Final Exam

Monday, December 8 1:00-3:00

open book, open notes, closed computer

comprehensive — covers the entire semester

This Course was About...

Fundamentals of programming

- From specification to implementation
- Software engineering principles

This Course was...

Not about...

- A particular programming language (e.g., Java, C++, Scheme)
- A particular programming tool (e.g., gcc, DrScheme)
- Specific libraries or protocols (e.g., Gtk, XML, HTTP)
- How programs get translated into electronic signals

Theme 1: Data Structures

Atomic data

```
num
1

string
"apple"
```

Theme 1: Data Structures

Compound data

```
; A posn is
;  (make-posn num num)

(make-posn 1 2)
```

```
class Snake {
  String name;
  double weight;
  String food;
  ...
}

new Snake("slinky", 10, "rats")
```

Theme 1: Data Structures

Inductively defined data

- Lists

```
; A list-of-num is either
;  - empty
;  - (cons num list-of-num)

(cons 1 (cons 2 empty))
```

Theme 1: Data Structures

Inductively defined data

- Lists

```
abstract class Pizza { ... }
class Crust extends Pizza {
  boolean wheat;
  ...
}
class topping extends Pizza {
  String top;
  Pizza bottom;
  ...
}

new Topping("tomato", 2, new Crust(false))
```

Theme 1: Data Structures

- Trees

```
; A rumor-mill is either
;  - empty
;  - (make-gossip string rumor-mill rumor-mill)

(make-gossip "Amir"
             (make-gossip "Joe"
                          empty
                          empty)
             (make-gossip "Linsey"
                          empty
                          empty))
```

Theme 1: Data Structures

- And more:

```
; A dir is
;  (make-dir sym lofd)

; A file is
;  (make-file sym num)

; A lofd is either
;  - empty
;  - (cons file lofd)
;  - (cons dir lofd)

(make-dir 'tmp
          (list (make-file 'preview.ps 10)
                (make-dir 'build
                          (list
                           (make-file 'x.c 30)
                           (make-file 'a.out 10)))))
```

Theme 1: Data Structures

- And more:

```
class Room {
  Door left;
  Door right;
  ... }
abstract class Door { ... }
class Escape extends Door { ... }
class Into extends Door {
  Room next;
  ...
}
...

new Into(new Room(new Escape("mars"),
                  new Escape("venus")))
```

Theme 2: Data Drives Design

Data

- Understand the input data

Contract, Purpose, and Header

- Describe (but don't write) the function

Examples

- Show what will happen when the function is done

Template

- Set up the body based on the input data (and *only* the input)

Body

- The most creative step: implement the function body

Test

- Run the examples

Theme 2: Data Drives Design

The template is a pivotal implementation step:

- Programs that match the shape of the data tend to work, and they can be understood by others
- Programs that do not match the shape of the data tend to fail in incomprehensible ways

```
; A list-of-num is either
;  - empty
;  - (cons num list-of-num)

; func : list-of-num -> ...
(define (func l)
  (cond
    [(empty? l) ...]
    [else (first l) ... (func (rest l)) ...]))
```

Theme 2: Data Drives Design

```
; A dir is
;  (make-dir sym lofd)

; A file is
;  (make-file sym num)

; A lofd is either
;  - empty
;  - (cons file lofd)
;  - (cons dir lofd)
```

```
; dir-func : dir -> ...
(define (dir-func d)
  ... (dir-name d)
  ... (lofd-func (dir-content d)) ...)

; file-func : file -> ...
(define (file-func f)
  ... (file-name f) ... (file-size f))

; lofd-func : lofd -> ...
(define (lofd-func l)
  (cond
    [(empty? l) ...]
    [(file? (first l))
     ... (file-func (first l))
     ... (lofd-func (rest l))]
    [(dir? (first l))
     ... (dir-func (first l))
     ... (lofd-func (rest l))]))
```

Theme 2: Data Drives Design

```
class Room {
  Door left;
  Door right; ...
  Path escapePath(Person p) {
    ... left.escapePath(p)
    ... right.escapePath(p) ...
  }
}

abstract class Door {
  abstract Path escapePath(Person p);
}
class Escape extends Door { ...
  Path escapePath(Person p) { ... }
}
class Into extends Door {
  Room next; ...
  Path escapePath(Person p) {
    ... next.escapePath(p) ...
  }
}
```

Theme 2: Data Drives Design

Good Java style essentially forces you to follow the template

Following the template essentially forces good Java style

Theme 3: Contracts

A contract specifies, *in advance*

- Obligations of a producer
- Restrictions for a consumer

```
; disk-usage : dir -> num
```

```
(define (disk-usage d)
  (foldr (lambda (f n)
           (+ n (file-size f)))
         0
         (dir-content d)))
```

Producer error: **`disk-usage`** should work on any **`dir`**

Theme 3: Contracts

A contract specifies, *in advance*

- Obligations of a producer
- Restrictions for a consumer

```
; disk-usage : dir -> num
```

```
...
(disk-usage (make-snake 'Slinky 10 'rats))
```

Consumer error: **disk-usage** accepts only **dir**s

Theme 3: Contracts

A contract identifies the relevant data definition

- for examples
- for the implementation (template)
- for testing — helps ensure coverage

```
; disk-usage : dir -> num
(define (disk-usage d)
  ... (dir-name d)
  ... (lofd-usage (dir-content d)) ...)
...
(disk-usage (make-dir 'home empty))
"should be" 0
```

Theme 3: Contracts

A contract identifies the relevant data definition

- for examples
- for the implementation (template)
- for testing — helps ensure coverage

Incorrect and abused contracts were the primary source of homework difficulties

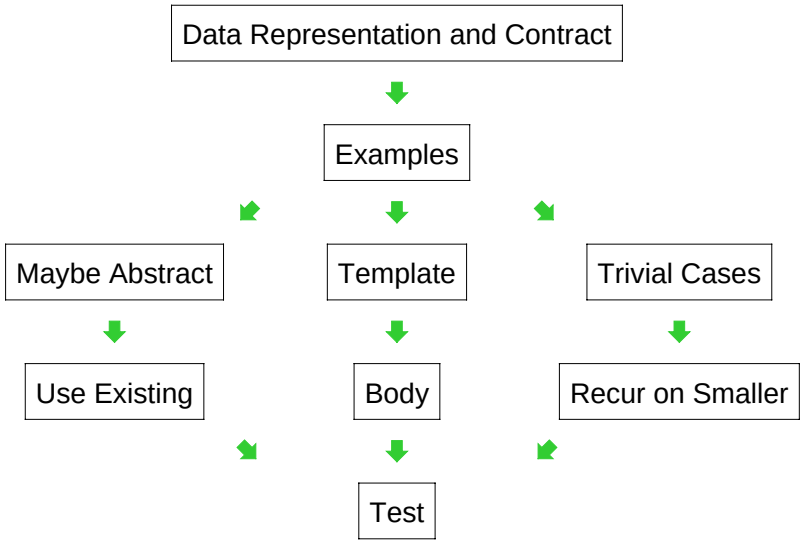
Theme 4: Reuse

Armed with data definitions and templates, you can write most things from scratch...

...but you shouldn't

If nothing else, cut and paste (or deja vu) should trigger reuse

Theme 4: Reuse



Theme 4: Reuse

Reuse from abstraction:

```
; sum : list-of-num -> num
(define (sum l)
  (cond
    [(empty? l) 0]
    [(cons? l)
     (+ (first l)
        (sum (rest l)))]))

; product : list-of-num -> num
(define (product l)
  (cond
    [(empty? l) 1]
    [(cons? l)
     (* (first l)
        (product (rest l)))]))
```

```
; combine-nums : list-of-num
;   (num num -> num) -> num
(define (combine-nums l base-n COMB)
  (cond
    [(empty? l) base-n]
    [(cons? l)
     (COMB (first l)
           (combine-nums (rest l)
                         base-n
                         COMB))]))

; sum : list-of-num -> num
(define (sum l)
  (combine-nums l 0 +))

; product : list-of-num -> num
(define (product l)
  (combine-nums l 1 *))
```

Theme 4: Reuse

Reuse from existing abstractions:

```
; sum : list-of-num -> num
(define (sum l)
  (foldr + l 0))

; product : list-of-num -> num
(define (product l)
  (foldr * l 1))
```

Theme 4: Reuse

Reuse from existing abstractions:

```
int sum(List l) {
  Enumerator e = l.elements();
  int s = 0;
  while (e.hasMoreElements()) {
    Integer i = (Integer)e.nextElement();
    s = s + i.intValue();
  }
  return s;
}
```

Theme 4: Reuse

Reuse by class extension:

```
class Into extends Door {
  ...
  Path escapePath(Person p) {
    return this.next.escapePath(p);
  }
}

class Short extends Into {
  ...
  Path escapePath(Person p) {
   if (p.height <= this.height)
     return super.escapePath(p);
   else
     return new Fail();
  }
  // everything else is like Into
}
```

Theme 5: Creativity

A good design process focuses your energy on two deeply creative problems:

- choosing and defining a data representation
- implementing the body of a function/method

Theme 5: Creativity

Problem: choose a data definition for mazes

```
class Room {
  Door left;
  Door right;
  ... }
abstract class Door { ... }
class Escape extends Door { ... }
class Into extends Door {
  Room next;
  ...
}
...
```

Theme 5: Creativity

Problem: combine images to check for disguises

```
; same-person-maybe-disguised? :
; image image image image -> bool
(define (same-person-maybe-disguised? p p2 g b)
  (or (image=? p p2)
      (wearing-glasses? p p2 g)
      (wearing-beard? p p2 b)
      (image=? p (add-beard (add-glasses p2 g) b))))
```

- Which part was automatic from contracts?
- Which part required creativity?

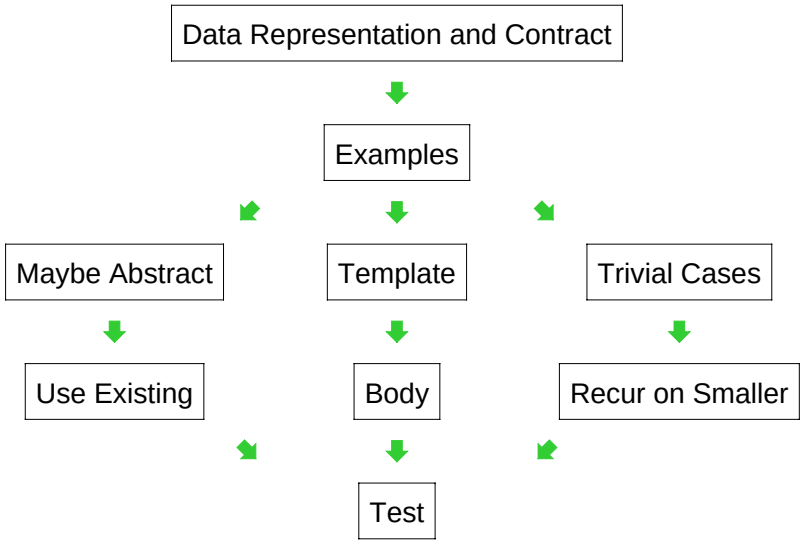
Theme 5: Creativity

Problem: produce an image's negative


```
; photo-negative : image -> image
(define (photo-negative i)
  (color-list->image
   (negate-colors (image->color-list i))
   (image-width i)
   (image-height i)))
```

- Which part was automatic from contracts?
- Which part required creativity?

Theme 5: Creativity



Theme 6: Programming Tools

- Structures
- Functions
- Classes
- Methods
- Contracts in comments and code
- Local declarations
- Assignment

- Computational complexity

Themes in the Final Exam

Expect the final exam to hit all of these themes:

- Data Structures
- Data Drives Design
- Contracts
- Reuse
- Creativity
- Programming Tools

More details next time