Universidad Nacional Mayor de San Marcos
School of Computer Science
Syllabus of Course
Academic Period 2018-II

1. **Code and Name:** CS3P03. Internet of Things (Mandatory)
2. **Credits:** 3
3. **Hours of theory and Lab:** 1 HT; 4 HL; (15 weeks)
4. **Professor(s)**

   Meetings after coordination with the professor

5. **Bibliography**

[KH13] David B. Kirk and Wen-mei W. Hwu. *Programming Massively Parallel Processors: A Hands-on Approach*. 2nd. Morgan Kaufmann, 2013. ISBN: 978-0-12-415992-1.

[Mat14] Norm Matloff. *Programming on Parallel Machines*. University of California, Davis, 2014. URL: `http://heather.cs.ucdavis.edu/~matloff/158/PLN/ParProcBook.pdf`.

[Pac11] Peter S. Pacheco. *An Introduction to Parallel Programming*. 1st. Morgan Kaufmann, 2011. ISBN: 978-0-12-374260-5.

[Qui03] Michael J. Quinn. *Parallel Programming in C with MPI and OpenMP*. 1st. McGraw-Hill Education Group, 2003. ISBN: 0071232656.

[SK10] Jason Sanders and Edward Kandrot. *CUDA by Example: An Introduction to General-Purpose GPU Programming*. 1st. Addison-Wesley Professional, 2010. ISBN: 0131387685, 9780131387683.

6. **Information about the course**

   (a) **Brief description about the course** The last decade has an explosive growth in multiprocessor computing, including multi-core processors and distributed data centers. As a result, parallel and distributed computing has evolved from a broadly elective subject to be one of the major components in mesh studies in undergraduate computer science. Both parallel computing and distribution involve the simultaneous execution of multiple processes on different devices that change position.

   (b) **Prerrequisites:** CS3P01. Parallel and Distributed Computing . (7^{th} Sem)

   (c) **Type of Course:** Mandatory

   (d) **Modality:** Face to face

7. **Specific goals of the Course**

   - That the student is able to create parallel applications of medium complexity by efficiently taking advantage of different mobile devices.

8. **Contribution to Outcomes**

a) An ability to apply knowledge of mathematics, science. (**Usage**)

b) An ability to design and conduct experiments, as well as to analyze and interpret data. (**Usage**)

i) An ability to use the techniques, skills, and modern computing tools necessary for computing practice. (**Usage**)

j) Apply the mathematical basis, principles of algorithms and the theory of Computer Science in the modeling and design of computational systems in such a way as to demonstrate understanding of the equilibrium points involved in the chosen option. (**Usage**)

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9. Competences (IEEE)

C2. Ability to have a critical and creative perspective in identifying and solving problems using computational thinking. ⇒ **Outcome a**

C4. An understanding of computer hardware from a software perspective, for example, use of the processor, memory, disk drives, display, etc.⇒ **Outcome b**

C16. Ability to identify advanced computing topics and understanding the frontiers of the discipline.⇒ **Outcome i**

CS2. Identify and analyze criteria and specifications appropriate to specific problems, and plan strategies for their solution.⇒ **Outcome i**

CS3. Analyze the extent to which a computer-based system meets the criteria defined for its current use and future development.⇒ **Outcome j**

CS6. Evaluate systems in terms of general quality attributes and possible tradeoffs presented within the given problem.⇒ **Outcome j**

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10. List of topics

1. Parallelism Fundamentals
2. Parallel Architecture
3. Parallel Decomposition
4. Communication and Coordination
5. Parallel Algorithms, Analysis, and Programming
6. Parallel Performance

11. Methodology and Evaluation

Methodology:

Theory Sessions:
The theory sessions are held in master classes with activities including active learning and roleplay to allow students to internalize the concepts.

Lab Sessions:
In order to verify their competences, several activities including active learning and roleplay will be developed during lab sessions.

Oral Presentations:
Individual and team participation is encouraged to present their ideas, motivating them with additional points in the different stages of the course evaluation.

Reading:
Throughout the course different readings are provided, which are evaluated. The average of the notes in the readings is considered as the mark of a qualified practice. The use of the UTEC Online virtual campus allows each student to access the course information, and interact outside the classroom with the teacher and with the other students.
Evaluation System:

12. Content

<table>
<tr><td colspan="2">Unit 1: Parallelism Fundamentals (18)</td></tr>
<tr><td colspan="2">Competences Expected: C2</td></tr>
<tr><td>Learning Outcomes</td><td>Topics</td></tr>
<tr><td>

Distinguish using computational resources for a faster answer from managing efficient access to a shared resource [Familiarity]
Distinguish multiple sufficient programming constructs for synchronization that may be inter-implementable but have complementary advantages [Familiarity]
Distinguish data races from higher level races [Familiarity]

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Multiple simultaneous computations
Goals of parallelism (e.g., throughput) versus concurrency (e.g., controlling access to shared resources)
Parallelism, communication, and coordination

Parallelism, communication, and coordination
Need for synchronization

Programming errors not found in sequential programming

Data races (simultaneous read/write or write/write of shared state)
Higher-level races (interleavings violating program intention, undesired non-determinism)
Lack of liveness/progress (deadlock, starvation)

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<tr><td colspan="2">Readings : [Pac11], [Mat14], [Qui03]</td></tr>
</table>

Unit 2: Parallel Architecture (12)	
Competences Expected: C4	
Learning Outcomes	**Topics**

• Explain the differences between shared and distributed memory [Assessment]
• Describe the SMP architecture and note its key features [Assessment]
• Characterize the kinds of tasks that are a natural match for SIMD machines [Usage]
• Describe the advantages and limitations of GPUs vs CPUs [Usage]
• Explain the features of each classification in Flynn's taxonomy [Usage]
• Describe the challenges in maintaining cache coherence [Familiarity]
• Describe the key performance challenges in different memory and distributed system topologies [Familiarity]
	• Multicore processors
	• Shared vs distributed memory
	• Symmetric multiprocessing (SMP)
	• SIMD, vector processing
	• GPU, co-processing
	• Flynn's taxonomy
	• Instruction level support for parallel programming
	  – Atomic instructions such as Compare and Set
	• Memory issues
	  – Multiprocessor caches and cache coherence
	  – Non-uniform memory access (NUMA)
	• Topologies
	  – Interconnects
	  – Clusters
	  – Resource sharing (e.g., buses and interconnects)

Readings : [Pac11], [KH13], [SK10]	

Unit 3: Parallel Decomposition (18)	
Competences Expected: C16	
Learning Outcomes	**Topics**

• Explain why synchronization is necessary in a specific parallel program [Usage]
• Identify opportunities to partition a serial program into independent parallel modules [Familiarity]
• Write a correct and scalable parallel algorithm [Usage]
• Parallelize an algorithm by applying task-based decomposition [Usage]
• Parallelize an algorithm by applying data-parallel decomposition [Usage]
• Write a program using actors and/or reactive processes [Usage]
	• Need for communication and coordination/synchronization
	• Independence and partitioning
	• Basic knowledge of parallel decomposition concept
	• Task-based decomposition
	  – Implementation strategies such as threads
	• Data-parallel decomposition
	  – Strategies such as SIMD and MapReduce
	• Actors and reactive processes (e.g., request handlers)

Readings : [Pac11], [Mat14], [Qui03]	

<table>
<tr><td colspan="2">Unit 4: Communication and Coordination (18)</td></tr>
<tr><td colspan="2">Competences Expected: C16</td></tr>
<tr><td>Learning Outcomes</td><td>Topics</td></tr>
<tr><td>

Use mutual exclusion to avoid a given race condition [Usage]
Give an example of an ordering of accesses among concurrent activities (eg, program with a data race) that is not sequentially consistent [Familiarity]
Give an example of a scenario in which blocking message sends can deadlock [Usage]
Explain when and why multicast or event-based messaging can be preferable to alternatives [Familiarity]
Write a program that correctly terminates when all of a set of concurrent tasks have completed [Usage]
Give an example of a scenario in which an attempted optimistic update may never complete [Familiarity]
Use semaphores or condition variables to block threads until a necessary precondition holds [Usage]

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Shared Memory
Consistency, and its role in programming language guarantees for data-race-free programs
Message passing

Point-to-point versus multicast (or event-based) messages
Blocking versus non-blocking styles for sending and receiving messages
Message buffering (cross-reference PF/Fundamental Data Structures/Queues)

Atomicity

Specifying and testing atomicity and safety requirements
Granularity of atomic accesses and updates, and the use of constructs such as critical sections or transactions to describe them
Mutual Exclusion using locks, semaphores, monitors, or related constructs

Potential for liveness failures and deadlock (causes, conditions, prevention)

Composition

Composing larger granularity atomic actions using synchronization
Transactions, including optimistic and conservative approaches

Consensus

(Cyclic) barriers, counters, or related constructs

Conditional actions

Conditional waiting (e.g., using condition variables)

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Unit 5: Parallel Algorithms, Analysis, and Programming (18)	
Competences Expected: CS2	
Learning Outcomes	**Topics**
• Define "critical path", "work", and "span" [Familiarity] • Compute the work and span, and determine the critical path with respect to a parallel execution diagram [Usage] • Define "speed-up" and explain the notion of an algorithm's scalability in this regard [Familiarity] • Identify independent tasks in a program that may be parallelized [Usage] • Characterize features of a workload that allow or prevent it from being naturally parallelized [Familiarity] • Implement a parallel divide-and-conquer (and/or graph algorithm) and empirically measure its performance relative to its sequential analog [Usage] • Decompose a problem (eg, counting the number of occurrences of some word in a document) via map and reduce operations [Usage] • Provide an example of a problem that fits the producer-consumer paradigm [Usage] • Give examples of problems where pipelining would be an effective means of parallelization [Usage] • Implement a parallel matrix algorithm [Usage] • Identify issues that arise in producer-consumer algorithms and mechanisms that may be used for addressing them [Usage]	• Critical paths, work and span, and the relation to Amdahl's law • Speed-up and scalability • Naturally (embarrassingly) parallel algorithms • Parallel algorithmic patterns (divide-and-conquer, map and reduce, master-workers, others) – Specific algorithms (e.g., parallel MergeSort) • Parallel graph algorithms (e.g., parallel shortest path, parallel spanning tree) (cross-reference AL/Algorithmic Strategies/Divide-and-conquer) • Parallel matrix computations • Producer-consumer and pipelined algorithms • Examples of non-scalable parallel algorithms
Readings : [Mat14], [Qui03]	

<table>
<tr><td colspan="2">Unit 6: Parallel Performance (18)</td></tr>
<tr><td colspan="2">Competences Expected: CS3</td></tr>
<tr><td>Learning Outcomes</td><td>Topics</td></tr>
<tr><td>

Detect and correct a load imbalance [Usage]
Calculate the implications of Amdahl's law for a particular parallel algorithm (cross-reference SF/Evaluation for Amdahl's Law) [Usage]
Describe how data distribution/layout can affect an algorithm's communication costs [Familiarity]
Detect and correct an instance of false sharing [Usage]
Explain the impact of scheduling on parallel performance [Familiarity]
Explain performance impacts of data locality [Familiarity]
Explain the impact and trade-off related to power usage on parallel performance [Familiarity]

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Load balancing
Performance measurement
Scheduling and contention (cross-reference OS/Scheduling and Dispatch)
Evaluating communication overhead
Data management

Non-uniform communication costs due to proximity (cross-reference SF/Proximity)
Cache effects (e.g., false sharing)
Maintaining spatial locality

Power usage and management

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