Standardizing RPAL AST's

Programming Languages
Lecture 6

Adeesha Wijayasiri

The Semantics of RPAL

We use the operational approach:

To specify the semantics of a language, we give an OPERATIONAL PROCESS.

PL constructs are "denoted" with functions whose behavior specify the meaning of the program.

The RPAL Operational Specification

- In the case of RPAL, the process is
    1. Scan and parse the program, transduce to a tree.
    2. Standardize the tree.

The RPAL Operational Specification (cont'd)

3. Flatten the tree into either:
    a. A lambda expression.
    b. Control Structures for a machine (more later)

- Important:
    - RPAL = lambda-calculus + syntactic sugar

Standardizing an RPAL AST

- "Desugar" the tree.
- Transform into a binary tree, whose internal nodes are exclusively 'gamma' and 'lambda'.

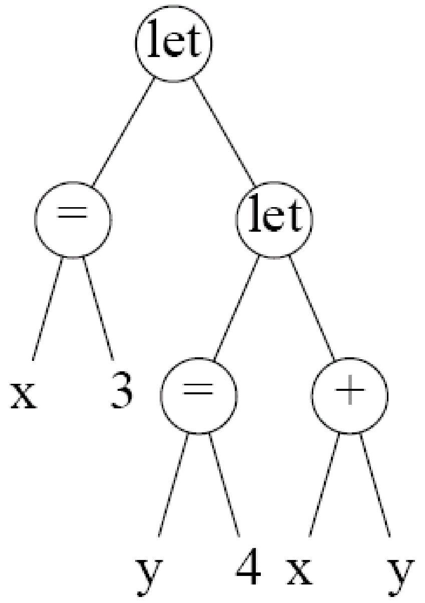
Standardizing 'let' and 'where'

- See example

```
  let            gamma         where
  /\                 /\           /\
  =  P  =>  lambda   E    <=   P   =
 /\              / \                /\
X   E           X   P            X   E
```

Standardizing 'let' and 'where':

```
let x=3 in let y=4 in x+y
```



Standardizing 'fcn_form'

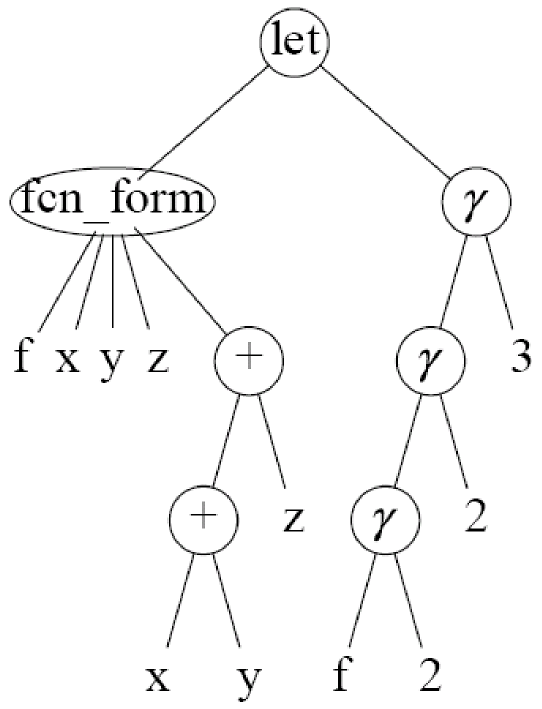
- See example

```
    fcn_form                 =
 /   |  \                   / \
    P   V+   E     =>      P   +lambda
                                  / \
                                 V   .E
```

- V+ means "one or more", to be repeated likewise on right side.
- The 'dot' indicates the location of the pattern's repetition.

Standardizing 'fcn_form':

```
let f x y z = x+y+z in f 1 2 3
```



Standardizing Tuples

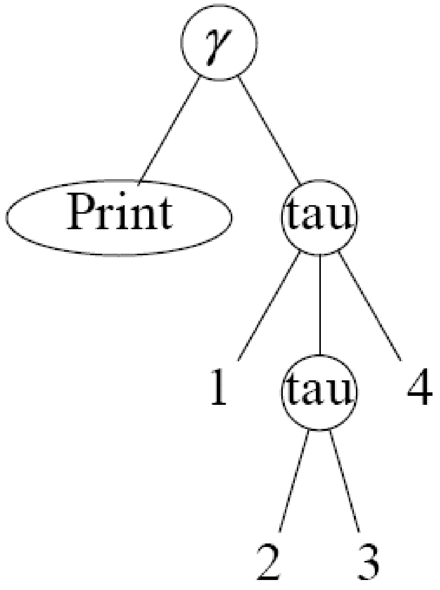
- See example

```
tau    =>      ++gamma
 |               / \
 E++          gamma   E
                / \
           aug   .nil
```

E++ means “two or more” E’s.

Standardizing tuples:

```
Print (1,(2,3),4)
```



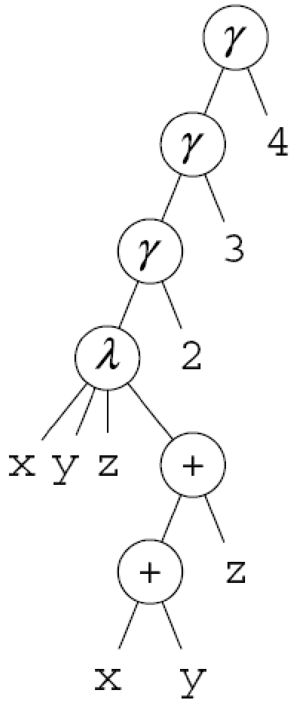
Standardizing Multi-Parameter Functions

- See example

```
   lambda   =>   ++lambda
  /  \              /  \
V++   E            V    .E
```

Standardizing multi-parameter functions:

```
(fn x y z. x + y + z) 2 3 4
```



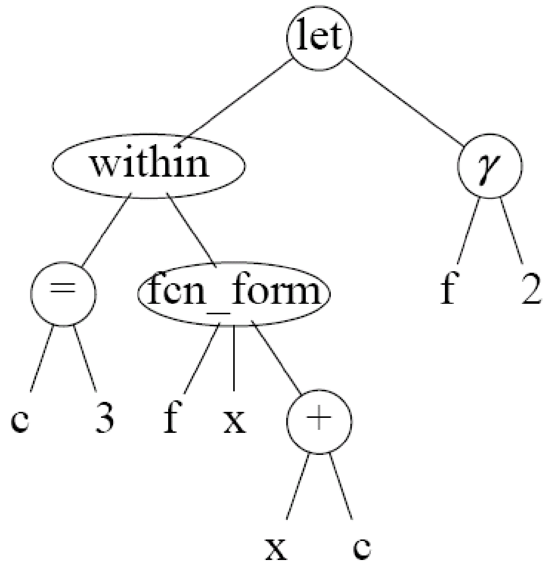
Standardizing the 'within'

- See example

```
 within      =>              =
   /    \                  /  \
  =      =                X2  gamma
  /\    /  \                     /  \
X1  E1  X2  E2               lambda   E1
                             / \
                            X1  E2
```

Standardizing the 'within':

```
let c = 3 within f x = x + c in f 2
```



Standardizing Unary and Binary Operators

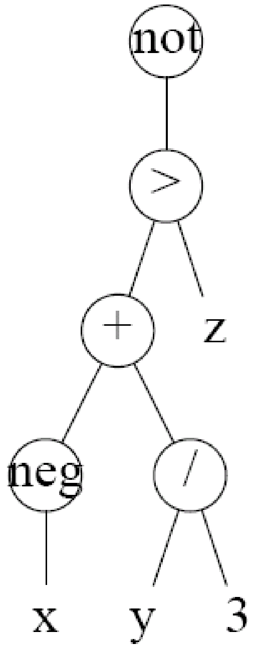
- See example

```
Uop     =>      gamma
 |              /  \
 E            Uop  E

 Op     =>     gamma
 /\                 /   \
E1  E2      gamma   E2
                   / \
              Op   E1
```

Standardizing unary and binary operators:

```
not - x + y / 3 > z
```



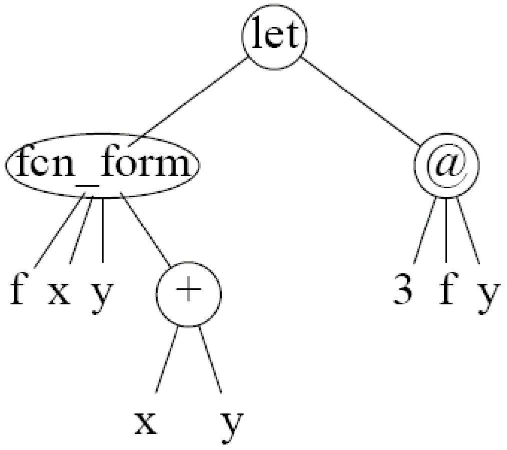
Standardizing the '@' Operator

- See example

```
  @  =>  gamma
 / | \       /  \
E1 N E2 gamma  E2
          / \
         N   E1
```

Standardizing the '@' operator:

```
let f x y = x + y in 3 @f y
```



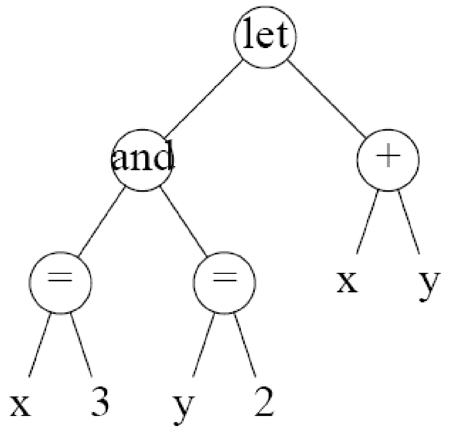
Standardizing Simultaneous Definitions

- See example

```
and   =>    =
  |          / \
 =++        ,  tau
 / \        |   |
 X  E      X++  E++
```

Standardizing simultaneous definitions:

```
let x = 3 and y = 2 in x + y
```



Standardizing Simultaneous Definitions (cont'd)

```
lambda      =>         lambda
  / \                    /   \
  ,  E        Temp     ++gamma
  |                             /  \
 X++i                    lambda   gamma
                            / \      / \
                         X.i  .E   Temp  \
                                        <INTEGER:i>
```

Standardizing the Conditional Operator

```
   →      =>         gamma
 /  |  \                  /  \
B   T  F        gamma       nil
                   /   \
        gamma          lambda
             / \              /  \
   gamma       lambda     ()   F
      /  \   / \
Cond     B         ()   T
```

Cond = fn B. fn T. fn F. B → T | F

Circular semantic definition !

Circular Semantic Definitions

- K. Goedel's Incompleteness Theorem (1930's): Every logic system is either incomplete or inconsistent.
- Incomplete is preferable to inconsistent.
- Inevitable in semantics
- English dictionary is useless to someone who understands no English.

Standardizing 'rec'

- Will do later

```
rec    =>      =
 |             / \
 =             X   gamma
/ \                 /  \
X   E          Ystar  lambda
                        / \
                        X   E
```

RPAL SUBTREE TRANSFORMATIONAL GRAMMA

```
     let     =>      gamma    |       where   =>      gamma
      / \             /   \   |        / \            /  \
     =   P        lambda  E   |       P   =       lambda  E
    / \             /  \      |          / \       /  \
   X   E           X    P     |         X   E     X    P

     tau     =>     ++gamma   |         ->    =>      gamma
      |               /  \    |       / | \          /   \
     E++          gamma   E   |      B  T  E       gamma nil
                    /  \      |                    /   \
                 aug   .nil   |                gamma    lambda
                              |                /  \        /  \
                              |             gamma lambda   ()  E
                              |             /   \   /  \
                              |          Cond    B ()   T

     not     =>      gamma    |       neg     =>      gamma
      |               /  \    |        |              /  \
      E            not    E   |        E           neg    E

   within    =>         =     |       rec     =>        =
    /   \             /  \    |        |               / \
   =     =          X2  gamma |        =              X  gamma
  / \   / \             /  \  |       / \               /   \
 X1 E1  X2 E2     lambda   E1 |      X   E            Ystar  lambda
                   /  \       |                               /  \
                 X1   E2      |                              X    E
 fcn_form  =>      =       |      lambda   =>      lambda
 /   |  \        /   \     |       /  \            /  \
P   V+   E       P  +lambda|      ,    E         Temp  ++gamma
                     /  \  |      |                     /   \
                    V   .E |     X++i                lambda gamma
                           |                         /  \     /  \
                           |                       X.i  .E Temp   \
                           |                                   <INTEGER:i>

   lambda  =>    ++lambda  |       Op      =>      gamma
   /   \          /     \  |      / \             /    \
  V++   E         V    .E  |     E1  E2        gamma  E2
                           |                    /  \
                           |                   Op  E1

   and     =>      =       |        @      =>      gamma
    |             /  \     |      / | \           /  \
   =++           ,  tau    |    E1  N E2        gamma  E2
   / \           |   |     |                   /  \
  X   E         X++  E++   |                   N   E1
                           |
   Uop     =>    gamma     |  Op in [aug,or,&,+,-,/,**,gr ...]
    |           /    \     |
    E         Uop     E    |  Uop in [not, neg]
```

Summary

- Transform AST into a standardized tree (ST).
- ST is binary.
- All internal nodes in the ST are either gamma or lambda.
- It’s called “desugaring” the program: reducing it to two constructs: function abstraction/definition (lambda), and function application (gamma).

Thank You!

REFERENCES

- Programming Language Pragmatics by Michael L. Scott. 3rd edition. Morgan Kaufmann Publishers. (April 2009).
- Lecture Slides of Dr.Malaka Walpola and Dr.Bermudez