**PMAS Arid Agriculture University**
**Rawalpindi**

**University Institute of Information Technology**

| CS- 687Parallel and Distributed Computing | | | |
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| **Credit Hours:** | **3(2-3)** | **Prerequisites:** | **None** |
| **Teacher:** | Asad-Ul-Haq Hashmi | Date | October 2021 Onwards |

| **Course Description:** |
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| Asynchronous/synchronous computation/communication, concurrency control, fault tolerance, GPU architecture and programming, heterogeneity, interconnection topologies, load balancing, memory consistency model, memory hierarchies, Message passing interface (MPI), MIMD/SIMD, multithreaded programming, parallel algorithms & architectures, parallel I/O, performance analysis and tuning, power, programming models (data parallel, task parallel, process-centric, shared/distributed memory), scalability and performance studies, scheduling, storage systems, synchronization, and tools(Cuda,Swift,Globus,Condor,AmazonAWS,OpenStack,Cilk,gdb,threads, MPICH, OpenMP, Hadoop, FUSE). |
| **Course Objective:** |
| – Learn about parallel and distributed computers.<br>– Write portable programs for parallel or distributed architectures using<br>Message-Passing Interface (MPI) library<br>– Analytical modeling and performance of parallel programs.<br>– Analyze complex problems with shared memory programming with OpenMPI |
| **Teaching Methodology:** |
| Lectures, Assignments, Presentations, etc. Major component of the course should be covered using conventional lectures. |
| **Courses Assessment:** |
| Exams, Assignments, Quizzes. Course will be assessed using a combination of written examinations. |
| **Reference Materials:** |
| • Distributed Computing Principles and Applications By M. L. Liu, 1st Edition, |

Pearson Education, 2009.

- Distributed Systems: Principles and Paradigms, A. S. Tanenbaum and M. V. Steen, Prentice Hall, 2nd Edition,2007
- Distributed and Cloud Computing: Clusters, Grids, Clouds, and the Future Internet, K Hwang, J Dongarra and GC. C. Fox, Elsevier, 1stEd.

| **Course Learning Outcomes (CLOs):** | | |
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| At the end of the course the students will be able to: | **Domain** | **BT Level*** |
| 1. Learn about parallel and distributed computers.. | C | 2 |
| 2. Write portable programs for parallel or distributed architectures using Message-Passing Interface (MPI)library | C | 3 |
| 3. Analytical modeling and performance of parallel programs | C | 3 |
| 4. Analyze complex problems with shared memory programming with openMP. | C | 4 |
| * BT= Bloom's Taxonomy, C=Cognitive domain, P=Psychomotor domain, A= Affective doma | | |

| **Week** | **Lecture #** | **Theory** |
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| Week 1 | 1 & 2 | Introduction to Course<br>Course Objective and Course Material<br>Serial Computing & Disadvantages of Serial Computing<br>Scope of Parallel Computing<br>Parallel Computing- Basic Definitions<br>Motivations of Parallel Computing<br>Moore's Law<br>Parallel Computing- Flynn's Taxonomy<br>1. SISD<br>2. SIMD<br>3. MISD<br>4. MIMD<br>Need of Parallel Computing<br>Limitations of Parallel Computing |

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| | 3 & 4 | Introductory Session on Exploring Java Using NetBeans<br>Variables, Decision Making and Looping |
| Week 2 | 5 & 6 | Parallel Computers<br>Parallel Computing Advantages<br>Parallel Computing Types<br>1. Bit-Level Parallelism<br>2. Instruction-Level Parallelism<br>3. Task Parallelism<br>**Parallel Programming Platforms**<br>Physical Organization of Parallel Platforms-Architecture of an Ideal Parallel Computer (PRAM--EREW, CREW, ERCW, CRCW )<br>PRAM Semantics |
| | 7 & 8 | Multithreading in Java Sample Demo Code-1 |
| Week 3 | 9 & 10 | **Interconnection Networks for Parallel Computers**<br>Static Vs Dynamin<br>**Network Topologies**<br>Bus-Based Networks<br>Crossbar Networks<br>Multistage Networks<br>Completely Connected Networks<br>Star-Connected Networks<br>Tree-based Networks<br>**Evaluating Static and Dynamic Interconnection** Networks<br>- Diameter<br>- Connectivity<br>- Bisection Width and Bisection Bandwidth<br>- Channel Width,<br>- Channel Rate, |

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| | | Channel Bandwidth |
| | 11 & 12 | Multithreading in Java Sample Demo Code-2<br>- Creating Threads Using Thread Class<br>- Creating Threads Using runnable Interface<br>- Synchronization of Threads Program |
| Week 4 | 13 & 14 | **Communication Cost in Parallel Machines**<br>• Message Passing Costs in Parallel Computers<br>- Startup time<br>- Per-hop time<br>- Per-word transfer time<br>• Store-and-Forward Routing<br>• Packet Routing<br>• Cut Through Routing<br>**Routing Mechanism**<br>• Minimal & non-Minimal<br>Deterministic & Adaptive |
| | 15 & 16 | Programming Using the Message-Passing Paradigm<br>Demo of MPI: the Message Passing Interface |
| Week 5 | 17 & 18 | **Principles of Parallel Algorithm Design**<br>• Decomposition, Tasks, and Dependency Graphs<br>• Granularity, Concurrency, and Task-Interaction<br>• Processes and Mapping<br>• Processes versus Processors<br>**Decomposition Techniques**<br>• Recursive Decomposition<br>• Data Decomposition<br>- Partitioning Input Data<br>- Partitioning Output Data<br>- Partitioning Input & output Data<br>- Partitioning Intermediate Data |

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| | | - The Owner-computes Rule<br>• Exploratory Decomposition<br>• Hybrid Decomposition |
| | 19 & 20 | MPI: the Message Passing Interface<br>- Hello world<br>- Odd-Even Sort |
| Week 6 | 21 & 22 | **Characteristics of Tasks**<br>• Task Generation Static Vs Dynamic<br>• Task Size Uniform vs non-Uniform<br>• Knowledge of Task Size<br>• Size of Data Associated with the Task<br>**Characteristics of Inter-Tasks**<br>• Static Vs Dynamic<br>• Regular Vs Dynamic<br>• Read-only Vs Read-Write<br>• One-Way Vs Two-Way |
| | 23 & 24 | Search Algorithms for Discrete Optimization Problems<br>• Sequential Search Algorithms<br>• Depth-First Search Algorithms<br>• Depth-First Branch-and-Bound<br>Depth-first branch-and-bound<br>Iterative Deepening A*<br>Iterative deepening A*<br>• Best-First Search Algorithms<br>• Parallel Depth-First Search |
| Week 7 | 25 & 26 | **Mapping Technique for Load Balancing**<br>• Static Mapping<br>Mappings Based on Data Partitioning<br>Mappings Based on Task Partitioning<br>Hierarchical Mappings |

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| | | • Dynamic Mapping<br>Centralized Schemes<br>Distributed Schemes |
| | 27 & 28 | The OpenMP Programming Model<br>Code for Computing PI using OpenMP directives<br>Specifying Concurrent Tasks in OpenMP |
| Week 8 | 29 & 30 | **Parallel Algorithm Models**<br>• The Data-Parallel Model<br>• The Task Graph Model<br>• The Work Pool Model<br>• The Master-Slave Model<br>• The Pipeline or Producer-Consumer Model<br>• Hybrid Models |
| | 31 & 32 | Synchronization Constructs in OpenMP<br>Data Handling in OpenMP<br>OpenMP Library Functions<br>Environment Variables in OpenMP |
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| Week 9 | 33 & 34 | **Graph Algorithms**<br>1. Definitions and Representations<br>2. Minimum Spanning Trees: Prims Algorithm & Parallel Formulation<br>3. Single Source Shortest Paths: Dijkstra's Algorithm Serial Vs Parallel Formulation |
| | 35 & 36 | Writing and Running Code for Prims Algorithm<br>Writing and Running Code for Dijkstra's Algorithm |
| Week 10 | 37 & 38 | **Graph Algorithms**<br>4. All Paris Shortest Path: Dijkstra's Algorithm with Parallel Formulation<br>5. Floydd's Algorithm Parallel Formulation |

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| | 39 & 40 | Writing and Running Code for Floydd's Algorithm |
| Week 11 | 41 & 42 | Distributed Computing<br>Definitions<br>History of Distributed Computing<br>Strengths and Weaknesses of Distributed Computing<br>Architecture of Distributed Applications |
| | 43 & 44 | Internet Applications<br>- Applets<br>- Servlets<br>- Web Services<br>- SOAP |
| Week 12 | 45 & 46 | Paradigm of Distributed Applications<br>- Message Passing<br>- The Client-Server Paradigm<br>- The Distributed Object Model<br>- The Mobile Agent Paradigm<br>- The Collaborative Application (Groupware) Paradigm |
| | 47 & 48 | COBRA Object Interface<br>Inter-ORB Protocols<br>Java IDL Package |
| Week 13 | 49 & 50 | The Client-Server Paradigm<br>Connection-Oriented and Connectionless Servers<br>Iterative Server and Concurrent Server |
| | 51 & 52 | Sending Message to Multicast Group<br>Receiving Message Sent to a Multicast Group |
| Week 14 | 53 & 54 | Distributed Objects<br>- Message Passing Vs Distributed Objects<br>- Distributed Object System<br>- Remote Procedure Calls |

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| | | - Remote Method Invocation |
| | 55 & 56 | API for Java RMI<br>- The Remote Interface<br>- The Server-side Software<br>- The Client Side Software<br>- Simple RMI Application |
| Week 15 | 57 & 58 | Internet Applications<br>- HTML<br>- XML<br>- HTTP<br>- Dynamically Generated Web Contents<br>- Common Gateway Interface |
| | 59 & 60 | Web Forms<br>Creating Web Session<br>Exploring Session data<br>Cookies |
| Week 16 | 61 & 62 | Final Project Presentations/Demonstration-1 (Half Class) |
| | 63 & 64 | Final Project Presentations/Demonstration-2 (Half Class) |
| **Final Term Exam** | | |