



Extensibility

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Extensibility for DSL design and implementation

A case study in Common Lisp

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Taxonomy of DSLs

[Fowler, 2005, Tratt, 2008]

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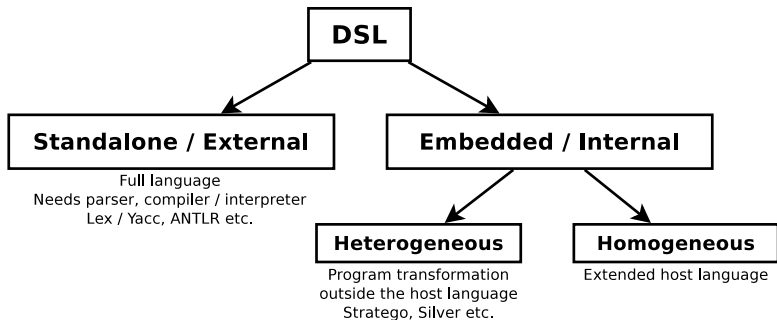
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Example

Command-line options highlighting

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```
Usage: advanced [-hd] [+d] [OPTIONS] cmd [OPTIONS]
```

```
Available commands: push pull.
```

```
Use 'cmd --help' to get command-specific help.
```

```
  -h, --help           Print this help and exit.
```

```
  -(+)d, --debug[=on/off] Turn debugging on or off.
```

```
  Fallback: on
```

```
  Environment: DEBUG
```

- Properties (bold, underline, foreground color...)
- Faces (localized property set)
- Themes (face trees)



Example

Underlying implementation

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The `face` class

```
(defclass face ()  
  ((name :initarg :name)  
   ;; Properties:  
   (foreground :initarg :foreground)  
   (background :initarg :background)  
   (boldp :initarg :bold)  
   ;; etc.  
   (subfaces :initarg :subfaces)))
```



Example

A DSL for theme customization

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How do we go from this...

```
;;; default.cth — Personal default theme for Clon
```

```
:background black
:face { option :foreground white
          :face { syntax :bold t :foreground cyan }
          :face { usage :foreground yellow }
}
```

...to that?

```
(setq default-theme
  (make-instance 'face :name 'toplevel
    :background 'black
    :subfaces (list (make-instance 'face :name 'option
      :foreground 'white
      :subfaces (list (make-instance 'face :name 'syntax
        :bold t
        :foreground 'cyan)
        (make-instance 'face :name 'usage
          :foreground 'yellow)))))))
```



Step 1

Hook into the Lisp parser: reader macros

- *readtable*: currently active syntax extensions table
- *macro character*: special syntactic meaning
- *reader macro*: implements macro character behavior

Let's do it!

- Make the `{ }` characters active
- Read a list of tokens until the closing brace
- Push the symbol `define-face` on top of that list

Note: RTMP (Read-Time Meta-Programming)

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Step 1

Hook into the Lisp reader

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This is how we go from this...

```
;;; default.cth — Personal default theme for Clon
```

```
:background black
:face { option :foreground white
          :face { syntax :bold t :foreground cyan }
          :face { usage :foreground yellow }
      }
```

... to that:

```
;;; default.cth — Personal default theme for Clon
```

```
:background black
:face (define-face option :foreground white
        :face (define-face syntax :bold t :foreground cyan)
        :face (define-face usage :foreground yellow))
```



Step 2

Hook into the Lisp compiler: macros

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- Ordinary Lisp functions
- Work on chunks of code (as data)
- Transform expressions into new expressions
- Control over evaluation

Let's make `define-face` a macro!

- Quoting its key arguments, except for the `:face` ones
- Generating a call to `make-face`

Note: CTMP (Compile-Time Meta-Programming)



Step 2

Hook into the Lisp compiler: macros

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This is how we go from this...

```
;;; default.cth — Personal default theme for Clon
```

```
:background black
:face (define-face option :foreground white
       :face (define-face syntax :bold t :foreground cyan)
       :face (define-face usage :foreground yellow))
```

...to that:

```
;;; default.cth — Personal default theme for Clon
```

```
:background 'black
:face (make-face 'option :foreground 'white
               :face (make-face 'syntax :bold t :foreground 'cyan)
               :face (make-face 'usage :foreground 'yellow))
```



Step 3

A couple of wrappers

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Lambda-list manipulation / 1st class functions

```
(defun make-face (name &rest args &key &allow-other-keys)
  (apply #'make-instance 'face :name name args))
```

```
(defun make-theme (&rest args)
  (apply #'make-face 'toplevel args))
```

And while we're at it. . .

```
(defmacro define-theme (&rest args)
  '(define-face toplevel ,@args))
```



Step 3

A couple of wrappers

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This is how we go from this. . .

```
;;; default.cth — Personal default theme for Clon
```

```
:background 'black
:face (make-face 'option :foreground 'white
      :face (make-face 'syntax :bold t :foreground 'cyan)
      :face (make-face 'usage :foreground 'yellow))
```

. . . to that:

```
;;; default.cth — Personal default theme for Clon
```

```
:background 'black
:face (make-instance 'face :name 'option :foreground 'white
      :face (make-instance 'face :name 'syntax :bold t :foreground 'cyan)
      :face (make-instance 'face :name 'usage :foreground 'yellow))
```



Step 4

Hook into the object system: the MOP

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The CLOS Meta-Object Protocol (MOP)

■ CLOS *itself* is object-oriented

- ▶ The CLOS MOP: a *de facto* implementation standard
- ▶ The CLOS components (classes, methods *etc.*) are (meta-)objects of some (meta-)classes

Generic functions, methods

```
(defmethod func ((arg1 class1) arg2 ...)  
  body)
```

Methods are *outside* the classes (ordinary function calls)

Multiple dispatch (multi-methods)



Step 4

Hook into the object system: the MOP

- Object instantiation (`make-instance`) is a protocol
- Slot initialization (`initialize-instance`) is a generic function

Let's extend it!

- Provide our own method for the `face` class
- Collect all `:face` arguments
- call the next (standard) method with a new `:subfaces` `initarg`

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Step 4

Hook into the object system: the MOP

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This is how we go from this...

```
;;; default.cth — Personal default theme for Clon
```

```
:background 'black
:face (make-instance 'face :name 'option :foreground 'white
      :face (make-instance 'face :name 'syntax :bold t :foreground 'cyan)
      :face (make-instance 'face :name 'usage :foreground 'yellow))
```

...to that:

```
;;; default.cth — Personal default theme for Clon
```

```
:background 'black
:subfaces (list (make-instance 'face :name 'option :foreground 'white
                  :subfaces (list (make-instance 'face
                                          :name 'syntax :bold t :foreground 'cyan)
                                  (make-instance 'face
                                          :name 'usage :foreground 'yellow))))))
```



Wrap Up

Using the DSL externally

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Mostly a matter of `read`, `compile` *etc.*

```
(defun read-user-theme ()
  (with-open-file (stream (merge-pathnames ".faces" (user-homedir-pathname)))
    (read (make-concatenated-stream (make-string-input-stream "(define-theme_"
                                                                stream
                                                                (make-string-input-stream ")"))))))

(defmacro make-user-theme (&optional compile)
  (if compile
      '(funcall (compile nil (lambda () ,(read-user-theme))))
      (read-user-theme)))
```



Wrap Up

Using the DSL internally

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Mostly a matter of... Just-Do-It™

```
(setq default-theme
  (define-theme
    :background black
    :face { option :foreground white
            :face { syntax :bold t :foreground cyan }
            :face { usage :foreground yellow }
          }
  ))
```




Conclusion

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- Impact of GPL on DSL design and implementation
- Key GPL aspect: extensibility
- Embedded homogeneous approach
 - ▶ A single language
 - ▶ DSL infrastructure smaller
 - ▶ DSL both internal and external
- Common Lisp
 - ▶ Functional, Imperative, Object-Oriented
 - ▶ MOP
 - ▶ CTMP (macros)
 - ▶ RTMP (reader macros)
 - ▶ `read, eval, compile`



Internal vs External DSLs

[Kamin, 1998, Czarnecki et al., 2004]

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■ Sub-optimal syntax **ok but...**

Not ok:

- ▶ [Fowler, 2010]: “external DSLs have their own custom syntax and you write a full parser to process them”
- ▶ [Kamin, 1998, Czarnecki et al., 2004]: “a prerequisite for embedding is that the syntax for the new language be a subset of the syntax for the host language”
- ▶ BTW, same disagreement at the semantic level (MOP)

■ Poor error reporting

- ▶ Research: [Tratt, 2008]
- ▶ Lisp: ? (but Cf. condition system & restarts)



Controversial aspects of extensibility

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■ Dynamic typing

- ▶ pros: end-user friendly
- ▶ cons: run-time type errors / checking
- ▶ Research: [Taha and Sheard, 1997]
- ▶ Hybrid languages (Cf. Racket)

■ Lazy Evaluation

- ▶ pros: infinite data structures, new control primitives *etc.*
- ▶ cons: pure functional languages only
- ▶ Lisp: laziness through macros (not as straightforward), but side-effects for free, and still functional.



The root of (Lisp) extensibility

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■ Reflection

- ▶ Introspection
- ▶ Intercession

■ Implementation

- ▶ By API
- ▶ Inherent: “homoiconicity” [McIlroy, 1960, Kay, 1969]

■ Further distinction [Maes, 1987, Smith, 1984]

- ▶ Structural Reflection (program)
- ▶ Behavioral Reflection (language)



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