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Institut für Integrierte Systeme
Integrated Systems Laboratory

Department of Information Technology and
Electrical Engineering

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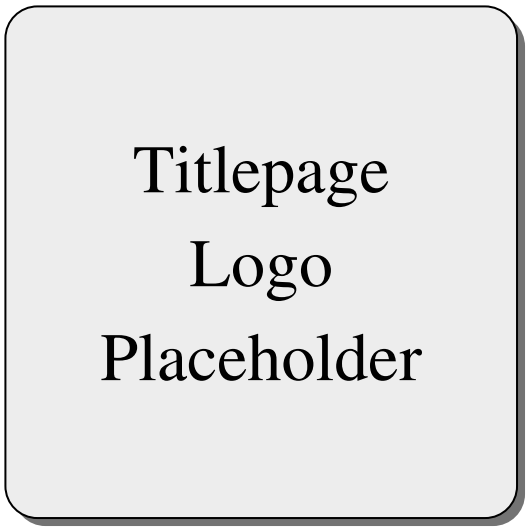
LaTeX Report Template

Semester Project / Master Project



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Ceci est un test de mon script

Abstract

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Declaration of Originality

I hereby confirm that I am the sole author of the written work here enclosed and that I have compiled it in my own words. Parts excepted are corrections of form and content by the supervisor. For a detailed version of the declaration of originality, please refer to Appendix **??**

Pierre-Hugues BLELLY,
Zurich, May 2020

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Chapter 1

Introduction

1.1 Heterogeneous systems

Heterogeneous Systems, relies on different accelerators to achieve the bbest possible efficiency. Most of them are composed of one Genereal Purpose Core and one or multiple Programmable Many Core Accelerator (PCMA). These systems are interesting because of their energy efficiency, the accelerators are designed to compute a lot of data in parallel, and the host allow for more flexibility and handle the program flow.

Hero is an heterogeneous system developped by the IIS (ETHZ) and the EEES (University of Bologna). This platform is composed of a hard multicore ARM 64 Juno SOC and one pulp cluster (eight RI5CY cores), running on an FPGA. During my project, I used this target to port Halide.

1.2 Design Issue with heterogeneous systems

Due to their heterogeneous nature, those systems are difficult to program. The compilation process is complex, requiering multiple passes on different toolchains to distribute the work to the host and the accelerator, and to allocate the memory. And this complexity is alsso forced on the end user, as he needs to know the target perfectly to make use of all the available resources.

1.3 Currently Available Workflow for Halide

Currently Hero support OpenMp, which is an API which "defines a portable, scalable model with a simple and flexible interface for developing parallel applications on plat-

forms from the desktop to the supercomputer" (Ref: OpenMP website). This API has been implemented on hero, and is currently used to develop some test application. But exploring the design space using OpenMp's directive, isn't perfect, and require the developper to adapt it's code to run with a specific schedule. This approach leads to an important developpement time but also an extensive texting process whenever the schedule is changed to ensure that the resulting code works as intended.

Halide is a programming language that was designed to allow the developper to explore multiple design choices quickly by separating the algorithm from the execution schedule. This language was designed to be used in image or array processing applications. Every processing pipeline designed with Halide have two parts. Teh first part consist of the functionnal description of the processing kernel, this is the algorithm that will be executed on the arry. And the second part is the schedule of the pipeline. This schedule describe how the algorithm will be executed on the system. This programming model is interesting because the developper can in the first time implement the algorithm without having to take into account the boundaries of the functions or the border effects. Then he can quickly bound the different variables of the pipeline and design it's schedule afterwards. All the constraints will be asserted during the compilation without any intervention from the developper.

Chapter 2

Preliminaries / Background

2.1 Hero

2.2 Halide Language

2.2.1 Programing model

Halide is a functionnal program embedded into C++ designed to write high performance image and array processing code (Halide Website). This language uses a functionnal paradigm to describe the functionnalities of the pipeline. The scheduling of the pipeline is described separately, which allow the developper to explore a wide range of schedule without having to rewrite most of the code. Every pipeline is a function (`Halide::Func` composed of other functions and expressions (`Halide:expr`). These two objects use special variables (`Halide:Vars`) to describe the operation executed on the array. The code snippet describe a basic pipeline which compute the distance of each coordinate of the array from on position specified by the vector

```
Halide::Var x, y;
Halide::Param center_x, center_y;
Halide::Expr offset = Halide::pow(x - center_x, 2)
                    + Halide::pow(y - center_y, 2);

  gradient(x, y) = offset;
```

Listing 2.1: Simple Pipeline Example

After designing the pipeline, we can define it's schedule via the different directive included in Halide. Halide implements all the basic scheduling option like parallelizing, unrolling, splitting ... These options will be described in the section Available Scheduling Options .

The snippet 2.2 shows a simple schedule applied on our gradient. This schedule consists of parallelizing the execution over the `x` axis, and unrolling along the `y` axis.

```
gradient.parallel(x);
gradient.unroll(y, 10);
\label{code:simple_pipeline_schedule}
```

Listing 2.2: Simple Pipeline Example

To execute our pipeline, Halide provides a large range of options, we can execute it directly using the `.realize(x_max, y_max)` directive, this will execute the pipeline on a rectangle starting from it's top left corner in `(0,0)` to it's bottom right corner in `(x_max, y_max)`.

But Halide also gives the programmer a lot off options to execute the pipeline, it's able to convert the code to C code, llvm assembly file, or already compiled object file specific to a given target. More over, Halide support a wire variety of CPU architecture (X86, ARM, MIPS, PowerPc, Risc-V), operating systems (Linux, Windows, Android, Mac) and also Gpu Api's (Cuda, OpenCL, OpenGl, DirectX ...). Halide support for new architecture is getting better and better, and is by design targeted for cross compilation and Heterogeneous systems.

2.2.2 Debugging Options

2.2.3 Basic Scheduling Options

Non Architecture specific Schedule

- Reorder
- Split
- Tile
- Fuse
- Unroll

Architecture specific Schedule

- Vectorize
- Parallel

2.2.4 Porting Halide to new Platforms

2.3 Compilation Workflow

Chapter 3

Design Implementation

3.1 Matrix Multiplication

3.2 Schedule Implementation

Chapter 4

Results

4.1 Test Setup

4.2 Comparaison between OpenMp and Halide on the different platforms

Chapter 5

Conclusion and Future Work

Draw your conclusions from the results you achieved and summarize your contributions. Comparisons (e.g., of hardware figures) with related work are also appropriate here. Point out things that could or need to be investigated further.

5.1 First Section

5.2 Second Section

Glossary

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