Lahore University of Management Sciences

CS 315 – Theory of Computation

Spring -2024

COURSE DESCRIPTION
This is an introductory course on the theory of computation. The course provides a comprehensive introduction to four broad areas in theoretical computer sciences, namely theory of automata, computability theory, complexity theory, and advanced computational models. 1. **Automata Theory:** In this section, we learn two broad concepts. a. Formal abstraction of the notion of computational problems via formal languages Regular, Context-free, Context-sensitive, Decidable, and Undecidable problems or languages) b. Formal abstraction of the notion of computation and computational devices (automata) (Non)-deterministic finite state machine, push-down automata, Stream Computer, and Turing machines 2. **Computability Theory:** In this section, we will study the notion of computable problems (decidable languages) and the limits of computations. We will also discuss the notion of reduction to demonstrate when the problem is incomputable. **3.** **Complexity Theory:** In this section, we discuss the classes of computable problems based on their computational time and space complexity. We will define complexity classes P, NP, co-NP, EXP, and PSPACE. We will introduce the concepts of intractability (NP-Hard and NP-complete problems) 4. **Advanced Topics:** The final section will introduce at least two of the following advanced topics in computation a. Approximate Computation b. Randomized Computation c. Quantum Computation d. Public-key cryptosystems

Course Distribution	
Core	Yes
Elective	No
Open for Student Category	Sophomore
Close for Student Category	None

COURSE PREREQUISITE(S)	
•	CS 210 Discrete Mathematics
•	CS 310 Algorithms

Instructor	Imdad Ullah Khan
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Course Basics				
Credit Hours	3			
Lecture(s)	Nbr of Lec(s) Per Week	2	Duration	75 minutes
Recitation/Lab (per week)	Nbr of Lec(s) Per Week		Duration	
Tutorial (per week)	Nbr of Lec(s) Per Week		Duration	

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Course Teaching Methodology (Please mention following details in plain text)
1. In class problem set will be solved in most of lectures a. A problem sheet will be distributed in class, students will have to write answers to all questions there b. These problem sets will be embedded into lecture, their answers will be in the lectures; this is essentially the analog of class interactions. c. Answers on them will not be strictly evaluated (except for explicitly identified quizzes) 2. Problem-sets (questions about each topic) a. These will be graded and will contain problems about applications of lecture material. b. These problems will be very similar to those on midterm and final exams 3. Midterm and Final Exam will be timed and detailed policy about how/when they will be conducted will be announced in due time

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)	
PEO-01	Demonstrate excellence in profession through in-depth knowledge and skills in the field of Computing.
PEO-02	Engage in continuous professional development and exhibit quest for learning.
PEO-03	Show professional integrity and commitment to societal responsibilities.

COURSE OBJECTIVES	
1.	To equip students with knowledge of structural way to describe computation and computational problems via formal models.
2.	To introduce students to the limits of computation and enable them to identify incomputable problems
3.	To provide students an introduction to advanced computational models

COURSE LEARNING OUTCOMES (CLOs) [Comment: CLOs as given in the original course outline]	
CLO1	Be able to rigorously and formally describe computational problems
CLO2	Understand the definitions of various computational models and learn tools to analyze their powers and limitations
CLO3	Gain experience in writing creative mathematical solutions to problems and develop an ability to write clear and concise arguments
CLO4	Mathematically formalize the computability and complexity of computational problems

[Comment: Please do not fill this table. The department will complete it, based on CLOs and lookup tables given in the Appendix-A]

CLO	CLO Statement	Bloom's Cognitive Level	PLOs/Graduate Attributes (Seoul Accord)
CLO1			
CLO2			
CLO3			

Grading Breakup and Policy (Tentative)

[Comment: Please fill in the ACM Recommended Disposition Column, based on the lookup table in Appendix-B]

Assessment	**Weight (%)**	**Related CLOs**	**ACM Recommended Disposition**
In-Class problem Sets + Quizzes	20%	CLO1 – CLO4	
Problem Sets	20%	CLO1 – CLO4	
Midterm Exam	25%	CLO1 – CLO3	
Final Exam (covering the whole course)	35%	CLO1 -CLO4	

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Examination Detail	
Midterm Exams	Yes/No: **Yes**
Final Exam	Yes/No: **Yes**

COURSE OVERVIEW
[Comment: Please fill in the related CLOs column and ACM Computing Knowledge Landscape column (see Appendix-C)]

Week/ Lecture/ Module	Topics	Recommended Readings	Objectives/ Application	**Related CLOs**	**ACM Computing Knowledge Landscape**
1-3	(Non) Deterministic finite state machine, Regular Languages, Non-Regular Languages, Pumping Lemma	Chapter 1		CLO1 – CLO3	
4-5	Context-Free Languages, Pushdown Automata, Non-Context-Free Languages, Pumping Lemma	Chapter 2		CLO1 – CLO3	
6-9	Turing Machines and Variants, Church-Turing thesis, Decidability and Decidable languages, Reductions and Rice's theorem	Chapter 3, 4, 5		CLO1 – CLO4	
10-13	Time and Space Complexity of Problems, Classes of Problems, Intractable Problems, Space Complexity, PSPACE	Chapter 7,8,9		CLO1 – CLO4	
14	Advanced Topics	Chapter 10		CLO1 – CLO4	

Textbook(s)/Supplementary Readings

1. **Textbook: Michael Sipser, Introduction to the Theory of Computation, 3rd Ed. (or any other edition)**

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[Comment: Please fill column-V, with appropriate information.]

Assignment Details:

Sr#	Assignment Title	Assignment Description	Topics Covered	Description of skills, tools, platform, etc. (e.g., Programming in C/C++, MS Visual Studio, Windows/Linux)	Proposed Duration

Appendix A
Bloom's Taxonomy

BLOOM's TAXONOMY*	
1 - Remember 2 - Understand 3 - Apply 4 - Analyze 5 - Evaluate 6 - Create	• Recall facts and basic concepts • Explain ideas or concepts • Use information in new situations • Draw connection among ideas • Justify a stand or decision • Produce new or original work

https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/

Appendix B
ACM Dispositions Table - I

CM Dispositions			
Element	**Elaboration**	**Element**	**Elaboration**
D1 Adaptable:	Flexible; agile, adjust in response to change	D7 Professional:	Professionalism, discretion, ethical, astute
D2 Collaborative:	Team player; willing to work with others	D8 Purpose-driven:	Goal driven, achieve goals, business acumen
D3 Inventive:	Exploratory; Look beyond simple solutions	D9 Responsible:	Use judgment, discretion, act appropriately
D4 Meticulous:	Attentive to detail; thoroughness, accurate	D10 Responsive:	Respectful; react quickly and positively
D5 Passionate:	Conviction, strong commitment, compelling	D11 Self-directed:	Self-motivated, determination, independent
D6 Proactive:	With initiative, self-starter, independent		

ACM Dispositions Table - II

Class Assessments and Proposed Dispositions												
Assessment Type	**D1 Adaptable**	**D2 Collaborative**	**D3 Inventive**	**D4 Meticulous**	**D5 Passionate**	**D6 Proactive**	**D7 Professional**	**D8 Purpose-driven**	**D9 Responsible**	**D10 Responsive**	**D11 Self-directed**	**Included**
Quiz				✓			✓		✓			Yes
Assignment-Individual			✓	✓			✓		✓			Yes
Assignment-Group		✓	✓	✓			✓		✓	✓		Yes
Project- Individual	✓		✓	✓	✓	✓	✓	✓	✓		✓	Yes
Project- Group	✓	✓	✓	✓	✓	✓	✓	✓	✓			Yes
Presentation-Individual				✓			✓		✓	✓	✓	Yes
Presentation- Group		✓		✓			✓		✓	✓		Yes
Labs- Individual			✓	✓			✓		✓			Yes
Labs- Group		✓	✓	✓			✓		✓	✓		Yes
Exams				✓			✓		✓			Yes
Included	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	

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Appendix C
ACM Computing Knowledge Landscape Table

ACM Computing Knowledge Landscape (CK)			
1. Users and Organizations	CK1.1: Social Issues and Professional Practice CK1.2: Security Policy and Management CK1.3: IS Management and Leadership CK1.4: Enterprise Architecture CK1.5: Project Management CK1.6: User Experience Design	**4. Software Development**	CK4.1: Software Quality, Verification and Validation CK4.2: Software Process CK4.3: Software Modeling and Analysis CK4.4: Software Design CK4.5: Platform-Based Development
2. Systems Modeling	CK2.1: Security Issues and Principles CK2.2: Systems Analysis & Design CK2.3: Requirements Analysis and Specification CK2.4: Data and Information Management	**5. Software Fundamentals**	CK5.1: Graphics and Visualization CK5.2: Operating Systems CK5.3: Data Structures, Algorithms and Complexity CK5.4: Programming Languages CK5.5: Programming Fundamentals CK5.6: Computing Systems Fundamentals
3. Systems Architecture and Infrastructure	CK3.1: Virtual Systems and Services CK3.2: Intelligent Systems (AI) CK3.3: Internet of Things CK3.4: Parallel and Distributed Computing CK3.5: Computer Networks	**6. Hardware**	CK6.1: Architecture and Organization CK6.2: Digital Design CK6.3: Circuits and Electronics CK6.4: Signal Processing