these should be highlighted and discussed.

1.5 Structure of the Report

The rest of the report is organized as follows. Chapter 2 gives an introduction to ...

Remark: Notice that chapter and section headings shall be written in lowercase, but that all main words should start with a capital letter.

The report should be no longer than 60 pages in this format (+ the CV).

Chapter 2

Equations, Figures, and Tables

The content of Chapter 2 will vary with the topic of your thesis. This chapter only gives guidance to some technical aspects of LaTeX.

Remark: If you want a shorter chapter or section title to appear in the Table of Contents and in the headings of the chapter, you just include the short title in square brackets before the title of the chapter/section. Example:

```
\section[Short Title]{Long Title}
```

.

2.1 Simple Equations

Mathematical symbols and equations can written in the text as λ, $F(t)$, or even $F(t) = \int_0^t \exp(-\lambda x)\,dx$, or as displayed equations

$$F(t) = \int_0^t \exp(-\lambda x)\,dx \tag{2.1}$$

The displayed equations are automatically given equation numbers – here (2.1) since this is the first equation in Chapter 2. Note that you can refer to the equation by referring to the "label" you specified as part of the equation environment.

You can also include equations without numbers:

$$F(t) = \sum_{i=1}^{n} \binom{n}{i} \sin(i \cdot t)$$

More Advanced Formulas

Long formulas that cannot fit into a single line can be written by using the environment `align` as

$$F(t) = \sum_{i=1}^{n} \sin(t^{n-1}) - \sum_{i=1}^{n} \binom{n}{i} \sin(i \cdot t) \tag{2.2}$$

$$+ \int_0^{\infty} n^{-x} e^{-\lambda x^t} \, dt \tag{2.3}$$

In some cases, you need to write ordinary letters inside the equations. You should then use the commands

```
\textrm  and/or \mathrm
```

The first command returns the normal text font and will be scaled automatically, while the second command will be scaled according to the use.

$$\mathrm{MTTF} = \int_0^{\infty} R_{\mathrm{avg}}(t) \, dt$$

Please consult the LaTeX documentation for further details about mathematics in LaTeX.

Definitions

If you want to include a definition of a term/concept in the text, I have made the following macro (see in `ramsstyle.sty`):

☞ **Reliability**: The ability of an item to perform a required function under stated environmental and operational conditions and for a stated period of time.

Figure 2.1: This is the logo of NTNU (rotated 15 degrees).

When text is following directly after the definition, it may sometimes be necessary to end the definition text by the command

`\newline`

I have not included this in the definition of the `defin` environment to avoid too much space when there is not a text-block following the definition.

2.2 Including Figures

If you use pdfLaTeX (as recommended), all the figures must be in pdf, png, or jpg format. We recommend you to use the pdf format. Please place the figure files in the directory **fig**. Figures are included by the command shown for Figure 2.1. Please notice the "path" to the figure file written by a *forward* slash (/). You should not include the format of the figure file (pdg, png, or jpg) – just write the "name" of the figure.

Each figure should include a unique *label* as shown in the command for Figure 2.1. You can then refer to the figure by the *ref* command. Notice that you can scale the size of the figure by the option `scale=k`. You may also define a specific width or height of the figure by replacing the `scale` options by `width=k` or `height=k`. The factor `k` can here be specified in mm, cm, pc, and many other length measures. You may also give `k` as a fraction of the width of the text or of the height of the text, for example, `width=0.45\textwidth`. If you later change the margins of the text, the figure width will change accordingly. As illustrated in Figure 2.1, you may also rotate the figure – and also do many other things (please check the documentation of the package `graphicx` – it is available on your computer, or you may find it on the Internet).

In LaTeX all figures are floating objects and will normally be placed at the top of a page. This is the standard option in all scientific reports. If you insist on placing the figure exactly where you

Table 2.1: The degree of newness of technology.

Experience with the operating condition	Level of technology maturity		
	Proven	Limited field history or not used by company/user	New or unproven
Previous experience	1	2	3
No experience by company/user	2	3	4
No industry experience	3	4	4

declare the figure, you may include the command `[h]` (here) immediately after `\begin{figure}`. If you will force the figure to be located either at the top or bottom of the page, you may alternatively use `[t]` or `[b]`. For more options, check the documentation.

Large figures may be included as a *sidewaysfigure* as shown in Figure 2.2:[1]

2.3 Including Tables

LaTeX has a lot of different options to include tables. Only one of them is illustrated here.

Remark: Notice that figure captions (Figure text) shall be located *below* the figure – and that the caption of tables shall be *above* the table. This is done by placing the `\caption` command beneath the command `\includegraphics` for figures, and above the command `\begin{tabular*}` for tables.

2.4 Copying Figures and Tables

In some cases, it may be relevant to include figures and tables from from other publications in your report. This can be a direct copy or that you retype the table or redraw the figure. In both cases, you should include a reference to the source in the figure or table caption. The caption might then be written as: *Figure/Table xx: The caption text is coming here (**?**).*

In other cases, you get the idea from a figure or table in a publication, but modify the figure/table to fit your purpose. If the change is significant, your caption should have the following format: *Figure/Table xx: The caption text is coming here (adapted from **?**).*

[1] You can use a similar command for large tables.

NTNU – Trondheim
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Figure 2.2: This is the logo of NTNU.

2.5 References to Figures and Tables

Remember that all figures and tables shall be referred to and explained/discussed in the text. If a figure/table is not referred to in the text, it shall be deleted from the report.

2.6 A Word About Font-encoding

When you press a button (or a combination of buttons) on your keyboard, this is represented in your computer according to the *font-encoding* that has been set up. A wide range of font-encodings are available and it may be difficult to choose the "best" one. In the template, I have set up a font-encoding called UTF-8 which is a modern and very comprehensive encoding and is expected to be the standard encoding in the future. Before you start using this template, you should open the Preferences ->Editor dialogue in TeXworks (or TeXShop if you use a Mac) and check that encoding UTF-8 has been specified.

If you use only numbers and letters used in standard English text, it is not very important which encoding you are using, but if you write the Norwegian letters æ, ø, å and accented letters, such as é and ä, you may run into problems if you use different encodings. Please be careful if you cut and paste text from other word-processors or editors into your LaTeX file!

Warning

If you (accidentally) open your file in another editor and this editor is set up with another font-encoding, your non-standard letters will likely come out wrong. If you do this, and detect the error, be sure *not* to save your file in this editor!!

This is not a specific LaTeX problem. You will run into the same problem with all editors and word-processors – and it is of special importance if you use computers with different platforms (Windows, OSX, Linux).

2.7 Plagiarism

Plagiarism is defined as "use, without giving reasonable and appropriate credit to or acknowledging the author or source, of another person's original work, whether such work is made up of

code, formulas, ideas, language, research, strategies, writing or other form", and is a very serious issue in all academic work. You should adhere to the following rules:

- Give proper references to all the sources you are using as a basis for your work. The references should be give to the original work and not to newer sources that mention the original sources.
- You may copy paragraphs up to 50 words when you include a proper reference. In doing so, you should place the copied text in inverted commas (i.e., "Copied text follows ..."). Another option is to write the copied text as a quotation, for example:

  > Birnbaum's measure of reliability importance of component i at time t is equal to the probability that the system is in such a state at time t that component i is critical for the system.

  ?

Chapter 3

Summary and Recommendations for Further Work

In this final chapter you should sum up what you have done and which results you have got. You should also discuss your findings, and give recommendations for further work.

3.1 Summary and Conclusions

Here, you present a brief summary of your work and list the main results you have got. You should give comments to each of the objectives in Chapter 1 and state whether or not you have met the objective. If you have not met the objective, you should explain why (e.g., data not available, too difficult).

This section is similar to the Summary and Conclusions in the beginning of your report, but more detailed—referring to the the various sections in the report.

3.2 Discussion

Here, you may discuss your findings, their strengths and limitations.

3.3 Recommendations for Further Work

You should give recommendations to possible extensions to your work. The recommendations should be as specific as possible, preferably with an objective and an indication of a possible approach.

The recommendations may be classified as:

- Short-term
- Medium-term
- Long-term

Appendix A

Acronyms

FTA Fault tree analysis

MTTF Mean time to failure

RAMS Reliability, availability, maintainability, and safety

Appendix B

Additional Information

This is an example of an Appendix. You can write an Appendix in the same way as a chapter, with sections, subsections, and so on.

B.1 Introduction

B.1.1 More Details

Bibliography

Larsen, E. S. and McAllister, D. (2001). Fast matrix multiplies using graphics hardware. In *Proceedings of the 2001 ACM/IEEE conference on Supercomputing*, pages 55–55. ACM.

Curriculum Vitae

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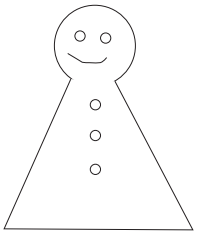

Your picture

Language Skills

Describe which languages you speak and/or write. Specify your skills in each language.

Education

- School 1
- School 2
- School 3

Computer Skills

- Program 1

- Program 2
- Program 3

Experience

- Job 1
- Job 2
- Job 3

Hobbies and Other Activities