A tutorial on Lisp extensibility

Impact on DSL design and implementation

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Introduction
The Challenges in DSL design and implementation

- Orthogonal expertise
  - Application domain
  - Language design and implementation
- DSLs *vs* GPLs
  - $\neq$ syntax
  - $\neq$ semantics
- DSLs and GPLs need to be completely different.

Really ?

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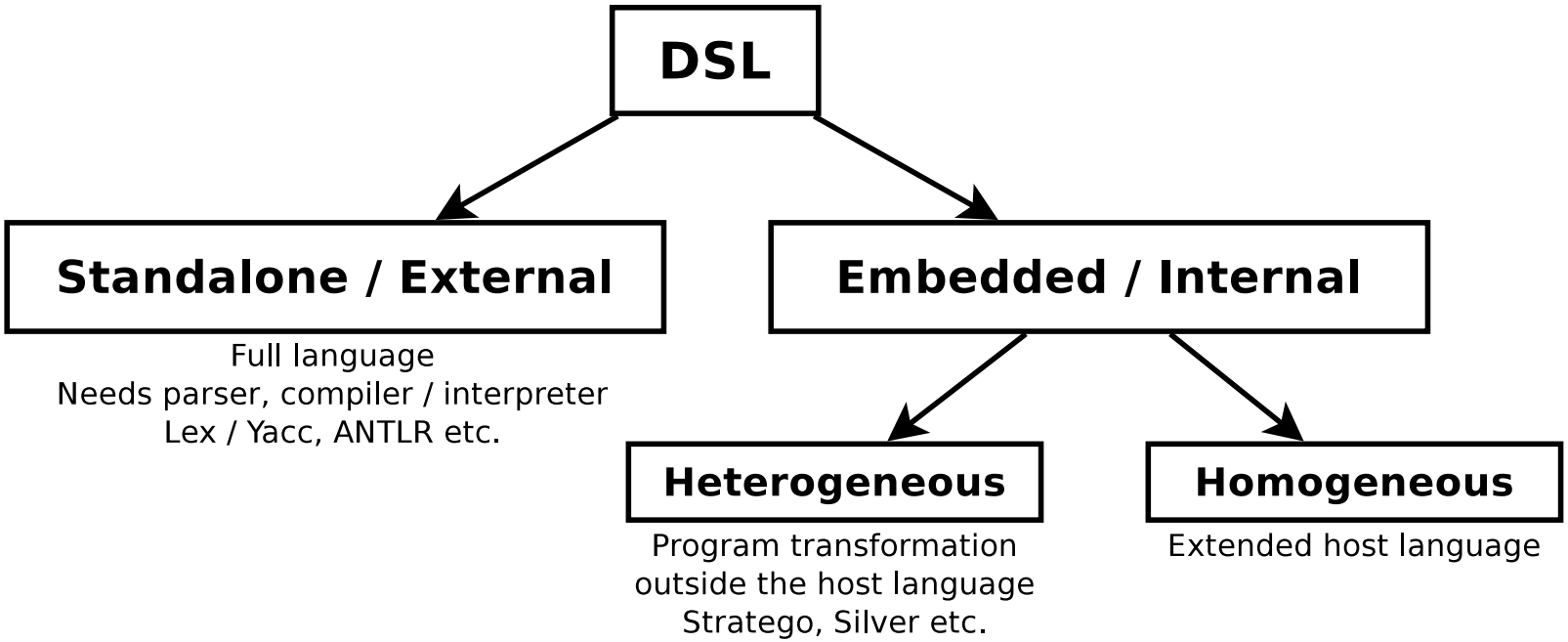
Taxonomy of DSLs
[Fowler, 2005, Tratt, 2008]



Extensibility at a glance I
[van Deursen et al., 2000, Vasudevan and Tratt, 2011]

- User-defined data types and (infix) operators
  Algol 68 [Denert et al., 1975, Pagan, 1979]
- Operator overloading
  C++ [McNamara and Smaragdakis, 2000]
- Compile-Time Meta-Programming
  C++ templates [Prud'homme, 2006]
  Template Haskell, Meta OCaml [Czarnecki et al., 2004]
  Meta Lua, Converge, Nermerle [Tratt, 2005, Fleutot and Tratt, 2007, Skalski et al., 2004]...
- Functional languages (Haskell, ML)
  [Kamin, 1998, Elliott, 1999, Hudak, 1998]

Extensibility at a glance II

[van Deursen et al., 2000, Vasudevan and Tratt, 2011]

- Forth: Operator extensibility + CTMP [Ahson and Lamba, 1985]
- Scala [Rompf et al., 2011]
- Marginally: TEX, m4

Example
Command-line options highlighting


```
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)

Step 1: the basic thing


```
(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))))))
```

Problems with `make-instance`:

1. Class name exposed
2. Name argument optional

Step 2: an instantiation wrapper


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

Problems:

1. Explicit `toplevel` face name
2. Explicit creation of sub-faces *list*
3. Lots of calls to `make-face`
4. Lots of quoting

Step 3: a theme creation wrapper

Solution to problem #1


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

Problems:

1. ~~Explicit `toplevel` face name~~
2. Explicit creation of sub-faces *list*
3. Lots of calls to `make-face`
4. Lots of quoting

Step 4: CLOS and the MOP

Solution to problem #2

Generic functions, methods

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

- Methods are *outside* the classes (ordinary function calls)
- Multiple dispatch (multi-methods)

The CLOS Meta-Object Protocol (MOP)

- **CLOS *itself* is object-oriented**
  - The CLOS MOP: a *de facto* implementation standard
  - The CLOS components (classes *etc.*) are (meta-)objects of some (meta-)classes

- `initialize-instance` is a generic function

Step 4: CLOS and the MOP

Solution to problem #2


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

Problems:

1. ~~Explicit `toplevel` face name~~
2. ~~Explicit creation of sub-faces *list*~~
3. Lots of calls to `make-face`
4. Lots of quoting

Step 5: syntax extension

Solution to problem #3

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

Step 5: syntax extension
Solution to problem #3


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

Problems:

1. ~~Explicit `toplevel` face name~~
2. ~~Explicit creation of sub-faces *list*~~
3. ~~Lots of calls to `make-face`~~
4. Lots of quoting

Step 6: macros

Solution to problem #4

- Ordinary Lisp functions
- Work on chunks of code (as data)
- Tranform expressions into a new expression
- Compile-time effect
- Control over evaluation

Step 6: macros
Solution to problem #4


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

Problems:

1. ~~Explicit `toplevel` face name~~
2. ~~Explicit creation of sub-faces *list*~~
3. ~~Lots of calls to `make-face`~~
4. ~~Lots of quoting~~

Final result

Looks pretty much like a DSL to me...

```
;; My personal theme with so cool colors

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

- `read`, `eval` and possibly `compile`

Conclusion

- 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
  - Syntax extension
  - `read`, `eval`, `compile`

Internal *vs* External DSLs
[Kamin, 1998, Czarnecki et al., 2004]

- Suboptimal 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

- 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: lazyness through macros (not as straightforward), but side-effects for free, and still functional.

The root of (Lisp) extensibility

- Reflexion
  - Introspection
  - Intercession
- Implementation
  - By API
  - Inherent: “homoiconicity” [McIlroy, 1960, Kay, 1969]
- Further distinction [Maes, 1987, Smith, 1984]
  - Structural reflexion (program)
  - Behavioral reflexion (language)

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