

Teaching parallelism in an interdisciplinary scientific computing programme

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Outline

Past

History
Hardware
Software

Present

Master in SC
Parallel SC

Future



Universiteit Utrecht

Past: parallel computing courses in Utrecht

History

Hardware

Software

Present: Utrecht master programme in scientific computing

Master in SC

Parallel SC

Future: revolutionary changes

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Parallel algorithms history in Utrecht

- ▶ 1990–1992 **Linear Algebra for Supercomputers** by Henk van der Vorst
- ▶ 1993–1995 **Linear Algebra for Supercomputers** by RB
- ▶ 1996–2002 **Parallel Algorithms for Supercomputers** by RB
- ▶ 2003–present **Parallel Algorithms** by RB
- ▶ 10–12 students each year take the course, from mainly maths, but also physics, and computer science
- ▶ Level: first year of MSc. Language: English (since 2004)
- ▶ 2009/2010: became part of Dutch national mathematics master (<http://www.mastermath.nl>), now 17 students
- ▶ Follow-up course **High-performance scientific computing**: individual project

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Dutch National Supercomputer Huygens



IBM Power 6 computer with 3328 processing cores named after Christiaan Huygens, Dutch astronomer who in 1655 proposed the form of the rings around Saturn

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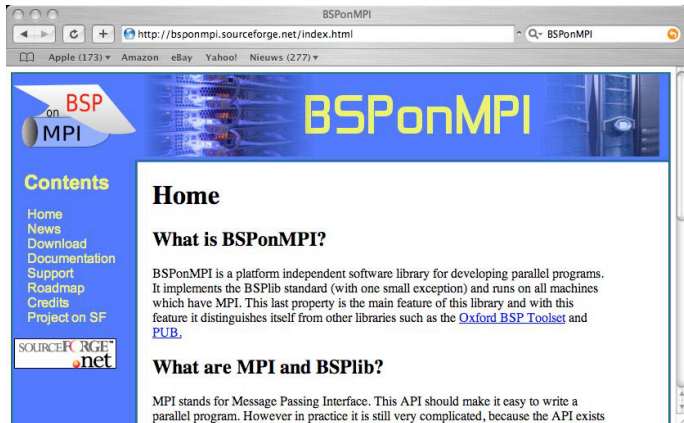
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BSPonMPI



The screenshot shows a web browser window with the URL <http://bsponmpi.sourceforge.net/index.html>. The page has a blue header with the text "BSP on MPI" and "BSPonMPI" in large yellow letters. A left sidebar contains a "Contents" menu with links to Home, News, Download, Documentation, Support, Roadmap, Credits, and Project on SF. The main content area features a "Home" section with the heading "What is BSPonMPI?" followed by a paragraph: "BSPonMPI is a platform independent software library for developing parallel programs. It implements the BSPlib standard (with one small exception) and runs on all machines which have MPI. This last property is the main feature of this library and with this feature it distinguishes itself from other libraries such as the [Oxford BSP Toolset](#) and [PUB](#)." Below this is another heading "What are MPI and BSPlib?" followed by a paragraph: "MPI stands for Message Passing Interface. This API should make it easy to write a parallel program. However in practice it is still very complicated, because the API exists".

BSPonMPI by Wijnard Suijlen, version 0.3 available since February 20, 2010 from <http://www.bsp-worldwide.org/>
Developed as a BSc thesis in Utrecht, written in C++

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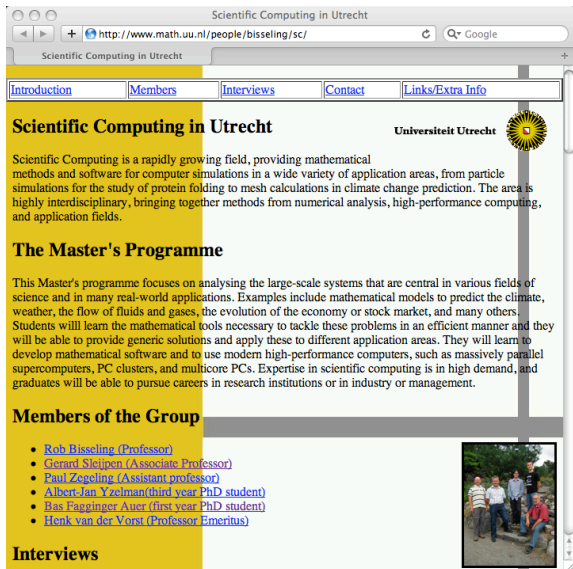
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Utrecht MSc programme in scientific computing




The screenshot shows a web browser window with the URL <http://www.math.uu.nl/people/bisseling/sc/>. The page has a yellow sidebar on the left with navigation links: [Introduction](#), [Members](#), [Interviews](#), [Contact](#), and [Links/Extra Info](#). The main content area features the title "Scientific Computing in Utrecht" and the "Universiteit Utrecht" logo. Below the title is a paragraph describing the field of scientific computing. The "The Master's Programme" section details the focus on large-scale systems and the skills students will learn. The "Members of the Group" section lists several individuals with their roles. A photograph of the group is shown at the bottom right of the page content.

Scientific Computing in Utrecht

[Introduction](#) [Members](#) [Interviews](#) [Contact](#) [Links/Extra Info](#)

Scientific Computing in Utrecht

Universiteit Utrecht 


Scientific Computing is a rapidly growing field, providing mathematical methods and software for computer simulations in a wide variety of application areas, from particle simulations for the study of protein folding to mesh calculations in climate change prediction. The area is highly interdisciplinary, bringing together methods from numerical analysis, high-performance computing, and application fields.

The Master's Programme

This Master's programme focuses on analysing the large-scale systems that are central in various fields of science and in many real-world applications. Examples include mathematical models to predict the climate, weather, the flow of fluids and gases, the evolution of the economy or stock market, and many others. Students will learn the mathematical tools necessary to tackle these problems in an efficient manner and they will be able to provide generic solutions and apply these to different application areas. They will learn to develop mathematical software and to use modern high-performance computers, such as massively parallel supercomputers, PC clusters, and multicore PCs. Expertise in scientific computing is in high demand, and graduates will be able to pursue careers in research institutions or in industry or management.

Members of the Group

- [Rob Bisseling \(Professor\)](#)
- [Gerard Sleijpen \(Associate Professor\)](#)
- [Paul Zegeling \(Assistant professor\)](#)
- [Albert-Jan Yzelman \(third year PhD student\)](#)
- [Bas Fagginger Auer \(first year PhD student\)](#)
- [Henk van der Vorst \(Professor Emeritus\)](#)



Interviews

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Programme consists of 10 MSc courses + thesis

- ▶ **Numerical linear algebra** (Gerard Sleijpen & Martin van Gijzen)
- ▶ **Scientific computing laboratory** (Albert-Jan Yzelman)
- ▶ **Parallel algorithms** (Rob Bisseling)
- ▶ **Numerical PDEs** (Paul Zegeling/Rob Stevenson)
- ▶ **Modelling and simulation** (Gerard Barkema)
- ▶ choice of: **Computational biology** (Paulien Hogeweg) or **Climate modelling** (Henk Dijkstra)
- ▶ 4 elective courses
- ▶ thesis (9 months research)

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Interdisciplinary programme

- ▶ Home base: Mathematics Institute
- ▶ Joint thesis supervision:
 - oceanographic modelling using GPUs
 - X-ray spectroscopy computations for space research using OpenMP
 - computer simulation of colloids on a PC
- ▶ Courses in other disciplines as electives
- ▶ Students from other disciplines take a specific course from the SC offerings
- ▶ Strong students from the Utrecht BSc/MSc programme with double major mathematics/physics are often interested, **discovering the joys of computation later in life**

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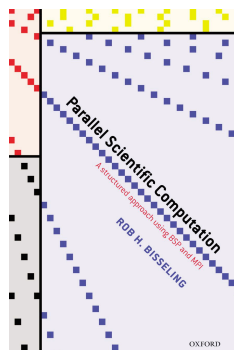
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Parallel Algorithms course: book



- ▶ Developed lecture material from 1993–2003. Appeared as a book in 2004.
- ▶ The book took a long time to write, but then it decays also slowly, if at all. **Machines come and go, but LU decomposition stays.**

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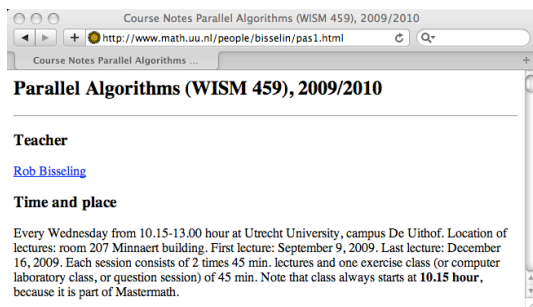
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Parallel Algorithms course: additional material



The screenshot shows a web browser window with the address bar containing the URL <http://www.math.uu.nl/people/bisselin/pas1.html>. The page title is "Course Notes Parallel Algorithms (WISM 459), 2009/2010". The main content includes the following sections:

- Teacher**
[Rob Bisseling](#)
- Time and place**
Every Wednesday from 10.15-13.00 hour at Utrecht University, campus De Uithof. Location of lectures: room 207 Minnaert building. First lecture: September 9, 2009. Last lecture: December 16, 2009. Each session consists of 2 times 45 min. lectures and one exercise class (or computer laboratory class, or question session) of 45 min. Note that class always starts at **10.15 hour**, because it is part of Mastermath.

- ▶ Software package: [BSPedupack](#), contains BSPlib programs for benchmarking, inner-product computation, dense LU decomposition, Fast Fourier Transform, sparse matrix–vector multiplication.
- ▶ Software package: [MPledupack](#) (MPI in BSP style).
- ▶ [Slides](#), including LaTeX sources (in Prosper, not yet Beamer). 26 lectures of 45 min. Good for other teachers, and to get some students started in LaTeX.



Parallel Algorithms course: computer laboratory

- ▶ Introductory lab class: run benchmarks to obtain BSP parameters for computation, communication, synchronisation
- ▶ First assignment: create list of primes by parallel Eratosthenes sieve
- ▶ Second assignment: choice of exercises, varies every year. Write a parallel program for:
 - Dense Cholesky
 - Compression by the Ziv-Lempel algorithm (LZ77), find repeats in “yabbbadabbadoo”
 - Decimals of π , using FFT to speed up large integer arithmetic (a lot of work, only for the ambitious). You get a good grade if you reach a million correct decimals
 - Sparse Conjugate Gradient
 - Wavelet transform
- ▶ Students may work in pairs on a program, but must hand in individual reports, to deter free riders while fostering collaboration

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Visualising partitioning for parallelism

Splitting the sparse matrix `1ns3937` into 5 parts. Film made using [MondriaanMovie](#) by Bas Fagginger Auer, part of `Mondriaan v3.0`, to be released Spring 2010. See the poster! Film can be found at <http://www.math.uu.nl/people/bisseling/oratiefilmpje.avi>

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Pictures of a revolution: the guillotine



King Louis XVI of France executed at the Place de la Concorde in Paris, January 23, 1793. Source:

http://www.solarnavigator.net/history/french_revolution.htm

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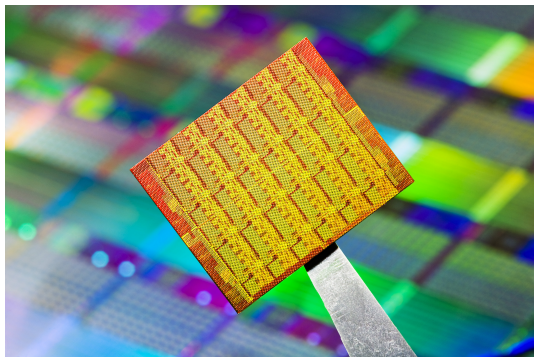
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The parallel computing revolution



Intel Single-Chip Cloud computer with 48 cores, announced December 2, 2009. Energy consumption from 25 to 125 Watt, depending on use. Each pair of cores has a variable clock frequency. Source: <http://techresearch.intel.com>

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Since 2008: what a typical student takes to class



- ▶ **Parallel computing on every student's lap:** e.g. a MacBook Pro with an Intel Core 2 Duo processor.
- ▶ Next year quadcore, octacore?
- ▶ Should this be our target architecture, or alternatively, our development tool for running on supercomputers? My view: both.

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Difficulties students encounter

- ▶ Parallel software has been **less tested** than sequential software.
- ▶ Students are **haunted by bugs**, usually their own, but you never know . . .
- ▶ They need to install Linux on a PC or buy a Mac with Unix under the hood, and they have to install OpenMPI and BSPonMPI. They become mature this way.
- ▶ They need to learn the interactive and batch system on a supercomputer.
- ▶ Things change all the time. **The teacher does not know all either.**

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Food for thought

- ▶ Why are computer science **curricula not radically changed**, by reinstating parallel computing courses? These had been removed over the past decade in many universities.
- ▶ Do we have to wait with teaching parallel algorithms until a clear picture has emerged about a **consensus parallel programming model**? This may never happen.
- ▶ **Simpler models** are needed, even simpler than BSP.
- ▶ **Hardware-oblivious** approaches are the way to go, like cache-oblivious reordering for sparse matrix–vector multiplication (Yzelman & Bisseling, *SISC* 2009).
- ▶ **Visualising algorithms** becomes more and more important, in teaching the YouTube generation, but also in research.

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