

SYLLABUS

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- B.S. and M.S. degrees in Electrical Engineering and Ph.D. degree in Computer Science
- Involved in the undergraduate Computer Engineering program administration
- Areas : computer architecture, parallel (multi-core) processing, reconfigurable and nano systems



2. Why Computer Architecture II : Computer architecture II is about high-speed computer systems.

- Students who learn high-speed computing are good at **advanced systems** (advanced microprocessors + GPUs + large-scale computer systems).
- ➔ Today's computing platforms, including laptops use advanced microprocessors + GPUs

3. Course topic : CS6143 is about **advanced pipelining**, and **parallel (multi-core) processing** that are used by microprocessors, GPUs and high-performance systems.

- Both advanced pipelining and parallel processing utilizes **parallelism** at various layers of a computer system.



4. What does industry want from college graduates :

- They need to be **critical thinkers** ! They **discover** and **explore** !
 - ➔ They are **creative** and **systems oriented** and can **solve problems** in a **global** environment.
 - ➔ They have **learning** as their target ! They **know** how to learn fast !
 - ⇒ They have analytical and synthesis skills
 - ➔ They are **adaptable**, **flexible** and **team players**.
 - ⇒ They have team work skills : **Interacting** with people to solve problems !
 - ➔ They have good **documentation skills** !

5. The course format :

The course stresses what industry wants and categorizes them : *Intellectual, technical* and *non-technical*:

- 1) The *intellectual* goals are that students **learn how to learn fast** and are **critical thinkers**. This is necessary during one's lifetime.
 - ➔ The more you learn, the better for you !
- 2) *Technical* goals are for a successful technical career : Acquiring skills to be **systems oriented** and a **problem solver** as well as acquiring the necessary course content which is *parallelism* :
 - ➔ **Main technical topic : Digital systems**, such as microprocessors, computers, calculators, DVDs, iPhones. The course focuses on developing a computer, by designing its *architecture* and then the *organization (microarchitecture)* layers :
 - ⇒ CS6143 introduces **parallelism** techniques to improve computer performance and capacity :
 - ★ **Advanced pipelining** techniques improve the uniprocessor system performance by exploiting instruction-level parallelism (ILP) and loop-level parallelism of programs.
 - ★ **Parallel processing** techniques to improve the performance and capacity, by utilizing multiple processors or processing elements to exploit loop-level and higher-levels of parallelism : thread-level, task-level and process-level parallelisms. The focus will be on PRAM, SIMD (single-instruction stream, multiple-data stream) and MIMD (multiple-instruction stream, multiple-data stream, multi-core) systems.
- 3) The *non-technical* goals include acquiring and improving skills needed for **interacting with** and **managing people** in a global environment. They are needed in the technical world which is **team-based** and becoming more **global**.

6. Course structure :

This is a **Computer Science and Engineering** Department course

Lecture Section :

➤ **24207**, Wednesday, 6:00 - 8:30

7. Prerequisite : CS 6133 Computer Architecture I.

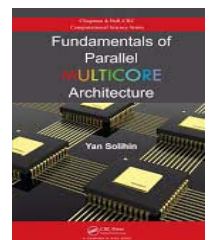
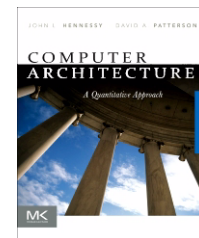
➤ Students who took CS 2214 at NYU-SOE can take the course

8. Course web page : NYU Classes

➤ Course handout files are at the course web site

9. Textbooks :

- a) *Computer Architecture : A Quantitative Approach*, **5th edition**, J. L. Hennessy and D. A. Patterson, Morgan Kaufmann Publishers Inc., 2012.



- Publisher's web site, <http://books.elsevier.com> has a large amount of material, including Appendices D through L of the textbook. Students are strongly suggested that they study the web site material and print the appendices that will be used especially during the exams.
 - ➔ Students are reminded about printing the appendices !

- b) *Fundamentals of Parallel Multicore Architecture*, Yan Solihin, CRC Press, 2016.

Also, Students will also read other books and papers, especially on multi-core, parallel random access machine (PRAM) and single-instruction stream, multiple-data stream (SIMD) machines.

10. Homework :

There are six homework assignments. The homework is submitted by teams.

- Students are expected to **show the work** (intermediate steps) to get full/partial credits on a question. Showing work helps students improve their documentation. The homework is graded by the professor. Although, the homework does not affect the term grade, it can help raise grades as explained below.
- Homework assignments have relevant questions and answers to help learn chapters and solve homework problems. Students need to study them before they solve homework problems, not before exams.

11. Exams :

There are a 150-minute midterm exam and a 150-minute final exam.

- Students are expected to **show the work** (intermediate steps) to get full/partial credits on a question. That is, both the final answer and the steps to get it, the approach, are important.
 - ➔ Showing the approach also helps students acquire and improve their documentation skills, critical for the technical world.
 - ⇒ In order to facilitate this, the exams are open book exams : Students can use their own material, i.e. their books, notebooks, homework and handouts during the exams. Note that once the exam starts there is no sharing.
 - ⇒ Students must prepare for the exams as if they are closed book exams !
- In addition, remembering the following is needed during the exams :
 - ➔ No multiple answers to a question,
 - ➔ Precise answers to questions, no answers like “the rest is similar,”
 - ➔ Answering the question asked,
 - ➔ Use the exam booklet space well: For example, start a new question on a new page.

Overall, students are expected to show their technical knowledge and documentation

12. Term Grade :

The term grade is calculated as follows :

10% Student Project 30% Midterm Exam 60% Final Exam

- The homework does not affect the term grade directly but it is taken into account when a student’s term grade is near a grade “border.” Also, taken into account are attendance and recitation performance. If they are good, the grade is raised. Finally, the professor may change the term grade computation.

13. Office Hours :

The professor has an **open-door** policy that if he is not busy, students can ask questions in his office. If a student wants to see the professor at a certain time, he/she makes an appointment with the professor.

- Students are requested that they see the professor to ask questions. Broadcast messages will be sent to the class to make announcements. Please note that grades are not given out to students via email or telephone. Students need to see the professor to learn their grades.
- TA assignments and their contact information will be given later in the semester.

14. Material Coverage : Chapters from Hennessy and Jordan books will be covered. Also, students will study other books and papers. They will be also given additional material in class. The **tentative** schedule is as follows :

| Day(s) | Subject |
|---------------------------|---|
| Jan 25 | Introduction ; Computer layers ; Computational methods ; Popular scientific applications ; CS613 Integer pipeline ; (Chp 1, 2 ; Appendix A, B, C) ; (Chp 1, 5) |
| Jan 25, Feb, 1, 8, 15, 22 | MIPS FP pipeline ; Advanced pipelining : Speculative execution, superscalar execution, VLIW computation ; (Chp 2, 3 ; Appendix A, B, C, H) ; (Chp 5) |
| Feb 22 | Vector processors ; (Chp 4 ; Appendix A, B, C, G) |
| Mar 8 | Midterm Exam : HW : 1 - 3 |
| Mar 1, 22 | Flynn's classification ; Interconnection networks ; (Chp 4, 5 ; Appendix G, I) ; (Chp 1, 2, 11) |
| Mar 22, 29, Apr 5 | Parallel processing overview ; Dependency analysis ; Levels of parallelism ; Parallelism issues ; Algorithm complexity ; PRAMs ; (Chp 3, 5 ; Appendix I) ; (Chp 1, 2) |
| Apr 12, 19 | MIMD machine overview ; Shared-memory MIMD systems ; Cache coherency; Shared Memory MIMD systems ; Synchronization ; Programming ; (Chp 3, 5 ; Appendix I) ; (Chp 3, 4, 6, 7, 8, 9, 10) |
| Apr 26 | Distributed Memory MIMD systems ; SIMD machines ; (Chp. 3, 5 ; Appendix I) ; (Chp 3, 4, 6, 7, 8, 9, 10) |
| May 3 | Student presentations ; Current parallel processing system and issues ; (Chp 3, 5 ; Appendix I) ; (All chapters) |
| May 10 | Final exam : HW : 1 - 6 |

15. References :

Students are suggested that they study **recent** computer architecture and parallel processing books since the field advances fast. Using the web to gather information is strongly discouraged !

The following references are recommended with respect to their relevance to the course and the textbooks :

- a) *MIPS RISC Architecture*, G. Kane and J. Heinrich, Prentice-Hall, 1992.
- b) *Parallel Computer Organization and Design*, M. Dubois, M. Annavaram and P. Stenstrom, Cambridge University Press, 2012.
- c) *Speculative Execution in High Performance Computer Architectures*, D. A. Kaeli and P. Yew, Editors, CRC Press, 2005.
- d) *CPU Design : Answers to Frequently Asked Questions*, C. M.R. Thimmannagari, Springer Verlag, 2005.
- e) *Programming Many-Core Chips*, A. Vajda, Springer Verlag, 2011.
- f) *Aundamentals of Parallel Procesing*, Harry F. Jordan and M. Gita Alaghband, Prentice-Hall, 2003.
- g) *Interconnection Networks : An Engineering Approach*, J. Duato, S. Yalamanchili and L. L., Morgan Kaufman, 2003.
- h) *Highly Parallel Computing*, G. S. Almasi and A. Gottlieb, 2/e, Benjamin/Cummings, 1994.
- i) *Programming Massively Parallel Processors : A Hands-on Approach*, 2nd edition, D. B. Kirk and W. W. Hwu, Morgan Kauffman, 2012.
- lj) *The Art of Multiprocessor Programming*, M. Herlihy and N. Shavit, Morgan Kauffman, 2008.
- k) *Computer Architecture : Pipelined and Parallel Processor Design*, M. J. Flynn, Jones & Bartlett, 1995
- l) *Parallel Computing : Theory and Practice*, Michael J. Quinn, McGraw-Hill, 1994.
- m) *Algorithms and Parallel Computing*, F. Gebali, John Wiley, 2011.
- o) *Structured Parallel Programming*, M. McCool, J. Reinders and A. Robison, Morgan Kaufman, 2012.

In additiona, journal and conference and workshop research papers on computer architecture, parallel processing, supercomputing, operating systems, algorithms, programming languages and compilers.

16. The Theme of the Course :

i) CS6143 explores higher computer performance and higher capacity through a more rigorous exploitation of parallelism. Parallelism on several layers of computers is targeted. The layers we will target are the computational method, algorithm, high-level language, architecture and microarchitecture.

ii) The first half of the semester is on low-level parallelism, including the instruction-level parallelism, **ILP**, and loop-level parallelism, that are on the architecture and microarchitecture layers. These two forms of parallelisms have been extensively exploited in the form of dynamic pipelining, superscalar execution, vector processing and VLIW (EPIC used by the Intel Itanium is a version of VLIW).

iii) The second half of the semester is on parallel processing, especially massively parallel processing, i.e. MIMD computers. We will start with interconnection networks used in MIMD computers. Then, we will cover PRAMs which are theoretical systems to help understand real parallel systems better. We will then discuss shared-memory MIMD systems and cache coherency (many current multi-core systems are shared-memory MIMD systems). This is followed by distributed memory MIMD systems. We will discuss their properties and why today's fastest supercomputers are distributed memory MIMD systems.

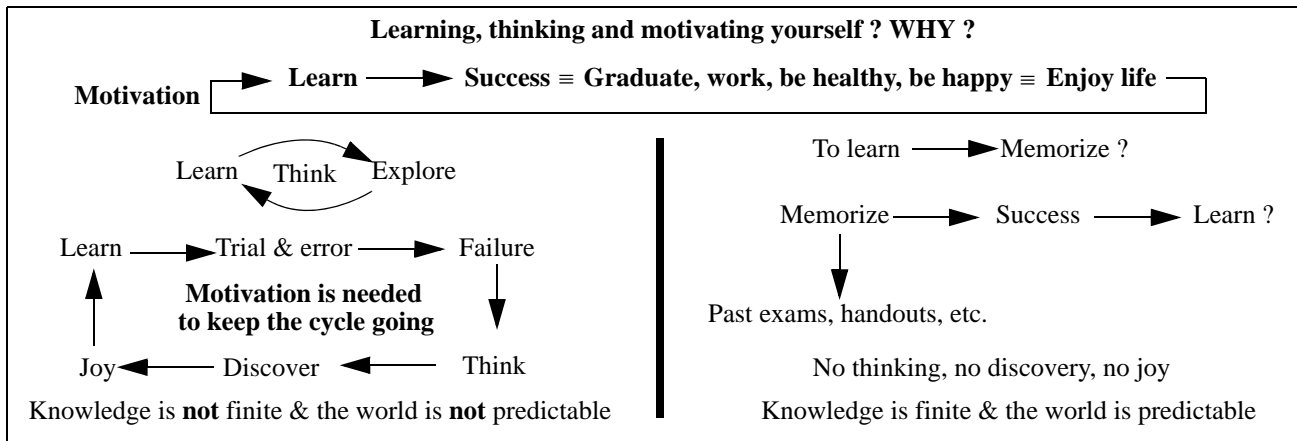
v) Finally, we will sum up the semester by studying current conference and workshop papers that outline issues for now and future for parallel processing systems.

17. Professor's message :

Please **attend classes** and **participate** in the work !

➤ If you do **not** hear the professor, you **cannot** know what is happening with the course !

Students are asked that they consider the learning and thinking style shown on the left below :



Students are suggested that they read the following book that describes the cycle on the left above :

➤ *Little Bets : How Breakthrough Ideas Emerge From Small Discoveries*, Peter Sims, Simon and Schuster, 2011.

19. Reminders about the course:

Students need to read web pages whose links are also provided at the course web site :

1) **NYU Code of Conduct web page** : <http://engineering.nyu.edu/life/student-affairs/code-of-conduct>

2) **NYU-SOE Life web page with links to Student Affairs, Public Safety, Students Resources and other** : <http://engineering.nyu.edu/life>. In addition, students need to keep the following in mind :

a) **Keeping contact with the professor and discussing personal matters in professor's office help you**

considerably

b) A successful course experience : To enjoy the course as much as possible and be ready for the follow up courses, students need to be committed to the course

➤ **Attending classes** and **doing the work** are needed.

c) Students must realize that every action they take has consequences. Making assumptions and decisions on the course (the exams, lectures, the homework and attendance) without asking the professor often lead to problems for students.

d) A reason for a low grade is **missing classes**. Even if one gets the notes, it does **not** help. This is because :

- The notes taken from the board may not be correct.
- Someone taking the notes may not write down all the verbal comments and suggestions made by the professor.
- Attending classes forms better memory because of visual (seeing the writing on the board), audio (listening to the professor) and tactile (writing down the notes) inputs.
- During lectures, the professor refers to earlier lectures (past topics, comments, suggestions, etc.) which refreshes students' memory and further reinforces their knowledge.

Overall, students learn and remember more. Finally, since their memory is fresh, students save time when they study for exams.

e) Missing an exam is **not** a minor case. A careful assessment is made to excuse a student or to grant an incomplete to a student. The professor makes the decision. The decision is made also based on the information by the student's academic department and the Student Affairs Office.

One of the requirements to excuse a student is that at the time the student is not able to take the exam, he/she **be in good standing in class**, i.e. has good attendance, a good homework performance, and a good exam performance : The professor wants to see that the student has been committed to the course and learning the material has been his/her main objective.

A student who is excused from a midterm exam is **not** given a make-up exam. The weight of the mid-term exam is distributed to the other exams at the discretion of the professor. The make-up exam for the final exam will be harder than the one given to the whole class.

If a student experiences **any** problem, including health/personal problems, needs to immediately contact **Judith Simonsen** who is the Coordinator of Student Advocacy and Compliance at Student Affairs. Her email address is **js6244@nyu.edu**. Her number is **(646) 997-3046**. Her office number is **LC 240C**.

f) For a course, the semester is over when the final exam is over. Students are **not** given extra work, a project, a make-up exam or any other kind of special treatment to raise their grade during or after the semester.

g) Some students do not know/follow NYU-SOE and CS2204 rules and regulations nor seek advice from Polytechnic staff. Students are strongly suggested that **they speak with the professor**, the TAs, the major advisor, the personnel of the Student Affairs Office, and the Counseling Center for a better experience.

20. Moses Center Statement of Disability :

If you are a student with a disability who is requesting accommodations, please contact New York University's Moses Center for Students with Disabilities at (212) 998-4980 or mosescsd@nyu.edu. You must be registered with CSD to receive accommodations. Information about the Moses Center can be found at www.nyu.edu/csd. The Moses Center is located at RH 042 in Brooklyn ((646) 997-3451) and 726 Broadway on the 2nd and 3rd floors in Manhattan ((212) 998- 4980).