

Metaprogramming and Reflection

Common Lisp

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Syntax

```
(function-name arg1 arg2 ... argn)
```

Syntax

```
(function-name arg1 arg2 ... argn)
```

```
> (+ 1 2)  
3
```

Creating Lists

```
> (cons 3 nil)  
(3)
```

Creating Lists

```
> (cons 3 nil)  
(3)  
> (cons 2 (3))
```

Creating Lists

```
> (cons 3 nil)  
(3)  
> (cons 2 (3))
```

Impossible as 3 is not a function

Creating Lists

```
> (cons 3 nil)  
(3)  
> (cons 2 (3))
```

Impossible as 3 is not a function

```
> (cons 2 ' (3))  
(2 3)
```

Creating Lists

```
> (cons 3 nil)
(3)
> (cons 2 (3))
```

Impossible as 3 is not a function

```
> (cons 2 ' (3))
(2 3)
> (cons 1 ' (2 3))
(1 2 3)
```


Creating Lists

```
> (cons 3 nil)  
(3)  
> (cons 2 (3))
```

Impossible as 3 is not a function

```
> (cons 2 ' (3))  
(2 3)  
> (cons 1 ' (2 3))  
(1 2 3)  
> (list 1 2 3)  
(1 2 3)
```

Creating Lists

```
> (cons 3 nil)
(3)
> (cons 2 (3))
```

Impossible as 3 is not a function

```
> (cons 2 ' (3))
(2 3)
> (cons 1 ' (2 3))
(1 2 3)
> (list 1 2 3)
(1 2 3)
> ' (1 2 3)
(1 2 3)
```

Studying Lists

```
> (car ' (1 2 3) )  
1
```

Studying Lists

```
> (car ' (1 2 3) )  
1  
> (cdr ' (1 2 3) )  
(2 3)
```

Studying Lists

```
> (car ' (1 2 3) )  
1  
> (cdr ' (1 2 3) )  
(2 3)  
> (first ' (1 2 3) )  
1
```

Studying Lists

```
> (car ' (1 2 3) )  
1  
> (cdr ' (1 2 3) )  
(2 3)  
> (first ' (1 2 3) )  
1  
> (last ' (1 2 3) 2)  
(2 3)
```

Studying Lists

```
> (car ' (1 2 3) )  
1  
> (cdr ' (1 2 3) )  
(2 3)  
> (first ' (1 2 3) )  
1  
> (last ' (1 2 3) 2)  
(2 3)  
> (last ' (1 2 3) )  
(3)
```

Creating Functions

```
> (defun mult2 (x)
    "Multiplies x by 2"
    (* x 2))
mult2
```


Creating Functions

```
> (defun mult2 (x)
    "Multiplies x by 2"
    (* x 2))
mult2
```

defun is itself a function, it creates functions

Creating Functions

```
> (defun mult2 (x)
    "Multiplies x by 2"
    (* x 2))
mult2
```

defun is itself a function, it creates functions

```
> (mult2 3)
6
```

Studying Functions

```
> #'mult2  
#<FUNCTION mult2>
```

Studying Functions

```
> #'mult2  
#<FUNCTION mult2>  
> (describe #'mult2)  
(defun mult2 (x)  
  "Multiplies x by 2"  
  (* x 2))
```

Calling Functions

```
> (mult2 3)  
6
```

Calling Functions

```
> (mult2 3)  
6  
> (funcall #'mult2 3)  
6
```

Calling Functions

```
> (mult2 3)
6
> (funcall #'mult2 3)
6
> (defvar fmult2 #'mult2)
fmult2
```

Calling Functions

```
> (mult2 3)
6
> (funcall #'mult2 3)
6
> (defvar fmult2 #'mult2)
fmult2
> (funcall fmult2 3)
6
```


Summary

In Lisp it is possible to:

- ▶ define new functions,
- ▶ retrieve a function by name,
- ▶ reference a function from a variable,
- ▶ call a function from a variable.

Summary

In Lisp it is possible to:

- ▶ define new functions,
- ▶ retrieve a function by name,
- ▶ reference a function from a variable,
- ▶ call a function from a variable.

This is very similar to pointer manipulation in C

Function Pointer Manipulation in C

```
int mult2 (int c) {  
    return c * 2;  
}
```

Function Pointer Manipulation in C

```
int mult2 (int c) {  
    return c * 2;  
}
```

```
int main(void) {  
    int (*fmult2) (int) = mult2;  
    (*fmult2) (3);  
}
```

Generating new Functions

```
> (get-source 'mult2)
(nil nil
  (defun mult2 (x)
    "Multiplies x by 2"
    (* x 2)))
```

Generating new Functions

```
> (get-source 'mult2)
(nil nil
  (defun mult2 (x)
    "Multiplies x by 2"
    (* x 2)))
```

requires ibcl

Generating new Functions

```
> (defvar smult2  
    (third (get-source 'mult2)))  
smult2
```

Generating new Functions

```
> (defvar smult2
    (third (get-source 'mult2)))
smult2
> smult2
(defun mult2 (x)
  "Multiplies x by 2"
  (* x 2))
```


Generating new Functions

```
> (first smult2)  
defun
```

Generating new Functions

```
> (first smult2)
defun
> (second smult2)
mult2
```

Generating new Functions

```
> (first smult2)
defun
> (second smult2)
mult2
> (third smult2)
(x)
```

Generating new Functions

```
> (first smult2)
defun
> (second smult2)
mult2
> (third smult2)
(x)
> (fourth smult2)
"Multiplies x by 2"
```

Generating new Functions

```
> (first smult2)
defun
> (second smult2)
mult2
> (third smult2)
(x)
> (fourth smult2)
"Multiplies x by 2"
> (fifth smult2)
(* x 2)
```

Generating new Functions

```
> (defvar smult10  
    (copy-list smult2))  
smult10
```

Generating new Functions

```
> (defvar smult10  
    (copy-list smult2))  
smult10  
> (nsubstitute 10 2 (fifth smult10))  
nil
```

Generating new Functions

```
> (defvar smult10
    (copy-list smult2))
smult10
> (nsubstitute 10 2 (fifth smult10))
nil
> smult10
(defun mult2 (x)
  "Multiplies x by 2"
  (* x 10))
```


Generating new Functions

```
> smult10  
(defun mult2 (x)  
  "Multiplies x by 2"  
  (* x 10))
```

Generating new Functions

```
> smult10
(defun mult2 (x)
  "Multiplies x by 2"
  (* x 10))
> (nsubstitute 'mult10 'mult2
               smult10)
(defun mult10 (x)
  "Multiplies x by 2"
  (* x 10))
```

Generating new Functions

```
> smult10  
(defun mult10 (x)  
  "Multiplies x by 2"  
  (* x 10))
```

Generating new Functions

```
> smult10
(defun mult10 (x)
  "Multiplies x by 2"
  (* x 10))
> (setf (fourth smult10)
      (cl-ppcre:regex-replace "2"
        (fourth smult10) "10"))
"Multiplies x by 10"
```

Generating new Functions

```
> smult10  
(defun mult10 (x)  
  "Multiplies x by 10"  
  (* x 10))
```

Generating new Functions

```
> smult10
(defun mult10 (x)
  "Multiplies x by 10"
  (* x 10))
> (eval smult10)
mult10
```

Generating new Functions

```
> smult10
(defun mult10 (x)
  "Multiplies x by 10"
  (* x 10))
> (eval smult10)
mult10
> (mult10 3)
30
```

Summary

- ▶ A function definition in Lisp is a list.
- ▶ This list can be studied like any list.
- ▶ New functions can be created from a list.

Beyond Functions

How would you implement **while** that executes its **body** *as long as* its **condition** stays true?

```
> (while condition body)
```

The While Construct

```
> (setq i 10)
> (while (/= i 0)
  (decf i)
  (format t "i is now: ~s~%" i))
```

The While Construct

```
> (setq i 10)
> (while (/= i 0)
      (decf i)
      (format t "i is now: ~s~%" i))
i is now: 9
i is now: 8
i is now: 7
...
i is now: 2
i is now: 1
i is now: 0
```

The While Construct: Using Loop

```
> (while (/= i 0)
    (decf i)
    (format t "i is now: ~s~%" i))
> (loop
    (if (not (/= i 0))
        (return)
        (progn
            (decf i)
            (format t "i = ~s~%" i))))
```

The While Construct: Function

```
> (defun while (test &rest body)
  (loop
    (if (not test)
        (return)
        (progn body) ) ) )
> (while (/= i 0)
  (decf i)
  (format t "i is now: ~s~%" i) )
```

The While Construct: Function

```
> (defun while (test &rest body)
    (loop
      (if (not test)
          (return)
          (progn body) ) ) )
> (while (/= i 0)
    (decf i)
    (format t "i is now: ~s~%" i))
```

doesn't work because parameters are evaluated immediately

```
> (while t nil)
```

Function Evaluation in C

```
int f(int c) {printf("f\n"); return c;}
int g(int c) {printf("g\n"); return c;}
int h(int c) {printf("h\n"); return c;}

int main(void) {
    f(g(h(1)));
}
```

Function Evaluation in C

```
int f(int c) {printf("f\n"); return c;}  
int g(int c) {printf("g\n"); return c;}  
int h(int c) {printf("h\n"); return c;}  
  
int main(void) {  
    f(g(h(1)));  
}
```

h
g
f

The While Construct: Function

```
> (defun while (test &rest body)
    (loop
      (if (not test)
          (return)
          (progn body) ) ) )
> (while (/= i 0)
    (decf i)
    (format t "i is now: ~s~%" i))
```

doesn't work because parameters are evaluated immediately

```
> (while t nil)
```

The While Construct: Function

```
> (while ' (/= i 0)  
    ' (decf i)  
    ' (format t "i is now: ~s~%" i))
```

The While Construct: Function

```
> (while ' (/= i 0)
    ' (decf i)
    ' (format t "i is now: ~s~%" i))
> (defun while (test &rest body)
    (loop
      (if (not (eval test))
          (return)
          (mapcar #'eval body))))
```

The While Construct: Function

```
> (while ' (/= i 0)
    ' (decf i)
    ' (format t "i is now: ~s~%" i))
> (defun while (test &rest body)
    (loop
      (if (not (eval test))
          (return)
          (mapcar #'eval body))))
```

works, but using **while** is less readable than intended

Summary

- ▶ Arguments of functions are evaluated first.
- ▶ To prevent evaluation, use **quote** (or **'**).
- ▶ Use **eval** to evaluate an expression.

The While Construct: Macro

```
> (loop
  (if (not (/= i 0))
    (return)
    (progn
      (decf i)
      (format t "~s~%" i)))))
```

The While Construct: Macro

```
> (loop
  (if (not (/= i 0))
    (return)
    (progn
      (decf i)
      (format t "i = ~s~%" i))))
> (defmacro while (test &body body)
  (list 'loop
    (list 'if (list 'not test)
      (list 'return)
      (cons 'progn body))))
```

The While Construct: Macro

```
> (loop
  (if (not (/= i 0))
    (return)
    (progn
      (decf i)
      (format t "i = ~s~%" i))))
> (defmacro while (test &body body)
  `(loop
    (if (not ,test)
      (return)
      (progn ,@body))))
```


Macros

Macros are programs that write programs

- ▶ they return lists representing Lisp code.
- ▶ they don't evaluate their arguments.
- ▶ they are evaluated at *compile time*.

Creating an OO language

```
> (makeClass Speaker (name)
    (makeMethod speak (sentence)
        (format t
            "Listen all of you: ~s~%"
            sentence)))
```

Creating an OO language

```
> (makeClass Speaker (name)
    (makeMethod speak (sentence)
        (format t
            "Listen all of you: ~s~%"
            sentence)))
> (defvar alex (new 'Speaker "Alex"))
```

Creating an OO language

```
> (makeClass Speaker (name)
    (makeMethod speak (sentence)
        (format t
            "Listen all of you: ~s~%"
            sentence)))
> (defvar alex (new 'Speaker "Alex"))
> (call alex 'speak "Hello World!")
Listen all of you: "Hello World!"
```

Creating an OO language

```
> (makeClass Speaker (name)
    (makeMethod speak (sentence)
        (format t
            "Listen all of you: ~s~%"
            sentence)))
> (defvar alex (new 'Speaker "Alex"))
> (call alex 'speak "Hello World!")
Listen all of you: "Hello World!"
> (getinstvar alex 'name)
Alex
```

Creating an OO language

```
> (makeClass Speaker ()  
    (makeMethod "..."))
```

Creating an OO language

```
> (makeClass Speaker ()  
    (makeMethod "..."))
```

A class is composed of:

- ▶ a name,
- ▶ some instance variables,
- ▶ and some method definitions.

Creating an OO language

```
> (makeClass Speaker ()  
    (makeMethod "..."))
```

A class is composed of:

- ▶ a name,
- ▶ some instance variables,
- ▶ and some method definitions.

```
> (defstruct cls  
    name  
    vars  
    mths)
```


Creating an OO language

```
> (makeClass Speaker ()  
    (makeMethod "..."))
```

```
> (defmacro makeClass (name iVars  
                        &body meths)  
  `(push  
    (make-cls  
      :name ', name  
      :vars ', iVars  
      :mths  
        ', (mapcar #'eval meths))  
    *classes*))
```

Creating an OO language

```
> (makeMethod speak (sentence)
   (format t "... " sentence))
```

Creating an OO language

```
> (makeMethod speak (sentence)
   (format t "... " sentence))
```

A method is composed of:

- ▶ a name,
- ▶ some parameters,
- ▶ a body

Creating an OO language

```
> (makeMethod speak (sentence)
    (format t "... " sentence))
```

A method is composed of:

- ▶ a name,
- ▶ some parameters,
- ▶ a body

```
> (defstruct mth
    name
    lmbd)
```

Creating an OO language

```
> (makeMethod speak (sentence)
   (format t "... " sentence))
```

Creating an OO language

```
> (makeMethod speak (sentence)
    (format t "... " sentence))
```

```
> (defmacro makeMethod (name
                        argNames &body body)
  `(make-mth
    :name ', name
    :lmbd (lambda , argNames
            , @body)))
```

Creating an OO language

```
> (new 'Speaker "Alex")
```

Creating an OO language

```
> (new 'Speaker "Alex")
```

An object is composed of:

- ▶ a reference to its class,
- ▶ some values for its instance variables

Creating an OO language

```
> (new 'Speaker "Alex")
```

An object is composed of:

- ▶ a reference to its class,
- ▶ some values for its instance variables

```
> (defstruct obj  
  cls  
  values)
```

Creating an OO language

```
> (call alex 'speak "Hello World!")  
Listen all of you: "Hello World!"
```

Creating an OO language

```
> (call alex 'speak "Hello World!")  
Listen all of you: "Hello World!"
```

A call is a function with:

- ▶ the receiver object,
- ▶ a method name,
- ▶ and a list of parameters.

Creating an OO language

```
> (call alex 'speak "Hello World!")  
Listen all of you: "Hello World!"
```

A call is a function with:

- ▶ the receiver object,
- ▶ a method name,
- ▶ and a list of parameters.

```
(defun call (obj name &rest params)  
  "...")
```

Creating an OO language

```
(defun call (obj name &rest params)
  (let* ((cls (obj-cls obj))
        (mth (getMethod cls name)))
    (apply (mth-lmbd mth)
            params)))
```

Creating an OO language

```
(defun call (obj name &rest params)
  (let* ((cls (obj-cls obj))
        (mth (getMethod cls name)))
    (apply (mth-lmbd mth)
            params)))
```

```
(defun getMethod (cls name)
  (find name (cls-mths cls)
        :key #'mth-name))
```

Creating an OO language

```
> (getinstvar alex 'name)  
Alex
```

Creating an OO language

```
> (getinstvar alex 'name)  
Alex
```

Looking for an instance variable value from its name involves:

- ▶ getting the position of the name in the list of all instance variables of the class,
- ▶ taking the value at this position in the list of all values of the object.

class:

$varname_1$	$varname_2$	\dots	$varname_n$
-------------	-------------	---------	-------------

object:

$value_1$	$value_2$	\dots	$value_n$
-----------	-----------	---------	-----------

Creating an OO language

class:

$varname_1$	$varname_2$	\dots	$varname_n$
-------------	-------------	---------	-------------

object:

$value_1$	$value_2$	\dots	$value_n$
-----------	-----------	---------	-----------

```
(defun getInstVar (obj name)
  (let* ((cls (obj-cls obj))
        (vars (cls-vars cls))
        (pos (position name vars)))
    (nth pos (obj-values obj))))
```

Handling this

An object must be able to get its instance variables and call methods by using `this`.

Handling this

An object must be able to get its instance variables and call methods by using **this**.

```
> (makeClass Speaker (name)
    (makeMethod getName ()
      (getInstVar 'this 'name)))
```

Handling this

An object must be able to get its instance variables and call methods by using **this**.

```
> (makeClass Speaker (name)
    (makeMethod getName ()
      (getInstVar 'this 'name)))
> (call alex 'getname)
Alex
```

Handling this

An object must be able to get its instance variables and call methods by using **this**.

```
> (makeClass Speaker (name)
    (makeMethod getName ()
      (getInstVar 'this 'name)))
> (call alex 'getname)
Alex
```

This requires the system to keep track of the *current object*.

Handling this

An object must be able to get its instance variables and call methods by using **this**.

```
> (makeClass Speaker (name)
    (makeMethod getName ()
        (getInstVar 'this 'name)))
> (call alex 'getname)
Alex
```

This requires the system to keep track of the *current object*.

```
> (defparameter *cur-obj* nil)
```

Handling this

```
(defun getInstVar (obj name)
  (let* ((theObj
          (if (equal obj 'this)
              *cur-obj*
              obj))
         (cls (obj-cls theObj))
         (vars (cls-vars cls))
         (pos (position name vars)))
    (nth pos (obj-values theObj))))
```

Handling this

```
(defun getInstVar (obj name)
  (let* ((theObj
          (if (equal obj 'this)
              *cur-obj*
              obj))
         (cls (obj-cls theObj))
         (vars (cls-vars cls))
         (pos (position name vars)))
    (nth pos (obj-values theObj))))
```

When is `*cur-obj*` updated?

Handling this

```
(defun getInstVar (obj name)
  (let* ((theObj
          (if (equal obj 'this)
              *cur-obj*
              obj))
         (cls (obj-cls theObj))
         (vars (cls-vars cls))
         (pos (position name vars)))
    (nth pos (obj-values theObj))))
```

When is `*cur-obj*` updated? Before it is *used*!

Handling this

```
(defun getInstVar (obj name)
  (let* ((theObj
          (if (equal obj 'this)
              *cur-obj*
              obj))
         (cls (obj-cls theObj))
         (vars (cls-vars cls))
         (pos (position name vars)))
    (nth pos (obj-values theObj))))
```

When is `*cur-obj*` updated? Before it is *used*!
As `this` is only used when a method is executed, the
method `call` needs to do the updating job.

Handling this

The method `call` needs to do the updating job:

```
(defun call (obj name &rest params)
  (let* ((cls (obj-cls obj))
        (mth (getMethod cls name))
        (*cur-obj* obj))
    (apply (mth-lmbd mth)
            params)))
```

Handling this

We also want to pass **this** as first argument to **call**:

```
(defun call (obj name &rest params)
  (let* ((theObj
          (if (equal obj 'this)
              *cur-obj*
              obj))
        (cls (obj-cls theObj))
        (mth (getMethod cls name)))
    (setf *cur-obj* theObj)
    (apply (mth-lmbd mth)
            params)))
```

Creating an OO language

Possible improvements:

- ▶ setting of instance variables
- ▶ inheritance
- ▶ constructors
- ▶ dedicated syntax

Creating Domain-Specific Languages

```
(makeClass Speaker (name)
  (makeMethod speak (s)
    (format t "I say: ~a" s)))
(makeMethod getName ()
  (call 'this 'speak "hi!"))
(getInstVar 'this 'name)))
```

Creating Domain-Specific Languages

```
(makeClass Speaker (name)
  (makeMethod speak (s)
    (format t "I say: ~a" s))
  (makeMethod getName ()
    (call 'this 'speak "hi!")
    (getInstVar 'this 'name)))
```

```
(makeMethod getName ()
  {c speak "hi!"}
  {i name})
```

Creating Domain-Specific Languages

```
;; {c speak "hi!"} {i name}
(set-macro-character #\{
  (lambda (str)
    (let ((type (read-char str))
          (l (read-delimited-list
                #\} str))))
    (case type
      (#\c `(call 'this
                  ', (car l)
                  ,@ (cdr l)))
      (#\i `(getInstVar 'this
                        ', (car l)))))))
```


Summary

- ▶ Lisp has powerful functions to manipulate lists.
- ▶ Lisp source code is made of lists.
- ▶ As a result, meta-programming is made easy.

Summary

Macros

- ▶ can be used to create source code,
- ▶ don't evaluate their arguments,
- ▶ are evaluated at compile time.

Summary

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- ▶ can be used to create source code,
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Macros are programs that write programs.

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Macros

- ▶ can be used to create source code,
- ▶ don't evaluate their arguments,
- ▶ are evaluated at compile time.

Macros are programs that write programs.

Macros can also be used to install a new syntax.

A Glimpse at CLOS

```
> (defclass circle ()  
    (radius center))  
#<standard-class circle>
```

A Glimpse at CLOS

```
> (defclass circle ()  
    (radius center))  
#<standard-class circle>  
> (make-instance 'circle)  
#<circle {B971249}>
```

A Glimpse at CLOS

```
> (defclass circle ()  
    ((radius :accessor circle-radius)  
     (center :accessor circle-center)))  
#<standard-class circle>
```

A Glimpse at CLOS

```
> (defclass circle ()  
    ((radius :accessor circle-radius)  
     (center :accessor circle-center)))  
#<standard-class circle>  
> (setf c (make-instance 'circle))  
#<circle {ABBFD49}>
```


A Glimpse at CLOS

```
> (defclass circle ()  
    ((radius :accessor circle-radius)  
     (center :accessor circle-center)))  
#<standard-class circle>  
> (setf c (make-instance 'circle))  
#<circle {ABBFD49}>  
> (setf (circle-radius c) 6)  
6
```

A Glimpse at CLOS

```
> (defclass circle ()  
    ((radius :accessor circle-radius)  
     (center :accessor circle-center)))  
#<standard-class circle>  
> (setf c (make-instance 'circle))  
#<circle {ABBFD49}>  
> (setf (circle-radius c) 6)  
6  
> (circle-radius c)  
6
```

A Glimpse at CLOS

```
> (defclass circle ()  
    ((radius :accessor circle-radius  
             :initarg :radius)  
     (center :accessor circle-center  
             :initarg :center)))  
#<standard-class circle>
```

A Glimpse at CLOS

```
> (defclass circle ()  
    ((radius :accessor circle-radius  
             :initarg :radius)  
     (center :accessor circle-center  
             :initarg :center)))  
#<standard-class circle>  
> (setf c (make-instance 'circle  
                          :radius 6))  
#<circle {AC2E0C9}>
```

A Glimpse at CLOS

```
> (defclass circle ()
    ((radius :accessor circle-radius
              :initarg :radius)
     (center :accessor circle-center
              :initarg :center)))
#<standard-class circle>
> (setf c (make-instance 'circle
                          :radius 6))
#<circle {AC2E0C9}>
> (circle-radius c)
6
```

A Glimpse at CLOS

```
> (defmethod area ((c circle))  
    (* pi (expt (circle-radius c) 2)))  
#<standard-method area (circle)>
```

A Glimpse at CLOS

```
> (defmethod area ((c circle))  
    (* pi (expt (circle-radius c) 2)))  
#<standard-method area (circle)>  
> (setf c (make-instance 'circle  
                          :radius 6))  
#<circle {ACBEC71}>
```

A Glimpse at CLOS

```
> (defmethod area ((c circle))  
    (* pi (expt (circle-radius c) 2)))  
#<standard-method area (circle)>  
> (setf c (make-instance 'circle  
                          :radius 6))  
#<circle {ACBEC71}>  
> (area c)  
113.09733552923255d0
```


Auxiliary methods

```
> (defmethod area ((c circle))  
    (* pi (expt (circle-radius c) 2)))
```

Auxiliary methods

```
> (defmethod area ((c circle))  
    (* pi (expt (circle-radius c) 2)))  
> (defmethod area :before ((c circle))  
    (format t "I'm tired..."))
```

Auxiliary methods

```
> (defmethod area ((c circle))  
    (* pi (expt (circle-radius c) 2)))  
> (defmethod area :before ((c circle))  
    (format t "I'm tired..."))  
> (area c)  
I'm tired...  
113.09733552923255d0
```

Auxiliary methods

```
(setf cache nil)
```

Auxiliary methods

```
(setf cache nil)
(defun from-cache (c)
  (find (circle-radius c) cache
    :key #'car))
```

Auxiliary methods

```
(setf cache nil)
(defun from-cache (c)
  (find (circle-radius c) cache
        :key #'car))
(defun to-cache (c area)
  (push (cons (circle-radius c) area)
        cache)
  area)
```

Auxiliary methods

```
(defmethod area :around ((c circle))  
  (let ((value (from-cache c)))  
    (if value  
      (progn  
        (princ "Using the cache :-) ")  
        (cdr value))  
      (progn  
        (princ "So tired...")  
        (to-cache c (call-next-method)))))))
```

Auxiliary methods

```
(defmethod area :around ((c circle))  
  (let ((value (from-cache c)))  
    (if value  
      (progn  
        (princ "Using the cache :-) ")  
        (cdr value))  
      (progn  
        (princ "So tired...")  
        (to-cache c (call-next-method))))))  
> (area c)  
So tired...I'm tired...  
113.09733552923255d0
```


Auxiliary methods

```
> (area c)  
So tired...I'm tired...  
113.09733552923255d0
```

Auxiliary methods

```
> (area c)  
So tired...I'm tired...  
113.09733552923255d0  
> (area c)  
Using the cache :-)  
113.09733552923255d0
```

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- ▶ [prxb](#)
- ▶ [ThomasH](#)

<https://github.com/DamienCassou/DSLides>