Uka Tarsadia University

B. Tech.

Semester VI

HIGH PERFORMANCE COMPUTING

XXXXXX

EFFECTIVE FROM July-2021

Syllabus version: 1.00

Subject Code	Subject Title	Teaching Scheme			
		Hours		Credits	
		Theory	Practical	Theory	Practical
XXXXXX	High Performance Computing	3	2	3	1

Subject Code	Subject Title	Theory Examination Marks		Practical Examination Marks	Total Marks
		Internal	External	CIE	
XXXXXX	High Performance Computing	40	60	50	150

Objectives of the course:

- To illustrate super scalar architecture of processors based on cache and programming for vector architecture.
- To explain the taxonomy of parallel computing and characteristics of network for high performance computing.
- To demonstrate parallel programing and distributed memory concept for shared memory using open MP and MPI.

Course outcomes:

Upon completion of the course, the student shall be able to

CO1: Understand the Moore's law for transistors galore and superscalar architecture and memory mapping.

CO2: Comprehend the basic performance characteristics of networks in computing.

CO3: Discuss the need of parallelism and scalability in high performance computing.

CO4: Understand the concept of efficient open MP programming and its case study.

CO5: Apply the MPI implementation for communication shared memory environment.

CO6: Analyze the implementation of hybrid parallelism and its benefits and drawbacks.

Sr. No.	Topics	Hours
	Unit – I	
1	**Modern Processors:** Stored-program computer architecture, General-purpose cache-based microprocessor architecture, Performance metrics and benchmarks, Transistors galore - Moore's Law, Superscalarity, SIMD, Memory hierarchies, Cache, Prefetch, Multicore processors, Multithreaded processors, Vector processors, Design principles, Maximum performance estimates.	5
	Unit – II	
2	**Parallel Computers:** Taxonomy of parallel computing paradigms, Shared-memory computers, Cache coherence, UMA, ccNUMA, Distributed-memory computers, Hierarchical (hybrid) systems, Networks, Basic	9

	performance characteristics of networks, Buses, Switched and fat-tree networks, Mesh networks, Hybrids.	
Unit – III		
3	**Basics of Parallelization:** Need of parallelization, Parallelism, Data parallelism, Functional parallelism, Parallel scalability, Factors that limit parallel execution, Scalability metrics, Serial performance versus strong scalability, Load imbalance.	8
	Shared-Memory Parallel Programming with OpenMP: Short introduction to OpenMP, Parallel execution, Data scoping, OpenMP work-sharing for loops, Synchronization, Reductions, Loop scheduling, Tasking, Miscellaneous, Case study - OpenMP-parallel Jacobi algorithm, Advanced OpenMP - Wave front parallelization.	
Unit – IV		
4	**Efficient OpenMP Programming:** Profiling OpenMP programs, Performance pitfalls, Ameliorating the impact of OpenMP work-sharing constructs, Serialization, False sharing.	5
Unit – V		
5	**Distributed-Memory Parallel Programming with MPI:** Message passing, A short introduction to MPI, Messages and point-to-point communication, Collective communication, Non-blocking point-to-point communication, Virtual topologies, Example - MPI parallelization of a Jacobi solver, MPI implementation, Performance properties.	9
Unit – VI		
6	**Efficient MPI Programming:** MPI performance tools, Communication parameters, Synchronization, Serialization, Contention, Implicit serialization and synchronization, Contention, Reducing communication overhead, Optimal domain decomposition, Aggregating messages, Non-blocking vs. asynchronous communication, Collective communication, Understanding intranode point-to-point communication.	9
	Hybrid Parallelization with MPI and OpenMP: Basic MPI/OpenMP programming models, Vector mode implementation, Task mode implementation, Case study - Hybrid Jacobi solver, MPI taxonomy of thread interoperability, Hybrid decomposition and mapping, Potential benefits and drawbacks of hybrid programming.	

Sr. No.	High Performance Computing (Practical)	Hours
1	a. Write a program which creates child and parent processes and prints its process id.	4

	b. Modify above program to check the process states (zombie, orphan).	
2	Write a program to demonstrate Pthreads using OpenMP. Also monitor the performance of CPU cores.	4
3	Write a program to implement storage and OS virtualization to increase computing of available resource.	4
4	Write a program for implementing matrix multiplication using OpenMP.	4
5	Create a cluster of raspberry pi and demonstrate booting of pi OS.	4
6	Perform a practical to install and configure CUDA programming platform.	4
7	Perform a practical to demonstrate CUDA programming.	6

Text book:

1. Georg Hager, Gerhard Wellein - "Introduction to High Performance Computing for Scientists and Engineers", CRC Press, 2011.

Reference books:

1. Charles Severance, Kevin Dowd - "High Performance Computing", O'Reilly, October, 2012.
2. Thomas Sterling, Matthew Anderson, Maciej Brodowicz - "High Performance Computing: Modern Systems and Practices", Morgan Kaufmann Publishers, 2018.
3. Rajkumar Buyya - "High Performance Cluster Computing Architectures and Systems", Pearson Publication, 2007.

Course objectives and Course outcomes mapping:

- To illustrate different super scalar architecture of processors based on cache and programming for vector architecture: CO1
- To explain the taxonomy of parallel computing and characteristics of network for high performance computing: CO1, CO2, CO3
- To demonstrate parallel programing and distributed memory concept for shared memory using open MP and MPI: CO1, CO2, CO3, CO4, CO5, CO6

Course units and Course outcomes mapping:

Unit No.	**Unit Name**	**Course Outcomes**					
		CO1	**CO2**	**CO3**	**CO4**	**CO5**	**CO6**
1	Modern Processors	✓					
2	Parallel Computers		✓				
3	Basic of Parallelization and Shared-Memory Parallel Programming with OpenMP			✓			
4	Efficient OpenMP Programming				✓		

5	Distributed-Memory Parallel Programming with MPI					✓	
6	Efficient MPI Programming and Hybrid Parallelization with MPI and OpenMP						✓

Programme outcomes:

PO 1: Engineering knowledge: An ability to apply knowledge of mathematics, science, and engineering.

PO 2: Problem analysis: An ability to identify, formulates, and solves engineering problems.

PO 3: Design/development of solutions: An ability to design a system, component, or process to meet desired needs within realistic constraints.

PO 4: Conduct investigations of complex problems: An ability to use the techniques, skills, and modern engineering tools necessary for solving engineering problems.

PO 5: Modern tool usage: The broad education and understanding of new engineering techniques necessary to solve engineering problems.

PO 6: The engineer and society: Achieve professional success with an understanding and appreciation of ethical behavior, social responsibility, and diversity, both as individuals and in team environments.

PO 7: Environment and sustainability: Articulate a comprehensive world view that integrates diverse approaches to sustainability.

PO 8: Ethics: Identify and demonstrate knowledge of ethical values in non-classroom activities, such as service learning, internships, and field work.

PO 9: Individual and team work: An ability to function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give/receive clear instructions.

PO 11: Project management and finance: An ability to demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO 12: Life-long learning: A recognition of the need for, and an ability to engage in life-long learning.

Programme outcomes and Course outcomes mapping:

Programme Outcomes	Course Outcomes					
	CO1	CO2	CO3	CO4	CO5	CO6
PO1	✓	✓	✓	✓	✓	✓
PO2	✓	✓	✓	✓	✓	✓
PO3	✓	✓	✓	✓	✓	✓

PO4	✓	✓	✓	✓	✓	✓
PO5	✓	✓	✓	✓	✓	✓
PO6						
PO7						
PO8						
PO9						
PO10	✓	✓	✓	✓	✓	✓
PO11						
PO12						