Instituto Tecnológico de Costa Rica
Área Académica de Ingeniería en Computadores

Proyecto de Diseño en Ingeniería en Computadores

Requirements Specification

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1 Introduction

1.1 Purpose

The purpose of this research is to evaluate the design of Application-Specific Instruction Set Processors (ASIPs) for error-tolerant applications. The ASIPs are meant to execute with improved performance (for instance, energy consumption or execution time would be lower) compared to a General Purpose Proccesor (GPP) but also with greater flexibility than Application-Specific Integrated Circuits (ASICs).

1.2 Scope

This research concerns the selection and optimization of error-tolerant applications. For this, ASIP configurations using specific approximate instructions for the selected applications are to be delivered. Furthermore, each ASIP configuration will be described by a set of parameters that the final system will possess, such as energy efficiency, area, execution time, and output error. This project is expected to help approximate computing to be a more widespread tendency and generate a strong base knowledge for future projects where there is freedom to choose the parameters of hardware running a certain type of application in terms of resource consumption and accepted error.

1.3 Product overview

1.3.1 Product perspective

The result of this wok will consist of studied and selected applications where a set of instructions, going from a single instruction up to an entire section, are replaced by an approximated version, to improve execution time, area, or power consumption while maintaining an acceptable error at the output. This research is a stand-alone project in the sense that ASIP configurations will be specific to a selected application and will not operate with other interfaces. This means that the configurations developed will only be constrained by each specific application's inherent constraints or limitations, for example, which section is error-tolerant or which parameter is the most critical.

1.3.2 Product functions

This research on ASIPs is an attempt to expand on the approximate computing paradigm, which is expected to enable more personalized applications that trade-off accuracy and performance to achieve an optimal balance between these two.

The ASIPs will be integrated to a specific application and they will have the following characteristics:

- Adjustable error threshold: The application's error level can vary according to a specific ASIP configuration.
- Adjustable resource consumption: The application's resource consumptiond can vary according to a specific ASIP configuration.
- Scalable: Regardless of the amount of hardware used, the ASIP parameters are expected to remain roughly the same.

1.3.3 User characteristics

Since approximated computing is still in its infancy, a lot of research and testing is still needed, so the users of the developed ASIPs are the same research groups behind this project. The research group members possess, in general, these characteristics:

- Technical knowledge: It is expected that users have an in-depth knowledge of the specific application that is being optimized, as well as a fair amount of knowledge of hardware architecture design.
- Access to specialized tools: Users are expected to have a set of tools that allow them to synthetize and simulate a hardware architecture, as well as a hardware board to implement a desired design.

1.3.4 Limitations

The following limitations are considered for the ASIPs to be developed:

- Performance gain: The gain in energy efficiency, area, and execution time, can never be greater than the theoretical possible gain given by the Amdahl equation, which is determined by the percentage of the application that is being optimized.
- Development time: The 16 weeks of the institutional calendar of the ITCR limit the scope of the project to the configurations that can be developed in that length of time.

The resources needed for the project (e.g hardware platform) are not considered as limitations since they are already available to the research group and the academic institutions.

1.4 Definitions, acronyms and abbreviations

Table 1 contains the specific terms used in this document.

Table 1: Definitions

Term	Definition
ASIP	Application Specific Instruction Set Processor. This means that, although the processor can execute a wide range of applications, it is optimized for a specific one, in which it can execute with improved performance (for instance, energy consumption or execution time would be lower) compared to a General Purpose Proccesor (GPP).
GPP	General Purpose Proccesor. In general, they show better flexibility than ASIPs because all the programs are executed in general-purpose components, but since they are not optimized, they show less resource efficiency.
ASIC	Application Specific Integrated Circuit. In general, they show better performance results than ASIPs, nevertheless, they are less flexible when executing anything other than the specific application they are meant to.
ITCR	Instituto Tecnológico de Costa Rica. Place from where this project is being developed.

2 Specific Requirements

2.1 External interfaces

As explained in section 1.3.1, the entire optimized application will not have external interfaces.

2.2 Functions

2.2.1 Functional requirement 1.1

ID: FR-1
Title: ASIP customization
Description: The ASIP configurations developed shall provide the user flexibility between the original version of an application and the optimized one, allowing for a customized balance between resource consumption and output error.

2.3 Usability requirements

As explained in section 1.3.3, the users are expected to be researchers. For this, only a few usability requirements are considered:

2.3.1 Usability requirement 1.1

ID: UR-1
Title: Knowledge documentation
Description: The research shall present the user a proper documentation for each selected application (application domain, i.e. the application without any modification) and the specific optimizations performed, which include test cases, gain in energy efficiency, area, and power consumption, as well as the output error.

2.4 Performance requirements

Since one of the objetives of this project is to identify how much a certain program can be optimized with the use of ASIPs to balance resource consumption and output error, therefore no performance requirements are presented because this is exactly the area which needs to be explored.

2.5 Logical database requirements

No database is used for this project, hence, no logical database requirements are presented.

2.6 Design constraints

Design contraints are understood as aspects which are fixed for the project. Since this is a research project, minimun design contraints besides the ones presented in section 1.3.4 are considered:

- Hardware development board: The project is going to use a Xilinx Virtex-V board, since it corresponds to the hardware that uses the development framework.
- Development framework: The ASIPs are going to be developed with the use of ASIP-Meister and Dlxsim, which are already available as part of the work environment.
- Software architecture: For a selected application, its general software architecture (i.e the algorithm or process done) is not going to be altered, because the optimizations are going to be implemented by hardware modules.

2.7 Software system attributes

Since the selection of an application is part of this project's objetive, no general software system attributes can be described. The ASIPs developed will be designed according to the

particular system attributes, which will be described in a future document.

2.8 Supporting information

Approximate computing has been studied by several research groups. The survey in [1] gathers several ways to implement this paradigm both by hardware or by software.

3 Verification

3.1 External interfaces

The section does not apply for this project.

3.2 Functions

Xilinx, Mentor and Synopsys programs will be used to simulate and verify the corresponding optimizations produced by the ASIPs, which then will be properly documented.

3.3 Usability requirements

The produced documentation will be carefully revised by the supervisor in order to approve it.

3.4 Performance requirements

The section does not apply for this project.

3.5 Logical database requirements

The section does not apply for this project.

3.6 Design constraints

The section does not apply for this project.

3.7 Software system attributes

The section does not apply for this project.

3.8 Supporting information

The section does not apply for this project.

4 Appendices

4.1 Assumptions and dependencies

This project is based on the assumption that, given research and articles in the area of approximate computation, it is feasible to introduce approximate functions or blocks in a given application in order to introduce error and at the same time have an improvement in resources consumption, so that both variables can be manipulated.

References

[1] Qiang Xu, Todd Mytkowicz, and Nam Sung Kim. Approximate computing: A survey. *IEEE Design & Test*, 2018.