Lists vs. Structures

CS 5010 Program Design Paradigms

Lesson 6.1

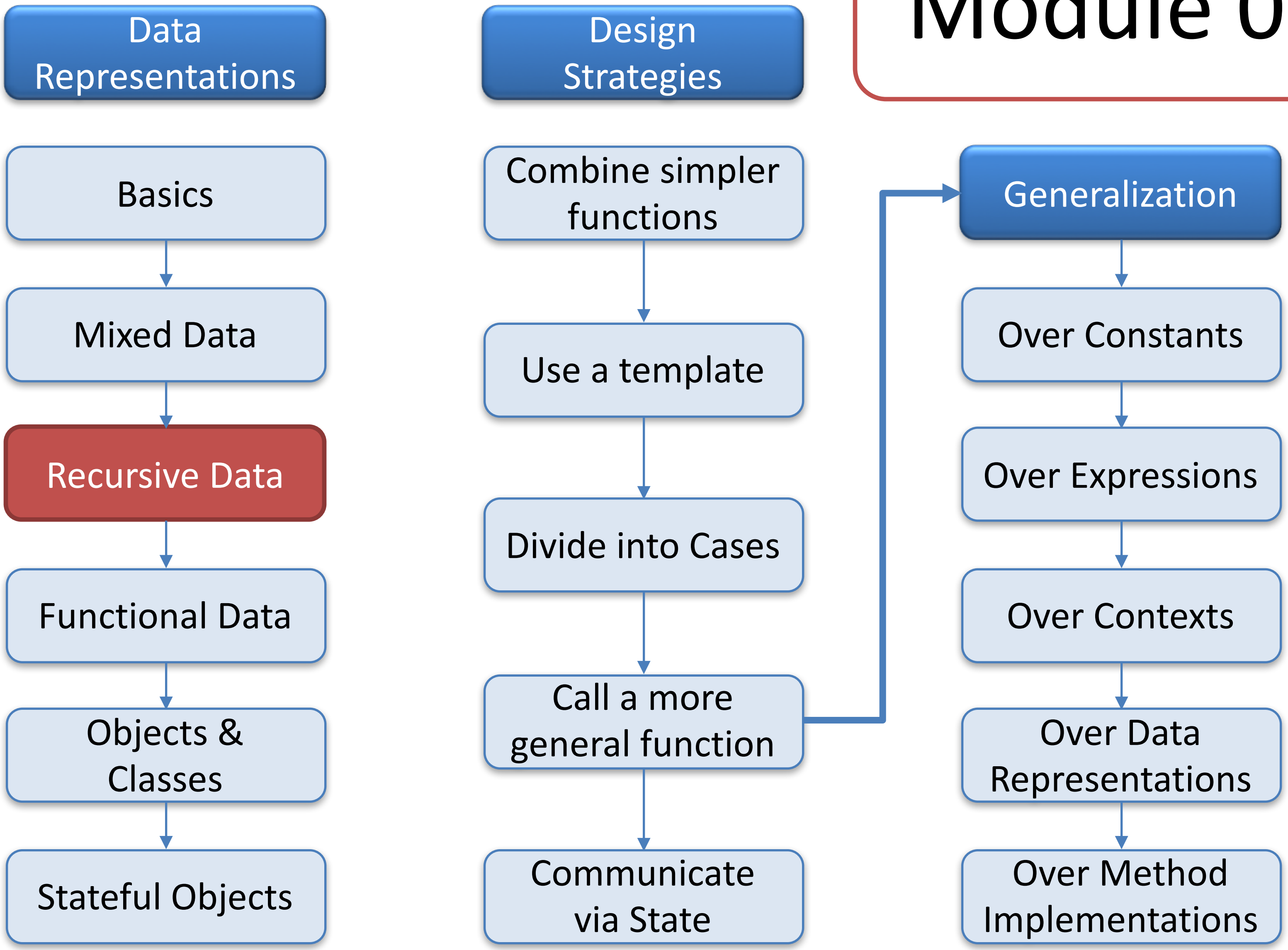
Module Introduction

- In this module we will learn about two related topics:
    - branching structures, such as trees
    - mutually recursive data definitions, such as lists of alternating strings and numbers.

Module Outline

- Lesson 6.1 begins by considering alternative representations for sequence information
  - This is a warm-up for Lessons 6.2-6.3
- Lessons 6.2 and 6.3 show how to represent information that has a naturally branching structure, such as trees
- Lesson 6.4 introduces mutually-recursive data definitions
- Lesson 6.5 applies these ideas to S-expressions
  - S-expressions are nested lists
  - These are the basis for XML and JSON
- Lesson 6.6 combines all these ideas into a case study
- Lesson 6.7 shows how to write halting measures for tree-like structures.

Module 06



Data Representations

- Basics
- Mixed Data
- Recursive Data
- Functional Data
- Objects & Classes
- Stateful Objects

Design Strategies

- Combine simpler functions
- Use a template
- Divide into Cases
- Call a more general function
- Communicate via State

Generalization

- Over Constants
- Over Expressions
- Over Contexts
- Over Data Representations
- Over Method Implementations

Lesson Introduction

- We've already studied how to represent sequences of data using lists.
- In this lesson, we will explore how to represent sequences of data using structures, like those we studied in Week 1, instead of lists.
- This is useful because many widely-used languages do not have built-in lists that we can use.

Learning Objectives for this Lesson

- At the end of this lesson the student should be able to:
  - convert a data definition using the **ListOfX** pattern to a recursive data definition using structures
  - write a template for a recursive data definition using structures

Recall our pizzas

```
;; A Topping is a String.

;; A Pizza is a ListOfTopping
;; interp: a pizza is a list of toppings, listed from top to bottom

;; pizza-fn : Pizza -> ??
; Given a Pizza, produce ....
;; (define (pizza-fn p)
;;   (cond
;;     [(empty? p) ...]
;;     [else (... (first p)
;;                (pizza-fn (rest p)))]))

;; Examples:
(define plain-pizza empty)
(define cheese-pizza (list "cheese"))
(define anchovices-cheese-pizza (list "anchovies" "cheese")
```

In Module 4, we represented a pizza as a list of toppings. This week, we will use this example to study the structure representation.

What if Racket didn't have cons?

- If Racket didn't have **cons**, we could still represent pizzas as mixed data, using a structure to represent a non-empty pizza.
- On the next slide, we'll see what the data definition would look like.
- We haven't written the template yet; we'll get to that soon.

What if Racket didn't have cons?

We could still write a data definition:

```
(define-struct plain-pizza ())
(define-struct topped-pizza (topping base))

A Topping is a String.

A Pizza is either
-- (make-plain-pizza)
-- (make-topped-pizza Topping Pizza)
Interp:
(make-plain-pizza)  represents a pizza with no toppings
(make-topped-pizza t p) represents a pizza like p,
                        but with topping t added on top.
```

This representation, using a set of alternatives each of which is a struct, is a standard strategy, sometimes called the "sum of products" representation. HINT: You won't go wrong if you use this as your default representation for data in Racket.

This data definition is *self-referential*

```
(define-struct topped-pizza (topping base))
A Topping is a String.
A Pizza is either
-- (make-plain-pizza)
-- (make-topped-pizza Topping Pizza)
```

This data definition is self-referential, just like **ListofToppings** was.

```
compare:

A ListOfToppings is either
-- empty
-- (cons Topping ListOfToppings)
```

Examples

Here are some examples of pizzas according to our new data definition.

```
                                    (make-plain-pizza)

    (make-topped-pizza "cheese" (make-plain-pizza))

  (make-topped-pizza "anchovies"
    (make-topped-pizza "cheese" (make-plain-pizza)))

(make-topped-pizza "onions"
  (make-topped-pizza "anchovies"
    (make-topped-pizza "cheese" (make-plain-pizza))))
```

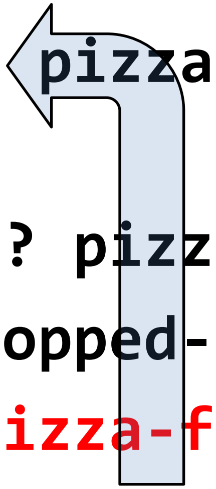
```
A Pizza is either
-- (make-plain-pizza)
-- (make-topped-pizza Topping Pizza)
```

Can you see why each of these is a Pizza, according to our new definition?

Template for pizza functions

```
pizza-fn : Pizza -> ??
(define (pizza-fn p)
  (cond
    [(plain-pizza? p) ...]
    [else (... (topped-pizza-topping p)
               (pizza-fn
                 (topped-pizza-base p)))]))
```

This template is *self-referential*



```
pizza-fn : Pizza -> ??
(define (pizza-fn pizza)
  (cond
    [(plain-pizza? pizza) ...]
    [else (... (topped-pizza-topping pizza)
               (pizza-fn
                 (topped-pizza-base pizza)))]))
```

We also call this a *recursive* template

Lists vs Structures: Data Definitions

```
A ListOfToppings (LoT) is
  either
-- empty
-- (cons Topping LoT)


Interp:
-- empty represents a pizza
   with no toppings
-- (cons t p)
represents the pizza p with
   topping t added on top.
```

```
A Pizza is either

-- (make-plain-pizza)
-- (make-topped-pizza
          Topping Pizza)


Interp:
(make-plain-pizza) represents
   a pizza with no toppings
(make-topped-pizza t p)
   represents the pizza p with
   topping t added on top.
```

Observe that both data definitions are self-referential in the same way.
You could represent pizzas either by lists or structures.

Lists vs. Structures: Templates

```
pizza-fn : Pizza -> ??
(define (pizza-fn p)
  (cond
    [(empty? p)
     ...]
    [else
     (...
       (first p)
       (pizza-fn
         (rest p)))]))
```

```
pizza-fn : Pizza -> ??
(define (pizza-fn p)
  (cond
    [(plain-pizza? p)
     ...]
    [else
     (...
      (topped-pizza-
        topping p)
      (pizza-fn
       (topped-pizza-base
         p)))]))
```

And here are the templates. Observe that they are also both self-referential in the same way.

Lists vs. Structures: Halting Measures

- For the list representation, we could use "length of the list" as a halting measure
- For the structure representation, we could use "number of toppings" as a halting measure.
- These will be a correct halting measure for any function that follows the template.

Lists vs. Structures: The Choice

- Use structures for compound information with a fixed size or fixed number of components.
- Use lists for homogeneous sequences of data items.
  - so we'll use mostly lists
  - DON’T use lists for data of fixed size or a fixed number of components
- Each language has its own idioms
  - some don't have lists at all
  - some have other ways of representing sequences– use them when possible

Summary

- You should now be able to
  - convert a data definition using the **ListOfX** pattern to a recursive data definition using structures
  - write a template for a recursive data definition using structures

Next Steps

- Study the file 06-1-recursive-structures.rkt in the Examples folder.
- If you have questions about this lesson, ask them on the Discussion Board
- Do Guided Practice 6.1
- Go on to the next lesson