Real-Time Imaging and Control

Project

MSCV

Antoine Lavault
antoine.lavault@u-bourgogne.fr

Image Filtering in VHDL

1 Project Description

This document describes the final project for the Real-Time Imaging and Control class.
The goal of the project is to implement a set of 3×3 filters on a fixed resolution (128×128) image (`Lena128x128_24.bmp`). The filters to implement are :

- The averaging filter
- The Gaussian filter
- The vertical Sobel filter
- The horizontal Sobel filter
- The Laplacian filter

We suggest the following for your architecture :

- The target image in the supplementary material is a 24bit RGB bitmap. You should convert it to 8 bit grayscale. You can use an IP module to store the image data for your image as a `.coe` file.
- Use *line buffers* made of flip-flops and FIFO to read a valid window of pixel. It can also be called *cache memory*
- Separate the multiplication and the addition in the convolution process.
- Reduce the complexity of your system by using smaller and specialized parts e.g an IO module (to read and write your images), a cache module (to get a pixel window) and a convolution processor.

Also, you are expected to justify your choices (no proof, no points). The results for this part can be obtained through simulation only. See section 3 for more details. You can use IP modules if needed but do not use filter IPs as it goes against the pedagogical purpose of this project. Comparison between IPs and custom components will be taken into account in the evaluation.
You are totally free to implement the described system (image filtering process) with the method of your choice, without using filter IPs.

2 Further Exploration

If you completed the first part, you can go further by doing some of the following suggestions:

- Performance comparison between your filter vs. filter IP (ressources and speed)
- Performance comparison between fixed-point and floating-point representation for image filters on FPGA (in terms of ressources and speed)
- Gradient calculation based on Sobel filters (handling of square root-function)
- Interfacing with the VGA port of the Nexys 4
- Handling of RGB signals and programmable coefficients
- Interfacing with a camera (you may find some in the robotics lab, maybe).

You are totally free to choose your own exploration path. As long you can justify your choices.

3 Evaluation and Deliverables

First thing first, this is not a project about interfacing devices. The main goal of the project is to evaluate your capacity to **implement a complex DSP system in VHDL** and **run simulations to validate its behaviour**. You can start interfacing things on the board when you have an up-and-running DSP in simulation.
The main evaluation will be on the design of your DSP processor. Further explorations will be taken into account if and only if your DSP processor is complete i.e you completed all of the items of section 1 while justifying your engineering choices.
You will have to provide a report before the **18th of December, 23h59 Paris Time**, to `antoine.lavault@u-bourgogne.fr` with the subject line "[RTIC] Report xxx" where you will replace xxx by your name(s). Late submissions will not be graded.
With the report, you will have to provide the project file, code, test-benches and binary files (if any) you used in order for the evaluator to check the repeatability of your results.
Repeatability is a necessity for high-quality research work.
For the report, you will tasked to describe your design, justify your design choices and discuss the shortcomings and issues of your system, if there are any.
We suggest the following structure for your report:

1. Introduction
2. System Description and Methods
3. Results
4. Further developements (if any)
5. Discussion (of all the results)
6. Conclusion

Plagiarism will not be tolerated.

4 Evaluation Guidelines

We give the evaluation guidelines in table 1 to help you to write your (awesome) report

	Expert	**Proficient**	**Apprentice**	**Novice**
Introduction	Presents a clear summary of the aims of the study and its significance. Briefly describes experimental design. Probably includes one or more references to supporting sources.	Either lacks clarity or is missing one of the primary elements.	Weak or missing primary elements.	No real introduction.
System Description and Methods	Gives the reader a clear picture of the methods used. Does not use prescriptive language. Uses specific, not general, terminology. Detailed, step-by-step procedures are clearly referenced. Avoids long, redundant descriptions.	Some methods are presented so briefly and/or vaguely that it is unclear how or why they were done. May be some written as a protocol rather than a description.	Some methods are omitted; others are presented in a piecemeal, vague form.	Methods barely mentioned.
Results	All figures and tables have titles and legends. All results are clearly presented, with a logical sequence.	Some data may be missing, or legends may be brief, vague or uninformative.	Data is presented haphazardly. It is sometimes not possible to tell what material or procedure was used to obtain the data.	No logical connection between methods and data. Irrelevant data may be included, and relevant data left out. No legends.
Discussion	It is clear that the methods and results have been understood. The results are related to the questions posed and analyzed for their effectiveness. Possible explanations for inconsistencies and/or unexpected results are given.	There may be some lack of clarity. Did the writer understand why certain methods were used, and how the results could shed light on the questions asked? Incomplete analysis of inconsistencies and unexpected results.	Very little analysis of the results. Statements are vague and general. Inconsistencies are explained by 'human error' or something similar.	Mostly a restatement of results. No analysis given. No recognition of error sources. No understanding of controls.
Cohesiveness	It is clear that the report covers a group of related procedures with a clear set of goals.	Sometimes the goals are not clearly related to the report. Some fragmentation occurs, with methods and results apparently unrelated to each other.	Transitions are abrupt. Each day's work seems unrelated to the next's. Aims are not clearly present throughout.	Disjointed. No flow. Very little use of headings, or explanatory sentences.

Table 1: Evaluation Guidelines