Macros

Principles of Programming Languages

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https://lambda.mines.edu
Motivation

- Even in the best software designs, it’s hard to avoid repetitive patterns.
- What if our language let us extend its syntax to account for these patterns?

Exercise for Home

Find a piece of code you wrote (in any language) which repeats a syntax pattern you couldn’t avoid by writing a function, class, etc.
What do I mean by "extend syntax"?

We can implement most all of the functionality we need in Python using functions. But can we implement something like Racket’s `let` in Python?

```
let (x = 10,
     y = 20) in:
  print(x, y)
```

(Python does not support above)
How about C Macros?

The C Preprocessor lets us do simple text substitutions:

```
#define FOREVER for (;;)

main () {
  FOREVER {
    printf("Hello, World!\n");
  }
}
```

(they can get a little more complicated than that...)

But what happens when we want to do more complex things? Like manipulate the body of that "FOREVER loop"?
At some point, textual source manipulation cannot serve the purpose we need anymore. Let this source from MicroPython serve as an example:

```c
STATIC mp_obj_t machine_spi_init(...) {
    ...
}
STATIC MP_DEFINE_CONST_FUN_OBJ_KW(machine_spi_init_obj, 1, machine_spi_init);

STATIC mp_obj_t machine_spi_deinit(...) {
    ...
}
STATIC MP_DEFINE_CONST_FUN_OBJ_1(machine_spi_deinit_obj, machine_spi_deinit);

STATIC mp_obj_t mp_machine_spi_read(...) {
    ...
}
MP_DEFINE_CONST_FUN_OBJ_VAR_BETWEEN(mp_machine_spi_read_obj, 2, 3, mp_machine_spi_read);

STATIC mp_obj_t mp_machine_spi_readinto(...) {
    ...
}
```

C Macros
Hopefully it’s become apparent that **symbolic computation** is the right tool for the job when it comes to macros.

**Lisp Macros:**
- Compile time
- Syntax → Syntax

**Lisp Functions:**
- Run time
- Data → Data

Lisp dialects usually make the run time available during the compile time, so the normal language can be used to write macros.
YOU ARE INSIDE A ROOM.
THERE ARE KEYS ON THE GROUND.
THERE IS A SHINY BRASS LAMP NEARBY.

IF YOU GO THE WRONG WAY, YOU WILL BECOME
HOPELESSLY LOST AND CONFUSED.

> pick up the keys

YOU HAVE A SYNTAX TRANSFORMER
Old-School Lisp Macros

Early Lisp macro systems operated on the simple contract of functions which take syntax, manipulate it, and returns a list containing the new syntax:

\[
\begin{align*}
\text{(defmacro repeat-forever (\&rest body) } & \text{ `(prog () a ,@body (go a)))} \\
\text{;; we can then use the macro like this:} & \\
\text{(repeat-forever (format t "HELLO WORLD~\%")))}
\end{align*}
\]
"let" as a macro:

(defmacro let (bindings &rest body)
  `((lambda ,((mapcar #'car bindings)
    ,@body)
    ,@(mapcar #'cadr bindings)))

;; we can then use let like this:
(let ((a 10)
      (b 20))
  (format t "~A \~A\%" a b))
Old-School: Another Example

Suppose we wanted to define a syntax like this:

```
(numeric-case num
   negative
   zero
   positive)
```

We could write a macro like this:

```
(defmacro numeric-case (num negative zero positive)
 `(
   let ((result ,num))
     (cond
      ((< result 0) ,negative)
      ( (= result 0) ,zero)
      (t ,positive))))
```

What could possibly go wrong?
gensym is here to save us when we need really obscure symbol names:

```
(defmacro numeric-case (num negative zero positive)
 (let ((sym (gensym)))
   `(let ((,sym ,num))
     (cond
      ((< ,sym 0) ,negative)
      ((= ,sym 0) ,zero)
      (t ,positive))))
)```
What happens if the programmer redefined one of the functions we used (e.g., < or =) in the previous example?

**Unhygienic Macros**

Modern Lisp dialects typically provide what is called **hygienic macros**: macro systems which eliminate the issues we discovered with old-school Lisp macros (to varying degrees).
Racket’s Hygienic Macros

- `define-syntax` defines compile-time syntax: a function that takes a "syntax" and returns a "syntax".
- Typical syntax operations provide a convenient way to manipulate the syntax in a hygienic manner.
- You can also go unhygienic: `syntax->datum` converts syntax to lists, symbols, etc., and `datum->syntax` goes back.
What is a "syntax"?

Syntax literals can be written using `#'`:

```
> #'(if (> 0 x) y z)
#<syntax:readline-input:1:2 (if (> 0 x) y z)>
> (define stx #'(if (> 0 x) y z))
```

We can convert this to a list if we wish:

```
> (syntax->datum stx)
'(if (> 0 x) y z)
```

And back:

```
> (datum->syntax stx (syntax->datum stx))
#<syntax (if (> 0 x) y z)>
```

If you didn’t have access to the original syntax object, you could pass `#f` as the first argument to `datum->syntax`.

Note this is completely different from the function-namespace thing in old-school Lisps.
Going Unhygienic

We could write our `let` macro without considerations for hygiene:

```
(define-syntax (my-let stx)
  (datum->syntax stx
    (let ([stx-list (syntax->datum stx)]
         `((lambda , (map car (cadr stx-list))
            ,@ (cddr stx-list))
         ,(map cadr (cadr stx-list))))))
```

A little bit yucky, but it worked.
Doing Things Hygienic

syntax-case acts like match but for syntax objects:

```
(define-syntax (my-let stx)
  (syntax-case stx ()
    [(_ ([name expr] ...) body ...)
     #'((lambda (name ...)
          body ...)
        expr ...)])
```

CSCI-400
define-syntax-rule is a shorthand for a define-syntax with a syntax-case of a single rule inside.

```
(define-syntax-rule (my-let ([name expr] ...) body ...) 
  ((lambda (name ...) 
    body ...) 
  expr ...))
```
Application of Macros: Anaphora

In natural language, anaphora is a reference to a previously defined noun:

Susan dropped the plate. It shattered loudly!

Lisp programmers call a similar technique the same name:

\[
\text{(printf "~a~\%"}
\begin{align*}
&\text{(aif (member 10 lst)} \\
&\hspace{1cm} \text{it} \\
&\hspace{2cm} \text{"10 not in the list")})
\end{align*}
\]

Available in a Racket Package

The "anaphoric" package provides aif, awhen, acond, and aand.
Anaphoric If

Example from "Fear of Macros", which you will read for the LGA this weekend.

(require racket/stxparam)

(define-syntax-parameter it
  (lambda (stx)
    (raise-syntax-error (syntax-e stx) "outside of anaphora")))

(define-syntax-rule (aif predicate consequent alternative)
  (let ([result predicate])
    (if result
      (syntax-parameterize ([it (make-rename-transformer #'result)]
                           consequent)
                         alternative))))