

Parallel Programming on Embedded Multicore System ESP32

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Abstract

The following documentation will focus on the principles of parallel programming in general and the mathematical background. In addition to the different parallel programming architectures, the various models for their implementation are also discussed. Moreover, in this thesis the prerequisites for mathematical calculation models, which are suitable for Parallel Programming, are elaborated.

For a practical example, the ESP32 microcontroller was chosen, an embedded multicore system. After a brief introduction to the hardware itself, further details of the project structure and the development of the application will be presented. Therefore, a short example will be explained to focus on the basics of parallel programming.

Finally, the aim of the project and the documentation is an automatic benchmark setup and a webfrontend result overview for visualization purposes, which will be discussed in more detail in the conclusion.

Declaration

I hereby certify that I have done the final thesis on my own, that I have completely and accurately stated all the aids I have used and identified everything individually, which was taken from the work of others unchanged or with modifications.

The topic of the submitted work was jointly with Mr. / Mrs. (...) (Bachelor and Master Thesis No. (...)).

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Non-disclosure notice

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Chapter 1

Introduction

Multicore systems are becoming increasingly popular as part of digitization and Industry 4.0¹ (German/EU) [2] [or 1] - also known as smart manufacturing in the USA [see 24, p1] - and are playing an important role in data processing and process automation [see 28, p294] [or 23, p1]. On the other hand, in addition to efficiency in energy consumption, performance in terms of computation time [see 28, p294] is required in almost every application field of multicore systems.

In fact, multicore hardware is not only especially for smart manufacturing. Nowadays in almost every smart application like smart phones², wearables³ or home automation we can find multicore embedded hardware platforms, which guaranteed high performance [see 4, p7], network connectivity, security and reliability [see 32, p5]. This field of application is also known as Internet of Things (IoT)⁴.

Especially for embedded systems mathematical models as well as numerical solutions, which can be executed both simply and parallel, are suitable. The question arises to what extent parallel execution of different sub-tasks to calculate a problem [see 27, p4] increases the desired cost factor in terms of energy consumption [see 9, chapter 3] and computational efficiency [see 27, p4 Figure 3].

¹add.: <https://www.epicor.com/en-ae/resource-center/articles/what-is-industry-4-0/>

²e.g. ARM based processors for mobile phones like <https://www.arm.com/solutions/mobile-computing/smartphones>

³add. information on ARM based solutions and the current trend in wearables: <https://www.arm.com/solutions/wearables>

⁴for additional information about Internet of Things, please see [16]

Chapter 2

Overview

2.1 Problem definition

Compared to single-core execution of tasks, multi-core embedded hardware platforms like the ESP32¹ provide the ability to develop advanced parallel computing software applications to reduce execution time and power consumption.

On the one hand, a major problem is choosing the right hardware platform to meet the cost and size factor, and moreover, whether a single-core or multi-core calculation is required. Therefore, context switching time, power consumption and total execution time must be included in the evaluation.

In order to develop an optimal solution, the hardware platform must be included in addition to the mathematical model of the problem itself. So in this case, suitable prerequisites and characteristics can be worked out in order to make an evaluation of "Parallel Computation Tasks on Embedded Multicore Systems" possible.

2.2 Objective of the documentation

The main goal of this documentation is to focus on the current parallel programming techniques, depending on the execution time in general and the required mathematical model. For this purpose, an application which can compute different sections of the Mandelbrot fractal [see 15, p11] will be developed to compare single core and multi-core calculations. Before the practical implementation, an investigation based on parallel architectures and programming models will be conducted.

The elaboration is divided into three different chapters: In the first chapter, the results of the general research are presented [see chapter 3 on the facing page]. After that, the second chapter is pointing out the practical implementation of the developed application on the ESP32 [see chapter 4 on page 6]. In the end, the results including the webfrontend and the automatic benchmark setup [see chapter 5 on page 11] will be discussed.

¹add. information: <https://www.espressif.com/en/products/hardware/socs>

Chapter 3

Parallel Programming in General

3.1 Basic Concept

...

3.1.1 Principles of Parallel Computing

...

3.2 Definition of parallel mathematical computations

...

3.3 Parallel Computer Architecture

...

3.3.1 Flynn's Taxonomy of Parallel Architectures

...[see 8, p5]

...[see 25, p13]

3.3.2 Thread Level Parallism

...[see 25, p24]

3.4 Parallel Programming Models

...

3.4.1 Classification of Parallel Programming Models

3.4.1.1 Process Interaction

...[see 8, p4]

3.4.1.2 Problem decomposition

...[see 25, p105 ff.]

Chapter 4

Project documentation

4.1 Concept development

...

4.2 Project structure

...

4.3 Simple mathematical computation examples for Parallel Programming

...

4.4 Class diagramm

...

4.4.1 C++ Backend benchmark

...

4.4.2 Vuejs Frontend

...

4.5 Benchmark setup

...

Chapter 5

Conclusion

...

Appendix A

Additional documents

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