

Object-Oriented Style

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Goals of the talk

- Explain conventional OOP

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- Explain conventional OOP
- Super method call

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- Super method call
- Object method call

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- Explain conventional OOP
- Super method call
- Object method call
- Using a style for OOP

Meta-goals of the talk

- Make explicit what's static

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- Use variables instead of symbols

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- `defines` could be `lets`

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- Use variables instead of symbols
- Recursion only through **it** (**self** or **this**)
- Make what's global potentially local
- **defines** could be **lets**
- **define-syntaxes** could be **let-syntaxes**

Structure of the talk

- What is a Style?

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- Familiar Examples

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- Position Environments

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- Three ways to Lift Methods

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- Installation of Position Environments
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- Familiar Example in the Style
- Protocols in the Style
- Three ways to Lift Methods
- Hygienic Macros (See paper)

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- Lexical Scope vs. Protected Scope

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- Protocols in the Style
- Three ways to Lift Methods
- Hygienic Macros (See paper)
- Lexical Scope vs. Protected Scope
- Conclusions

What is a style?

- An encoding of an idiom

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- Encode everything that matters

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- Advantage of programming languages

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- They hide idioms
- A style makes explicit what's implicit

Continuation-Passing is a style

- An encoding of `call/cc`

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- An encoding of `call/cc`
- Encode every continuation
- Advantage of programming languages
- We don't see all the continuations
- Disadvantage of programming languages
- Understanding `call/cc` is hard
- But, not if you learn `CPS` first.

Mutual-Recursive Example

```
(define vr vector-ref)

(define eo-procs
  (vector
    (lambda (it n)
      (if (zero? n) #t
          ((vr it 1) it (- n 1))))
    (lambda (it n)
      (if (zero? n) #f
          ((vr it 0) it (- n 1))))))

> ((vr eo-procs 0) eo-procs 5)
#f
```

Familiar Example: Color Points

- One chain

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- $\langle o \rangle$: Root

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- <o>: Root
- <p>: Points:
x, y;
move, get-loc, diag

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- <cp>: Color Points:
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get-hue, diag&set

Familiar Example: Color Points

- One chain
- <o>: Root
- <p>: Points:
x, y;
move, get-loc, diag
- <cp>: Color Points:
hue;
get-hue, diag&set
- <scp>: Stationary Color Points:
y;
move, show-y

Familiar Example: Shadows

- Host Class = Host Shadow + Super Class

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- «o»: Root Shadow
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Familiar Example: Shadows

- Host Class = Host Shadow + Super Class
- One chain
- «o»: Root Shadow
- «p»: Point Shadow
- «cp»: Color Point Shadow
- «scp»: Stationary Color Point Shadow

Points (no details)

```
(define-syntax <<p>>
  (extend-shadow <<o>> (x y)
    ([move      (method (dx dy) ---)]
     [get-loc   (method () ---)]
     [diag      (method (a)
                        (move it a a))])))
```

```
(define <p>
  (create-class <<p>> <o>))
```

Points

```
(define-syntax <<p>>
  (extend-shadow <<o>> (x y)
    ([move      (method (dx dy)
                        (set! x (+ x dx))
                        (set! y (+ y dy))))]
     [get-loc   (method ()
                    (list x y))]
     [diag      (method (a)
                        (move it a a))]))

(define <p>
  (create-class <<p>> <o>))
```

Color Points

```
(define-syntax <<cp>>
  (extend-shadow <<p>> (hue)
    ([get-hue (method () hue)]
     [diag&set (method (a)
                       (diag it a)
                       (set! hue a))])))
```

```
(define <cp>
  (create-class <<cp>> <p>))
```

Stationary Color Points

```
(define-syntax <<scp>>
  (extend-shadow <<cp>> (y)
    ([move (method (x^ y^))
      (show-y it))]
     [diag (method (a)
      (write hue)
      (diag sup a))]
     [show-y (method ()
      (display y))]))

(define <scp>
  (create-class <<scp>> <cp>))
```

Position Environments

A map from variables to positions
Represented by a list of pairs.

```
(define penv '([a 0][b 1][c 2]))  
(define qenv '([a 0][d 1]))
```

```
(append-env penv qenv)
```

```
==>> ([a 0][b 1][c 2][a 3][d 4])
```

Installation

```
(list 5 3 1 2 6 4)
```

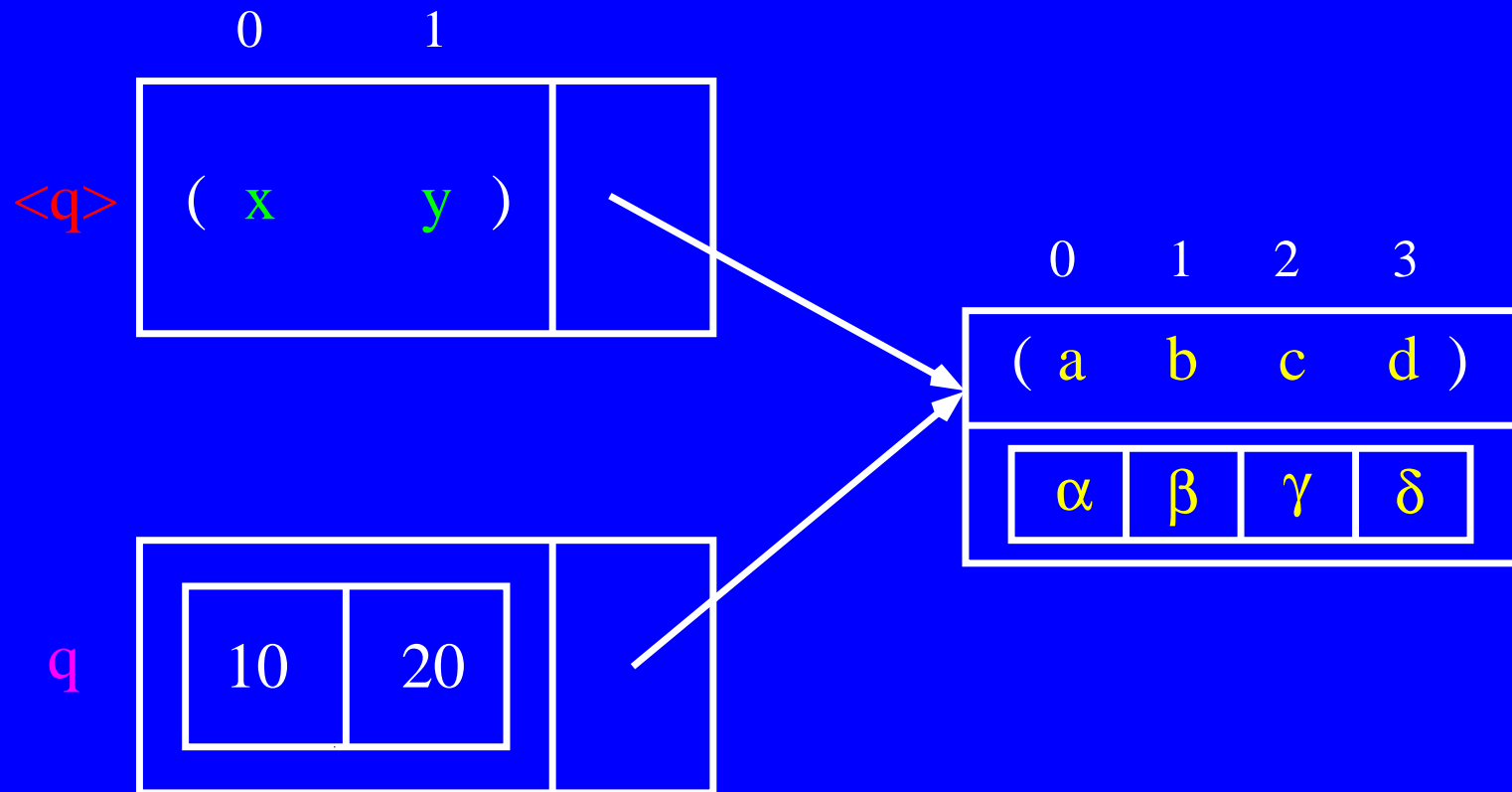
```
(let* ([a 0][b 1][c 2][a 3][d 4])  
  (list 5 a b c 6 d))
```

```
(let ([b 1][c 2][a 3][d 4])  
  (list 5 a b c 6 d))
```

```
==>> (5 3 1 2 6 4)
```

Data Structures

Classes, Objects, Fields, and Methods



Five Interface operators

Assume α , β , γ , and δ are closures.

$\langle q \rangle = ((x\ y) (a\ b\ c\ d) \#(\alpha\ \beta\ \gamma\ \delta))$

$q = \#(10\ 20) . , (\text{cdr } \langle q \rangle)$

$(fx\ \langle q \rangle\ ' (y)) = (x\ y\ y)$

$(mx\ \langle q \rangle\ ' (e)) = (a\ b\ c\ d\ e)$

$(fp\ q\ 1) = 20$

$(fp!\ q\ 1\ 30) = \text{unspecified}$

$(fp\ q\ 1) = 30$

$(mp\ q\ 2) = \gamma$

$(mp\ \langle q \rangle\ 2) = \gamma$

Binding variables to values

- Because we know that there is a one-to-one correspondence between the variables in the **field** environment of a class and the positions in the **field** vector of its associated class, we can think of the **fields** in the vector as if they had a name.

Binding variables to values

- Because we know that there is a one-to-one correspondence between the variables in the **field** environment of a class and the positions in the **field** vector of its associated class, we can think of the **fields** in the vector as if they had a name.
- Because we know that there is a one-to-one correspondence between the variables in the **method** environment of a class and the positions in the **method** vector of the class, we can think of the **methods** in the vector as if they had a name.

The Style Template

```
(list
  (fx <super> ' (field-var ...))
  (mx <super> ' (method-var ...))
  (vector
    (lambda (it arg ...) ---)
    (lambda (it arg ...) ---)
    (mp <super> 2)
    (lambda (it arg ...) ---)
    (mp <super> 4)
    (mp <super> 5)
    (lambda (it arg ...) ---)
    (lambda (it arg ...) ---)
    (lambda (it arg ...) ---)))
```

The Style (Part 1)

- The arguments to `fx` are the super class and the fresh `field` variables. These variables cannot contain duplicates, and their order matters.

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- The arguments to **fx** are the super class and the fresh **field** variables. These variables cannot contain duplicates, and their order matters.
- The arguments to **mx** are the super class and the fresh **method** variables. These variables cannot contain duplicates, their order matters, and they are different from those in the super class.

The Style (Part 2)

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- 1. The result of evaluating an expression (e.g., an **mp** expression), yielding a *contributed* (or *inherited*) method, or

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- 1. The result of evaluating an expression (e.g., an **mp** expression), yielding a *contributed* (or *inherited*) method, or
- 2. The result of evaluating an expression (e.g., a **lambda** expression), yielding a *replaced* (or *overridden*) method, or
- 3. The result of evaluating an expression (e.g., a **lambda** expression), yielding a *fresh* method.

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- The contributed methods fill in the vector with (`mp` `<super>` `position`).
- As the method vector is filled in, each method must fit into the right position. The replaced and contributed methods must be in the same position as in their super class. The fresh methods follow these, and they must be in the order they appear in the call to `mx`.

The Style (Part 4)

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The Style (Part 4)

- Some methods are not expressed as a procedure built from a lambda expression, but those that are, have **it**, which may be bound to an object or a class, as their first argument.
- When **it** is bound to an object, we can reference or update its fields through a constant position in its field vector.
- Every object uses the same position in its field vector for each field defined by the class of its object.

The Style (Part 5)

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- To invoke a method of an object or a class, first obtain the method through a constant position of a method vector and invoke it on some object or class and perhaps some additional arguments.
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The Style (Part 5)

- To invoke a method of an object or a class, first obtain the method through a constant position of a method vector and invoke it on some object or class and perhaps some additional arguments.
- If the method is from an object, then its first argument is the object.
- If the method is from a class, then its first argument is either the class or *it*.
- There are no restrictions on the method bodies.

The Style (Part 6)

- If a class is passed to an interface operator, it should be the host's super class.

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- If a class is passed to an interface operator, it should be the host's super class.
- There are no more constraints on how the method vector is built.

Points in the Style

```
(define <p>
  (list
    (fx <o> '(x y))
    (mx <o> '(move get-loc diag))
    (vector
      (lambda (it dx dy)
        (fp! it 0 (+ (fp it 0) dx))
        (fp! it 1 (+ (fp it 1) dy))))
      (lambda (it)
        (list (fp it 0) (fp it 1)))
      (lambda (it a)
        ((mp it 0) it a a))))))
```

Color Points in the Style

```
(define <cp>
  (list
    (fx <p> ' (hue))
    (mx <p> ' (get-hue diag&set))
    (vector
      (mp <p> 0)
      (mp <p> 1)
      (mp <p> 2)
      (lambda (it) (fp it 2))
      (lambda (it a)
        ((mp it 1) it a)
        (fp! it 2 a))))))
```


Stat. Color Points in the Style

```
(define <scp>
  (list
    (fx <cp> ' (y))
    (mx <cp> ' (show-y))
    (vector
      (lambda (it x^ y^ )
        ((mp it 5) it))
      (mp <cp> 1)
      (lambda (it a)
        (write (fp it 2))
        ((mp <cp> 2) it a))
      (mp <cp> 3)
      (mp <cp> 4)
      (lambda (it)
        (display (fp it 3))))))
```

Three Protocols

- `sup` is a lexical variable

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- Installing `method` environments

Three Protocols

- `sup` is a lexical variable
- Installing `method` environments
- Installing `field` environments

Stationary Color Points: **super**

```
(define <scp>
  (let ([sup <cp>])
    (list
      (fx sup '(y))
      (mx sup '(show-y))
      (vector
        (lambda (it x^ y^)
          ((mp sup 5) it))
        (mp sup 1)
        (lambda (it a)
          (write (fp it 2))
          ((mp sup 2) it a))
        (mp sup 3)
        (mp sup 4)
        (lambda (it)
          (display (fp it 3)))))))
```

Installing **method** envs: (Part 1)

```
(define <scp>
  (let ([move 0]
        [get-loc 1]
        [diag 2]
        [get-hue 3]
        [diag&set 4]
        [show-y 5]
        (let ([sup <cp>])
          -----)))
```

Installing **method** envs: (Part 2)

```
(list
  (fx sup '(y))
  (mx sup '(show-y))
  (vector
    (lambda (it x^ y^)
      ((mp it show-y) it))
    (mp sup get-loc)
    (lambda (it a)
      (write (fp it 2))
      ((mp sup diag) it a))
    (mp sup get-hue)
    (mp sup diag&set)
    (lambda (it)
      (display (fp it 3))))))
```

Installing **field** envs: (Part 1)

```
(define <scp>
  (let* ([x 0][y 1][hue 2][y 3])
    (let ([move 0]
          [get-loc 1]
          [diag 2]
          [get-hue 3]
          [diag&set 4]
          [show-y 5])
      (let ([sup <cp>]
            -----)
        )))
```


Installing **field** envs: (Part 2)

```
(list
  (fx sup '(y))
  (mx sup '(show-y))
  (vector
    (lambda (it x^ y^)
      ((mp it show-y) it))
    (mp sup get-loc)
    (lambda (it a)
      (write (fp it hue))
      ((mp sup diag) it a))
    (mp sup get-hue)
    (mp sup diag&set)
    (lambda (it)
      (display (fp it y))))))
```

Fully-colored (Part 1)

```
(define <scp>
  (let* ([x 0][y 1][hue 2][y 3])
    (let ([move 0]
          [get-loc 1]
          [diag 2]
          [get-hue 3]
          [diag&set 4]
          [show-y 5])
      (let ([sup <cp>]
            -----) ) ) ) )
```

Everything above this line remains unchanged.

Fully-colored (Part 2)

```
(list
  (fx sup '(y))
  (mx sup '(show-y))
  (vector
    (lambda (it x^ y^ )
      ((mp it show-y) it))
    (mp sup get-loc)
    (lambda (it a)
      (write (fp it hue))
      ((mp sup diag) it a))
    (mp sup get-hue)
    (mp sup diag&set)
    (lambda (it)
      (display (fp it y))))))
```

Three Ways to Lift Methods

- Naive Lifting

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- Triply-Nested `let`

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- Triply-Nested `let`
- Quadruply-Nested `let`

Naive Lifting: (Part 2)

```
(let ([move (lambda ---)]
      [diag (lambda ---)]
      [show-y (lambda ---)])
  (list
    (fx sup '(y))
    (mx sup '(show-y))
    (vector
      move
      (mp sup get-loc)
      diag
      (mp sup get-hue)
      (mp sup diag&set)
      show-y)))
```

Triply-Nested let: (Part 2)

```
(let ([h-move (lambda ---)]
      [h-diag (lambda ---)]
      [h-show-y (lambda ---)])
  (let ([move (mp sup move)]
        [get-loc (mp sup get-loc)]
        [diag (mp sup diag)]
        [get-hue (mp sup get-hue)]
        [diag&set (mp sup diag&set)]))
```


Nested let: (Part 3)

Everything below this line remains unchanged.

```
(let ([move h-move]
      [diag h-diag]
      [show-y h-show-y])
  (list
    (fx sup '(y))
    (mx sup '(show-y))
    (vector
      move
      diag
      get-loc
      get-hue
      diag&set
      show-y)))
```

Quadruply-Nested let: (Part 2)

```
(let ([s-move      (mp sup move)]
      [s-get-loc   (mp sup get-loc)]
      [s-diag      (mp sup diag)]
      [s-get-hue   (mp sup get-hue)]
      [s-diag&set  (mp sup diag&set)])
  (let ([h-move     (lambda ---)]
        [h-diag     (lambda ---)]
        [h-show-y   (lambda ---)]
        (let ([move      s-move]
              [get-loc   s-get-loc]
              [diag      s-diag]
              [get-hue   s-get-hue]
              [diag&set  s-diag&set])
```

Zoom in on Methods: (Part 3)

```
(let ([h-move
      (lambda (it x^ y^)
        ((mp it show-y) it))]
    [h-diag
      (lambda (it a)
        (write (fp it hue))
        (s-diag it a))]
    [h-show-y
      (lambda (it)
        (display (fp it y)))]))
```

Zoom out on **diag**: (Part 3)

```
(let* ([x 0][y 1][hue 2][y 3])
  (let ([diag 2] ...)
    (let ([sup <cp>] ...)
      (let ([s-diag ---] ...)
        (let ([h-diag ---] ...)
          (let ([diag s-diag] ...)
            (let ([diag h-diag] ...)
              (list
                (fx ...)
                (mx ...)
                (vector
                  ... diag ...))))))))))
```

Two Scope Issues

- Lexical Scope

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- Lexical Scope
- Protected Scope

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- Protected Scope
- Which one should shadow the other?

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Two Scope Issues

- Lexical Scope
- Protected Scope
- Which one should shadow the other?
- Where should one shadow the other?
- Assume that we have extended `<scp>` with the method `show-y`.

Lexical Scope (Part 1)

```
[show-y
  (let ([hue* "outside "]
        [diag* (lambda (x y)
                  (display
                   "moving "))]
        )
    (method ()
      (display hue)
      (diag* 5 5)
      (let ([hue "inside "]
            [diag (lambda (n self)
                    (diag self n))]
            )
          (display hue)
          (diag 5 it)))))]
```

Lexical Scope (Part 2)

```
[show-y
  (let ([hue "outside "]
        [diag (lambda (x y)
                  (display
                    "moving " ))])
    (method ()
      (display hue)
      (diag 5 5)
      (let ([hue "inside "]
            [diag (lambda (n self)
                      (diag self n))]
            (display hue)
            (diag 5 it))))))]
```

Lexical Scope (Part 3)

```
(define <e>-maker
  (lambda (x)
    (let-syntax
      ([<<e>>
        (extend-shadow <<scp>> ()
          ([e
            (begin
              (write x)
              (let ([y 1])
                (method (q . a)
                  (+ x y q
                    (car a)))))))]))
      (lambda (s)
        (create-class <<e>> s))))))
```

Conclusions

- Meta-goal: Everything as static as possible

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- Goal: Clarified super and object method calls

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- Continuation-Passing Style vs. Object-Oriented Style

Conclusions

- Meta-goal: Everything as static as possible
- Goal: Clarified super and object method calls
- Continuation-Passing Style vs. Object-Oriented Style
- Both get their power by harnessing properties with an extra argument