Programming Languages and Techniques (CIS1200)

Lecture 1

Introduction to Program Design

Introductions

- Dr. Stephanie Weirich*
  - Levine 510
  - http://www.cis.upenn.edu/~sweirich
  - sweirich@seas.upenn.edu
  - Office hours: Tuesdays 2:30-3:30PM and by appointment

Extra Office hours TODAY: 3-4PM in Levine 510

*Pronounced phonetically as: "why rick". I won't get upset if you mispronounce my name (really!). I will answer to anything remotely close, or, you can just call me Stephanie. Whatever you feel comfortable with.

Head Teaching Assistants

Lauren Velegol

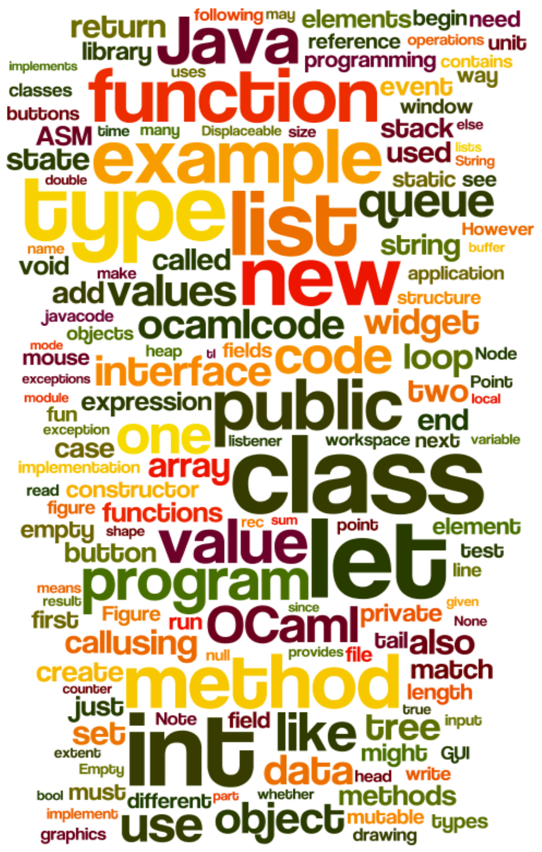
Claire Keller

Katrina Liu

Mehak Dhaliwal

What is CIS 1200?

- CIS 1200 is a course in **program design**
- Practical skills
  - ability to write larger (~1000 lines) programs
  - increased independence ("working without a recipe")
  - test-driven development, principled debugging
- Conceptual foundations
  - common data structures and algorithms
  - several different programming idioms
  - focus on modularity and compositionality
  - derived from first principles throughout
- It will be fun!



Prerequisites

- We assume you can already write small programs (10 to 100 lines) in some imperative or object-oriented language
  - Java experience is *strongly recommended*
  - CIS 1100 or AP CS is typical
  - You should be familiar with editing code and running programs in some language
- If you're wondering whether you should be in CIS 1100 or 1200, see here:
  - https://advising.cis.upenn.edu/skip-1100
  - If you still have doubts, come talk to us

CIS 1200 Tools

- OCaml
  - Industrial-strength, statically-typed ***functional*** programming language
  - Lightweight, approachable setting for learning about program design
  - Browser-based development tools: codio.com
- Java
  - Industrial-strength, statically-typed ***object-oriented*** language
  - Many tools/libraries/resources available
  - Browser-based development or local IDE

Why two languages??

- Clean pedagogical progression
- Everyone starts at the same place
- Practice in learning new tools
- New perspectives on programming

"[The OCaml part of the class] was very essential to getting fundamental ideas of comp sci across. Without the second language it is easy to fall into routine and syntax lock where you don't really understand the bigger picture.''
--- CIS 1200 Student

"[OCaml] made me better understand features of Java that seemed innate to programming, which were merely abstractions and assumptions that Java made. It made me a better Java programmer.''
--- CIS 1200 Student

Course Structure and Logistics

All course material is available on the course website

http://www.seas.upenn.edu/~cis1200/

Course Grade Components

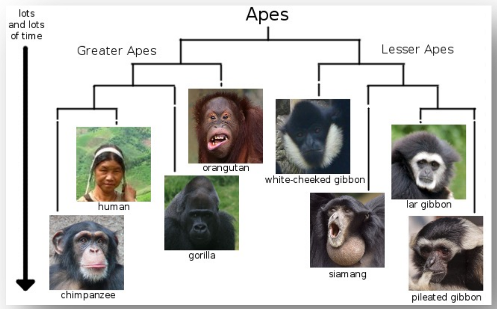
- Lectures (2% of final grade)
  - Presentation of ideas and concepts, interactive demos, etc.
  - Lecture notes, slides & video recordings available
  - Participation using “Poll Everywhere”
- Recitations / Labs (8% of final grade)
  - Practice and discussion in small group setting
  - Wed/Thurs, grade based on participation
  - Please help us rebalance, if asked
- Homework (40% of final grade)
  - Practice with individual problem solving
  - Help available from course staff in office hours
  - Due Tuesdays, grade based on automated tests + style
- Exams (50% of final grade)
  - Test foundations of program design
  - Do you understand the terminology? Can you reason about programs? Can you synthesize solutions?
  - 2 midterms (14% each, dates on website) and a final (22%, TBA)

Warning: This will be a *challenging* and *time consuming* (and rewarding) course!

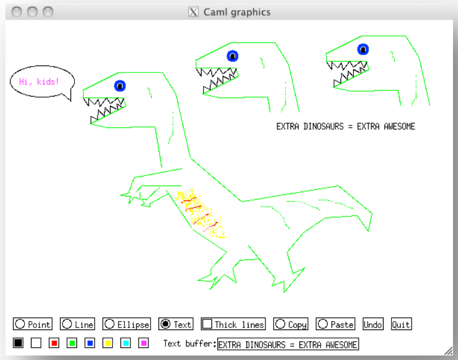
Homework: 9 programming assignments

- Submit on the course website
  - You'll get automated grade and style feedback
  - Each will have limited submission attempts
- Due at midnight (23:59pm ET) on the due date
- Standard late policy, applies to most situations
  -10 points if up to 24 hours late
  -20 points if 24-48 hours late
  no submissions accepted after that
- In ***emergencies***, contact course staff at cis1200@seas.upenn.edu

Some of the homework assignments…



Computing with DNA



Caml graphics
Hi, kids!
EXTRA DINOSAURS = EXTRA AWESOME
Point
Line
Ellipse
Text
Thick lines
Copy
Paste
Undo
Quit
Text buffer: EXTRA DINOSAURS = EXTRA AWESOME

Building a GUI Framework

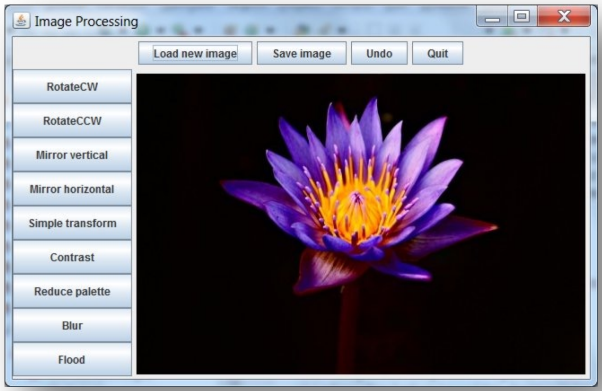
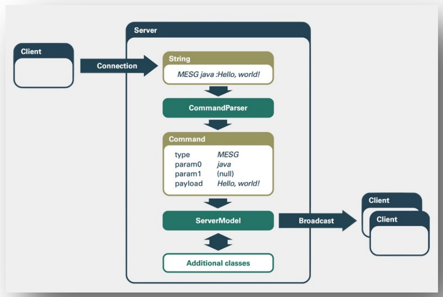
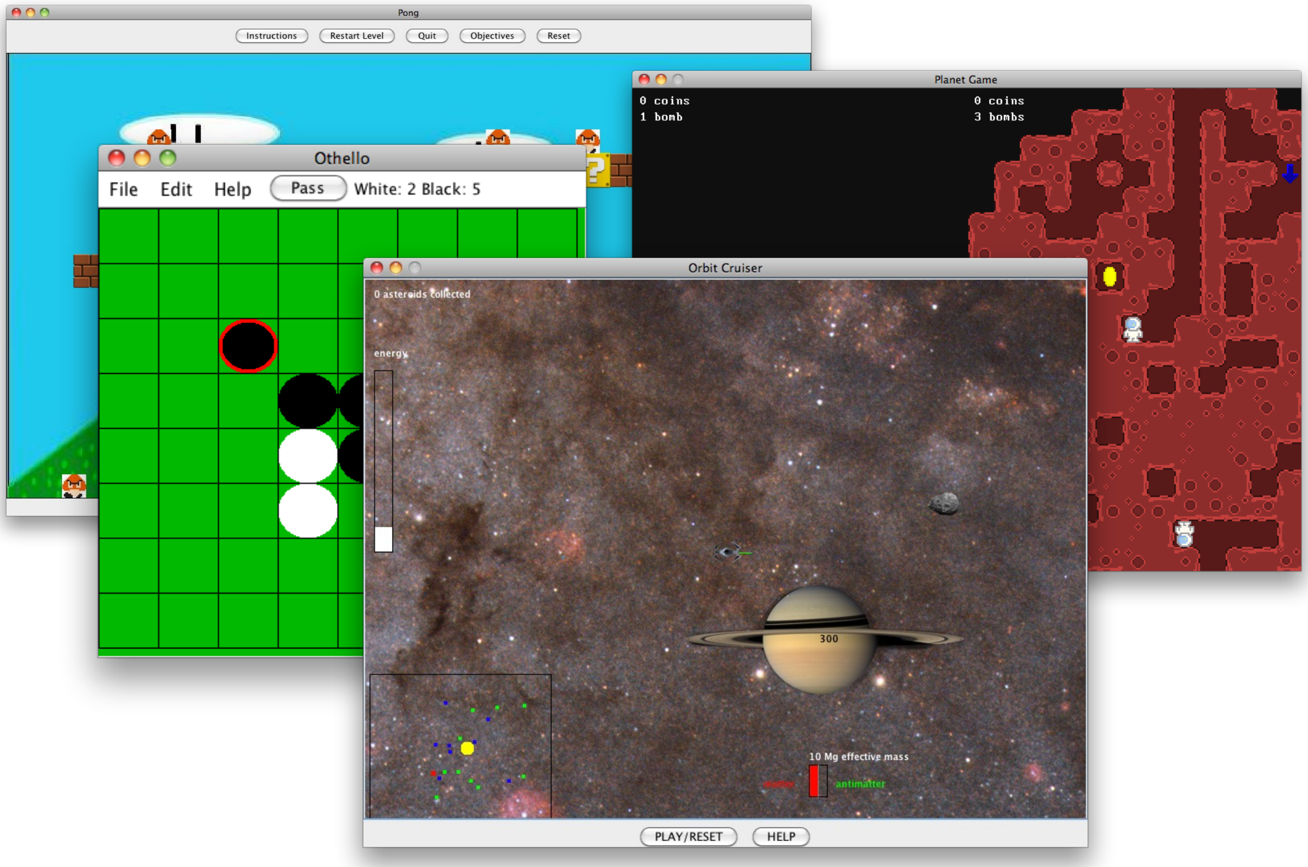


Image Processing



Chat Client/Server

Final project: Design a Game



Ed

- We use Ed for most communication in this course
  - from us to you
  - from you to us
  - from you to each other
- If already registered for the course, you should be already signed up
  - If not, you'll get added when you enroll
- Ed supports *anonymous* questions
  - Please check to see whether your question has already been asked; it helps us deliver higher quality responses

Look to Ed for course announcements,
weekly "todo" lists, reminders, etc

In-Class Announcements

Each lecture will **start** with reminders, announcements, and a short recap

- Make sure you read the syllabus on the course website before the next class

  http://www.seas.upenn.edu/~cis1200/

- If you are late to lecture, you will **miss** these announcements

Recitations / Lab Sections

- Recitations start *next week*
  - First meeting January 22/23
  - Room locations on Path@Penn
  - Please play a bit with the Codio platform before the first recitation (instructions will be posted on Ed)
- Goals of first recitation
  - Meet your TAs and classmates
  - Practice with OCaml before your first homework is due

Academic Integrity

- Submitted homework must be *your individual work*
- OK (and encouraged!)
  - Discussions of concepts
  - Discussion of debugging strategies
  - Verbally sharing experience
- Not OK
  - Copying or otherwise looking at someone else's code (including ChatGPT)
  - Sharing your code in any way (cloud drive, github, paper and pencil, …)
  - Using code from a previous semester

Penn's code of academic integrity:
https://catalog.upenn.edu/pennbook/code-of-academic-integrity/

Enforcement

- Course staff will check for copying
  - We use plagiarism-detection tools on your code

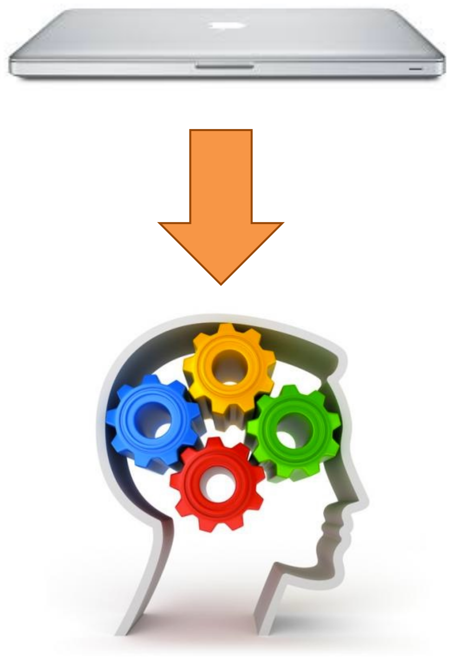
Violations will be treated seriously!

- *zero credit*
- *lowered course grade*
- *referral to Center for Community Standards and Accountability*

- *Questions? See the course FAQ. If in doubt, ask.*

No Devices during Lecture

- Laptops *closed*… minds *open*
  - Although this is a computer science class, the use of electronic devices – laptops, phones, etc., during lecture (*except for participating in polls*) is *prohibited*
- Why?
  - Device users tend to surf/chat/ email/game/text/tweet/etc.
  - They also distract those around them
  - Better to take notes *by hand*
  - You will get plenty of time in front of your computer while working on the homework :-)



Program Design

Fundamental Design Process

Design is the process of translating informal specifications ("word problems") into running code

1. *Understand* the problem
   What are we trying to achieve?
   What are the relevant concepts and how do they relate?
2. Formalize the *interface*
   How should the program interact with its environment?
3. Write *test cases*
   How does the program behave on typical inputs?
   On unusual ones? On invalid ones?
4. *Implement* the required behavior
   Often by decomposing the problem into simpler ones
   and applying the same recipe to each

A Design Problem

Imagine that you own a movie theater. The more you charge, the fewer people can afford tickets. In a recent experiment, you determined a relationship between the price of a ticket and average attendance. At a price of $5.00 per ticket, 120 people attend a performance. Decreasing the price by a dime ($.10) increases attendance by 15. However, increased attendance also comes at increased cost: each attendee costs four cents ($0.04). Every performance also has a base cost of $180.

What profit do you make at any given price?

Step 1: Understand the problem

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Calculate profit as a function of ticket price

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Step 1: Understand the problem

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What profit do you make at any given price?

Step 1: Understand the problem

What are the relationships among them?

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What profit do you make at any given price?

profit = revenue – cost
revenue = price * attendees
cost = $180 + attendees * $0.04
attendees = *some function of the ticket price*

Step 2: Formalize the Interface

Goal: write a ***function*** *that returns the profit when given the price*
Idea: we'll represent money in cents, using integers

comment documents the design decision

type annotations declare the input and output types

```
(* Money is represented in cents. *)
let profit (price : int) : int = …
```

`let` keyword indicates a top-level function or variable definition

N.b. Floating point is generally a *bad* choice for representing money: bankers use different rounding conventions than the IEEE floating point standard, and floating point arithmetic isn't as exact as you might like. Try calculating 0.1 + 0.1 + 0.1 sometime in your favorite programming language…

N.b. OCaml will let you omit type annotations for functions, but including them is *mandatory* for CIS1200. Using type annotations is good documentation; they also improve the error messages you get from the compiler. When you get a type error message from the compiler, the first thing you should do is check that your type annotations are correct.

Step 3: Write test cases

The design problem gives us an easy way to calculate the expected result for one specific test case:

Type annotations for variables are optional (but recommended)

Local variables introduced with `let … = … in` syntax

```
let profit_500 : int =
    let price     = 500 in
    let attendees = 120 in
    let revenue   = price * attendees in
    let cost      = 18000 + 4 * attendees in
    revenue - cost
```

Top-level variable defined using `let` without `in`

Write test cases

With a little thinking, we write down another test case:

```
let profit_490 : int =
    let price     = 500 - 10 in
    let attendees = 120 + 15 in
    let revenue   = price * attendees in
    let cost      = 18000 + 4 * attendees in
    revenue - cost
```

Recall: “Decreasing the price by a dime ($.10) increases attendance by 15”

Add the Test Cases to the Program

Record the test cases as *assertions*:

a *test* is a function that takes no input and returns true if the test succeeds

parentheses are only used for *disambiguation* and are not always required when calling functions

```
let test500p () : bool =
   (profit 500) = profit_500

;; run_test "profit at $5.00" test500p
```

double semicolons mark top-level commands

the command `run_test` executes a test

the string in quotes identifies the test in printed output (in case it fails)

Step 4: Implement the Behavior

profit, **revenue**, and **cost** are easy to define:

```
let attendees (price : int) : int =  …write it later…

let revenue (price : int) : int =
   price * (attendees price)

let cost (price : int) : int =
   18000 + (attendees price) * 4

let profit (price : int) : int =
   (revenue price) - (cost price)
```

Apply the Design Pattern Recursively

attendees requires a bit of thought. Start with tests…

```
let attendees (price : int) : int =
    failwith “unimplemented”

let test500a () : bool =
    (attendees 500) = 120
;; run_test "attendees at $5.00" test500a

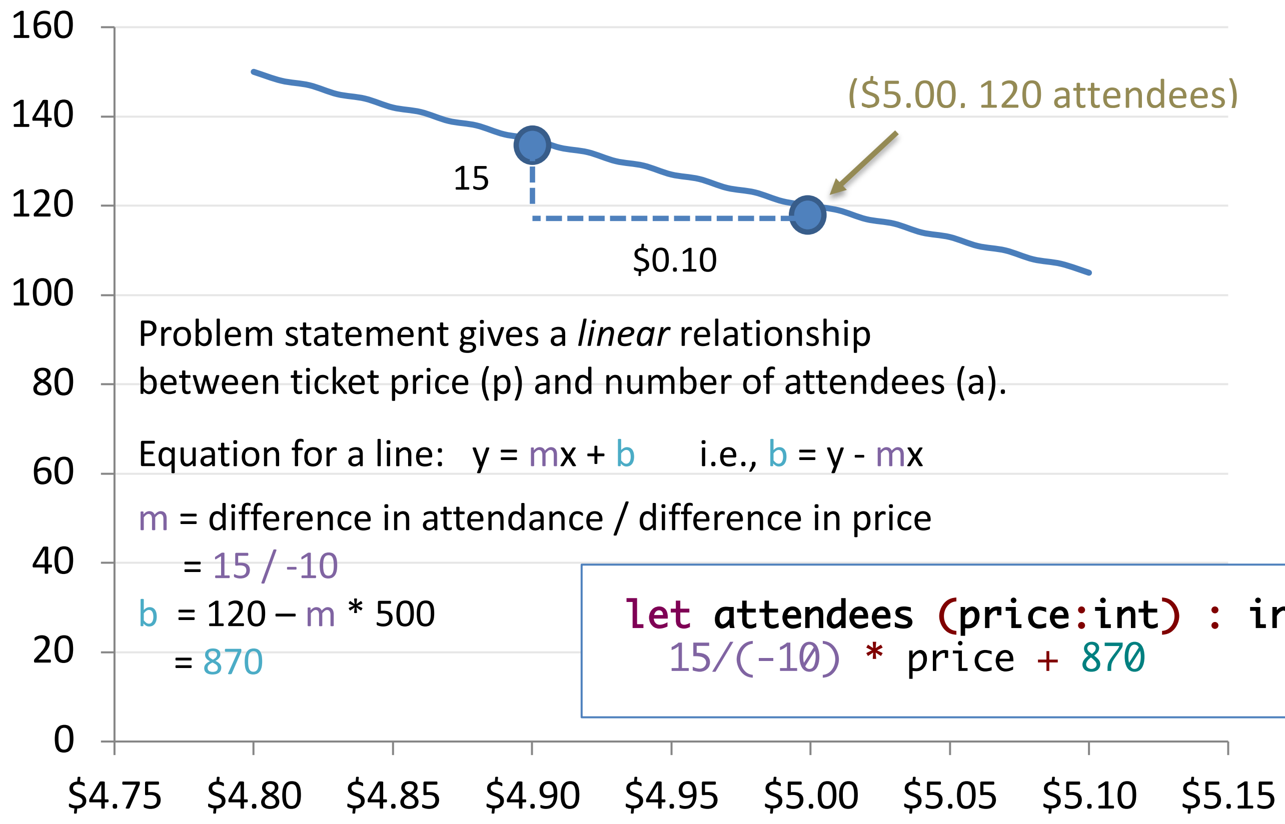
let test490a () : bool =
    (attendees 490) = 135
;; run_test "attendees at $4.90" test490a
```

“stub out” unimplemented functions

create the tests from the problem statement *first*.

*Note that the definition of attendees must go *before* the definition of profit because profit uses attendees.

Attendees vs. Ticket Price



Problem statement gives a *linear* relationship between ticket price (p) and number of attendees (a).

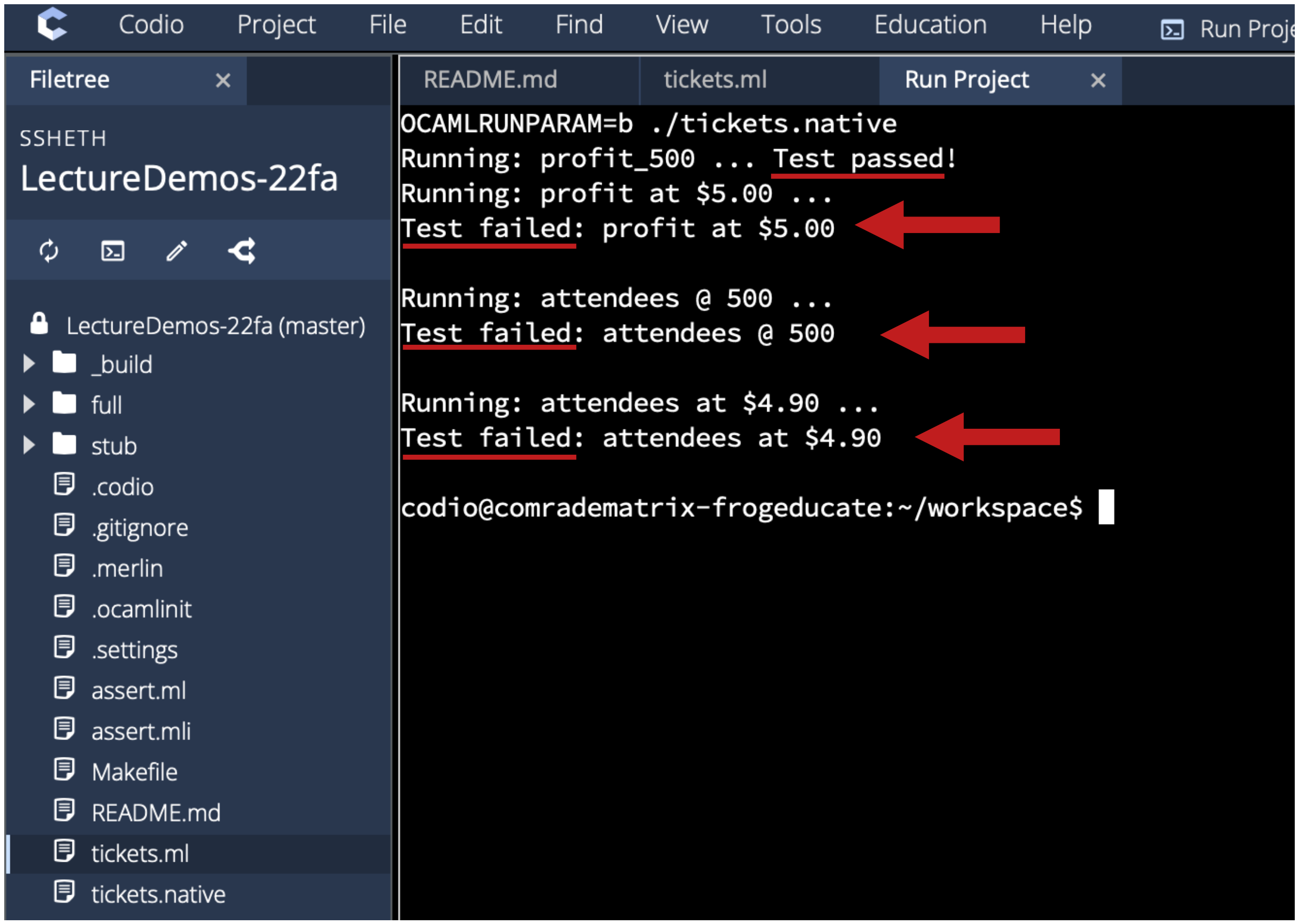
Equation for a line: y = mx + b   i.e., b = y - mx

m = difference in attendance / difference in price
  = 15 / -10

b = 120 – m * 500
  = 870

```
let attendees (price:int) : int =
  15/(-10) * price + 870
```

Run it!



```
OCAMLRUNPARAM=b ./tickets.native
Running: profit_500 ... Test passed!
Running: profit at $5.00 ...
Test failed: profit at $5.00

Running: attendees @ 500 ...
Test failed: attendees @ 500

Running: attendees at $4.90 ...
Test failed: attendees at $4.90

codio@comradematrix-frogeducate:~/workspace$
```

Uh Oh…

The test cases for attendees failed!

Why?

```
let attendees (price:int) : int =
  15/(-10) * price + 870
```

Uh Oh…

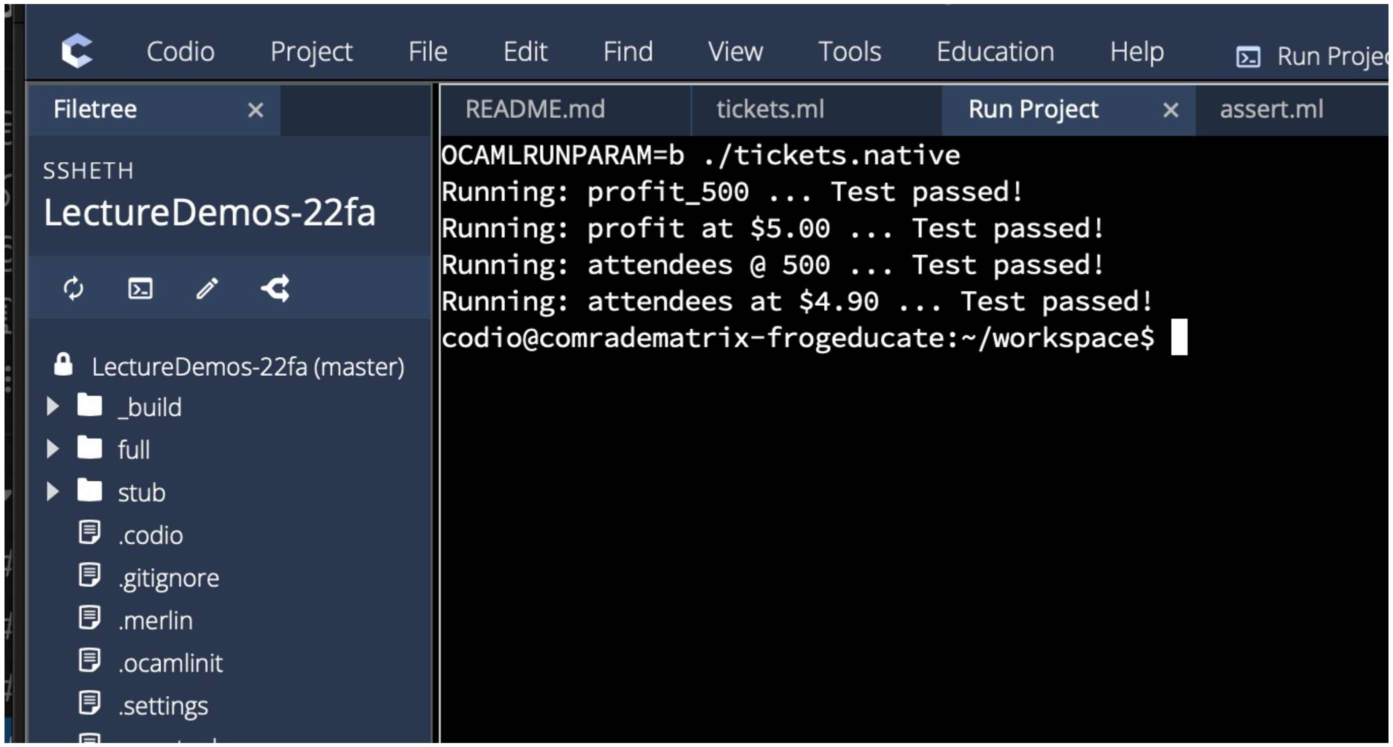
The test cases for attendees failed!

Integer division produces integers:
15 / -10 evaluates to -1, because -1.5 rounds to -1

Improved* version:

```
let attendees (price:int) : int =
    (15 * price) / (-10) + 870
```

* Multiplying `15*price` before dividing by -10 increases the precision because rounding errors don't creep in.



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Running: profit_500 ... Test passed!
Running: profit at $5.00 ... Test passed!
Running: attendees @ 500 ... Test passed!
Running: attendees at $4.90 ... Test passed!
codio@comradematrix-frogeducate:~/workspace$
```

How *Not* to Solve This Problem

This program also passes all our tests…

```
let profit price =
   price * (15 * price / (-10) + 870) -
     (18000 + 4 * (15 * price / (-10) + 870))
```

Nevertheless, it is bad because it…

– hides the structure and abstractions of the problem

– duplicates code that could be shared

– doesn’t document its interface via types and comments

Summary (I)

CIS1200 promotes a *structured design process:*

1. Understand the problem
2. Formalize the interface
3. Write test cases
4. Implement the desired behavior

Summary (II)

Modern software development relies heavily on *test-driven development* in *strongly typed languages*

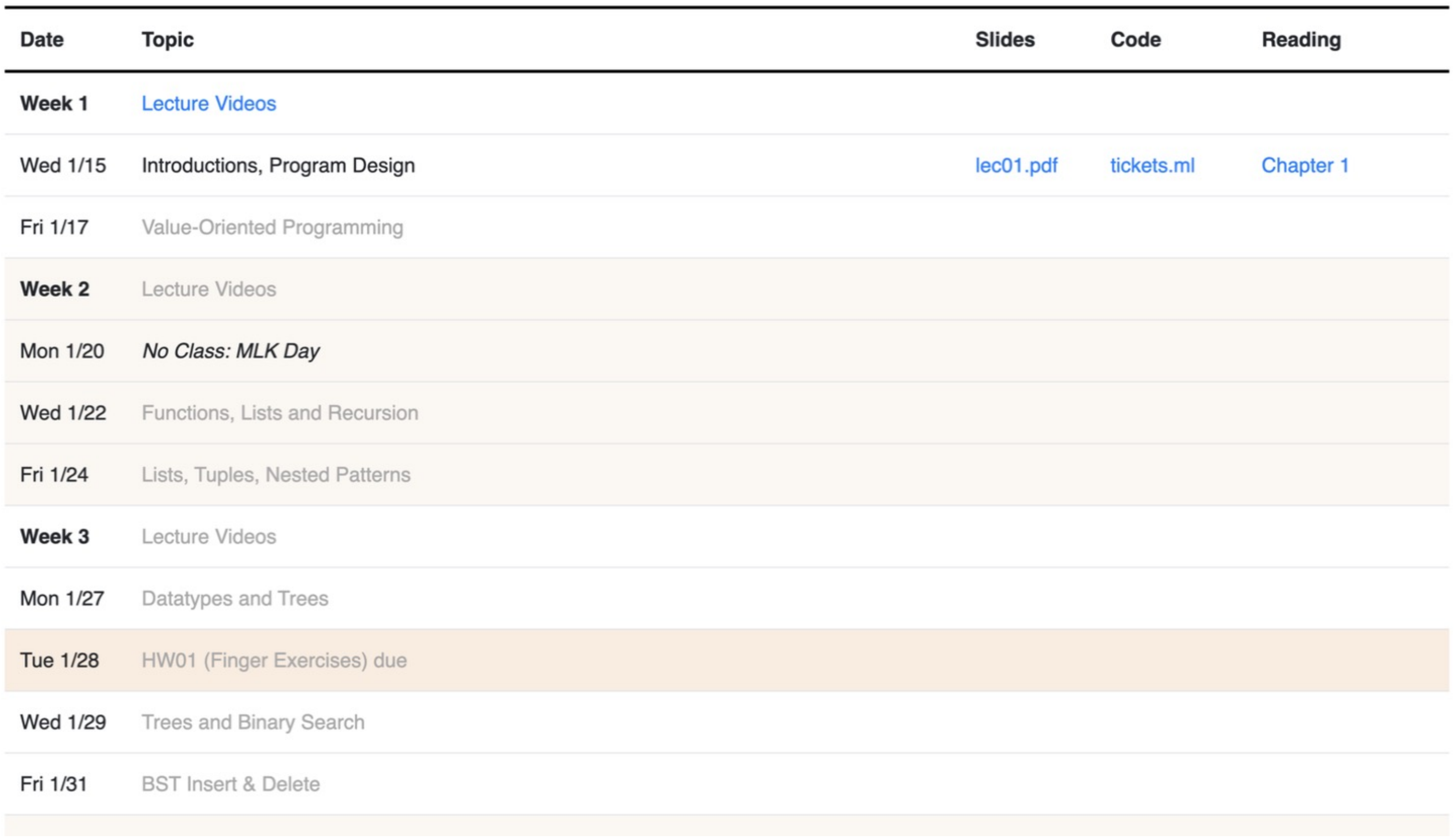
- Write tests early in the programming process and use them to drive the rest of the process

Types help structure the code.
Tests help get the details right.

For CIS 1200 homework:

- We will provide initial tests for each part of the project
- They will generally not be complete
- You should *start* each part by making up *more* tests

What's next?



Date	Topic	Slides	Code	Reading
Week 1	Lecture Videos			
Wed 1/15	Introductions, Program Design	lec01.pdf	tickets.ml	Chapter 1
Fri 1/17	Value-Oriented Programming			
Week 2	Lecture Videos			
Mon 1/20	*No Class: MLK Day*			
Wed 1/22	Functions, Lists and Recursion			
Fri 1/24	Lists, Tuples, Nested Patterns			
Week 3	Lecture Videos			
Mon 1/27	Datatypes and Trees			
Tue 1/28	HW01 (Finger Exercises) due			
Wed 1/29	Trees and Binary Search			
Fri 1/31	BST Insert & Delete			