Lab 1: CSG 711: Programming to Structure

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Using Dr. Scheme

- context-sensitive help
- use F1 as your mouse is on an identifier. HelpDesk is language sensitive. Be patient.
- try the stepper
- develop programs incrementally
- definition and use: Check Syntax
- use 299 / intermediate with lambda

General Recipe

- Write down the requirements for a function in a suitable mathematical notation.
- Structural design recipe: page 368/369 HtDP

Designing Algorithms

- Data analysis and design
- Contract, purpose header
- Function examples
- Template
- Definition
  - what is a trivially solvable problem?
  - what is a corresponding solution?
  - how do we generate new problems
  - need to combine solutions of subproblems
- Test

Template

```
(define (generative-rec-fun problem)
  (cond
    [(trivially-solvable? problem)
      (determine-solution problem)]
    [else
     (combine-solutions … problem …
      (generative-rec-fun (gen-pr-1 problem))
      …
      (generative-rec-fun (gen-pr-n problem)))]))
```

Template for list-processing

```
(define (generative-rec-fun problem)
  (cond
    [(empty? problem) (determine-solution
   problem)]
   [else
     (combine-solutions
        problem
        (generative-rec-fun (rest problem)))]))
```

duple (EOPL page 24)

(duple n x)

li:= empty;

for i :=1 to n do add x to li (does not matter where);

Structural recursion:

if i=0 empty

else (cons x (duple (- n 1))

History (Programming to Structure)

- Frege: Begriffsschrift 1879: “The meaning of a phrase is a function of the meanings of its immediate constituents.”
- Example:

AppleList : Mycons | Myempty.

Mycons = <first> Apple <rest> AppleList.

Apple = <weight> int.

Myempty = .

Meaning of a list of apples? Total weight

- (tWeight al)
  - [(Myempty? al) 0]
  - [(Mycons? al)

    (Apple-weight(Mycons-first al))

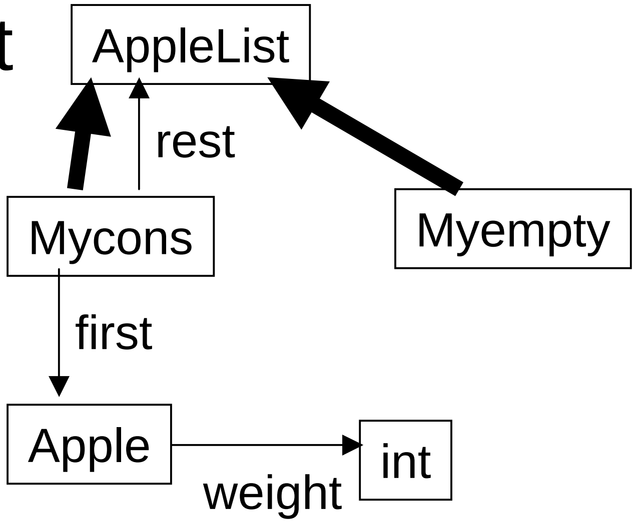
    // meaning of first constituent

    \+

    (tWeight(Mycons-rest al))]

    // meaning of rest constituent

```
AppleList : Mycons | Myempty.
Mycons = <first> Apple <rest> AppleList.
Apple = <weight>  int.
Myempty = .
```



PL independent

In Scheme: Structure

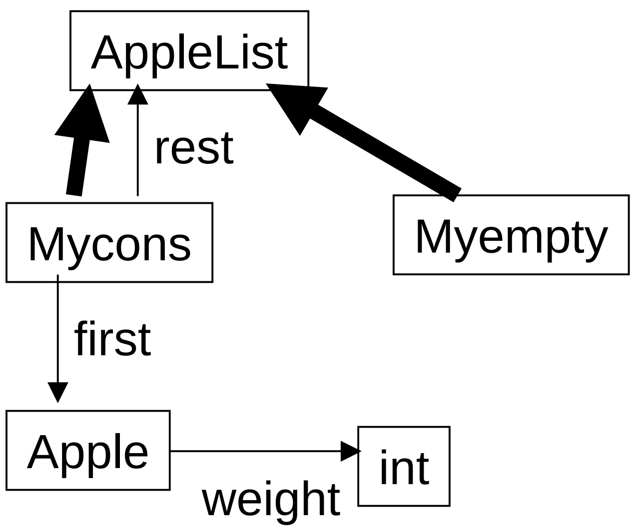
```
(define-struct Mycons (first rest))
(define-struct Apple (weight))
(define-struct Myempty ())
```

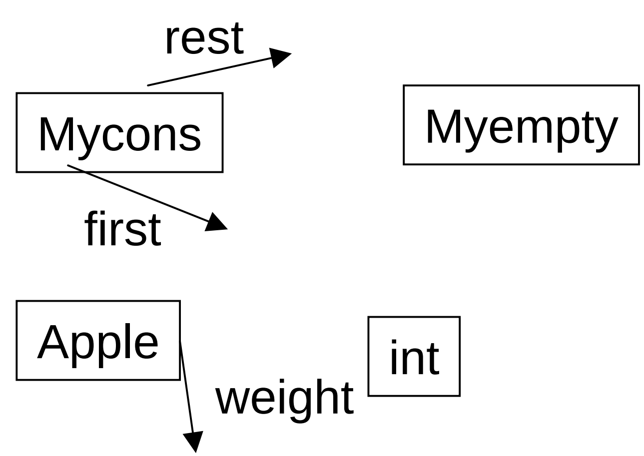
Design Information

AppleList : Mycons | Myempty.
Mycons = <first> Apple <rest> AppleList.
Apple = <weight> int.
Myempty = .

Scheme solution

(define-struct Mycons (first rest))
(define-struct Apple (weight))
(define-struct Myempty ())





In Scheme: Behavior

```
(define (tWeight al)
  (cond
    [(Myempty? al) 0]
    [(Mycons? al) (+
        (Apple-weight (Mycons-first al))
        (tWeight (Mycons-rest al)))]))
```

In Scheme: Testing

(define list1 (make-Mycons (make-Apple 111) (make-Myempty)))

(tWeight list1)

111

(define list2 (make-Mycons (make-Apple 50) list1))

(tWeight list2)

161

Note: A test should return a Boolean value.

See tutorial by Alex Friedman on testing in DrScheme.

Reflection on Scheme solution

- Program follows structure
- Design translated somewhat elegantly into program.
- Dynamic programming language style.
- But the solution has problems!

Behavior

- While the purpose of this lab is programming to structure, the Scheme solution uses too much structure!

```
(define (tWeight al)
  (cond
    [(Myempty? al) 0]
    [(Mycons? al) (+
         (Apple-weight (Mycons-first al))
         (tWeight (Mycons-rest al)))]))
```

duplicates all of it!

How can we reduce the duplication of structure?

- First small step: Express all of structure in programming language once.
- Eliminate conditional!
- Implementation of tWeight() has a method for Mycons and Myempty.
- Extensible by addition not modification.
- Big win of OO.

Solution in Java

```
AppleList: abstract int tWeight();
Mycons: int tWeight() {
  return (first.tWeight() + rest.tWeight());
}
Myempty: int tWeight() {return 0;}
```

\+

```
AppleList : Mycons | Myempty.
Mycons = <first> Apple <rest> AppleList.
Apple = <weight>  int.
Myempty = .
```

translated
to Java

What is better?

- structure-shyness has improved.
- No longer enumerate alternatives in functions.
- Better follow principle of single point of control (of structure).

Problem to think about (while you do hw 1)

- Consider the following two Shape definitions.
  - in the first, a combination consists of exactly two shapes.
  - in the other, a combination consists of zero or more shapes.
- Is it possible to write a program that works correctly for both shape definitions?

First Shape

Shape : Rectangle | Circle | Combination.

Rectangle = "rectangle" <x> int <y> int <width> int <height> int.

Circle = "circle" <x> int <y> int <radius> int.

Combination = "(" <top> Shape <bottom> Shape ")".

Second Shape

Shape : Rectangle | Circle | Combination.

Rectangle = "rectangle" <x> int <y> int

<width> int <height> int.

Circle = "circle" <x> int <y> int

<radius> int.

Combination = "(" List(Shape) ")".

List(S) ~ {S}.

Input (for both Shapes)

```
(
  rectangle 1 2 3 4
  (
    circle 3 2 1
    rectangle 4 3 2 1
  )
)
```

Think of a shape as a list!

- A shape is a list of rectangles and circles.
- Visit the elements of the list to solve the area, inside and bounding box problems.

Help with the at function

- Design the function at. It consumes a set S and a relation R. Its purpose is to collect all the seconds from all tuples in R whose first is a member of S.

Deriving Scheme solution (1)

```
at: s: Set r: Relation
Set s0 = {};
  from r:Relation to p:Pair:
    if (p.first in s) s0.add(p.second);
return s0;
```

definition

```
at: s: Set r: Relation
if empty(r) return empty set else {
  Set s0 = {}; p1 := r.first();
  if (p1.first in s) s0.add(p1.second);
  return union(s0, at(s, rest(r))}
```

decompose based
on structure of a relation:
either it is empty or
has a first element

Deriving Scheme solution (2)

```
at: s: Set r: Relation
Set s0 = {};
  from r:Relation to p:Pair:
    if (p.first in s) s0.add(p.second);
return s0;
```

definition

Why not implement this definition directly using iteration ???

```
at: s: Set r: Relation
if empty(r) return empty set else {
  p1 := r.first(); rst = at(s, rest(r));
  if (p1.first in s)  return rst.add(p1.second) else rst}
```

decompose based
on structure of a relation:
either it is empty or
has a first element

Close to final solution

```
;; at : Symbol Relation -> Set
(define (at s R)
  (cond
    [(empty? R) empty-set]
    [else (local ((define p1 (first R))
                  (define rst (at s (rest R))))
            (if (element-of (first p1) s)
                (add-element (second p1) rst)
                rst))]))
```

```
at: s: Set r: Relation
if empty(r) return empty set else {
  p1 := r.first(); rst = at(s, rest(r));
  if (p1.first in s)  return rst.add(p.second)
    else rst}
```

dot example

- Compute the composition of two relations.
- r and s are relations. r.s (dot r s) is the relation t such that x t z holds iff there exists a y so that x r y and y s z.

Why not implement iterative solution?

```
dot Relation r1, r2
Relation r0 = {};
from r1: Relation to p1: Pair
  from r2: Relation to p2: Pair
    if (= p1.second p2.first) r0.add( new Pair(p1.first,p2.second));
return r0;

if empty(r1) return empty-set else
;; there must be a first element p11 in r1
  Relation r0 = empty-set;
  from r2: Relation to p2: Pair
    if (= p11.second p2.first) r0.add(new Pair(p11.first,p2.second));
return union (r0, dot((rest r1),r2));
```

Closer to Scheme solution: reuse at

```
dot Relation r, s;
if empty(r) return empty-set else
;; there must be a first element fst in r
  x=fst.first; y=fst.second;
  zs = at(list(y), s);
  turn x and zs into list of pairs: r0;
  return union (r0, dot((rest r),s));
```

Scheme solution

```
(define (dot.v0 r s)
  (cond
    [(empty? r) empty]
    [else (local ((define fst (first r))
            (define x (first fst))
            (define y (second fst))
            (define zs (at (list y) s)))
             (union (map (lambda (s) (list x s)) zs)
                    (dot.v0 (rest r) s)))]))
```

Save for later

Abstractions

- abstraction through parameterization:
  - planned modification points
- aspect-oriented abstractions:
  - unplanned extension points

Structure

- The Scheme program has lost information that was available at design time.
  – The first line is missing in structure definition.
  – Scheme allows us to put anything into the fields.

```
AppleList : Mycons | Myempty.
Mycons = <first> Apple <rest> AppleList.
Apple = <weight>  int.
Myempty = .
```

Information can be expressed in Scheme

- Dynamic tests
- Using object system