Parallel Programming on Embedded Multicore System ESP32

Universitatea Politehnica Timișoara

Marian Belean
Franz Joseph Pal

WS2019/2020
October 21, 2019

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. (...)).

Timișoara, the October 21, 2019

Signature:

Non-disclosure notice

This work contains confidential information. In spite of the anonymous presentation of the researched organisations, readers might conclude their identity. Therefore copying, quoting or publishing is not allowed without my explicit authorisation. Furthermore, disclosure of the information to anyone other than the examination board or lectors is not authorized.

Contents

Chapter 1

Introduction

Multicore Systeme finden im Rahmen der Digitalisierung und der Industrie 4.0 immmer mehr Einzug und spielen eine zunehmend wichtige Rolle in der Datenverarbeitung und der Automatisierung. Auf der anderen Seite sind neben Effizienz im Energieverbrauch auch Performance bezüglich der Rechenzeit gefordert.

Gerade für Embedded Systeme eignen sich hier mathematische Modelle wie auch numerische Lösungen, die zum einen einfach wie auch parallel ausgeführt werden können. Dabei stellt sich die Frage, inwieweit ein paralleles Ausführen unterschiedlicher Teil-Tasks zur Berechnung eines Problems den gewünschten Kostenfaktor hinsichtlich Energieverbrauch und Berechnungseffizienz steigert.

Um eine optimale Lösung zu erarbeiten, sind neben dem mathemathischen Modell auch die Hardwareplattform einzubeziehen. Nur so können geigntete Voraussetzungen und Eigenschaften erarbeitet werden, um eine Bewertung von "Parallel Computation Taks on Embedded Multicore Systems" zu ermöglichen.

Chapter 2

Overview

2.1 Problem definition

...

2.2 Objective of the documentation

...

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 5, p5]
...[see 16, p13]

3.3.2 Thread Level Parallism

...[see 16, p24]

3.4 Parallel Programming Models

...

3.4.1 Classification of Parallel Programming Models

3.4.1.1 Process Interaction

...[see 5, p4]

3.4.1.2 Problem decomposition

...[see 16, 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

Bibliography

[1] Umut A. Acar and Guy E. Blelloch. *Algorithms: Parallel and Sequential*. Pittsburgh, USA: Carnegie Mellon University, Department of Computer Science, Feb. 2019.

[2] Aydin Buluç and John Gilbert. "Highly Parallel Sparse Matrix-Matrix Multiplication". In: *CoRR* abs/1006.2183 (Jan. 2010).

[3] Jeffrey R. Chasnov. *Introduction to Numerical Methods*. The Hong Kong University of Science and Technology, 2012.

[4] Gabriel Edgar. *An Introduction to Parallel Computing*. URL: http://www2.cs.uh.edu/~gabriel/courses/mpicourse_03_06/Introduction.pdf.

[5] Prof. Robert van Engelen. *Parallel Programming Models*. URL: https://www.cs.fsu.edu/~engelen/courses/HPC/Models.pdf.

[6] J. Holt et al. "Software Standards for the Multicore Era". In: *IEEE Micro* 29.3 (May 2009), pp. 40–51. DOI: http://dx.doi.org/10.1109/MM.2009.48.

[7] Jovan Ivković and Jelena Ivković. "Analysis of the performance of the new generation of 32-bit Microcontrollers for IoT and Big Data Application". In: Mar. 2017.

[8] George Karniadakis and Robert Kirby. "Parallel Scientific Computing in C++ and MPI : A Seamless Approach to Parallel Algorithms and their Implementation". In: (Jan. 2003). DOI: 10.1017/CBO9780511812583.

[9] Asanović Krste et al. "The Landscape of Parallel Computing Research: A View from Berkeley". In: (2006). URL: https://www2.eecs.berkeley.edu/Pubs/TechRpts/2006/EECS-2006-183.html.

[10] Vipin Kumar et al. *Introduction to parallel computing. Design and analysis of algorithms*. Vol. 2. Jan. 1994.

[11] Ami Marowka. "Analytic Comparison of Two Advanced C Language-Based Parallel Programming Models". In: *Parallel Research Lab* (2004). DOI: http://dx.doi.org/10.1109/ISPDC.2004.11.

[12] Ami Marowka. "Think Parallel: Teaching Parallel Programming Today". In: *IEEE* (2008). DOI: http://dx.doi.org/10.1109/MDSO.2008.24.

[13] Tim Mattson, Beverly Sanders, and Berna Massingill. "Patterns for Parallel Programming". In: (Sept. 2004).

[14] John Owens and U.C. Davis. *Parallel Programming Models Overview*. 2008. URL: http://s08.idav.ucdavis.edu/owens-parallel-prog-models-overview.pdf.

[15] Kota Sujatha et al. “Multicore Parallel Processing Concepts for Effective Sorting and Searching”. In: *IEEE* (2015). DOI: http://dx.doi.org/10.1109/SPACES.2015.7058238.

[16] Gudula Rünger Thomas Rauber. *Parallel Programming for Multicore and Cluster Systems*. Germany: Second Edition, Springer Verlag, 2013.

[17] Massimo Torquati et al. *Smart Multicore Embedded Systems*. New York, Heidelberg, Dordrecht and London: Springer Verlag, 2014. DOI: http://dx.doi.org/10.1007/978-1-4614-8800-2.

[18] Zhu Yang-Ming and Cochoff Steven M. “Medical Image Viewing on Multicore Platforms Using Parallel Computing Patterns”. In: *IEEE* (2010). DOI: http://dx.doi.org/10.1109/MITP.2010.62.

[19] N. Zhang. “A Novel Parallel Scan for Multicore Processors and Its Application in Sparse Matrix-Vector Multiplication”. In: *IEEE Transactions on Parallel and Distributed Systems* 23.3 (Mar. 2012), pp. 397–404. DOI: http://dx.doi.org/10.1109/TPDS.2011.174.

[20] Nan Zhang. “Working towards efficient parallel computing of integral images on multi-core processors”. In: vol. 2. May 2010, pp. V2–30. DOI: 10.1109/ICCET.2010.5485338.