



Standard Protocols



Meta-Classes



Redefinitions

Object-Oriented Approaches to Programming

~ Advanced CLOS ~

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 Outline

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- Generic Functions

- Instantiation

- eq1 Specializers

Meta-Classes

- Principle

- Applications

Redefinitions

 Plan

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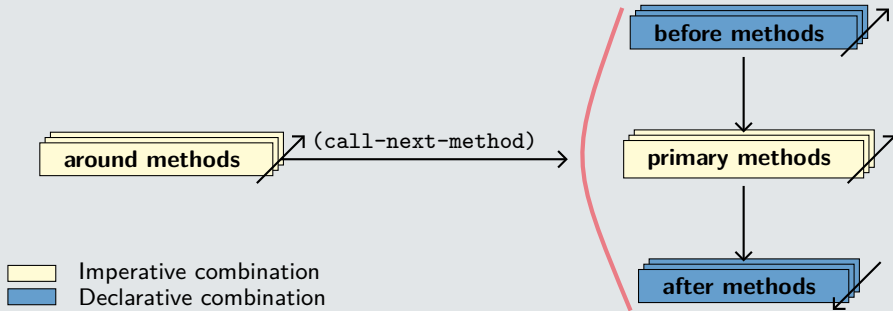
Redefinitions

Method Combinations

- ▶ Use of one or several applicable (primary) methods
- ▶ Declarative (rather than imperative) specification
- ▶ Standard combination (default): most specific method
+ before, after et around
- ▶ Available combinations (built-in)
 - ▶ +, min, max, list, nconc, append, and, or, progn
 - ▶ No before, no after
 - ▶ call-next-method prohibited
- ▶ Programming new combinations
 - ▶ define-method-combination (macro)
 - ▶ Two forms
- ▶ See also [Verna, 2018], [Verna, 2023]

Regular Generic Functions

Standard Protocol



► Method roles:

- primary: main work, return value
- before / after: side effects
- around: auxiliary work

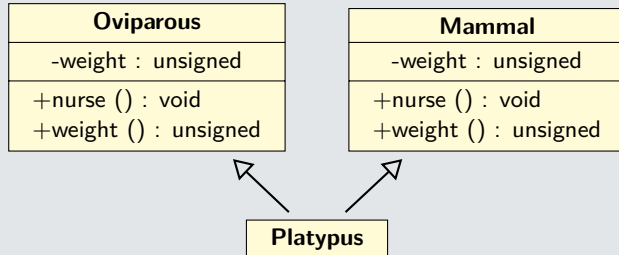
Application I: Declarative Accumulation

```
(defmethod hello ((human human))
  (format t "Hello! I'm ~A, ~Am, ~Ayo.~%"
    (name human)
    (size human)
    (age human))
  (values))

(defmethod hello :after ((employee employee))
  (call-next-method)
  (format t "Working at ~A for ~A euros, started at the age of ~A.~%"
    (company employee)
    (salary employee)
    (hiring-age employee))
  (values))
```

Application II

Reminder



- ▶ weight: problem already solved (slot definitions fusion)
- ▶ nurse ?

Application II

The progn combination

```
(defgeneric nurse (animal)
  (:method-combination progn))

(defmethod nurse progn ((oviparous oviparous))
  (when (next-method-p) (call-next-method))
  (format t "I brood my eggs.~%")
  (values))

(defmethod nurse progn ((mammal mammal))
  (when (next-method-p) (call-next-method))
  (format t "I suckle my children.~%")
  (values))
```

► **Note:** no platypus-specific method required

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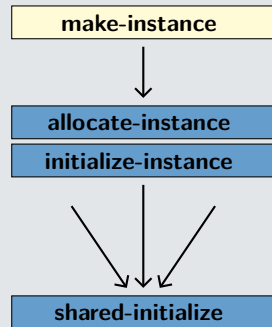
Applications

Redefinitions

Instantiation

- ▶ `make-instance`:
initialization options computation and validity checks
- ▶ `allocate-instance`:
uninitialized object allocation
- ▶ `initialize-instance`:
call to `shared-initialize`
- ▶ `shared-initialize`:
slots initialization
- ▶ **Note:** generic functions
specializable

Protocole



Layer 2
Layer 3

Application: Post-Initialization Checks

```
(defmethod initialize-instance :after ((human human) &key)
  (slot-value human 'name)
  (slot-value human 'size)
  (incf (slot-value human 'population))) ;; bonus

(defmethod initialize-instance :after ((employee employee) &key)
  (slot-value employee 'company)
  (slot-value employee 'salary)
  (slot-value employee 'hiring-year))
```

► See also:

- slot-boundp (function)
- slot-unbound (generic function)
- unbound-slot (condition)

► Remark: dynamic (run-time) checks

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eq1 Specializers

- Specialization on specific objects

Exemple: pattern matching

```
(defgeneric product (x y)
  (:method (x (y (eq1 0))) 0)
  (:method ((x (eq1 0)) y) 0)
  (:method (x y) (* x y)))
```

eq1 Specializers

- The objects may be classes

Example: a singleton class

```
(defclass singleton (#/.../#)
  (#/.../#))
(let (instance)
  (defmethod make-instance ((class (eq1 (find-class 'singleton))) &key)
    (or instance (setf instance (call-next-method))))))
```

eq1 Specializers

- The objects may be classes (names)

Example: a fake shared slot

```
(defclass human (#!/.../#!)
  (#!/.../#!))
(let ((population 0))
  (defmethod initialize-instance :after ((human human) &key)
    (incf population))
  (defgeneric census (obj)
    (:method ((human human)) population)
    (:method ((class (eq1 (find-class 'human)))) population)
    (:method ((symbol (eq1 'human))) population)))
```

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User-Level Meta-Classes

▶ Principle:

- ▶ Specialize the behavior of a *set* of classes
- ▶ Class of classes (meta-class)

▶ Process:

1. Create a meta-class (sub-class standard-class)
2. Macrology (layer 1)
3. Declare its validity (layer 3 / MOP)
4. Specialize (:metaclass option to defclass)

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Application: Abstract Classes

```
(defclass abstract-class (standard-class) ())

(defmethod validate-superclass ((class abstract-class) (superclass standard-class))
  t)
(defmethod validate-superclass ((class standard-class) (superclass abstract-class))
  t)

(defmethod make-instance :before ((class abstract-class) &key)
  (error "~A is an abstract class." (class-name class)))

;; (defclass foobar (#/.../#)
;;   (#/.../#)
;;   (:metaclass abstract-class))
```

Application: Final Classes

```
(defclass final-class (standard-class) ())

(defmethod validate-superclass ((class final-class) (superclass standard-class))
  t)
(defmethod validate-superclass ((class standard-class) (superclass final-class))
  nil)
(defmethod validate-superclass ((class final-class) (superclass final-class))
  nil)

;; (defclass foobar (#/.../#)
;;   (#/.../#)
;;   (:metaclass final-class))
```

Application: Singleton Classes

```
(defclass singleton-class (standard-class)
  ((instance :initform nil)))

(defmethod validate-superclass ((class singleton-class) (superclass standard-class))
  t)
(defmethod validate-superclass ((class standard-class) (superclass singleton-class))
  nil)

(defmethod make-instance ((singleton-class singleton-class) &key)
  (or (slot-value singleton-class 'instance)
      (setf (slot-value singleton-class 'instance) (call-next-method))))

;; (defclass foobar (#/.../#)
;;   (#/.../#)
;;   (:metaclass singleton-class))
```

Application: Accounting Classes

```
(defclass counting-class (standard-class)
  ((counter :initform 0)))

(defmethod validate-superclass ((class counting-class) (superclass standard-class))
  t)

(defmethod validate-superclass ((class standard-class) (superclass counting-class))
  t)

(defmethod make-instance :after ((counting-class counting-class) &key)
  (incf (slot-value counting-class 'counter)))

;; (defclass foobar (#/.../#)
;;   (#/.../#)
;;   (:metaclass counting-class))
```

Application: A(nother) Fake Shared Slot

```
(defclass population-class (standard-class)
  ((population :initform 0 :accessor population)))

(defmethod validate-superclass ((class population-class) (superclass standard-class))
  t)
(defmethod validate-superclass ((class standard-class) (superclass population-class))
  t)

(defclass human () (#/.../#) (:metaclass population-class))
(defmethod initialize-instance :after ((human human) &key)
  (incf (population (find-class 'human))))

(defgeneric census (object)
  (:method ((class population-class) (population class))
    (population (find-class 'human)))
  (:method ((symbol (eql 'human)))
    (population (find-class 'human)))
  (:method ((human human))
    (population (find-class 'human))))
```

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Redefinitions

▶ Reminder (Static Languages / AOP1):

- ▶ Class $\Leftrightarrow$ Type
Fixed, known at compile-time
- ▶ Object $\Leftrightarrow$ Value
Variables of a fixed type, known at compile-time

▶ New context:

- ▶ Dynamic Language
Values ($\neq$ variables) carry their own type information
- ▶ MOP
Every object system component is itself a (meta-)object, hence modifiable

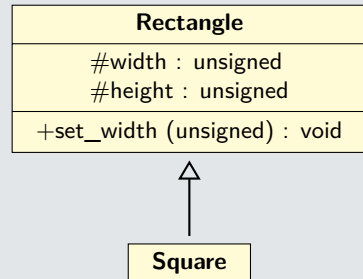
▶ New features:

- ▶ Addition / Suppression / Modification of classes, methods, generic functions
- ▶ Change of an instance's class

Reminder: Inheritance by Restriction

- ▶ The elliptic circle (square rectangle) problem
- ▶ A square is a rectangle...
- ▶ ...with additional constraints, static...
- ▶ ...and dynamic
- ▶ Differential programming:
 - ▶ Inherit additively, as opposed to restrictively
 - ▶ Problem tightly related to mutation
- ▶ Cf. the Liskov Substitution Principle

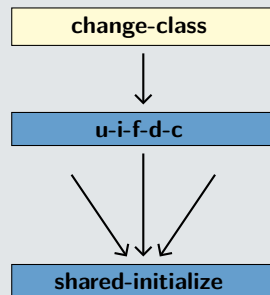
Example



Class Change

- ▶ `change-class`:
destructive modification of an object (identity preserved)
- ▶ `update-instance-for-different-class`:
initialization options validity checks
- ▶ `shared-initialize`:
slots initialization
- ▶ **Note:** generic functions
specializable
- ▶ **Caution:** choose your moment carefully!

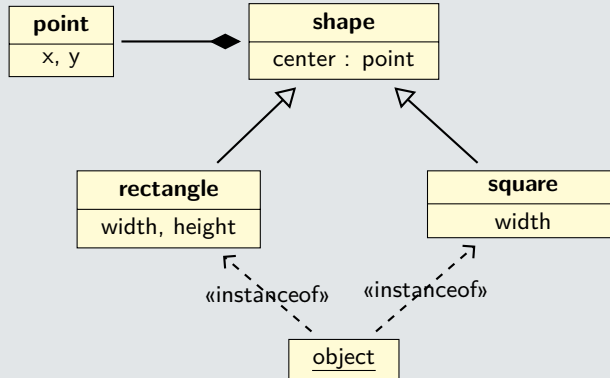
Protocol



Layer 2
Layer 3

Application: Squares / Rectangles

Pseudo-UML



Rectangle-Wise

```
(defun make-rectangle (width height)
  (if (= width height)
      (make-instance 'square :width width)
      (make-instance 'rectangle :width width :height height)))

(defmethod (setf width) :after (width (rectangle rectangle))
  (when (= (width rectangle) (height rectangle))
    (change-class rectangle 'square)))

(defmethod (setf height) :after (height (rectangle rectangle))
  (when (= (width rectangle) (height rectangle))
    (change-class rectangle 'square)))
```

Square-Wise

```
(defclass square (shape)
  ((width :initarg :width :reader width :reader height :accessor side)))

(defmethod (setf width) (width (square square))
  (let ((side (side square)))
    (unless (= width side)
      (change-class square 'rectangle :width width :height side)))
  width)

(defmethod (setf height) (height (square square))
  (unless (= height (side square))
    (change-class square 'rectangle :height height))
  height)
```

Bibliography

Bibliography

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Method Combinators
ELS, 2018
-  Didier Verna
A MOP-Based Implementation for Method Combinations
ELS, 2023