

CS4613 Lecture 3

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Local Binding Examples

What can we learn by comparing these two programs in stacker? **p. 47**

```
(defun (f x)
  (let ([y 2])
    (+ x y)))
(f 7)
```

stacker

```
(defun (f x)
  (defvar y 2)
  (+ x y))
(f 7)
```

stacker

└ Local Binding

└ Local Binding Examples

1. Compare syntax in other languages
2. What about execution?

What can we learn by comparing these two programs in stacker? 

```
(defun (f x)
  (let ([y 2])
    (+ x y)))
```

```
(f 7)
```

```
(defun (f x)
  (doval y 2)
  (+ x y))
```

```
(f 7)
```

A simplified local binding syntax

Let's look ahead a bit to Desugaring and define a compatible syntax to the book.

p. 72

```
(define-syntax-rule (let1 (var expr) body)
  (let ([var expr]) body))
```

Now we can look at how some examples **should** work

p. 49

```
ex1 {let1 {x 1} {+ x x}}
```

```
{let1 {x 1}
      {let1 {y 2}
            {+ x y}}}
```

└ Local Binding

└ A simplified local binding syntax

1. this is a bit subtle. In some sense we have implemented the feature, but not as part of our interpreter

A simplified local binding syntax

Let's look ahead a bit to Desugaring and define a compatible syntax to the book.

```
(define-syntax-rule (let1 (var expr) body)
  (let ([var expr]) body))
```

Now we can look at how some examples **should** work

```
let1 {x 1} {+ x x}

let1 {x 1}
  {let1 {y 2}
   {+ x y}}
```

Inner and Outer Scope

p. 50

```
ex2 {let1 {x 1}
      {let1 {y 2}
          {let1 {x 3}
              {+ x y}}}}}
```

- ▶ What feature does this example introduce?
- ▶ Where can we find this feature in other languages?

```
ex3 {let1 {x 1}
      {+ x
        {let1 {x 2} x}}}}
```

```
■ {let1 {x 1}
    {let1 {y 2}
      {let1 {x 3}
        {+ x y}}}}
```

- ▶ What feature does this example introduce?
- ▶ Where can we find this feature in other languages?

```
■ {let1 {x 1}
    {+ x
     {let1 {x 2} x}}}
```

1. We can use DrRacket to trace the bindings
2. We don't need to rewrite things in racket, because we cheated and changed the syntax of plait to match our examples

Static Scoping

p. 52

```
scope1 (defvar x 1)
        (defun (f)
          (+ x 1))

stacker (let ([x 2])
         (f))
```

Static Scope

Variable binding is determined by **position** in the source program, not order of **execution**.


```
(defvar x 1)
(defun (f)
  (+ x 1))

(let ([x 2])
  (f))
```

Static Scope

Variable binding is determined by **position** in the source program, not order of **execution**.

1. The book uses a different set of examples for dynamic scope, but for me these go beyond dynamic scope by not obeying the block structure of `let`

Dynamic scope

```
scope2 (defvar x 1)
      (defun (f)
        (+ x 1))

      (let ([x 2])
        (f))
```

Dynamic scope

Binding is determined by **execution** environment.

Dynamic scope makes many traps

```
scope3 (defun (blah func val) (func val))  
(let ([x 3])  
  (let ([f (λ (y) (+ x y))])  
    (let ([x 5])  
      (blah f 4))))
```

```
scope4 (defun (blah func x) (func x))  
(let ([x 3])  
  (let ([f (λ (y) (+ x y))])  
    (let ([x 5])  
      (blah f 4))))
```

└ Local Binding

└ Dynamic scope makes many traps

```
❏ (defun (blah func val) (func val))  
  (let ((x 3))  
    (let ((f (lambda (y) (+ x y))))  
      (let ((x 5))  
        (blah f 4))))))  
  
❏ (defun (blah func x) (func x))  
  (let ((x 3))  
    (let ((f (lambda (y) (+ x y))))  
      (let ((x 5))  
        (blah f 4))))))
```

1. Can you see what changed between the two examples? They are run with the same interpreter (i.e. the same #lang)

Controlled Dynamic Scope



- ▶ plait has **parameters** for dynamic scope
- ▶ internally used by smol/dyn-scope-is-bad

```
scope5 (define location (make-parameter "here"))
(define (foo) (parameter-ref location))
(parameterize ([location "there"]) (foo))
(foo)
(parameterize ([location "in a house"])
  (list (foo)
        (parameterize ([location "with a mouse"])
          (foo))
        (foo)))
(parameter-ref location)
```

Update AST

p. 54

```
(define-type Exp
  [numE (n : Number)]
  [plusE (left : Exp) (right : Exp)]
  [timesE (left : Exp) (right : Exp)]
  [varE (name : Symbol)]           ;; new
  [let1E (var : Symbol)           ;; new
         (value : Exp)
         (body : Exp)])
```

Environments

How to interpret variables?

p. 55

```
(define (interp e)
  (type-case (Exp) e
    [(numE n) n]
    [(varE s) ....]))
```

Let's take a closer look at how stacker evaluates let:

```
(let ([y 2])
  (+ 7 y))
```

stacker

Implementing environments

We will use **hash tables** to implement environments

p. 55

```
(define-type-alias Env (Hashof Symbol Value))  
(define mt-env (hash empty)) ;; "empty environment"
```

Our interpreter will need to take an extra argument

```
(interp : (Exp Env -> Value))
```

Encapsulate the use **Optional values** as a way of handling errors.

```
(define (lookup (s : Symbol) (n : Env))  
  (type-case (Optionof Value) (hash-ref n s)  
    [(none) (error s "not bound")]  
    [(some v) v]))
```


└ Evaluating Local Binding

└ Implementing environments

1. Somewhere along the way `calc` was renamed to `interp`
2. The extra argument is mainly for use in recursive evaluations of sub-expressions
3. There is many debates about the best way to handle errors. In this simple interpreter it is easiest to throw an (uncaught) exception to report an unbound variable

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(define (lookup (s : Symbol) (e : Env))  
  (type-case (Optionof Value) (hash-ref e s)  
    [(none) (error s "not bound")]  
    [(some v) v]))
```

Evaluation strategy

Checking our example again

p. 56

```
(let ([y 2])  
  (+ 7 y))
```

stacker

We need to

1. evaluate the body of the expression, in
2. an environment that has been extended, with
3. the new name
4. bound to its value.

Extending environments

Encapsulating some more hash-table manipulation

```
(define (extend old-env new-name value)
  (hash-set old-env new-name value))

[(let1E var val body)
 (let ([new-env (extend nv ;; 2
                        var ;; 3
                        (interp val nv))] ;; 4
       (interp body new-env))] ;; 1
```

1. evaluate the body of the expression, in
2. an environment that has been extended, with
3. the new name
4. bound to its value.

Interpreter for let1

```
let1 (define (interp e nv)
      (type-case Exp e
        [(numE n) n]
        [(varE s) (lookup s nv)]
        [(plusE l r) (+ (interp l nv) (interp r nv))]
        [(timesE l r) (* (interp l nv) (interp r nv))]
        [(let1E var val body)
         (let ([new-env (extend nv
                                var
                                (interp val nv))])
           (interp body new-env))]))
```

Extending the parser



```
let1 [(? `(let1 (SYMBOL ANY) ANY))
      (let* ([def (sx 1)]
              [parts (s-exp->list def)]
              [var (s-exp->symbol (list-ref parts 0))]
              [val (parse (list-ref parts 1))]
              [body (px 2)])
          (let1E var val body)))]
```