CSCI203

# Algorithms and Data Structures

## Problem Complexity

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# Classes of Algorithms

- Logarithmic
  - (all bases have the same growth rate)
  - $\Theta(\log(\log n))$ ,
  - $\Theta(\log n)$
- Poly-logarithmic
  - $\Theta(n \log n)$
  - $\Theta(n^2 \log n)$
  - …
- Polynomial
  - (exponential is constant)
  - $\Theta(1)$ - sub-linear
  - $\Theta(n^{0.001})$- sub-linear
  - $\Theta(n^{0.5})$ - sub-linear
  - $\Theta(n)$ – linear
  - $\Theta(n^2)$
  - $\Theta(n^3)$
  - …$\Theta(n^{100})$

# Classes of Algorithms

- Expotential
  - (base makes a bug difference)
  - $\Theta(2^n)$
  - $\Theta(3^n)$
  - $\Theta(n^n)$
- Exponential-Exponential
  - $\Theta(n^{n^n})$
- Factorial
  - $kC^n < \mathrm{n!} < \mathrm{n^n}$
  - $k$ is a constant and $c$ is a constant less than $n$

# The Great Divide

- All polynomial algorithms, include
  - Linear
  - Poly-log
  - Log
  - Constant
  - Sub-linear
- All exponential algorithms, include
  - Factorial
  - Exponential

# Problems vs. Algorithm

- A problem can have many algorithms with different efficiencies, e.g. sorting integers
  - Mergesort $\Theta(n \log n)$
  - Permutation sort $\Theta(n!)$
- A specific algorithm's efficiency can vary depending on the input, e.g. Quicksort
  - $\Theta(n \log n)$ - on most unsorted list
  - $\Theta(n^2)$ – on pre-sorted or partially sorted list

# Problems vs. Algorithms

- So what can we say about sorting problem?
- The sorting problem can be
  - Solved in $\Theta(n \log n)$
  - Solved in $\Theta(n!)$

- We say that the sorting problem is polynomial
  - Because there exists at least one polynomial algorithm for solving the problem

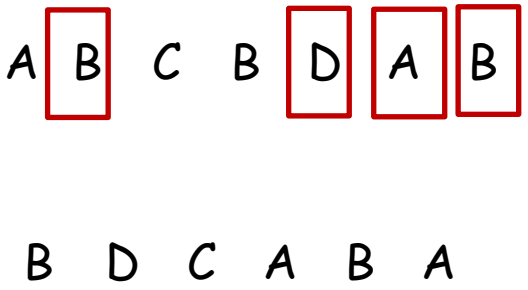
# Problems vs. Algorithms

- Some problems have solution algorithms that are intrinsically polynomial
- But, some problems can NOT be solved in polynomial time
  - At least most people think so…
  - But it's hard to prove that something can't be done

# Longest Common Subsequence (LCS) Problem

- Finding the longest common subsequence to all sequences in a set of sequences (often just two sequences).
- It differs from the longest common substring problem:
  - unlike substrings, subsequences are not required to occupy consecutive positions within the original sequences.

- E.g. $X = ABCBDAB; Y = BDCABA$
  - The length of LCS is 4
  - LCS are $BDAB, BCAB, BCBA$



# LCS: 1960's

- The LCS problem
  - Fastest known algorithm can only solve the problem in $\Theta(2^n)$
- Does there exist an optimal LCS algorithm that has a polynomial time?
  - In 1960, most computer scientists were leaning towards an answer of "no", i.e. there does NOT exist a polynomial algorithm

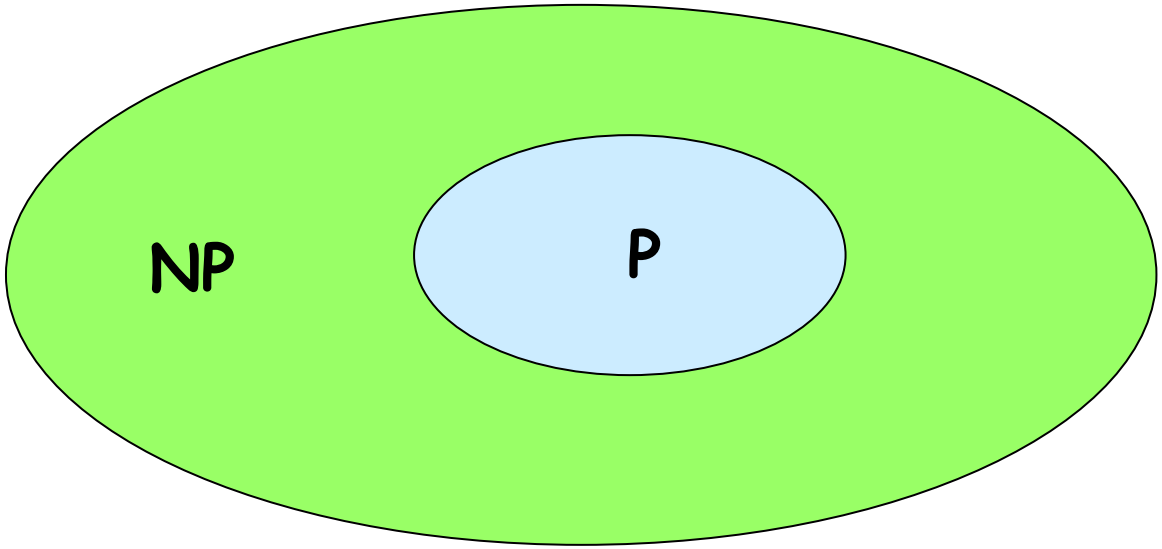
# LCS: 1980's

- In 1981, Smith and Waterman used dynamic programming to solve LCS problem in $\Theta(n^2)$ time using $\Theta(n^2)$ memory
- This discover and many other discoveries led the following questions:

- Can all problems be solved in Polynomial Time?
  - Maybe we just haven't discovered all the good algorithms yet

# P and NP

- NP – set of problems where the solution can not be computed deterministically in polynomial time
- P – set of problems that can be solved deterministically in polynomial time



# Nondeterministic algorithm

- a nondeterministic algorithm is an algorithm that, even for the same input, can exhibit different behaviours on different runs
  - The nondeterministic algorithms are often used to find an approximation to a solution, when the exact solution would be too costly to obtain using a deterministic one

- a deterministic algorithm is an algorithm that, given a particular input, will always produce the same output, with the underlying machine always passing through the same sequence of states.

# Polynomial Problems

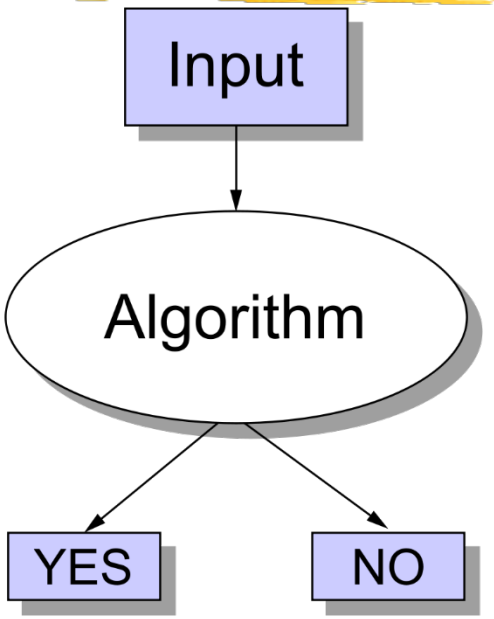
- Searching
- Sorting
- Minimum Spanning Tree
- LCS Problem
- Shortest Path Problem

# Non-deterministically Polynomial Problems

- The **graph isomorphism** – problem of determine whether two graph can be drawn identically
- The **traveling salesman problem** – where we want to know if there is a route of same length that goes through all nodes in a certain network (graph)

# What is a decision problem?

- a decision problem is a problem that can be posed as a yes-no question of the input values
  - whether a given natural number is prime
  - given two numbers $x$ and $y$, does $x$ evenly divide $y$?



# NP-completeness

- $NP - complete$
  - Is short for "nondeterministic polynomial-time complete"
- A decision problem $D_1$ is said to be $polynomially\ reducible$ to a decision problem $D_2$, if there exists a function $t$ that transforms instances of $D_1$ to instances of $D_2$ such that:
  - $t$ maps all yes instances of $D_1$ to yes instances of $D_2$ and all no instances of $D_1$to no instances of $D_2$
  - $t$ is computable by a polynomial time algorithm
- A decision problem $D$ is said to be $NP - complete$ if:
  - it belongs to class $NP$
  - every problem in $NP$ is polynomially reducible to $D$

# What about optimization problems?

- $NP - completeness$ has been studied in the framework of decision problems.
- Most problems are not decision problems, but optimization problems (where some value needs to be minimized or maximized).
- In order to apply the theory of NP-completeness to optimization problems, we must recast them as decision problems.

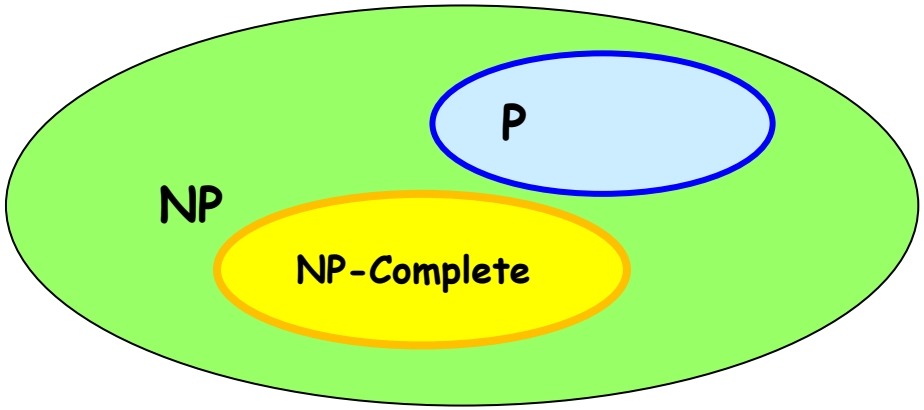
- We provide an example of how an optimization problem can be transformed into a decision problem.

# An example

- Optimization problem
  - SHORTEST-PATH that finds a shortest path between two given vertices in an unweighted, undirected graph $G = (V, E)$.
- Decision problem - A decision problem PATH related to the SHORTEST-PATH problem above is :
  - Given a graph $G = (V, E)$, two vertices $u, v \in V$, and a non-negative integer $k$, does a path exist in G between $u$ and $v$ whose length is at most $k$ ?

# P, NP and NP-Complete

- $P$ – Problems with polynomial deterministic algorithms
- $NP$ – problems with polynomial non-deterministic algorithms
- $NP\ Complete$ – A Problem $X$ is $NP$-complete if t for any $NP$ problem $Y$, $Y$ is reducible to $X$ in polynomial time.



# Related References

- Introduction to the Design and Analysis of Algorithms, A. Levitin, 3rd Ed., Pearson 2011.
  - Chapters 11.3

CSCI203

# Algorithms and Data Structures

## Subject Review & Final Examination

Lecturer: Xueqiao Liu

Room: 3.117

# Topics covered in the subject

- Week01
  - Comparing algorithms and complexity classes
  - 1D and 2D Peak finding, phone books and Quick sort
  - Basic data structures – array, list, stack, queue and record
- Week02
  - Merge sort, heap, heapsort, compact string storage using arras
  - Algorithm efficiency
- Week03
  - Discrete event-driven simulation
  - Min-max heap, priority queue

# Topics covered in the subject…

- Week04
  - Binary search trees (BST), AVL trees
  - Binary express trees
- Week05
  - 2-4 trees
  - B-trees of order $m$
  - Quadtrees and fast search (hashing)
- Week06
  - Hashing - chainning, open addressing, linear probing and double hashing

# Topics covered in the subject…

- Week07 – String Searching and Improving Sorting II
  - Karp-Rabin string search
  - Lower Bound for Comparison Sort &Sorting in Linear Time
  - Big Numbers
- Week08 – Graphs
  - Adjacency list & matrix, Breadth-first-search (BFS), DFS, edge classification, cycle detection, topological sort
  - Articulation points
- Week09 – Weighted Graphs
  - Shortest path (Dijkstra's, Bellman-Ford's)

# Topics covered in the subject…

- Week10 ~ 11 – Dynamic Programming
  - Optimal structure, recursive formula
  - Implementation (recursive, recursive + memorization, bottom-up with tabular)
  - Fibonacci, coin-row, change-making, shortest paths, coin-collection, rod-cutting
  - Matrix-chain multiplication
- Week12
  - Multi-dimensional tree and Huffman tree
- Week13
  - P, NP and NP-complete Problems

# Subject Materials for Review

- Lecture slides:
  - Available on the subject Moodle.
- Your notes
- Recommended references:
  - Introduction to the Design and Analysis of Algorithms, A. Levitin, 3rd Ed., Pearson 2011.
  - Introduction to Algorithms, T. H. Cormen, 3rd Ed, MIT Press 2009.
- Assignments
- Lab exercises

# Assessments

- Assignments (45% in total)
  - 3x Coding assignments = 45%
- Final Exam (55%)
  - Minimum requirement 40% = 22 marks

# Final Examination

- Only Materials on Moodle site are Allowed
  - Restricted Materials
- Exam Structure
  - Short answer questions
  - 8 questions, 6-8 marks each as specified
  - Each question has multiple sub-questions
- This exam will run on Moodle and be invigilated using Proctorio.

# Final Examination…

- Exam Date & Starting time
  - **Please check SOLS**
- Exam Duration
  - 3 hours + 15-min upload allowance at the end of exam

# Final Examination - Instructions

- Have a set of A4 blank paper ready
- On each page, write
  - Your full name, Student Number
- Answer each question on a separate page clearly
  - Handwrite your answers
- Scan or take photos of your answer sheets
- Convert the answers for each question into an individually pdf file (<200MB)
- Name the pdf file as
  - <your login name Qn>.pdf
- Submit each pdf file via Moodle file box for the question
- Only PDF is accepted by Moodle

# How to create one pdf file

- Important: Be prepared with knowing how to create one pdf file from your working solutions.
- There is freely available software that can be used to scan your answer sheets and convert them into a single pdf file. These links may be of assistance.

- **Android**

  https://www.youtube.com/watch?v=BCccqxhPyJw (Scan documents)
  https://www.youtube.com/watch?v=d_olWftSgIM (Convert image to pdf)

- **iPhone**

  https://www.idownloadblog.com/2017/05/12/how-to-save-photos-pdf-iphone-ipad/

  https://www.igeeksblog.com/how-to-convert-photos-to-pdf-on-iphone-ipad/

# 15-minutes Upload Allowance

- An extra fifteen minutes has been added to your exam time limit.
- This is strictly reserved for uploading any documents before you submit your exam.
- During this final fifteen minutes, you are not permitted to work on any exam questions.
- Working on any exam questions may lead to academic misconduct.

# 15-minutes Upload Allowance

- You could use your phone or scanner to scan your answer only in this period
- Use UOW email address to send file from phone to your computer
  - to ensure that there is no potential for students to be flagged for academic misconduct.

# Important Tips on Moodle

**Important:**

- If you need to leave the view of your camera for any extenuating reason (such as a bathroom break), clearly state to the camera 'I am leaving the desk for a bathroom break/due to an urgent issue'.
- If you are in a shared space, you should determine a suitable location where you can undertake your exam away from others. You should also inform others in the shared space that you are taking an exam using Proctorio where video and audio recordings will take place.
- Headphones are **not** permitted to be worn unless arranged as part of a Reasonable Adjustment to your exam sitting. Foam ear plugs are permitted, if you intend to wear ear plugs, at the beginning of the exam before attempting any questions, show them to the camera before placing them in your ears.
- If a UOW Approved Calculator is permitted, show the calculator to the camera before commencing any questions.
- If any paper reference material is permitted, show the reference material papers to the camera before commencing any questions.
- If working out or exam answers are permitted on paper, show your papers to the camera at the end of your exam once you've completed all questions.
- If you become aware of having taken an unauthorised action inadvertently, you should attempt to rectify the matter immediately, including recording a statement via the webcam on the circumstances that arose.
- You may not collaborate on the quiz.

# On Exam day

- **What if I'm late to the start of my exam?**
  - You can still commence your exam late, however you may not be permitted to commence your exam 30 minutes after the scheduled exam time and you will not be given extra time to compensate for starting late

**Exam Time**

Please pay close attention to your exam's time limit which will start when you begin your quiz attempt and is displayed as Time left in the Quiz navigation block. Your exam time will not commence until after you have completed your Proctorio pre-checks, for example if you have a 3 hour exam and do your Proctorio pre-checks from 9:00 and start the exam at 9:10, your time limit would then expire at 12:25. Please ensure that you note the time you commenced the quiz and plan your exam time hours accordingly.

# On Exam day

- **What if I have technical issues during an online exam (e.g., Moodle exam won't submit)?**
  - If you experience any technical difficulties contact the Exam Support team for advice as soon as practicable
  - Live Chat:: **IT Support Chat** (use the chat icon on the right of the screen once logged in. Do not use the Proctorio support live chat)
  - Phone: +61 4221 3927
- There is NO need to inform your Subject Coordinator if you are experiencing any technical difficulties, the Exam Support team provides each Subject Coordinator with this information

# On Exam Day

- **What if I get interrupted during my exam(e.g., need bathroom break)?**
  - We strongly recommend that students go to the bathroom and take care of anything which may require their attention before the exam start time.
  - If you do need to use the bathroom or leave your desk for another urgent reason during the exam, the period you are away from your desk will be flagged as a potential irregularity for review. Before you leave your room and move away from your device, you can speak to your device camera "having a bathroom break". This will assist invigilators with the review.

# On Exam day

- **Resources for you during exams can be found**
  - https://www.uow.edu.au/student/exams/faq/

# Test your technology

**Even if you have previously sat a Proctorio exam, you need to test your technology as your hardware, internet or many other factors may have changed since last session.**

**Download Google Chrome or Microsoft Edge** (The Proctorio extension will only work on these browsers.)

**Complete the Proctorio practice quiz** to ensure everything is set up and ready well before your exam day.

Test your tech here

**VIDEO | How to test your tech**


**Completing the practice quiz well before the exam will:**

- Allow time to troubleshoot
- Allow time to make alternative arrangements if required
- Ease stress on the day of the exam
- Lead to less wait times for Exam Support if you need them on the day
- If the practice quiz is not completed prior to the exam, it may affect any Academic Consideration outcomes for technology failure during the exam.

# That's all!

Thank you!