CS 525 - Computational Complexity

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1 General Information

(a) Instructor: K. Subramani.

(b) Meeting Times: Mon-Wed: 9:00 pm - 10:15 pm.
Location: 401 ESB-E.

(c) Contact Information: 749 ESB, k.subramani@mail.wvu.edu

(d) Office Hours: By appointment.

(e) Textbook - [MM11] is the course textbook. [Pap94] is strongly recommended for supplementary reading.

(f) URL - http://www.csee.wvu.edu/~ksmani/courses/sp15/complexity/complexity.html.

(g) Assessment:

(a) Homework Assignments - You will be handed four homework assignments. These assignments constitute 80% of your grade. Table (1) details the homework schedule.

Assignment Date	Submission Date
02/02	02/09
03/02	03/09
04/02	04/09
05/02	05/09

Table 1: Homework Schedule

(b) Presentations - You will be required to present allotted material. The presentations will be graded on the basis of clarity, comprehensiveness and effectiveness. The presentations will be worth 20% of your grade.

A maximum of 5 bonus points will be awarded for class performance.

(h) Grade Boundaries:

Grade	Boundary
A	80 and up
B	$65 - 79$
C	$50 - 64$
D	$45 - 49$
F	$0 - 44$

Table 2: Grade Boundaries

(i) Grading policy - If you have any questions about the grading, you must contact the instructor within two days of your paper being returned.

(j) Makeup Policy - If for some reason, you are unable to attend a test or an exam, please meet me at the earliest and I will set an alternate date.

(k) **Course Objectives** - The objectives of this course are as follows:

(a) Introducing machine-independent notions of resource (time and space) analysis.

(b) Rigorously establishing time and space bounds for selected problems.

(c) Developing the notions of undecidability and completeness.

(d) Developing the notion of complexity classes.

(e) Categorizing problems into appropriate complexity classes.

(l) **Learning Outcomes** - Upon successful completion of this course, students will be able to:

(i) Recognize undecidability in a language.

(ii) Distinguish between complexity classes.

(iii) Appreciate the logical characterization of complexity classes.

(iv) Categorize problems into appropriate complexity classes.

(v) Identify the possibility of intractability for a given problem.

2 Syllabus

2.1 Mathematical Preliminaries

Asymptotic Notation, Approximations and Inequalities, Probability, Concentration inequalities, Asymptotic Integrals, Abstract algebra. These topics will be covered from Appendix A of [MM11].

2.2 Basics of Computational Complexity

The Konigsberg Bridge problem, The Hamilton Path problem, verification in chess, problems and solutions, Time and Space, Intrinsic complexity, Tractability and Intractiability. These topics will be covered from Chapters 1 and 2 of [MM11].

2.3 Algorithm Design

Recursion, Divide and Conquer, Dynamic Programming, Greedy, Iterative approach, linear programming and duality, Transformations and Reductions. These topics will be covered from Chapter 3 of [MM11].

2.4 The class NP

Needles and Haystacks, A tour of **NP**, Search, Existence and Nondeterminism, Knots and Primes. These topics will be covered from Chapter 4 of [MM11].

2.5 NP-completeness

Notion of Completeness, Circuits and Formulas, Designing Reductions, Completeness as a surprise, The boundary between easy and hard, Hamilton Path. These topics will be covered from Chapter 5 of [MM11].

2.6 P vs. NP

Consequences of **P**=**NP**, easiness of upper bounds, hardness of lower bounds, Diagonalization and the Time Hierarchy, Possible Worlds, Natural Proofs, Problems in the Gap, Nonconstructive Proofs, The Road Ahead. These topics will be covered from Chapter 6 of [MM11].

2.7 The Grand Unified Theory of Computation

Babbage's vision and Hilbert's dream, Universality and Undecidability, Building blocks: Recursive Functions, Form is function: the λ-calculus, Turing's applied philosphy, Computation everyhwhere. These topics will be covered from Chapter 7 of [MM11].

2.8 Memory Paths and Games

The notion of State Space, Reachability and Nondeterministic Space, **L** and **NL**-Completeness, Middle-first search and Nondeterministic Space, closure of Nondeterministic space under complementation, **PSPACE**, Games and Quantified SAT, Secular games, Symmetric space. These topics will be covered from Chapter 8 of [MM11].

I would like to reiterate that this is a sketch of the topics that we will be covering. For various reasons, I may choose to drop a mentioned topic or cover a new topic. In such cases, advance notice will be given.

2.9 Topics for Student Presentations

1. Optimization and Approximation.
2. Randomized Algorithms.
3. Interaction and Pseudorandomness.
4. Random Walks and Rapid Mixing.
5. Counting and Sampling.
6. Phase Transitions.

3 Academic Integrity Statement

The integrity of the classes offered by any academic institution solidifies the foundation of its mission and cannot be sacrificed to expediency, ignorance, or blatant fraud. Therefore, I will enforce rigorous standards of academic integrity in all aspects and assignments of this course. For the detailed policy of West Virginia University regarding the definitions of acts considered to fall under academic dishonesty and possible ensuing sanctions, please see the Student Conduct Code at `http://www.arc.wvu.edu/admissions/integrity.html`. Should you have any questions about possibly improper research citations or references, or any other activity that may be interpreted as an attempt at academic dishonesty, please see me before the assignment is due to discuss the matter.

4 Inclusivity Statement

West Virginia University community is committed to creating and fostering a positive learning and working environment based on open communication, mutual respect, and inclusion. If you are a person with a disability and anticipate needing any type of accommodation in order to participate in this class, please advise me and make appropriate arrangements with the Accessibility Services (293-6700). For more information on West Virginia Universitys Diversity, Equity, and Inclusion initiatives, please see http://diversity.wvu.edu.

References

[MM11] Cristopher Moore and Stephen Mertens. *The Nature of Computation*. Oxford University Press, 1^{st} edition, 2011.

[Pap94] Christos H. Papadimitriou. *Computational Complexity*. Addison-Wesley, New York, 1994.