

# Implementing Recursion via State

CS 350

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## **Recursion via State**

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- Goals

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- Key Concepts
  - Landin's Knot

## Recursion in Curly-Rec

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    - Exactly like `letvar`, except **`x` is also in scope in `e1`**

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  - `{letrec x {+ x 1} ....}`
  - Should raise an error or loop forever
  - In a later lecture we'll see a way to give this semantics

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  - Definitions that refer to  $x$  but don't try to evaluate it
  - **Recursive occurrences of the variable must be in the body of a lambda**
    - Lambda bodies aren't evaluated until call time

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  - Interpret e1 in the environment extended with x's location
    - If ever fetch from that location, get the dummy value and raise an error
    - Shouldn't ever fetch if self-references are in the bodies of functions
  - Then, **update the store to contain the value of e1 at the location of x**
  - Then, interpret the body e2 with this updated store

## Interpreting Recursion: Value

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```
(define-type Value
  (ClosureV [arg : Symbol]
            [body : Expr]
            [env : Env])
  (NumV [num : Number])
  (BoxV [loc : Location])
  ;; NEW
  ;; Placeholder for implementing recursion
  ;; If we ever produce this, we should get an error
  (DummyV))
```

## Interpreting Recursion: Code

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```
(define (interp [env : Env]
                [e : Expr]
                [sto : Store]) : Result
  (type-case Expr e
    [(LetRec x xexpr body)
     (let* ([x-loc (new-loc sto)] ;; Location for x
            [dummy-sto ;; Put a dummy value at x's location
              (override-store (cell x-loc
                                   (DummyV)) sto)])
       (with ([x-val x-sto]
              ;; Interpret xexpr in env with x's location
              (interp (extendEnv (bind x x-loc) env)
                      xexpr
                      dummy-sto))
               ;; Interpret body in env with x's location
               ;; and store with x's newly computed value
               ;; plus any side-effects from xexpr
              (interp (extendEnv (bind x x-loc) env) body
                      (override-store (cell x-loc x-val) x-sto)))))]
```

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                  {if0 x
                     1
                     {* x {fact {- x 1}}}}}
  {fact 3}}
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- To evaluate letrec we:
  - Make a new location 0 for fact
  - Evaluate the value for fact
    - Env: fact := 0

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- To evaluate letrec we:
  - Make a new location  $\Theta$  for fact
  - Evaluate the value for fact
    - Env: fact :=  $\Theta$
    - Store:  $\Theta \Rightarrow (\text{DummyV}) \sim\sim$

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    (Times (Var 'x)
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- Never fetch from location 0
  - Interp of function doesn't interp body of function
- Closure captures environment with `fact := 0`
  - Only captures environment, **not store**

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  - Closure stores environment (`fact := 0`)

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- If0 in closure body goes to branch with call
- fact in call evaluates to *the same closure* at location 0
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  - Etc. until we reach 0 and don't have a recursive call

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- You can simulate recursion in any language with
  - First-class functions/closures
  - Mutable references/variables
- Useful in typed languages that can't give the Y-combinator a type