**Jackson State University**

**Department of Computer Science**

**Course Number and Title:** CSC425.01 Parallel Computing

**Semester and Year: Fall** 2025

**Instructor:** Dr.Sugnbum Hong

**Office Location**: ENB 269

**Office Hours:** MWF 3 to 5 PM (Fall 2025)

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**Required Text(s):**

* [Victor] Victor Eijkhout, *Parallel Programming in MPI and OpenMP*, ‎ Lulu.com (November 27, 2017) ISBN-10 138740028

o  [*https://bitbucket.org/VictorEijkhout/parallel-computing-book/downloads*](https://bitbucket.org/VictorEijkhout/parallel-computing-book/downloads)

* [Sunita] Sunita Chandrasekaran and Guido Juckeland, *OpenACC for Programmers: Concepts and Strategies*, 2017, ISBN-13 978-0134694283

**Reference**

* *The MPI standard is online:*

o *http://mpi-forum.org/docs/mpi-3.1/mpi31-report.pdf (document)*

o *http://www.mcs.anl.gov/research/projects/mpi/www/www3/ (index of all routines).*

* *The OpenMP standard and examples are likewise electronically available:*

o *http://www.openmp.org/specifications/.*

o *http://www.openmp.org/wp-content/uploads/openmp-4.5.pdf*

**Course Description**

CSC 425 (3) Parallel Computing. Prerequisite: CSC325 Operating Systems. A study of the hardware and software issues in parallel computing. Theoretical and practical survey of parallel processing, including a discussion of parallel architectures, parallel programming languages, and parallel algorithms. Programming on multiple parallel platforms in a higher-level parallel language. It should also be helpful for those who want to learn programming multi-core processors.

**Prerequisites**

CSC325 Operating Systems

**Course Objectives (must be measurable student outcomes)**

Each student who completes this course should be able to:

CO-1: Understand parallel computer architecture.

CO-2: Become skilled at multi-core programming with OpenMP.

CO-3: Become skilled in programming on massively parallel architecture (GPU) (OpenACC)

CO-4: Become skilled in message-passing programming with MPI

CO-5: Analysis of Performance of Parallel Algorithms.

CO-6: Understand fundamental parallel algorithms: Dense matrix, Sorting, Graph algorithm, Search Algorithms, Dynamic Programming, and Fast Fourier Transform.

**Course Content and Assignment Schedule**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **No.** | **Topic name** | **Assignments** | **CO** | **Weeks** |
| **1** | Introduction to HPC and Cluster: vim, Linux Cluster Institute  Getting started with MPI, Basic model, Making and running an MPI program, Language bindings, and how to read routine signatures. | Lab 1  vim, HPC LCI. |  | 1 |
| **2** | **Functional Parallelism.**  The SPMD model, Starting and running MPI processes, Processor identification, Processor name, Functional parallelism, Distributed computing and distributed data.  **Collectives.**  Working with global information,  Reduction, Rooted collectives: broadcast, reduce, Scan Operations, gather and scatter, All-to-all as data transpose, Reduce-scatter, Barrier, Variable-size-input collectives, MPI Operators, Nonblocking collectives, Performance of collectives, Collectives and synchronization, Performance considerations. | [Victor] Ch1-4  Lab 2  Compiling a program on HPC | CO1 | 1 |
| **3** | **Point-to-Point**  Blocking and nonblocking point-to-point operations, the status object and wildcards, and more about point-to-point communication.  Communication.  Persistent Communication.  Partitioned communication, Synchronous and asynchronous communication, Local and nonlocal operations, and Buffered communication.  **Data types**  Predefined data types, Derived datatypes,  Big data types, Type maps, and type matching, Reconstructing types, Packing. | [Victor] Ch 5-6  Project #1 with MPI  Implementing Fibonacci computation  Algorithms | CO4 | 1 |
| **4** | **Communicators**  Basic communicators, Duplicating communicators, Sub-communicators,  Splitting a communicator, Communicators and groups, Intercommunicators.  **Process Management**  Process spawning, Socket-style communications, Sessions,  **One-Sided Communication.**  Windows, Active target synchronization: epochs, Put, get, accumulate, Passive target synchronization, More about window memory, Assertion, Implementation | [Victor] Ch7-9 |  | 2 |
| Project #2 with MPI,  Implementing Principal Component Analysis (PCA) for Large Data Sets with Parallel Data Summarization | CO4 |
| **5** | (**Exam 1**)  **File I/O**  File reading and writing, Consistency, Constants, and Error handling.  **Topology**  Cartesian grid topology, Distributed graph topology,.  **Shared memory**  Recognizing shared memory, Shared memory for windows. **MPI support for threading**  **Tools interface**  Initializing the tools interface,  [Control variables](https://theartofhpc.com/pcse/mpi-tools.html#Controlvariables) Performance variables, Performance experiment sessions, Categories of variables, Events | [Victor] Ch 9-14 | CO4 | 2 |
| Project #3 with MPI,  Implementing DNA Sequential Algorithm | CO4  CO6 |
| **6** | **Getting started with OpenMP**  The OpenMP model  Compiling and running an OpenMP program, Your first OpenMP program, Thread data, Creating parallelism.  **Parallel regions**  Creating parallelism with parallel regions, Nested parallelism, Cancel parallel construct.  **Loop parallelism**  An example, Loop schedules  Reductions, Nested loops, Ordered iterations, nowait, While loops | [Victor]- Ch17-19  Project #4 with OpenMP,  Topic: Parallel Implementing  Fibonacci computation  Algorithms | CO2 | 1.5 |
| **7** | **Reductions**: why, what, how?  Built-in reduction, Initial value for reductions, User-defined reductions  Scan / prefix operations, Reductions and floating-point math.  Work sharing constructs  **Sections**  Single/master  Fortran array syntax parallelization  **Shared data,** Private data, Data in dynamic scope, Temporary variables in a loop, Default, First and last private, Array data, Persistent data through thread private, Allocators. | [Victor] Ch20-Ch22 | CO6 | 1.5 |
| Project #5 with OpenMP,  Implementing  Principal Component Analysis (PCA) for Large Data Sets with Parallel Data Summarization | CO2 |
| **8** | **Synchronization.**  Barrier, Mutual exclusion, Locks, Relaxed memory model.  **Task**  Task generation, [Task data](https://theartofhpc.com/pcse/omp-task.html#Taskdata), Task synchronization, Task dependencies, Task reduction, Task canceling.  (**Exam #2**) | [Vicotr]-Ch23  Project #6  With OpenMP,  Implementing DNA Sequential Algorithm | CO2 | 1 |
| **10** | **Affinity**  OpenMP thread affinity control  First-touch, Affinity control outside, OpenMP.  **SIMD processing**  **Offloading** | [Victor] Ch 25-Ch27 | CO2 | 1 |
|  | CO3 |
| **11** | Open Accelerators (OpenACC), Fundamental Parallel Algorithms |  | CO6 | 1 |
| OpenACC in a Nutshell, Loop-Level Parallelism,  Programming Tools for OpenACC,  Compiling OpenACC | [Sunita] Ch 1-5  Project #7  With Open ACC,  Implementing  Fibonacci computation  Algorithms | CO3 |
| **12** | Best Programming Practices,  OpenACC and Performance Portability. | [Sunita] CH 6-7  Project #8  With Open ACC,  Implementing Principal Component Analysis (PCA) for Large Data Sets with Parallel Data Summarization | CO3 | 1 |
| **13** | Additional Approaches to Parallel Programming  OpenACC and Interoperability,  Advanced OpenACC | [Sunita] Ch8-10  With Open ACC, Implementing DNA Sequential Algorithm | CO3 | 2 |

**Instructional Strategies**

All students are required to do homework and one course project. Three assignments of homework and the course project will be completed through teamwork and collaborative learning. In such assignments, teams of students will be formed and learn collaboratively relevant core concepts in the course subject for completing three assignments of homework and one course project. The team collaboration will take place on the online discussion board. Students in each team will be assigned with different roles for the discussion and will in turn take

different roles during the discussion. Participation in dissuasion will be part of required course participation for developing teamwork and communication skills. However, each student required completing and submitting his or her homework and course project individually. The requirement for the teamwork and grading criteria for participation of collaborative learning will be provided.

Students will have an optional opportunity to earn bonus points by participating in self-assessment on their learning and skill. The self-assessment processes would promote students to think of their learning activities and strategy utilization , remind them of other available learning activities and strategies that they may not try before an may help them, identify their weakness and strength, and reflect on their success and failure to adjust their learning strategies and efforts.

**Student Activities**

**Homework and Programming Projects:** Students will be given at the end of each major topic.

- Students should submit their homework before start class and also is should be typed.

- Programming Projects can be done in the server that the instructor provided.

**Online Quizzes and Pop Quizzes:** Students will be given quizzes at the class room and through the Black Board. It should be done within a term or at the place that the instructor requested.

**Exams (Test 1 and Test 2 Final ) :** There will be three exams during the semester (the two tests and Final Exam). The exams will cover the topics discussed throughout the semester and will be given during the scheduled exam times.

**Method of Student Evaluation**

Grading Policy:

- Homework and Quizzes 20%

- Lab and Programming Projects 20%

- Midterm Exam (test 1 and Test2 ) 40%

- Final Exam 20%

- Total 100%

**Grading Scale**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Range | **90% - 100%** | **80% - 89%** | **70% - 79%** | **60% - 69%** | **below 60%** |
| **Letter grader** | **A** | **B** | **C** | **D** | **F** |

**Method of Course Evaluation**

- SIRS

- Evaluation by students on their ability to perform in each of the course outcomes during the semester using Tests , Homework, Programming Projects, and Quizzes (ABET).

**Special Needs Learners**

(If you have a disability for which you are or may be requesting an accommodation, you are encouraged to contact both your instructor and the Office of the Americans with Disabilities Act (ADA) Coordinator and Compliance Office, P.O. Box 17999, Jackson, MS 39217; (601) 979-2485 as early as possible in the term.)

**Diversity Statement**

(Jackson State University is committed to creating a community that affirms and welcomes persons from diverse backgrounds and experiences and supports the realization of their human potential. We recognize that there are differences among groups of people and individuals based on ethnicity, race, socioeconomic status, gender, exceptionalities, language, religion, sexual orientation, and geographical area. All persons are encouraged to respect the individual differences of others.)

**Caveat (if needed)**

· Not allow students come/go, Not allow students to use cell-phone after class starts.

· Not allow to bring any type of food into class.

· No make-up tests will be given, except in cases of verifiable emergencies.

· All assignments must be turned in at the beginning of class on the day due.

· Late assignments will be deducted 20% each week for which they are late. Assignments handed in more than 2 weeks (including week-end days) after the deadline will not be accepted, nor marked. No exceptions will be made.

**Class Attendance Policy**

Students at Jackson State University must fully commit themselves to their program of study. One hundred percent (100%) punctual class attendance is expected from each student for all the scheduled classes and activities. Instructors keep attendance records and any absence for which a student does not provide written official excuse is counted as an unexcused absence. With or without official excuses, students are responsible for the work required during their absences.

**Academic Honesty Statement**

- Assignments must be done individually; you may not work in groups. You may not copy another person's work in any manner (electronically or otherwise). Furthermore, you must not give a copy of your work to another person. We will be randomly checking for similarities between programs, and you may be asked to present and explain your program to the instructor.

- Cheating will not be tolerated. Students guilty of cheating on a test or program will be given an F in the course. Remember that allowing others to copy your work is considered cheating.

**Bibliography/References (current knowledge)**

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Peter S. Pacheco , *An Introduction to Parallel Programming* Elsevier Science Ltd ISBN-13: 9780123742605

Andrea Marongiu and Luca Benini. *Efficient OpenMP support and extensions for MPSoCs with explicitly managed memory hierarchy.* In Proceedings of the Conference on Design, Automation and Test in Europe (DATE '09). Belgium, Belgium, 809-814.

Bensoudane, and Gabriela Nicolescu*. Parallel programming models for a multi-processor SoC platform applied to high-speed traffic management.* In Proceedings of the 2nd IEEE/ACM/IFIP international conference on Hardware/software codesign and system synthesis (CODES+ISSS '04). ACM, New York, NY, USA

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Kengo Nakajima and Hiroshi Okuda. *Parallel Iterative Solvers for Unstructured Grids Using an OpenMP/MPI Hybrid Programming Model for the GeoFEM Platform on SMP Cluster Architectures*. In Proceedings of the 4th International Symposium on High Performance Computing (ISHPC '02), Hans P.

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J. Steven Kirtzic. 2012. *A Parallel Algorithm Design Model for the Gpu Architecture*. Ph.D. Dissertation. University of Texas at Dallas, Richardson, TX, USA. Advisor(s) Ovidiu Daescu.

Pablo Toharia, Oscar D. Robles, José L. Bosque, and Angel Rodríguez. *Video shot extraction on parallel architectures*. In Proceedings of the 4th international conference on Parallel and Distributed Processing and Applications (ISPA'06), Springer-Verlag, Berlin, Heidelberg, 869-883.

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