Course Outline CSCI4300

2023-2024

COURSE OUTLINE

1. **Course Title:** Computation and Complexity

2. **Course Code:** CSCI 4300

3. **Credit Value:** 3

4. **Course Synopsis:**

The course considers fundamental computation models such as finite automata, regular grammars, regular expressions, context-free grammars, pushdown automata, and Turing machines. It discusses limitations of computation, decidable and undecidable problems, complexity classes. Moreover, the course covers linear programming fundamentals, backtracking and branch-and-bound techniques as well as approximation and randomized algorithms.

5. **SAF Elements:**

The students will *learn to know* the core of computer science, consisting of how the computational power of "computers" is measured and how the problems are classified based on their complexity (*Iqra'*). With the knowledge, they will learn to construct the automata and grammars, as well as advanced algorithms that can be used to compensate the limitation of computation (*learning to do*). Since this is the core and fundamental base that builds the idea of Computer Science, it could be considered as a responsibility for computer scientists to understand the fundamental principles in this course (*'Amānah*). The knowledge, when is applied to real-life situation, may assist towards suitable decision making and problem solving, which can *protect* not only *intellect*, but also *life* and *wealth* (*Maqāṣid Ash-Sharī'ah*). The topics learnt together with SAF elements would induce the appreciation of the beauty of Allah's design, for example, where Allah knows every possible transition in every path, thus encouraging the students to learn from Allah's magnificence.

6. **Course Classification within the Curriculum:** Core

7. **Pre-r**

9. Course Learning Outcomes:

No.	Learning Outcomes (CLO)	Programme Outcomes (PLO)
1	Construct automata and grammars for different problem sets	1
2	Analyse the computational limitations of computation models	2
3	Develop applied algorithms using advanced algorithm design techniques	6

10. Constructive Alignment:

CLO	Teaching-Learning Methods	Assessment Methods
LO1	Lecture	Final assessment
LO1, LO2	Problem-based learning	Assignments, quizzes
LO3	Lecture, Problem-based learning	Project

11. Assessment Distribution:

Assessment Methods	Percentage
Assignments	20
Quizzes	20
Project	20
Final assessment	40
Must-pass Assessment Method(s)	Percentage
Total	100

12. Course Contents

Week	Course Contents	Guided Learning SLT	Independent Learning SLT
1	**Introduction** 1. Languages 2. Automata 3. Grammars	3	5
2	**Finite Automata** ▯ Deterministic Finite Automata (DFA) ▯ Nondeterministic Finite Automata (NFA) ▯ Equivalence of DFA and NFA	3	5
3	**Regular Languages and Grammars** ▯ Regular Expressions ▯ Regular Grammars ▯ Equivalence between Regular Languages and Regular Grammars	3	5
4	**Context-Free Languages** ▯ Context-Free Grammars ▯ Methods for Transforming Grammars ▯ Chomsky Normal Form ▯ A Membership Algorithm for Context-Free Grammars	3	5
5	**Pushdown Automata** ▯ Nondeterministic Pushdown Automata ▯ Deterministic Pushdown Automata	3	5
6	**Turing Machines** ▯ The Standard Turing Machine ▯ Turing Machines as Language Accepters and Transducers ▯ Turing's Thesis.	3	5

7	**Limits of Algorithmic Computation** ☐ Unsolvable Problems ☐ Halting Problem, Reduction ☐ Undecidable Problems	3	5

8	**Computational Complexity** ☐ Efficiency of Computation ☐ Turing Machines and Complexity ☐ Complexity Classes	3	5
9	**NP-Completeness** ☐ P and NP ☐ NP-Completeness ☐ NP-Complete Problems	3	5
10	**Backtracking** ☐ Backtracking Technique ☐ The N-Queen's Problem ☐ Graph Colouring Problem ☐ The Hamiltonian Cycle Problem	3	5
11	**Branch-and-Bound** ☐ Branch-and-Bound Technique ☐ 0-1 Knapsack Problem ☐ The Traveling Salesman Problem	3	5
12	**Approximation Algorithms** ☐ The Metric Traveling Salesman Problem		

9	**NP-Completeness** ☐ P and NP ☐ NP-Completeness ☐ NP-Complete Problems	3	5
10	**Backtracking** ☐ Backtracking Technique ☐ The N-Queen's Problem ☐ Graph Colouring Problem ☐ The Hamiltonian Cycle Problem	3	5
11	**Branch-and-Bound** ☐ Branch-and-Bound Technique ☐ 0-1 Knapsack Problem ☐ The Traveling Salesman Problem	3	5
12	**Approximation Algorithms** ☐ The Metric Traveling Salesman Problem ☐ Approximation of Covering Problems ☐ Polynomial-Time Approximation Schemes	3	5
13	**Randomized Algorithms** ☐ Stable Marriages and Coupon Collecting ☐ Minimum Cuts ☐ Finding Prime Numbers ☐ Skip Lists	3	5
14	**Group Project Presentations** ☐ Written Report ☐ Oral Presentation	3	5
Final Assessment (if applicable)			10
Total		42	80

13. References:

1. **Required**

Linz, P. (2022) *An Introduction to Formal Languages and Automata*. 7th ed. USA: Jones & Bartlett Publishers

2. **Recommended**

Sipser, M. (2021) *Introduction to the Theory of Computation*. 5th ed. USA: Cengage Learning

Goodrich, M.T., Tamassia, R. (2015) *Algorithm Design and Applications*. USA: AddisonWesley.

Hopcroft, J., Motwani, R. & Ullman, J. (2007) *Introduction to Automata Theory, Languages and Computation*. 3rd ed. USA: Addison-Wesley Publishing Co.

Sudkamp, T.A. (2006) *Languages and Machines: An Introduction to the Theory of Computer Science*. 3rd ed. USA: Addison-Wesley Publishing Co.

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CONTENTS AND MAIN ACTIVITIES (Topics, Teaching-Learning Activities)	SLT DISTRIBUTION			⁵REMARKS
	Synchronous	Asynchronous	Independent Learning	
1 **Introduction** • Languages • Automata • Grammars	3		5	
2 **Finite Automata** • Deterministic Finite Automata (DFA) • Nondeterministic Finite Automata (NFA) • Equivalence of DFA and NFA	3		5	Assignment
3 **Regular Languages and Grammars** • Regular Expressions • Regular Grammars • Equivalence between Regular Languages and Regular Grammars	3		5	Quiz
4 **Context-Free Languages** • Context-Free Grammars • Methods for Transforming Grammars • Chomsky Normal Form • A Membership Algorithm for Context-Free Grammars	3		5	Assignment
5 **Pushdown Automata** • Nondeterministic Pushdown Automata • Deterministic Pushdown Automata	3		5	

6	**Turing Machines** ▪ The Standard Turing Machine ▪ Turing Machines as Language Accepters and Transducers ▪ Turing's Thesis.	3		5	
7	**Limits of Algorithmic Computation** ▪ Unsolvable Problems ▪ Halting Problem, Reduction ▪ Undecidable Problems	3		5	Assessment
8	**Computational Complexity** ▪ Efficiency of Computation ▪ Turing Machines and Complexity ▪ Complexity Classes	3		5	
9	**NP-Completeness** ▪ P and NP ▪ NP-Completeness ▪ NP-Complete Problems	3		5	Quiz
10	**Backtracking** ▪ Backtracking Technique ▪ The N-Queen's Problem ▪ Graph Colouring Problem ▪ The Hamiltonian Cycle Problem	3		5	Assignment
11	**Branch-and-Bound** ▪ Branch-and-Bound Technique ▪ 0-1 Knapsack Problem ▪ The Traveling Salesman Problem	3		5	
12	**Approximation**				Assignment

12	**Approximation Algorithms** ▪ The Metric Traveling Salesman Problem ▪ Approximation of Covering Problems	3		5	Assignment
	▪ Polynomial-Time Approximation Schemes				
13-14	**Randomized Algorithms** ▪ Stable Marriages and Coupon Collecting ▪ Minimum Cuts ▪ Finding Prime Numbers ▪ Skip Lists	3		5	Assessment
	Final Assessments			10	
	TOTAL SLT	42		80	

8	**Computational Complexity** ☐ Efficiency of Computation ☐ Turing Machines and Complexity ☐ Complexity Classes	3	5
9	**NP-Completeness** ☐ P and NP ☐ NP-Completeness ☐ NP-Complete Problems	3	5
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14	**Group Project Presentations** ☐ Written Report ☐ Oral Presentation	3	5

12	**Approximation Algorithms** ▪ The Metric Traveling Salesman Problem ▪ Approximation of Covering Problems	3		5	Assignment

	▪ Polynomial-Time Approximation Schemes				
13-14	**Randomized Algorithms** ▪ Stable Marriages and Coupon Collecting ▪ Minimum Cuts ▪ Finding Prime Numbers ▪ Skip Lists	3		5	Assessment
	Final Assessments			10	
	TOTAL SLT	42		80	