COMP9020

Foundations of Computer Science

Lecture 1: Course Introduction

Lecturers: Katie Clinch (LIC)
Paul Hunter
Simon Mackenzie

Course admin: Nicholas Tandiono

Course email: `cs9020@cse.unsw.edu.au`

Pre-course polls

Pre-course questionnaire

Pre-course poll

Acknowledgement of Country

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

Outline

Course introduction

- Who are we?
- Why are we here?
- How will you be assessed?
- What do we expect from you?

How to write mathematics

- Examples
- Proofs
- Proofs - common mistakes
- Proof strategies

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COMP9020 23T2 Staff

Lectures

Lecturers:	Katie Clinch (LIC), Paul Hunter, Simon Mackenzie
Times:	Thursday 11-1pm and Friday 12-2pm

Online consultations (anyone is welcome to attend)

Tutors:	Mark Raya, Malhar Patel
Times:	Tuesday 7-8pm, Wednesday 7-8pm

In-person help sessions (anyone is welcome to attend)

Tutors:	Different tutors each session
Times:	Thursday 2-4pm, Friday 2-4pm
Location:	OShane 105

Links

Course webpages:

- webCMS
- Moodle

Lectures:

- Recordings available on echo360 (through Moodle)

Consultations:

- Microsoft Teams

Other points of contact:

- Course forums (edforum)
- Email: `cs9020@cse.unsw`

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Pre-course questionnaire - results

Pre-course questionnaire

What is this course about?

What is Computer Science?

> *"Computer science is 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

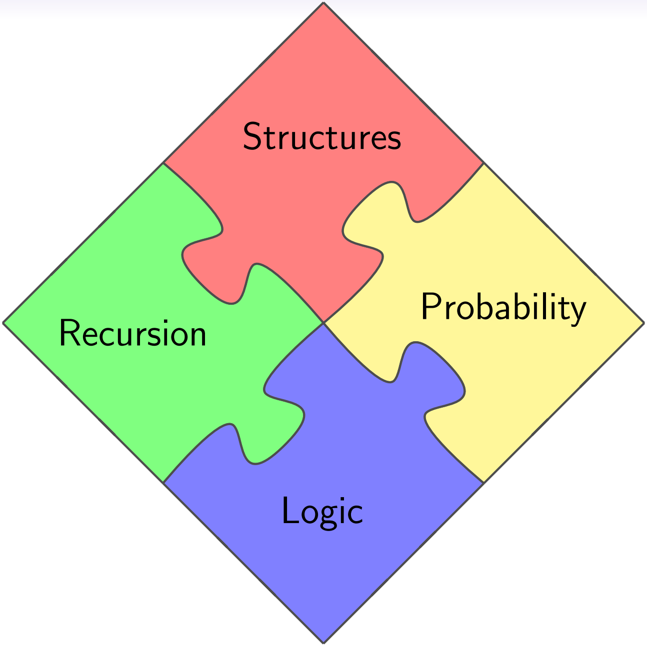
Course Goals

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

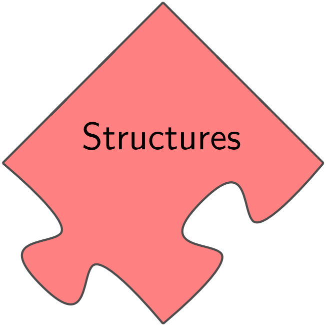
- How does RSA encryption work?
- Why do we use Relational Databases?
- How does Deep Learning work?
- Can computers think?
- How do Quantum Computers work?

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

Course Topics

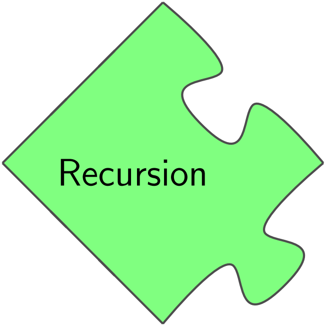


Course Topics



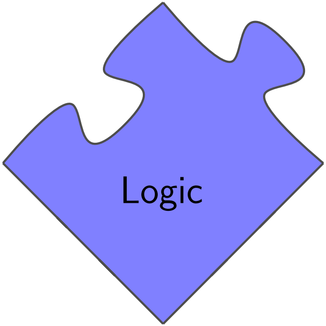
- Week 1: Number theory
- Week 2: Set Theory
- Week 2: Formal Languages
- Week 3: Graph Theory
- Week 4: Relations
- Week 5: Functions

Course Topics



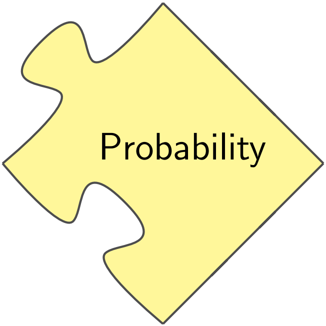
- Week 5: Recursion
- Week 7: Induction
- Week 8: Algorithmic Analysis

Course Topics



- Week 8: Boolean Logic
- Week 9: Propositional Logic

Course Topics



- Week 9: Combinatorics
- Week 10: 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
- Quizzes and Assignments
- Course Forums
- Practice questions

Course Material

Textbooks:

- KA Ross and CR Wright: Discrete Mathematics
- E Lehman, FT Leighton, A Meyer:
  Mathematics for Computer Science

Alternatives:

- K Rosen: Discrete Mathematics and its Applications

Outline

Assessment Philosophy

What is the purpose of assessment?

Assessment Philosophy

What is the purpose of assessment?

Types of assessment:

- Quizzes,
- Assignments,
- Final exam

Assessment Summary

60% exam, 30% assignments, 10% quizzes.

Quizzes

- 9 weekly quizzes
- only your best 7 quiz marks will count towards your final grade
- Each quiz contains: 4-6 threshold questions and 4-6 mastery questions on the week's material
- Released on Wednesday of weeks: 1,2,3,4,5,7,8,9,10.
- Due on Wednesday of weeks: 2,3,4,5,6,8,9,10,11.

Assignments

- 4 assignments, worth up to 7.5 marks each
- Each covers two weeks of material
- Released: weeks 1,3,5 and 8.
- Due on Thursdays of weeks: 3,5,8,10.

Final exam

- **You must achieve 40% on the final exam to pass**

Late policy and Special Consideration

All assessments are submitted through the course website

Lateness policy

- Assignments: 5% of total grade off raw mark per 24 hours or part thereof
- Quizzes: Late submissions not accepted
- 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 here:

https://webcms3.cse.unsw.edu.au/COMP9020/24T1/outline

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

Outline

Learning Objectives

We want 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?

Pre-course poll - results

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Guidelines for good mathematical writing

Mathematical writing should be:

- Clear
- Logical
- Convincing

Mathematical communication

Guidelines for good mathematical writing

Mathematical writing should be:

- Clear
- Logical
- Convincing

NB

All submitted work must be typeset. Diagrams may be hand drawn.

How can you do well?

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

Opportunities for you:

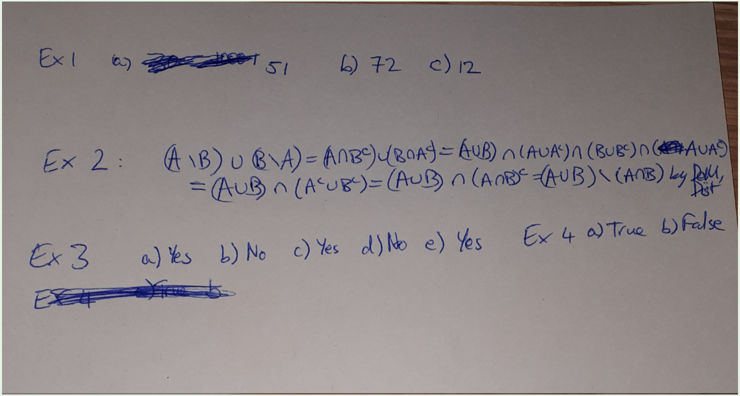
- Weekly quizzes
- Four assignments of longer questions
- Practice questions – including past exam questions
  - Looking for solutions! (Post to forum)
- Textbook and other questions (links on the course website)

Support:
If you get stuck, you can get one-on-one support from our tutors by

- attending face-to-face **help sessions**
- attending **online consultations**
- posting questions on **edforum**.

Examples

Example (Bad)



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.

Outline

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

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

Proofs

Example

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Proofs

Example

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

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

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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- Depends on the context (question, expectation, audience, etc)
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Guiding principle

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

Outline

Proofs: pitfalls

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

Example

Prove: $0 = 1$

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

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

$$-20 = -20$$

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

Proofs: pitfalls

Make sure each step is logically valid

Example

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

Proofs: pitfalls

Make sure each step is logically valid

Example

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

Proofs: pitfalls

Make sure each step is logically valid

Example

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

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

Outline

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	
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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
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$A \Rightarrow B$	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
$\exists x.A$	

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A and B	not A or not B
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$A \Leftrightarrow B$	A and not B, or B and not A
$\forall x.A$	$\exists x.$ 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 $n \geq 37$.

That's it!

See you in tomorrow's lecture