COMP9020

Foundations of Computer Science

Lecture 1: Course Introduction

Pre-course polls

Pre-course questionnaire

Pre-course poll

Acknowledgement of Country

I would like to acknowledge and pay my respect to the Bedegal people who are the Traditional Custodians of the land on which UNSW is built, and of Elders past and present.

Outline

Who are we?

Why are we here?

How will you be assessed?

What do I expect from you?

COMP9020 25T1 Staff

Lecturer:	Paul Hunter
Email:	cs9020@cse.unsw.edu.au
Lectures:	Mondays 2-4pm and Wednesdays 2-4pm
Tutorials:	From Week 2
Research:	Theoretical CS: Algorithms, Formal verification
Course Admins:	Varun Agarwal, Ronald Chiang

Interactions

Lectures:

- Recordings available on echo360 (through Moodle)

Tutorials:

- From Week 2
- Small group discussion: Assessment feedback, Practice problems

Other points of contact:

- Formatif Learning Environment
- Course forums (ed)
- Email: cs9020@cse.unsw.edu.au
- Weekly feedback

Outline

What is this course about?

What is Computer Science?

> *"Computer science no more about computers than astronomy is about telescopes"*
>
> – E. Dijkstra

Course Aims

Computer Science is about exploring the ability, and limitation, of computers to solve problems. It covers:

- **What** are computers capable of solving?
- **How** can we get computers to solve problems?
- **Why** do these approaches work?

This course aims to increase your level of mathematical maturity to assist with the fundamental problem of **finding, formulating, and proving** properties of programs.

Key skills you will learn:

- Working with abstract concepts
- Giving logical (and rigorous) justifications
- Formulating problems so they can be solved computationally

Course Goals

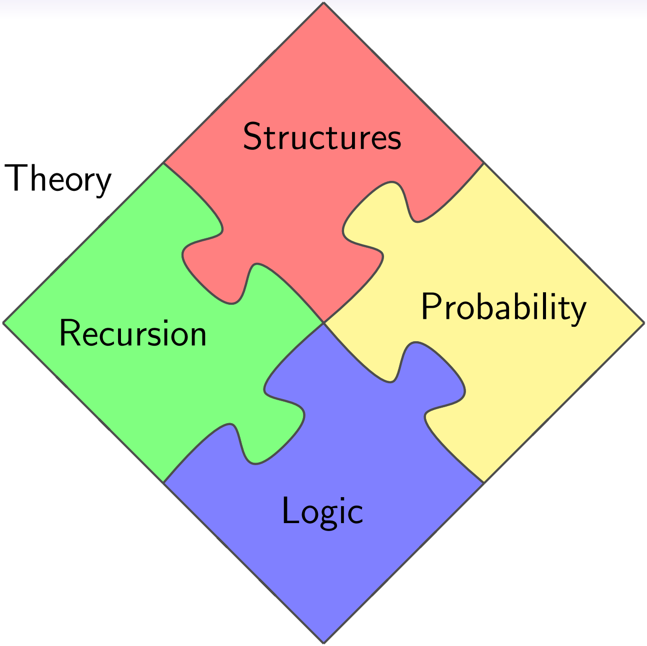
By the end of the course, you should know enough to **understand** the answers to questions like:

- How does RSA encryption work?
- Why do we use Relational Databases?
- How does Deep Learning work?
- Can computers think?
- How do Quantum Computers work?

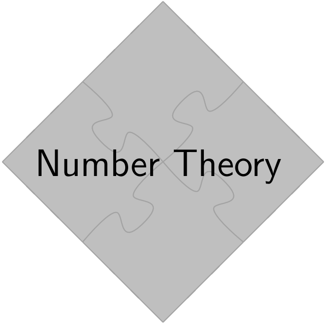
What other questions would you like to know the answer to?

Course Topics

Number Theory

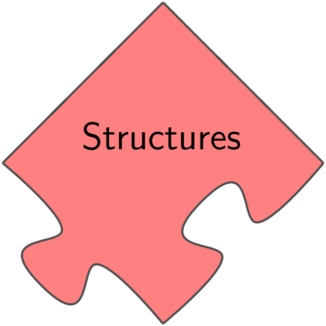


Course Topics



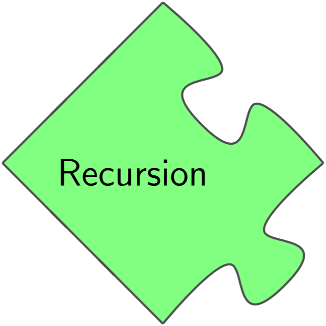
- Week 1: Number Theory

Course Topics



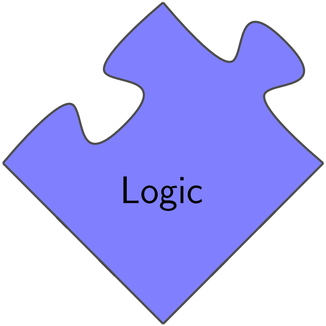
- Week 2: Set Theory
- Week 2: Formal Languages
- Week 3: Relations
- Week 4: Functions
- Week 5: Graph Theory

Course Topics



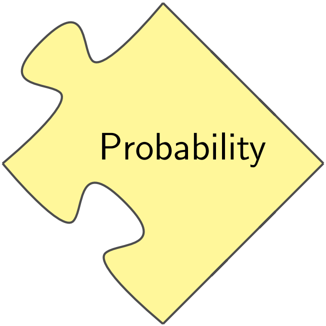
- Week 6: Recursion
- Week 7: Algorithmic Analysis
- Week 7: Induction

Course Topics



- Week 8: Boolean Logic
- Week 8: Propositional Logic

Course Topics



- Week 9: Combinatorics
- Week 9: Probability
- Week 10: Statistics

Course Material

All course information is placed on the course website

www.cse.unsw.edu.au/∼cs9020/

Content includes:

- Lecture slides and recordings
- Tutorial sheets and solutions
- Assignment questions and solutions
- Course Forums
- Puzzle games

Course Material

Textbooks:

- E Lehman, FT Leighton, A Meyer: Mathematics for Computer Science

Alternatives:

- K Rosen: Discrete Mathematics and its Applications
- KA Ross and CR Wright: Discrete Mathematics
- S Epp: Discrete Mathematics with Applications

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Assessment Philosophy

What is the purpose of assessment?

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Two types of assessment:

- Formative: Formatif Tasks
- Summative: Quizzes, Assignments, Exam

Assessment Summary

60% exam, 40% assignments:

- Weekly Formatif tasks, worth up to 40 marks
- Final Exam (2 hours, in person) worth up to 60 marks

You must achieve 40% on the final exam to pass

Your final score will be taken from Formatif portfolio and final exam.

Formatif system

- Feedback-driven competency-based assessment framework
- Weekly tasks
  - 4-7 tasks per week depending on target grade
  - Proof-based questions
  - First attempt to be submitted **Monday 6pm** before tutorial in formatif system
  - Discussion in tutorials
  - Final submission **Friday 6pm** after tutorial
- Final grade is based on an "overall picture" consisting of completed tasks and a self-reflection on performance

Late policy and Special Consideration

Equitable Learning Services:

- https://www.student.unsw.edu.au/equitable-learning

Lateness policy

- Formatif tasks: Request extensions in the system
- Exam: Late submissions not accepted

If you cannot meet a deadline through illness or misadventure you need to apply for Special Consideration.

More information

View the course outline at:

https://webcms3.cse.unsw.edu.au/COMP9020/25T1/outline

Particularly the sections on **Student conduct** and **Plagiarism**.

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Learning Objectives

I am always looking for you to demonstrate:

- Your understanding of the material
- Your ability to work with the material

NB

How you get an answer is as, if not more important than what the answer is.

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Why?

Guidelines for good mathematical writing

Mathematical writing should be:

- Clear
- Logical
- Convincing

How can you do well?

The best way to improve is to **practice**.

Opportunities for you:

- Formatif tasks - proof-based questions in an environment for providing quick feedback
- Practice questions – including past exam questions
- Textbook and other questions (links on the course website)

How can you do well?

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Opportunities for you:

- Formatif tasks - proof-based questions in an environment for providing quick feedback
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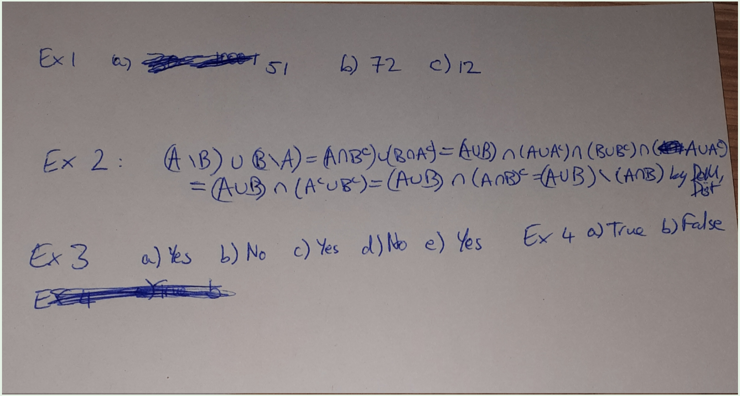
- Textbook and other questions (links on the course website)

Opportunities from you:

- Post questions to the forum
- Bring questions to the tutorials

I am always looking for more questions!

Example (Bad)



Ex 1 a) [illegible] 51 b) 72 c) 12

Ex 2: $(A \setminus B) \cup (B \setminus A) = (A \cap B^c) \cup (B \cap A^c) = (A \cup B) \cap (A \cup A^c) \cap (B \cup B^c) \cap ([illegible] A \cup A^c)$
$= (A \cup B) \cap (A^c \cup B^c) = (A \cup B) \cap (A \cap B)^c = (A \cup B) \setminus (A \cap B)$ by DeM, Dist

Ex 3 a) Yes b) No c) Yes d) No e) Yes Ex 4 a) True b) False

~~Ex 4 a) True b)~~

Examples

Example (Good)

Ex. 2

$$\begin{aligned}
(A \setminus B) \cup (B \setminus A) &= (A \cap B^c) \cup (B \cap A^c) && \text{(Def.)} \\
&= ((A \cap B^c) \cup B) \cap ((A \cap B^c) \cup A^c) && \text{(Dist.)} \\
&= (A \cup B) \cap (B^c \cup B) \\
&\quad \cap (A \cup A^c) \cap (B^c \cup A^c) && \text{(Dist.)} \\
&= (A \cup B) \cap (A^c \cup B^c) && \text{(Ident.)} \\
&= (A \cup B) \cap (A \cap B)^c && \text{(DeM.)} \\
&= (A \cup B) \setminus (A \cap B) && \text{(Def.)}
\end{aligned}$$

Examples

Example (Good)

Ex. 4a

We will show that if R_1 and R_2 are symmetric, then $R_1 \cap R_2$ is symmetric.

Suppose $(a, b) \in R_1 \cap R_2$.

Then $(a, b) \in R_1$ and $(a, b) \in R_2$.

Because R_1 is symmetric, $(b, a) \in R_1$; and because R_2 is symmetric, $(b, a) \in R_2$.

Therefore $(b, a) \in R_1 \cap R_2$.

Therefore $R_1 \cap R_2$ is symmetric.

Proofs

A large component of your work in this course is giving **proofs** of **propositions.**

A **proposition** is a statement that is either true or false.

Example

Propositions:

- $3 + 5 = 8$
- All integers are either even or odd
- There exist a, b, c such that $1/a + 1/b + 1/c = 4$

Not propositions:

- $3 + 5$
- x is even or x is odd
- $1/a + 1/b + 1/c = 4$

Proposition structure

Common proposition structures include:

If A then B	$(A \Rightarrow B)$
A if and only if B	$(A \Leftrightarrow B)$
For all x, A	$(\forall x.A)$
There exists x such that A	$(\exists x.A)$

$\forall$ and $\exists$ are known as **quantifiers**.

Proofs

A large component of your work in this course is giving **proofs** of **propositions.**

A proof of a proposition is an argument to convince the reader/marker that the proposition is true.

A **proof** of a proposition is a finite sequence of logical steps, starting from base assumptions (**axioms** and **hypotheses**), leading to the proposition in question.

Proofs

Example

Prove: $3 \times 2 = 2 \times 3$

$$3 \times 2 = (2 + 1) \times 2$$

Proofs

Example

Prove: $3 \times 2 = 2 \times 3$

$$\begin{aligned} 3 \times 2 &= (2+1) \times 2 \\ &= (2 \times 2) + (1 \times 2) \end{aligned}$$

Proofs

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Proofs

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$$\begin{aligned} 3 \times 2 &= (2+1) \times 2 \\ &= (2 \times 2) + (1 \times 2) \\ &= (1 \times 2) + (2 \times 2) \\ &= 2 + (2 \times 2) \end{aligned}$$

Proofs

Example

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Proofs

Example

Prove: $3 \times 2 = 2 \times 3$

$$\begin{aligned} 3 \times 2 &= (2 + 1) \times 2 \\ &= (2 \times 2) + (1 \times 2) \\ &= (1 \times 2) + (2 \times 2) \\ &= 2 + (2 \times 2) \\ &= (2 \times 1) + (2 \times 2) \\ &= 2 \times (1 + 2) \\ &= 2 \times 3. \end{aligned}$$

Proofs: How much detail?

- Depends on the context (question, expectation, audience, etc)
- Each **step** should be justified (excluding basic algebra and arithmetic)

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Guiding principle

Proofs should demonstrate your **ability** and your **understanding**.

Proofs: pitfalls

Starting from the proposition and deriving true **is not valid**.

Example

Prove: $0 = 1$

$$\begin{array}{llcll} & 0 & = & 1 & \\ \text{So (mult. by 2)} & 0 & = & 2 & \\ \text{So (subtract 1)} & -1 & = & 1 & \\ \text{So} & (-1)^2 & = & (1)^2 & \\ \text{So} & 1 & = & 1 & \text{which is true.} \end{array}$$

Does this mean that $0 = 1$?

Proofs: pitfalls

Make sure each step is logically valid

Example

$$-20 = -20$$

Proofs: pitfalls

Make sure each step is logically valid

Example

$$
\begin{aligned}
& -20 &=& -20 \\
\text{So} \quad & 25 - 45 &=& 16 - 36
\end{aligned}
$$

Proofs: pitfalls

Make sure each step is logically valid

Example

$$-20 = -20$$

So $$25 - 45 = 16 - 36$$

So $$5^2 - 2 \cdot 5 \cdot \frac{9}{2} = 4^2 - 2 \cdot 4 \cdot \frac{9}{2}$$

Proofs: pitfalls

Make sure each step is logically valid

Example

$$\begin{aligned} -20 &= -20 \\ \text{So} \quad 25 - 45 &= 16 - 36 \\ \text{So} \quad 5^2 - 2 \cdot 5 \cdot \tfrac{9}{2} &= 4^2 - 2 \cdot 4 \cdot \tfrac{9}{2} \\ \text{So} \quad 5^2 - 2 \cdot 5 \cdot \tfrac{9}{2} + \left(\tfrac{9}{2}\right)^2 &= 4^2 - 2 \cdot 4 \cdot \tfrac{9}{2} + \left(\tfrac{9}{2}\right)^2 \end{aligned}$$

Proofs: pitfalls

Make sure each step is logically valid

Example

$$
\begin{aligned}
& & -20 &= -20 \\
&\text{So} & 25-45 &= 16-36 \\
&\text{So} & 5^2-2\cdot 5\cdot \tfrac{9}{2} &= 4^2-2\cdot 4\cdot \tfrac{9}{2} \\
&\text{So} & 5^2-2\cdot 5\cdot \tfrac{9}{2}+\left(\tfrac{9}{2}\right)^2 &= 4^2-2\cdot 4\cdot \tfrac{9}{2}+\left(\tfrac{9}{2}\right)^2 \\
&\text{So} & (5-\tfrac{9}{2})^2 &= (4-\tfrac{9}{2})^2
\end{aligned}
$$

Proofs: pitfalls

Make sure each step is logically valid

Example

$$
\begin{array}{lrcl}
 & -20 & = & -20 \\
\text{So} & 25-45 & = & 16-36 \\
\text{So} & 5^2 - 2\cdot 5\cdot \frac{9}{2} & = & 4^2 - 2\cdot 4\cdot \frac{9}{2} \\
\text{So} & 5^2 - 2\cdot 5\cdot \frac{9}{2} + \left(\frac{9}{2}\right)^2 & = & 4^2 - 2\cdot 4\cdot \frac{9}{2} + \left(\frac{9}{2}\right)^2 \\
\text{So} & (5-\frac{9}{2})^2 & = & (4-\frac{9}{2})^2 \\
\text{So} & 5-\frac{9}{2} & = & 4-\frac{9}{2}
\end{array}
$$

Does this mean that $5 = 4$?

Proofs: pitfalls

Make sure each step is logically valid

Example

Suppose $a = b$. Then,

$$\begin{array}{lrcl} & a^2 & = & ab \\ \text{So} & a^2 - b^2 & = & ab - b^2 \\ \text{So} & (a-b)(a+b) & = & (a-b)b \\ \text{So} & a+b & = & b \\ \text{So} & a & = & 0 \end{array}$$

This is true no matter what value a is given at the start, so does that mean everything is equal to 0?

Proofs: pitfalls

For propositions of the form $\forall x.A$ where x can have infinitely many values:

- You cannot enumerate infinitely many cases in a proof.
- Only considering a finite number of cases is not sufficient.

Example

$$\text{For all } n,\ n^2 + n + 41 \text{ is prime}$$

True for $n = 0, 1, 2, \ldots, 39$. Not true for $n = 40$.

Proofs: pitfalls

The order of quantifiers matters when it comes to propositions:

Example

- For every number x, there is a number y such that y is larger than x
- There is a number y such that for every number x, y is larger than x

Proof strategies: direct proof

Proposition form	You need to do this
$A \Rightarrow B$	Assume A and prove B
$A \Leftrightarrow B$	Prove "If A then B" and "If B then A"
$\forall x.A$	Show A holds for every possible value of x
$\exists x.A$	Find a value of x that makes A true

Proof strategies: contradiction

To prove A is true, assume A is false and derive a contradiction.
That is, start from the negation of the proposition and derive false.

Example

Prove: $\sqrt{2}$ is irrational
Proof: Assume $\sqrt{2}$ is rational ...

Negating propositions

Proposition form	Its negation
A and B	
A or B	
$A \Rightarrow B$	
$A \Leftrightarrow B$	
$\forall x.A$	
$\exists x.A$	

Negating propositions

Proposition form	Its negation
A and B	not A or not B
A or B	
$A \Rightarrow B$	
$A \Leftrightarrow B$	
$\forall x.A$	
$\exists x.A$	

Negating propositions

Proposition form	Its negation
A and B	not A or not B
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Negating propositions

Proposition form	Its negation
A and B	not A or not B
A or B	not A and not B
$A \Rightarrow B$	A and not B
$A \Leftrightarrow B$	A and not B, or B and not A
$\forall x.A$	
$\exists x.A$	

Negating propositions

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A and B	not A or not B
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$\forall x.A$	$\exists x.$ not A
$\exists x.A$	

Negating propositions

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A and B	not A or not B
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$\forall x.A$	$\exists x.$ not A
$\exists x.A$	$\forall x.$ not A

Proof strategies: contrapositive

To prove a proposition of the form "If A then B" you can prove "If not B then not A"

Example

Prove: If $m + n \geq 73$ then $m \geq 37$ or $n \geq 37$.

Proof strategies: dealing with $\forall$

How can we check infinitely many cases?

- Choose an **arbitrary** element: an object with no assumptions about it (may have to check several cases)
- Induction (see week 5)

Example

Prove: For every integer n, n^2 will have remainder 0 or 1 when divided by 4.

Note: "Arbitrary" is not the same as "random".