

EM Graduate course

Practical Introduction to Parallel Programming

March 20th – 24th 2023

Department of Applied Mathematics, Numerical Analysis, Delft University of Technology

Dynaflow Research Group

General

This course is a practical introduction to parallel programming. The course explains the basic concepts of programming for parallel computers and focuses on the two common parallel programming models: the message passing model in combination with MPI, and the shared memory model in combination with both OpenMP and (POSIX) threads. You will learn how to divide a set of computations into parallel tasks; how to coordinate the execution of those tasks; how to transfer data between the tasks; and how to resolve dependencies between the tasks. The course mixes theory with practical, hands-on exercises. These exercises enable you to apply newly learned knowledge in smaller and larger contexts, and thus provide an opportunity to really understand different aspects related to parallel programming. Some of the exercises involve implementing the same algorithm with different programming models so that the differences between those models become more apparent. After completing the course, you should be able to design and implement parallel algorithms using a programming model that provides the best match with the algorithm and the target hardware. You should be able to assess the performance of the implementation and solve all kinds of practical problems that will pop up during the implementation of the algorithm.

The course has an informal character with ample opportunity for discussions with the lecturers and other participants.

Local organization

The course is organized by the Numerical Analysis group of the Department of Applied Mathematics at Delft University of Technology (TUD) in collaboration with Dynaflow Research Group.

The local organizing committee is composed of

- Dr. rer.nat. Matthias Möller
- Mrs. Evelyn Sharabi (secretary)

Lecturers

- Dr. rer.nat. Matthias Möller (TUD, Numerical Analysis)
- Dr. ir. Erik Jan Lingen (Dynaflow Research Group)

Time schedule

		Time	Subject	Lecturer
Day 1: Monday March 20 AE-Comp. Room 007 (62.0.07)	AM	9:00-9:15	<i>welcome + coffee</i>	
		9:15-9:30	Opening	Matthias
		9:30-10:30	Introduction to parallel programming	Erik Jan
		10:30-11:00	<i>coffee break</i>	
		11:00-12:00	Performance characteristics + exercise	Erik Jan
	PM	12:00-13:00	<i>lunch</i>	
		13:00-14:00	Parallel programming models + exercise	Matthias
		14:00-14:30	<i>coffee break</i>	
		14:30-15:30	Parallel program design + exercise	Matthias
		15:30-...	<i>self-study</i>	
18:00-20:00	<i>Getting acquainted dinner</i>			
Day 2: Tuesday March 21 IDE-Comp. Room Shift (32.D-0-160)	AM	9:30-10:30	Introduction to MPI + hello world exercise	Erik Jan
		10:30-11:00	<i>coffee break</i>	
		11:00-12:00	Point-to-point communication + exercise	Erik Jan
	PM	12:00-13:00	<i>lunch</i>	
		13:00-14:00	Non-blocking communication + exercise	Matthias
		14:00-14:30	<i>coffee break</i>	
		14:30-15:30	Collective communication + exercise	Matthias
15:30-...	<i>self-study</i>			
Day 3: Wednesday March 22 AE-Comp. Room (62.0.07)	AM	9:30-10:30	Communicators + exercise	Matthias
		10:30-11:00	<i>coffee break</i>	
		11:00-12:00	MPI wrap-up	Matthias
	PM	12:00-13:00	<i>lunch</i>	
		13:00-14:00	Introduction into OpenMP	Erik Jan
		14:00-14:30	<i>coffee break</i>	
		14:30-15:30	Parallel regions and reductions+ exercise	Erik Jan
15:30-...	<i>self-study</i>			
Day 4: Thursday March 23 AE-Comp. Room (62.0.07)	AM	9:30-10:30	Barriers and parallel sections+ exercise	Matthias
		10:30-11:00	<i>coffee break</i>	
		11:00-12:00	Nested parallelism and SIMD + exercise	Matthias
	PM	12:00-13:00	<i>lunch</i>	
		13:00-14:00	Tasks and task groups + exercise	Matthias
		14:00-14:30	<i>coffee break</i>	
		14:30-15:30	OpenMP wrap-up	Matthias
15:30-...	<i>self-study</i>			
Day 5: Friday March 24	AM	9:30-10:30	Introduction into thread programming	Erik Jan
		10:30-11:00	<i>coffee break</i>	
		11:00-12:00	Synchronization primitives + exercise	Erik Jan
	PM	12:00-13:00	<i>lunch</i>	
		13:00-14:00	Thread-local storage + exercise	Erik Jan
		14:00-14:30	<i>coffee break</i>	
14:30-15:30	Threads in C++ and wrap-up	Erik Jan		

AE-Comp. Room (62.0.07)		15:30-...	<i>self-study</i>
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The AE-Computer Room 007 is in building 62 (Faculty of Aerospace Engineering), Kluyverweg 1, 2629 HS Delft. The IDE-Computer Room Shift is in building 32 (Faculty of Industrial Design Engineering), Landbergstraat 15, 2628 CE Delft. If you come by public transport, the closest stop to building 62 is “Delft Kluyverpark”. The closest stop to building 32 is “Delft Aula”. If you come by car, you can park it at TU parking P3 (TNW Zuid) for building 62 and TU parking P5 (Rotterdamseweg). More information about parking at TU Delft can be found at <https://www.tudelft.nl/en/about-tu-delft/contact-and-campus/parking-policy> and <https://www.tudelftcampus.nl/accessibility/>.

Lecture notes

Lecture notes and course material will be made available in digital form before the start of the course.

Prerequisites

Experience with the C programming language is required. In particular, you must be familiar with the type system, basic statements, pointers, arrays, dynamic memory allocations, functions and structures. In particular, we build on topics described in this primer on the C programming language: https://en.wikibooks.org/wiki/A_Little_C_Primer. If you are less familiar with C, then this primer might be a good starting point to get up to speed with C before the course.

Contents

The course consists of both lectures and computer-practical sessions and will cover the following topics:

- 1) *Introduction*
 - a) Parallel Computer Architectures
 - b) Performance Characteristics
 - c) Parallel Programming Models
 - d) Parallel Program Design
- 2) *Parallel Programming with the Message Passing Interface (MPI)*
 - a) Point-to-Point Communication
 - b) Blocking and Non-blocking Communication
 - c) Collective Communication
- 3) *Parallel Programming with OpenMP*
 - a) Parallel Regions
 - b) Parallel Reduction
 - c) Critical Sections and Atomic Operations
- 4) *Programming with Threads*
 - a) Spawning and Joining Threads

- b) Mutexes
- c) Condition Variables

5) Final Exercise

Highlights:

- Focus on scientific computing and performance
- Learn about parallel computer hardware characteristics
- Learn about and compare different programming models
- Apply different concepts and techniques in many hands-on exercises

Fee/Registration

The course is free for registered members of the graduate school Engineering Mechanics and for the research members of the contributing research groups. The course fee for non EM members is € 200 for students and € 900 for other participants. They will receive an invoice after accepted registration.

Participants need to register by completing the online registration form, which can be found at <https://engineeringmechanics.nl/2022/10/18/20-24-march-2023-practical-introduction-to-parallel-programming/> before March 5th, 2023 to the Secretariat of the Graduate School Engineering Mechanics, Eindhoven University of Technology. Members of the Graduate School Engineering Mechanics receive priority in case of over-subscription.

Location/date

The course will take place on the campus of Delft University of Technology on March 20 – 24, 2023. The course language is English. Hotels close to the TU Delft campus can be found at https://www.booking.com/landmark/nl/tu-delft.nl.html?auth_success=1.

Further information

For more information on the contents of the course, contact:

Dr. rer.nat. Matthias Möller (TUD)

E-mail: m.moller@tudelft.nl

Dr. ir. Erik Jan Lingen (Dynaflow)

E-mail: erikjan.lingen@dynaflow.com

For information on the organization of the course, contact:

Mrs. Evelyn Sharabi

E-mail: e.w.m.sharabi@tudelft.nl

Further information about the educational programme and other activities of the Graduate School on Engineering Mechanics can be found at: <https://engineeringmechanics.nl/>.