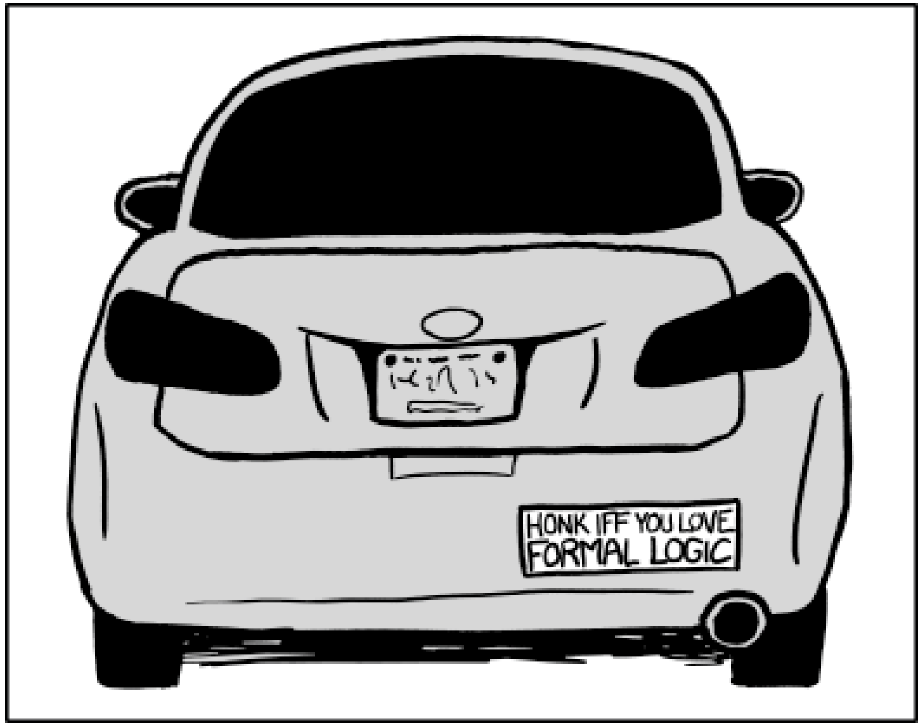
# Here Early?

Here for CSE 311?

Welcome! You’re early!

Want a copy of these slides to take notes?

- You can download them from the calendar webpage cs.uw.edu/311




# Logistics and Propositional Logic

CSE 311: Foundations of Computing I
Lecture 1

# Outline

Course logistics

What is the goal of this course?

Start of Propositional Logic

# Staff

Instructor: Robbie Weber

Ph.D. from UW CSE in theory
Fourth year as teaching faculty
Seventh time teaching 311

Office: CSE2 311
Email: rtweber2@cs.washington.edu

## TAs

Jacob Berg
Owen Boseley
Cade Dillon
Alex Fu
Anna Kuznetsova
Karim Maftoun
Alan Li
Alysa Meng
Allie Pfleger
Aruna Srivastava
Timothy Tran

# This is where syllabus information would go

If we had time…

We'll cover a few highlights at the starts of lectures over the next few weeks.

Detailed information is in an extra recording on panopto. Part of HW1 is watching that video.

And the syllabus is on the webpage.

# What you need to know right now

We’ll have a mix of zoom and in-person office hours.

But most are in-person.

We’ll have an **evening** midterm (Mon Feb 12, time TBD)

We’ll have a final exam (Mon Mar 12, 2:30)

Section participation is **required**.

The course is designed to give you high-level ideas here and practice in section.

Details on the syllabus (including what to do if you can’t attend section).

Sections aren’t recorded, but resources are available.

Lecture attendance won’t be tracked (and recordings go on panopto).

# What you need to know right now

Each Lecture will have a “concept check” associated with it.

Idea: Make sure you’ve understood today’s topic before we build on it 2 days later.

Available on gradescope.

You can submit as many times as you want.

When you get an answer correct the explanation will appear.

Worth a small amount of your grade, and an 80% average for the quarter is all you need for full credit.

Details in the syllabus.

# If something unusual happens

In a 160-person class, a few of you will have something significant happen during the quarter.

- Illness or family emergency or something else.
- We can give some kinds of accommodations (e.g., extra late days) in some cases.
- We can only help if you tell us something is going on.

Now is a great time to:

- Ask DRS for accommodations if you think you might need formal ones.
- Start looking for a study group!

# CSE 390Z

390Z is:
Practice with concepts
Lessons on study skills
Place to find study groups

390Z is NOT:
Extra office hours
Homework help

CSE 390Z **is a workshop** designed to provide academic support to students enrolled concurrently in CSE 311. During each 2-hour workshop, students will reinforce concepts through:

- **collaborative problem solving**
- **practice study skills and effective learning habits**
- **build community for peer support**

All students enrolled in CSE 311 are welcome to register for this class.

Subject to size constraints on the course

Contact Melissa Lin for more information

BIT.LY/CSE390Z-WIN24

# What is this course?

# What is this course?

In this course, you will learn how to make and communicate rigorous and formal arguments.

Why? Because you'll have to do technical communication in real life.

If you become a PM – you'll have to convert non-technical requirements from experts into clear, unambiguous statements of what is needed.

If you become an engineer – you'll have to justify to others exactly why your code works, and interpret precise requirements from your PM.

If you become an academic – to explain to other academics how your algorithms and ideas improve on everyone else's.

# What is this course?

In this course, you will learn how to make and communicate rigorous and formal arguments.

Two verbs

Make arguments – what kind of reasoning is allowed and what kind of reasoning can lead to errors?

Communicate arguments – using one of the common languages of computer scientists (no one is going to use your code if you can’t tell them what it does or convince them it’s functional)

# Course Outline

## Symbolic Logic (training wheels; lectures 1-8)

Just make arguments in mechanical ways.

- Using notation and rules a computer could understand.

Understand the rules that are allowed, without worrying about pretty words.

## Set Theory/Arithmetic (bike in your backyard; lectures 9-19)

Make arguments, and communicate them to humans

Arguments about numbers and sets---objects you already know

## Models of computation (biking in your neighborhood; lectures 20-28)

Still make and communicate rigorous arguments

But now with objects you haven't used before.

- A first taste of how we can argue rigorously about computers.

# Symbolic Logic

# What is symbolic logic and why do we need it?

Symbolic Logic is a language, like English or Java, with its own

words and rules for combining words into sentences (syntax)

ways to assign meaning to words and sentences (semantics)

Symbolic Logic will let us **mechanically** simplify expressions and make arguments.

The new language will let us focus on the (sometimes familiar, sometimes unfamiliar) rules of logic.

Once we have those rules down, we'll be able to apply them "intuitively" and won't need the symbolic representation as often

but we'll still go back to it when things get complicated.

# Propositions: building blocks of logic

**Proposition**

**A statement that has a truth value (i.e. is true or false) and is "well-formed"**

Propositions are the basic building blocks in symbolic logic.

Here are two propositions.

All cats are mammals

True, (and a proposition)

All mammals are cats

False, but is well-formed and has a truth value, so still a proposition.

# Analogy

In Intro Programming you talked about a variable type that could be either true or false.

You called it a "`Boolean`"

Boolean variables are a useful analogy for propositions.

They aren't identical, but they're very similar.

# Are These Propositions?

$2 + 2 = 5$

$x + 2 = 5$

Akjsdf!

Who are you?

There is life on Mars.

# Are These Propositions?

$2 + 2 = 5$ This is a proposition. It's okay for propositions to be false.

$x + 2 = 5$ Not a proposition. Doesn't have a fixed truth value

Akjsdf! Not a proposition because it's gibberish.

Who are you?

This is a question which means it doesn't have a truth value.

There is life on Mars.

This is a proposition. We don't know if it's true or false, but we know it's one of them!

# Propositions

We need a way of talking about *arbitrary* ideas…

To make statements easier to read we'll use propositional variables like $p, q, r, s, \ldots$

Lower-case letters are standard.

Usually start with $p$ (for proposition), and avoid $t$,$f$, because…

Truth Values:

T for true (note capitalization)

F for false

# Analogy

We said propositions were a lot like Booleans…

How did you connect Booleans in code?

```
&&
||
!
```

# Logical Connectives

- And (&&) works exactly like it did in code.
  - But with a different symbol ∧
- Or (||) works exactly like it did in code.
- But with a different symbol ∨
- Not (!)works exactly like it did in code.
  - But with a different symbol ¬

# Some Truth Tables

| ***p*** | **¬*p*** |
|---|---|
| | |
| | |

| ***p*** | ***q*** | ***p* ∧ *q*** |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

| ***p*** | ***q*** | ***p* ∨ *q*** |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

Truth tables are the simplest way to describe how logical connectives operate.

# Some Truth Tables

| $p$ | $\neg p$ |
|---|---|
| T | F |
| F | T |

| $p$ | $q$ | $p \wedge q$ |
|---|---|---|
| T | T | T |
| T | F | F |
| F | T | F |
| F | F | F |

| $p$ | $q$ | $p \vee q$ |
|---|---|---|
| T | T | T |
| T | F | T |
| F | T | T |
| F | F | F |

Truth tables are the simplest way to describe how logical connectives operate.

# Implication

Another way to connect propositions

If $p$ then $q$.

"If it is raining, then I have my umbrella."

$p \rightarrow q$

Think of an implication as a promise.

# Implication

The first two lines should match your intuition.

The last two lines are called “vacuous truth.” For now, they’re the definition. We’ll explain why in a few lectures.

| $p$ | $q$ | $p \to q$ |
|---|---|---|
| T | T | T |
| T | F | F |
| F | T | T |
| F | F | T |

This is the definition of implication. When you write “if…then…” in a piece of mathematical English, this is how you will be interpreted.

# Implication ($p \to q$)

*"If it's raining, then I have my umbrella"*

*It's useful to think of implications as promises. An implication is false exactly when you can* ***demonstrate*** *I'm lying.*

| | It's raining | It's not raining |
|---|---|---|
| I have my umbrella | | |
| I do not have my umbrella | | |

| $p$ | $q$ | $p \to q$ |
|---|---|---|
| T | T | T |
| T | F | F |
| F | T | T |
| F | F | T |

# Implication ($p \to q$)

*"If it's raining, then I have my umbrella"*

*It's useful to think of implications as promises. An implication is false exactly when you can* ***demonstrate*** *I'm lying.*

| | It's raining | It's not raining |
|---|---|---|
| I have my umbrella | No lie. True | No lie. True |
| I do not have my umbrella | **LIE! False** | No lie. True |

| $p$ | $q$ | $p \to q$ |
|---|---|---|
| T | T | T |
| T | F | F |
| F | T | T |
| F | F | T |

# $p \rightarrow q$

$p \rightarrow q$ and $q \rightarrow p$ are different implications!

"If the sun is out, then we have class outside."

"If we have class outside, then the sun is out."

Only the first is useful to you when you see the sun come out.

Only the second is useful if you forgot your umbrella.

# $p \rightarrow q$

Implication:

*p* implies *q*

whenever *p* is true *q* must be true

if *p* then *q*

*q* if *p*

*p* is sufficient for *q*

*p* only if *q*

*q is necessary for p*

| $p$ | $q$ | $p \rightarrow q$ |
|---|---|---|
| **T** | **T** | **T** |
| **T** | **F** | **F** |
| **F** | **T** | **T** |
| **F** | **F** | **T** |

Implications are super useful, so there are LOTS of translations.
You'll learn these in detail in section.

# A More Complicated Statement

"Robbie knows the Pythagorean Theorem if he is a mathematician and took geometry, and he is a mathematician or did not take geometry."

Is this a proposition?

We'd like to *understand* what this proposition means.

In particular, is it true?

# A Compound Proposition

"Robbie knows the Pythagorean Theorem if he is a mathematician and took geometry, and he is a mathematician or did not take geometry."

We'd like to *understand* what this proposition means.

First find the simplest (atomic) propositions:

| | |
|---|---|
| $p$ | "Robbie knows the Pythagorean Theorem" |
| $q$ | "Robbie is a mathematician" |
| $r$ | "Robbie took geometry" |

($p$ if ($q$ and $r$)) and ($q$ or (not $r$))

$$(p \text{ if } (q \land r)) \land (q \lor (\neg r))$$

# A Compound Proposition

"Robbie knows the Pythagorean Theorem if he is a mathematician and took geometry, and he is a mathematician or did not take geometry."

$$(p \text{ if } (q \wedge r)) \wedge (q \vee (\neg r))$$

| | |
|---|---|
| $p$ | **"Robbie knows the Pythagorean Theorem"** |
| $q$ | **"Robbie is a mathematician"** |
| $r$ | **"Robbie took geometry"** |

How did we know where to put the parentheses?

- Subtle English grammar choices (top-level parentheses are independent clauses).
- Context/which parsing will make more sense.
- Conventions

A reading on this is coming soon!

# Back to the Compound Proposition…

"Robbie knows the Pythagorean Theorem if he is a mathematician and took geometry, and he is a mathematician or did not take geometry."

$$(p \text{ if } (q \wedge r)) \wedge (q \vee (\neg r))$$

| | |
|---|---|
| $p$ | **"Robbie knows the Pythagorean Theorem"** |
| $q$ | **"Robbie is a mathematician"** |
| $r$ | **"Robbie took geometry"** |

What promise am I making?

$$((q \wedge r) \rightarrow p) \wedge (q \vee (\neg r)) \qquad (p \rightarrow (q \wedge r)) \wedge (q \vee (\neg r))$$

The first one! Being a mathematician and taking geometry goes with the "if." Knowing the Pythagorean Theorem is the consequence.

# A Compound Proposition

"Robbie knows the Pythagorean Theorem if he is a mathematician and took geometry, and he is a mathematician or did not take geometry."

We'd like to *understand* what this proposition means.

First find the simplest (atomic) propositions:

$p$ "Robbie knows the Pythagorean Theorem"

$q$ "Robbie is a mathematician"

$r$ "Robbie took geometry"

($p$ if ($q$ and $r$)) and ($q$ or (not $r$))

$$(p \text{ if } (q \wedge r)) \wedge (q \vee (\neg r))$$

# Analyzing the Sentence with a Truth Table

| $p$ | $q$ | $r$ | $\neg r$ | $q \vee \neg r$ | $q \wedge r$ | $(q \wedge r) \rightarrow p$ | $((q \wedge r) \rightarrow p) \wedge (q \vee \neg r)$ |
|---|---|---|---|---|---|---|---|
| F | F | F | T | T | F | T | T |
| F | F | T | F | F | F | T | F |
| F | T | F | T | T | F | T | T |
| F | T | T | F | T | T | F | F |
| T | F | F | T | T | F | T | T |
| T | F | T | F | F | F | T | F |
| T | T | F | T | T | F | T | T |
| T | T | T | F | T | T | T | T |

# Order of Operations

Just like you were taught PEMDAS

e.g. $3 + 2 \cdot 4 = 11$ not $24$.

Logic also has order of operations.

Parentheses

Negation

And

Or, exclusive or

Implication

Biconditional

For this class: each line is its own level!
e.g. “and”s have precedence over “or”s

Within a level, apply from left to right.

Some textbooks place And, Or at the same level – it’s good practice to use parentheses even if not required.

# Logical Connectives

| | |
|---|---|
| **Negation (not)** | $\neg p$ |
| **Conjunction (and)** | $p \land q$ |
| **Disjunction (or)** | $p \lor q$ |
| **Exclusive Or** | $p \oplus q$ |
| **Implication(if-then)** | $p \longrightarrow q$ |
| **Biconditional** | $p \longleftrightarrow q$ |

These ideas have been around for so long most have at least two names.

Two more connectives to discuss!

# Biconditional: $p \leftrightarrow q$

Think: $(p \rightarrow q) \wedge (q \rightarrow p)$

*p* if and only if *q*

*p iff q*

*p* is equivalent to *q*

*p* implies *q* and *q* implies *p*

*p* is necessary and sufficient for *q*

| $p$ | $q$ | $p \leftrightarrow q$ |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

# Biconditional: $p \leftrightarrow q$

Think: $(p \rightarrow q) \wedge (q \rightarrow p)$

*p* if and only if *q*

*p iff q*

*p* is equivalent to *q*

*p* implies *q* and *q* implies *p*

*p* is necessary and sufficient for *q*

| $p$ | $q$ | $p \leftrightarrow q$ |
|---|---|---|
| **T** | **T** | **T** |
| **T** | **F** | **F** |
| **F** | **T** | **F** |
| **F** | **F** | **T** |

$p \leftrightarrow q$ is the proposition: "$p$" and "$q$" have the same truth value.

# Exclusive Or

Exactly one of the two is true.

$p \oplus q$

| $p$ | $q$ | $p \oplus q$ |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

In English "either $p$ or $q$" is the most common, but be careful.

Often translated "$p$ or $q$" where you're just supposed to understand that exclusive or is meant (instead of the normal inclusive or).

Try to say "either…or…" in your own writing.

# Exclusive Or

Exactly one of the two is true.

$p \oplus q$

| $p$ | $q$ | $p \oplus q$ |
|---|---|---|
| T | T | F |
| T | F | T |
| F | T | T |
| F | F | F |

In English "either $p$ or $q$" is the most common, but be careful.

Often translated "$p$ or $q$" where you're just supposed to understand that exclusive or is meant (instead of the normal inclusive or).

Try to say "either…or…" in your own writing.

# Active learning!

We'll pause lectures for a few minutes

Why? It works!

https://www.pnas.org/content/111/23/8410 a meta-analysis of 225 studies.

Just listening to me isn't as good for you as listening to me then trying problems on your own and with each other.

# Lecture 1 Activity

Go to pollev.com/robbie

You have to login, but no "points" are associated; these help me adjust explanation.

Introduce yourselves!

Break this sentence down into its smallest propositions and convert it into logical notation.

"If I read the book or watch the movie, then I'll know the plot."

# What’s next?

A proof!

We want to be able to make iron-clad guarantees that something is true.

And convince others that we really have ironclad guarantees.

# Todo

**Tonight:**

Make sure you can access the Ed discussion board.

If you can't, send an email to Robbie.

Make sure you can access Gradescope, and do the concept check (due date is Monday, but we encourage you to check by Friday).

If you can't, make a private post on Ed.

**Thursday:**

Go to section (in-person)

**Soon:**

Form a study group! Threads to organize on the Ed board.