THE CHINESE UNIVERSITY OF HONG KONG
Print Course Catalog Details

Academic Org: Dept of Computer Sci & Engg – Subject: Computer Science

Course: CSCI3360 **Course ID:** 014759 **Eff Date:** 2025-07-01 **Crse Status: Active** **Apprv. Status:** Approved **[**New Course**]**
Introduction to Computational Complexity 計算複雜度導論

This course offers a deep dive into the field of computational complexity, a cornerstone of theoretical computer science (TCS) that studies the inherent difficulty of computational problems and classifies them according to their computational resources, such as time and space. The course is designed to elucidate the pivotal role of computational complexity in shaping the landscape of modern computing, touching on its interplay with algorithm design, cryptography, network, and the burgeoning field of quantum computing. By exploring these interdisciplinary connections, students will gain a holistic view of how complexity theory informs and is informed by other scientific and technological domains, thereby enhancing their ability to innovate and solve complex problems.

Topics include:
- Resources for computation (time, space, nondeterminism, randomness) and their associated complexity classes
- Relationships among resources (P vs NP and more), Reductions, and completeness
- Space complexity: PSPACE, L, NL
- Randomized computation: RP, BPP
- Alternation: the polynomial hierarchy, time-space trade-offs for SAT
- Basic circuit complexity (P/poly, NC, and more)
- Interactive proofs (AM, MA, IP)
- Probabilistically checkable proofs (PCP) and non-approximability
- Counting: #P, Toda's Theorem, approximate counting
- Average-case complexity and cryptography: TFNP, Kolmogorov complexity, one-way functions, Factoring, Discrete log, Diffie-Hellman
- Quantum complexity classes: BQP, QMA, PostBQP, quantum auxiliary advice, hidden subgroup problems, (local) Hamiltonian problems

本科深入探討計算複雜性領域，這是理論計算機科學 (TCS) 的基石，研究計算問題的固有難度，並根據計算資源（例如時間和空間）對它們進行分類。本科旨在闡明計算複雜性在塑造現代計算格局中的關鍵作用，涉及其與演算法設計、密碼學、網路和新興的量子計算領域的相互作用。透過探索這些跨學科聯繫，學生將全面了解複雜性理論如何影響其他科學技術領域以及如何被其他科學技術領域所影響，從而提高他們的創新和解決複雜問題的能力。

主題包括：
- 計算資源（時間、空間、不確定性、隨機性）及其相關的複雜性類別
- 資源之間的關係（P 與 NP 等）、縮減與完整性
- 空間複雜度：PSPACE、L、NL
- 隨機計算：RP、BPP
- 交替：多項式層次結構、SAT 的時空權衡
- 基本電路複雜度（P/poly、NC 等）
- 互動式校樣（AM、MA、IP）
- 機率可檢查證明（PCP）和不可近似性
- 計數：#P、戶田定理、近似計數
- 平均情況複雜性與密碼學：TFNP、Kolmogorov 複雜性、單向函數、因式分解、離散對數、Diffie-Hellman

- 量子複雜度類別：BQP、QMA、PostBQP、量子輔助建議、隱藏子群問題、（局部）哈密頓問題

Grade Descriptor:

A

EXCELLENT – exceptionally good performance and far exceeding expectation in all or most of the course learning outcomes; demonstration of superior understanding of the subject matter, the ability to analyze problems and apply extensive knowledge, and skillful use of concepts and materials to derive proper solutions.

有關等級說明的資料，請參閱英文版本。

B

GOOD – good performance in all course learning outcomes and exceeding expectation in some of them; demonstration of good understanding of the subject matter and the ability to use proper concepts and materials to solve most of the problems encountered.

有關等級說明的資料，請參閱英文版本。

C

FAIR – adequate performance and meeting expectation in all course learning outcomes; demonstration of adequate understanding of the subject matter and the ability to solve simple problems.

有關等級說明的資料，請參閱英文版本。

D

MARGINAL – performance barely meets the expectation in the essential course learning outcomes; demonstration of partial understanding of the subject matter and the ability to solve simple problems.

有關等級說明的資料，請參閱英文版本。

F

FAILURE – performance does not meet the expectation in the essential course learning outcomes; demonstration of serious deficiencies and the need to retake the course.

有關等級說明的資料，請參閱英文版本。

Equivalent Offering:
Units: 3 (Min) / 3 (Max) / 3 (Acad Progress)
Grading Basis: Graded
Repeat for Credit: N
Multiple Enroll: N
Course Attributes:

Topics:

COURSE OUTCOMES

Learning Outcomes:

At the end of the course of studies, students will be able to:
1. Analyze and evaluate computational problems using complexity theory principles, assessing the required resources and potential computational limits.
2. Apply mathematical tools and techniques, such as concentration bounds and Markov chains, to solve practical problems in computer science and related fields.
3. Interpret, discuss, and synthesize theoretical computer science texts and research, identifying key questions and collaboratively exploring advanced topics in computational complexity.
4. Engage with ongoing research in computational complexity, applying theoretical knowledge to practical challenges in cryptography, networking, and quantum computing.

Course Syllabus:

Week 1: Course overview, computational models and Turing machines, halting problem and uncomputability, deterministic complexity classes
Week 2: nondeterminism, NP, co-classes, reductions, completeness, Cook-Levin theorem
Week 3: Diagonalization, (non-deterministic) time hierarchy theorem, polynomial hierarchy
Week 4: Polynomial Hierarchy and alternations, time-space trade-offs for SAT, Oracle machine and relativizing
Week 5: Boolean circuits, non-uniform advice, Karp-Lipton theorem, AC and NC, circuit lower bounds
Week 6: Counting complexity, #P, permanent, Valiant's theorem, Toda's theorem

Week 7: Randomness, promise problems, randomized complexity classes: ZPP, RP, BPP, PP
Week 8: interactive proofs (IP, MA), Goldwasser-Sipser AM protocol, IP=PSPACE
Week 9: Probabilistically checkable proofs (PCP), Micali-Kilian CS proofs
Week 10: Hardness amplification and Error Correcting Codes
Week 11: average-case complexity and cryptography: TFNP, Kolmogorov complexity, one-way functions, Factoring, Discrete log, Diffie-Hellman
Week 12: Quantum computational complexity I: crash course on quantum computing, BQP
Week 13: Quantum computational complexity II: QMA, PostBQP, quantum auxiliary advice, hidden subgroup problems, (local) Hamiltonian problems

Assessment Type:

Examination	: 40%
Homework or assignment	: 30%
Project	: 30%

Feedback for Evaluation:

1. Course evaluation and questionnaire;
2. Results of assignments and examination;
3. Question-and-Answer sessions during class;
4. Student consultation during office hours or online

Required Readings:

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Recommended Readings:

1. Computational Complexity: A Modern Approach, by Sanjeev Arora and Boaz Barak
2. Computational Complexity: A Conceptual Perspective, by Oded Goldreich
3. Mathematics and Computation, by Avi Wigderson
4. Computational Complexity, by Christos Papadimitriou
5. The Complexity of Quantum States and Transformations: From Quantum Money to Black Holes, by Scott Aaronson

OFFERINGS

1. CSCI3360 — Acad Organization=CSD; Acad Career=UG

COMPONENTS

LEC : Size=50; Final Exam=Y; Contact=3
TUT : Size=50; Final Exam=N; Contact=1

ENROLMENT REQUIREMENTS

1. CSCI3360

Enrollment Requirement Group:
Prerequisite: ENGG2760 or ESTR2018 or ESTR2308 or IERG2470

New Enrollment Requirement(s):
Pre-requisite = ENGG2760 or ESTR2018 or ESTR2308 or IERG2470

Additional Information

VTL-Onsite face-to-face hrs	0
VTL-Online synch. hrs	0
VTL-Online asynch. hrs	0
No. of micro-modules	0
Research components (UG)	0%

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