Department of Computer Science

National University of Singapore

**CS3210 – Parallel Computing**

AY 2012/13 – Semester 1

[**L01 – Introduction**](L01-Introduction.pptx)[chapter 1]

* Motivation
* What is Parallel Computing
* Why Parallel Computing
* How – Strategies to Increase Performance
* Computational Model Attributes
* Parallel Computing Landscape
* Summary

**References**

* [**A View of the Parallel Computing Landscape**](file:///\\Stfsambahost.comp.nus.edu.sg\teoym\public_html\cs3210-12\slides\2009-ACM-parallel-computing-landscape.pdf)**, CACM Vol. 52 No. 10, pp. 56-67, October 2009. [Technical Report:** [**The Landscape of Parallel Computing Research: A View from Berkeley**](file:///\\Stfsambahost.comp.nus.edu.sg\teoym\public_html\cs3210-12\slides\2006-EECS-2006-183.Berkerly-parallel-computing.pdf)**, Dec 2006, Slides:** [**The Parallel Computing Landscape**](file:///\\Stfsambahost.comp.nus.edu.sg\teoym\public_html\cs3210-12\slides\2007-PattersonISLPED07-parallel-computing-landscape.pdf)**, Oct 2007].**

**PARALLEL COMPUTER ARCHITECTURE [L03-L04]**

[**L02 – Processor Architecture & Memory Organization**](L02-Architecture-Memory.pptx)[chapter 2]

* Processor Architecture and Technology Trends
* Flynn’s Parallel Architecture Taxonomy
* Memory Organization
* Distributed-memory Systems
* Shared-memory Systems
* Reducing Memory Access Time
* Thread-level Parallelism
* Multithreading Classification
* Architecture of Multicore Processors
* Summary

**References**

1. Platform 2012: Intel Processor and Platform Evolution for the Next Decade, 2005.

[**L03 – Memory Hierarchy and Interconnection Networks**](L03-Interconnection-Networks.pptx)[chapter 2]

* Cache and Memory
* Cache
* Mapping of Memory to Cache Blocks
* Write policy
* Cache Coherency
* Example: Matrix Multiplication and Cache
* Memory Consistency
* Sequential
* Relaxed
* Summary
* Design Criteria for Interconnection Networks
* Types of Interconnection Networks
* Direct (Static)
* Indirect (Dynamic)
* Routing Algorithms (what)
* Switching Strategies (how)
* Summary

[**L04 – Performance Analysis of Parallel Systems**](L04-Performance.pptx)[chapter 4]

* Goals and Factors
* Execution Time
* Sequential
* Parallel
* Speedup and Efficiency
* Scalability
* Fixed Problem Size – Amdahl’s Law (1967)
* Fixed Time – Gustafson’s Law (1987)
* Summary

**References**

1. B.M. Tudor, Y.M. Teo and S. See, [**Understanding Off-chip Contention of Parallel Programs in Chip Multiprocessors**](http://www.comp.nus.edu.sg/%7Eteoym/pub/11/teoym-bogdan-ICPP-2011.pdf)**,** Proceedings of 40th International Conference on Parallel Processing, pp 602-611, Taipei, Taiwan, Sep 13-16, 2011.
2. B.M. Tudor and Y.M. Teo, [**A Practical Approach for Performance Analysis of Shared Memory Programs**](http://www.comp.nus.edu.sg/%7Eteoym/pub/11/teoym-bogdanma-IPDPS-2011.pdf), Proceedings of 25th IEEE International Parallel & Distributed Processing Symposium, IEEE Computer Society Press, Anchorage, USA, May 16-20, 2011.

**PARALLEL PROGRAMMING MODELS [L05-L07]**

[**L05 – Parallel Programming Models I**](L05-Parallel-Programming-Models-I.pptx)[chapter 3]

* Parallel Programming Models
* Program Parallelization
* Parallelism
* Levels (types) of Parallelism
* Representation of Parallelism
* Parallel Programming Patterns
* Summary

[**L06 – Parallel Programming Models II**](L06-Parallel-Programming-Models-II.pptx)

* Information Exchange
* Shared variables
* Communication operations
* Processes and Threads
* Summary

**References**

1. [**OpenMP Tutorial**](https://computing.llnl.gov/tutorials/openMP/)
2. Duy-Khanh Le, Wei-Ngan Chin, Yong-Meng Teo, [**Variable Permissions for Concurrency Verification**](http://www.comp.nus.edu.sg/~leduykha/pubs/ldk-vperm-icfem2012.pdf)*,* 14th International Conference on Formal Engineering Methods (ICFEM), Kyoto, Japan, 2012.

[**L07 – Message-passing Programming**](L07-Message-Passing.pptx)[chapter 5]

* Overview
* MPI
* Semantic Terms of MPI Operations
* MPI Overview
* Initialization, Finalization and Abort
* Process Groups and Communicators
* Point-to-point Communication
* Collective Communication
* Summary

**References**

* [**MPI Tutorial**](https://computing.llnl.gov/tutorials/mpi/)

[**L08 – Cloud Computing**](L08-Cloud-Computing.pptx)

* What is Cloud Computing?
  + Virtualization
  + Key Cloud Characteristics (Features)
  + Cloud Delivery Models
  + Cloud Services Model
  + Technical and non-Technical Challenges
* Cloud Reference Architecture
  + Actors in Cloud Computing
  + Interactions between the Actors
  + Usage Scenarios
  + Cloud Consumer, Provider & Broker
  + Service Orchestration and Management
  + Cloud Use Cases
  + Pros-Cons of Service Models
* Examples of Systems
  + Amazon Web Services: EC2 and S3
  + SkyBoxz: Elastic Computing with Multiple Clouds
* Summary

**References**

1. *The NIST Definition of Cloud Computing*, Sep 2011.
2. *NIST Cloud Computing Reference Architecture*, Sep 2011.
3. M. Armbrust, et al., *Above the Clouds: A Berkeley View of Cloud Computing*, Technical Report No. UCB/EECS-2009028, University of California at Berkeley, Feb 2009.
4. J. Varia, *Architecting for the Cloud: Best Practices, Amazon Web Services*, May 2010.
5. D. Hinchcliffe, *Comparing Amazon’s and Google’s PaaS Offerings,* ZDNET, 2008.
6. M. Mihailescu and Y.M. Teo, [**Strategic-Proof Dynamic Resource Pricing of Multiple Resource Types on Federated Clouds**](http://www.comp.nus.edu.sg/%7Eteoym/pub/10/ICA3PP2010-teoym.pdf), Proceedings of the 10th International Conference on Algorithms and Architectures for Parallel Processing, pp. 337-350, LNCS 6081, Springer-Verlag, Busan, Korea, May 21-23, 2010 (Best paper award).
7. M. Mihailescu and Y.M. Teo, [**The Impact of User Rationality in Federated Clouds**](http://www.comp.nus.edu.sg/%7Eteoym/pub/12/ccgrid-2012-marian.pdf), Proceedings of 12th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing, pp. 620-627, Ottawa, Canada, May 13-16, 2012.

[**L09 – Parallel Algorithm Design**](L09-Parallel-Algorithm-Design.pptx)

* Motivation
* Task/channel Model
* Algorithm Design Methodology
* Partitioning
* Communication
* Agglomeration
* Mapping
* Example – Parallel Reduction
* Summary

[Chapter 3 – Parallel Algorithm Design, in Parallel Programming in C with MPI and OpenMP, M.J. Quinn, McGraw-Hill, 2003]

[**L10 – Summary & Conclusions**](L10-Summary.pptx)

**Text: Parallel Programming for Multicore and Cluster Systems,** Thomas Rauber and Gudula Rünger, 1st Edition, Springer-Verlag, 2010.

**Tutorials**

1. Parallel Computer Architecture – I
2. Parallel Computer Architecture – II
3. Performance Analysis of Parallel Systems
4. Parallel Programming Models
5. Message-passing Programming

**Labs (10%)**

1. Parallel Computing and Data Centers [visit to SoC data center]
2. Setting up a Parallel Computer Cluster [setup and basic configuration of a Linux cluster]
3. Running Parallel Program and Performance Instrumentation [run first parallel (OpenMP) program and basic of performance measurement (processor hardware event counters and PAPI-C)]
4. Introduction to Distributed-memory Programming [basic of running MPI program and mapping of MPI processes to processors]
5. Message-passing in Distributed-memory Programming with MPI [blocking and non-blocking process communication, collective communication, arranging processes using virtual topology]

**Assignments:**

1. Cache Profiling and Performance Optimizations (15%)

[Learn the important of cache performance and exploiting SIMD parallelism]

1. MPI Basketball (20%)

[Simulate basketball match to reinforce learning of message-passing operations using MPI]