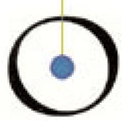
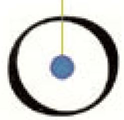


Last update:3 May 2006

Software Architecture

Lecture 9: About design patterns



Reading assignment

- Chapter 20 & 21 of OOSC (Multi-panel & Undo-redo)
- Componentization of the visitor pattern:
  http://se.ethz.ch/~meyer/publications/computer/visitor.pdf

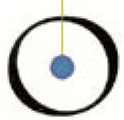
Topics

- Patterns
- Abstract Factory Pattern
- Visitor
- Observer
- Chain of responsibility
- Command

- From patterns to components

Patterns in software development

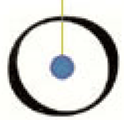
- Document that describes a general solution to a design problem that recurs in many applications.
- Developers adapt the pattern to their specific application.



Some design patterns

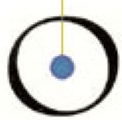
- Creational
  - Abstract Factory
  - Builder
  - Factory Method
  - Prototype
  - Singleton
- Structural
  - Adapter
  - Bridge
  - Composite
  - Decorator
  - Façade
  - Flyweight
  - Proxy
- Behavioral
  - Chain of Responsibility
  - Command
  - Interpreter
  - Iterator
  - Mediator
  - Memento
  - Observer
  - State
  - Strategy
  - Template Method
  - Visitor

Erich Gamma, Ralph Johnson, Richard Helms, John Vlissides: *Design Patterns*, Addison-Wesley, 1994

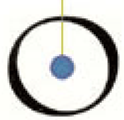


Benefits of design patterns

- Capture the knowledge of experienced developers
- Teachable to newcomers
- Yield a better structure of the software
- Facilitate discussions between programmers and managers

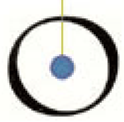


Abstract factory pattern



Creational patterns

- Hide the creation process of objects
- Hide the concrete type of these objects
- Allow dynamic and static configuration of the software system



Some design patterns

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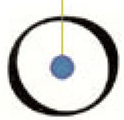
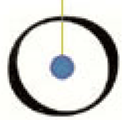


Abstract factory - Intent

"Provide an interface for creating families of related or dependent objects without specifying their concrete classes." [Gamma et al.]



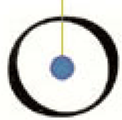
Abstract Factory: example need

Widget toolkit

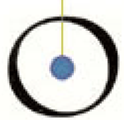
- Different look and feel, e.g. for Unix & Windows
- Family of widgets: Scroll bars, buttons, dialogs…
- Want to allow changing look & feel

→Most parts of the system need not know what look & feel is used

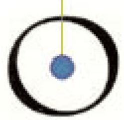
→Creation of widget objects should not be distributed



Architecture for widget example

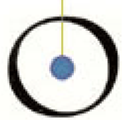


Architecture of a general example



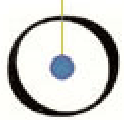
Sketch of class *FACTORY*


```
deferred class
    FACTORY

feature -- Basic operations

    new_button: BUTTON is
                    -- New button
        deferred
        end

    new_checkbox: CHECKBOX is
                    -- New checkbox
        deferred
        end
...
end
```



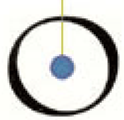
Sketch of class *WIN_FACTORY*


```
class
    WIN_FACTORY
inherit
    FACTORY

feature -- Basic operations

    new_button: BUTTON is
                -- New windows button
        do
                create {WIN_BUTTON} Result
        end

    new_checkbox: CHECKBOX is
                -- New windows checkbox
        do
                create {WIN_CHECKBOX} Result
        end
...
end
```



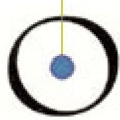
Ancestor factory class


```
class
    SHARED_FACTORY
...
feature -- Basic operations

    factory: FACTORY is
                    -- Factory used for widget instantiation
            once
                    if is_windows_os then
                            create {WIN_FACTORY} Result
                    else
                            create {UNX_FACTORY} Result
                    end
            end

...
end
```



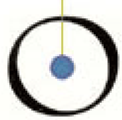
Usage of *FACTORY*


```
class
    WIDGET_APPLICATION
inherit
    SHARED_FACTORY
...
feature -- Basic operations

    some_feature is
                -- Generate a new button and use it.
        local
                my_button: BUTTON
        do
                ...
                my_button := factory.new_button
                ...
        end
...
end
```



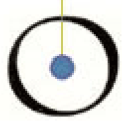
Reasons for using an abstract factory

- Most parts of a system should be independent of how its objects are created, represented and collaborating
- The system needs to be configured with one of multiple families
- A family of objects is to be designed and only used together
- You want to support a whole palette of products, but only want to show the public interface

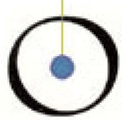


Abstract factory: pattern properties

- Isolates concrete classes
- Makes exchanging product families easy
- Promotes consistency among products
- Supporting new kinds of products is difficult



Visitor

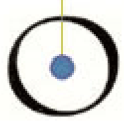


Visitor - Intent

"Represents an operation to be performed on the elements of an object structure. Visitor lets you define a new operation without changing the classes of the elements on which it operates."

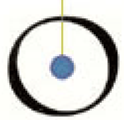
[Gamma et al., p 331]

- Static class hierarchy
- Need to perform traversal operations on corresponding data structures
- Avoid changing the original class structure



Visitor application example

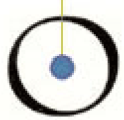
- Set of classes to deal with XML documents
  - *XML_NODE*
  - *XML_DOCUMENT*
  - *XML_ELEMENT*
  - *XML_ATTRIBUTE*
  - *XML_CONTENT*
- One parser
- Many formatters
  - Pretty-print
  - Compress
  - Convert to different encoding
  - ...



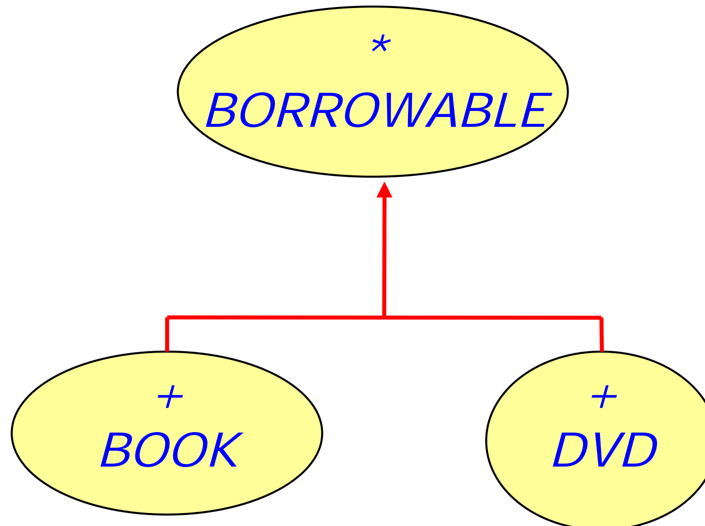
Another example

AST of program

- Nodes: Class, Feature, instruction, ...
- Operations:
  - Compile
  - Pretty print
  - Generate documentation
  - Refactor

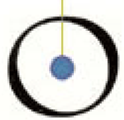


Library example



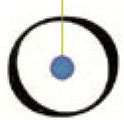
We want to add external functionality, for example:

- Maintenance
- Visualization



Maintenance

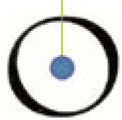

```
maintain (b: BORROWABLE) is
            -- Perform maintenance operations on n.
    require
            exists: b /= Void
     local
            book: BOOK
            dvd: DVD
    do
            book ?= b
            if book /= Void then
                    ... Check binding ...
            end
            dvd ?= b
            if dvd /= Void then
                    ... DVD maintenance ...
            end
    end
end
```



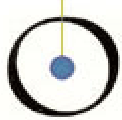
Visualization


```
display (b: BORROWABLE) is
            -- Maintain b.
      require
            exists: b /= Void
      local
            book: BOOK
            dvd: DVD
      do
            book ?= b
            if book /= Void then
                  ... Put book on display ...
            end
            dvd ?= b
            if dvd /= Void then
                  ... Put DVD on display ...
            end
      end
end
```

Why is this approach bad ?

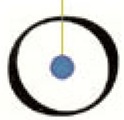


Visitor pattern: a typical example



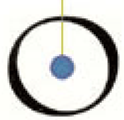
Class *MAINTENANCE_VISITOR*


```
class
    MAINTENANCE_VISITOR
inherit
    VISITOR
feature -- Basic operations
    visit_book (b: BOOK) is
                        -- Perform maintenance operations on b.
            do
                        b.check_binding
                        if b.damaged then
                                b.repair
                        end
            end
    visit_dvd (d: DVD) is
                        -- Perform maintenance operations on d.
            do
                        d.check_surface
                        if d.damaged then
                                d.order_replacement
                        end
            end
end
```



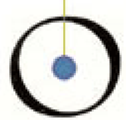
Class *BOOK*


```
class
    BOOK
inherit
    BORROWABLE
feature
    accept (v: VISITOR) is
                    -- Apply to v the book visit mechanism.
        do
                v.visit_book (Current)
        end
end
```



Class *DVD*


```
class
    DVD
inherit
    BORROWABLE
feature -- Visitor pattern
    accept (v: VISITOR) is
                -- Apply to d the DVD visit mechanism.
        do
            v.visit_dvd (Current)
        end
end
```



Visitor - Usage


```
local
    item: BORROWABLE
    maintainer: MAINTENANCE_VISITOR
do
...
    item.accept (maintainer)
...
end
```

accept*

*
BORROWABLE

\+
BOOK

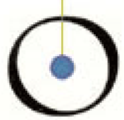
\+
DVD

accept+

accept+

Calls *VISITOR.visit_book*

Calls *VISITOR.visit_dvd*



Visitor - Participants

- **Visitor**

  Common ancestor for all concrete visitors.

- **Concrete Visitor**

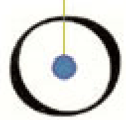
  Represents a specific operation, applicable to all elements.

- **Element**

  Common ancestor for all concrete elements.

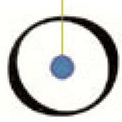
- **Concrete Element**

  Represents a specific element in class hierarchy.

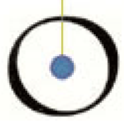


Visitor - Consequences

- Makes adding new operations easy
- Gathers related operations, separates unrelated ones
- Avoids assignment attempts
  - Better type checking
- Adding new concrete element is hard



Observer



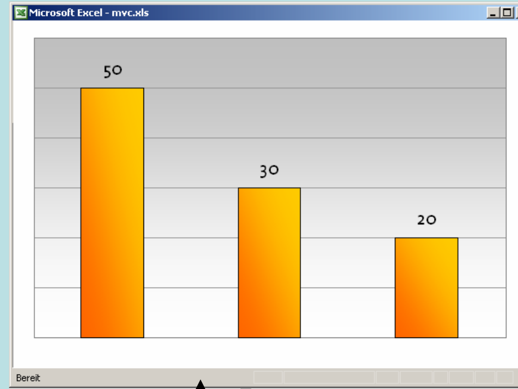
Observer

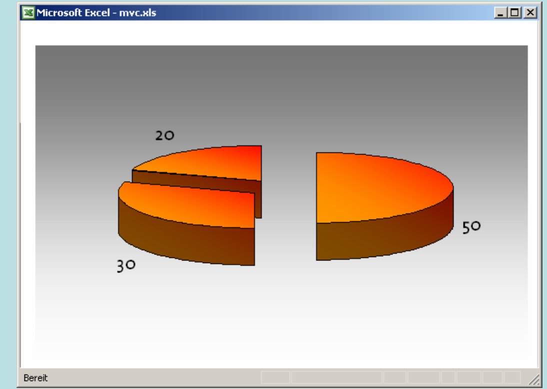
Observers

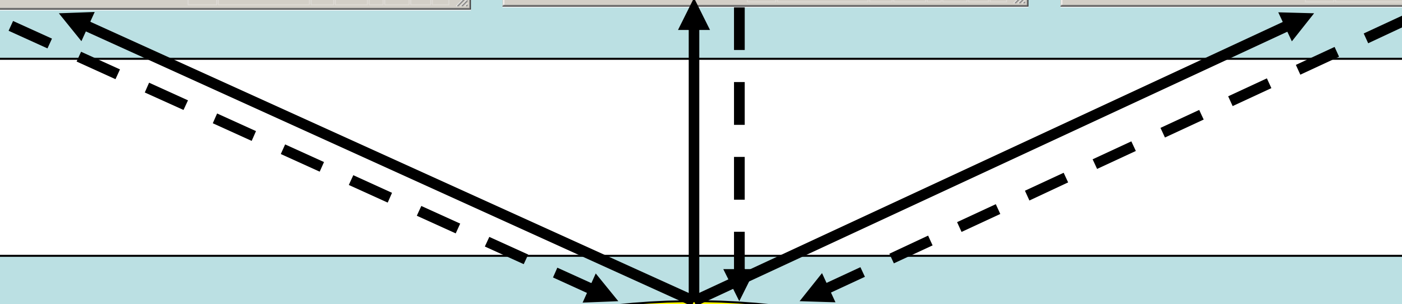
Microsoft Excel - mvc.xls

	A	B	C	D	E	F	G
1	50	30	20				
2	10	20	70				
3	30	60	10				
4							
5							
6							
7							

Bereit

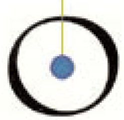






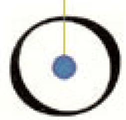
Subject

A = 50%
B = 30%
C = 20%



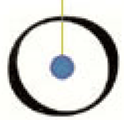
Observer pattern

"Define[s] a one-to-many dependency between objects so that when one object changes state, all its dependents are notified and updated automatically." [Gamma et al., p 293]



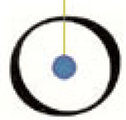
Book library example (1/4)


```
class
    LIBRARY
inherit
    SUBJECT
        redefine
            default_create
        end
feature {NONE} -- Initialization
    default_create is
            -- Create and initialize the library with an empty
            -- list of books.
        do
            Precursor {SUBJECT}
            create books.make
        end
```



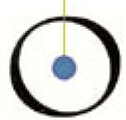
Book library example (2/4)


```
feature -- Access
    books: LINKED_LIST [BOOKS]
                        -- Books currently in the library
feature -- Element change
    add_book (b: BOOK) is
                        -- Add b to the list of books and notify all library observers.
        require
                        b_not_void: b /= Void
                        not_yet_in_library: not books.has (b)
        do
                        books.extend (b)
                        notify_observers
        ensure
                        one_more: books.count = old books.count + 1
                        book_added: books.last = b
        end
...
invariant
    books_not_void: books /= Void
    no_void_book: not books.has (Void)
end
```



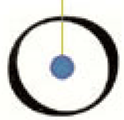
Book library example (3/4)


```
class
    APPLICATION
inherit
    OBSERVER
            rename
                    update as display_book
            redefine
                    default_create
            end
feature {NONE} -- Initialization
    default_create is
                    -- Initialize library and subscribe current application as
                    -- library observer.
            do
                    create library
                    library.add_observer (Current)
            end
...
```



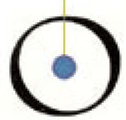
Book library example (4/4)


```
feature -- Observer pattern
    library: LIBRARY
                -- Subject to observe
    display_book is
                -- Display title of last book added to library.
        do
                print (library.books.last.title)
        end
invariant
    library_not_void: library /= Void
    consistent: library.observers.has (Current)
end
```



Drawbacks of the Observer

- The subject knows its observers
- No information passing from subject to observer when an event occurs
- An observer can register to at most one subject
    - Could pass the *SUBJECT* as argument to *update* but would yield many assignment attempts to distinguish between the different *SUBJECT*s.

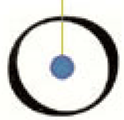


A refresher on agents

- objects representing potential computations

$$\int_{a}^{b} my_function (x) \, dx$$

my_integrator.*integral* (**agent** *my_function*, *a*, *b*)



Normal call vs. agent call

- Normal call

  a0.f (*a1*, *a2*, *a3*)

- Agent call (expression): preface it by keyword **agent**, yielding

  agent *a0.f* (*a1*, *a2*, *a3*)

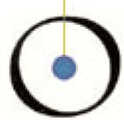
- For example:

  u := **agent** *a0.f* (*a1*, *a2*, *a3*)

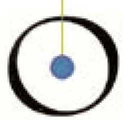
- This represents the routine, ready to be called. To call it:

  u.call ([])
  -- For type of *u*, see next

- Recall original name of agents: "delayed calls".



Agent types: Kernel library classes



Creating vs. calling an agent

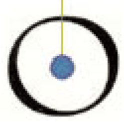
- Writing:

  agent *my_feature*

  creates an agent, i.e. an object of type *ROUTINE*.

- To call an agent, one needs to execute *call* (with the proper arguments) to this *ROUTINE* object, e.g:

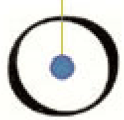
  my_routine.*call* ([*args*])



Keeping arguments open

- An agent can have both “closed” and “open” arguments.
- Closed arguments set at time of agent definition; open arguments set at time of each call.
- To keep an argument open, just replace it by a question mark:

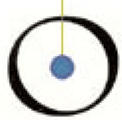
u := **agent** *a0*.*f* (*a1*, *a2*, *a3*)
-- All closed (as before)
w := **agent** *a0*.*f* (*a1*, *a2*, ?)
x := **agent** *a0*.*f* (*a1*, ?, *a3*)
y := **agent** *a0*.*f* (*a1*, ?, ?)
z := **agent** *a0*.*f* (?, ?, ?)



Event Library

- Basically:
  - One generic class: *EVENT_TYPE*
  - Two features: *publish* and *subscribe*

- For example: A button *my_button* that reacts in a way defined in *my_procedure* when clicked (event *mouse_click*):



Example using the Event Library

- The publisher ("subject") creates an event type object:

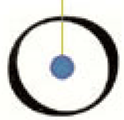
```
mouse_click: EVENT_TYPE [TUPLE [INTEGER, INTEGER]] is
            -- Mouse click event type
    once
            create Result
    ensure
            mouse_click_not_void: Result /= Void
    end
```

- The publisher triggers the event:

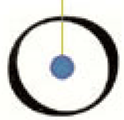
```
mouse_click.publish ([x_positition, y_position])
```

- The subscribers ("observers") subscribe to events:

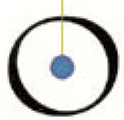
```
my_button.mouse_click.subscribe (agent my_procedure)
```



Publisher, subscriber, subscribed object (2/2)

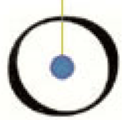



```
class
   LIBRARY
...
feature -- Access

   books: LINKED_LIST [BOOK]
              -- Books in library

feature -- Event type

   book_event: EVENT_TYPE [TUPLE [BOOK]]
              -- Event associated with attribute books
```



Book library example with the Event Library (2/2)

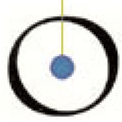

```
feature -- Element change
    add_book (b: BOOK) is
                    -- Add b to the list of books and
                    -- publish book_event.
            require
                    b_not_void: b /= Void
                    not_yet_in_library: not books.has (b)
            do
                    books.extend (b)
                    book_event.publish ([b])
            ensure
                    one_more: books.count = old books.count + 1
                    book_added: books.last = b
            end
invariant
    books_not_void: books /= Void
    book_event_not_void: book_event /= Void
end
```



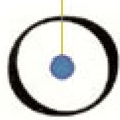
Observer pattern vs. Event Library

- In case of an existing class *MY_CLASS*:
  - With the Observer pattern:
    - Need to write a descendant of *OBSERVER* and *MY_CLASS*

    $\Rightarrow$ Useless multiplication of classes
  - With the Event Library:
    - Can reuse the existing routines directly as agents

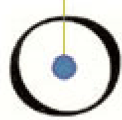


Chain of responsibility, Command



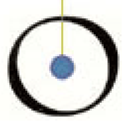
Behavioral design patterns (1/2)

- Creational
  - Abstract Factory
  - Builder
  - Factory Method
  - Prototype
  - Singleton
- Structural
  - Adapter
  - Bridge
  - Composite
  - Decorator
  - Façade
  - Flyweight
  - Proxy
- Behavioral
  - Chain of Responsibility
  - Command
  - Interpreter
  - Iterator
  - Mediator
  - Memento
  - Observer
  - State
  - Strategy
  - Template Method
  - Visitor

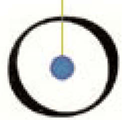


Behavioral design patterns (2/2)

- Deal with:
  - Algorithms
  - Assignment of responsibilities between objects
  - Communication between objects
- How:
  - Through inheritance or composition

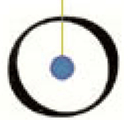


Chain of Responsibility pattern



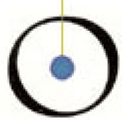
Chain of Responsibility: Intent

"Avoid[*s*] *coupling the sender of a request to its receiver by giving more than one object a change to handle the request.* [It] *chain*[*s*] *the receiving objects and pass*[*es*] *the request along the chain until an object handles it."* [GoF, p 223]

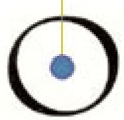


Class *HANDLER*


```
deferred class
    HANDLER
...
feature -- Basic operation
    handle is
            -- Handle request if can_handle otherwise forward it to next.
            -- If next is void, set handled to False.
        do
            if can_handle then
                do_handle
                handled := True
            else
                if next /= Void then
                    next.handle
                    handled := next.handled
                else
                    handled := False
                end
            end
        ensure
            can_handle implies handled
            (not can_handle and then next /= Void) implies handled = next.handled
            (not can_handle and then next = Void) implies not handled
        end
...
end
```

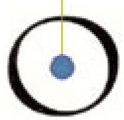


Chain of Responsibility



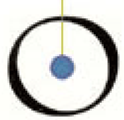
Class *HANDLER* [*G*] (1/3)


```
deferred class
    HANDLER [G]
feature {NONE} -- Initialization
    make (a_successor: like next) is
                    -- Set next to a_successor.
        do
                    next := a_successor
        ensure
                    next_set: next = a_successor
        end
feature -- Access
     next: HANDLER [G]
               -- Successor in the chain of responsibility
feature -- Status report
    can_handle (a_request: G): BOOLEAN is deferred end
                    -- Can current handle a_request?
    handled: BOOLEAN
                    -- Has request been handled?
```



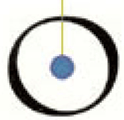
Class *HANDLER* [*G*] (2/3)


```
feature -- Basic operation
    handle (a_request: G) is
            -- Handle a_request if can_handle otherwise forward it to next.
            -- If next is void, set handled to False.
        do
            if can_handle (a_request) then
                do_handle (a_request)
                handled := True
            else
                if next /= Void then
                    next.handle (a_request)
                    handled := next.handled
                else
                    handled := False
                end
            end
        ensure
            can_handle (a_request) implies handled
            (not can_handle (a_request) and then next /= Void)
                                        implies handled = next.handled
            (not can_handle (a_request) and then next = Void)
                                        implies not handled
        end
```



Class *HANDLER* [*G*] (3/3)


```
feature -- Element change
    set_next (a_successor: like next) is
                -- Set next to a_successor.
        do
                next := a_successor
        ensure
                next_set: next = a_successor
        end

feature {NONE} -- Implementation
    do_handle (a_request: G) is
                -- Handle a_request.
        require
                can_handle: can_handle (a_request)
        deferred
        end
end
```



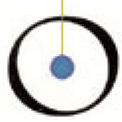
Chain of Responsibility: feature *handle*

require -- ???
not *handled*

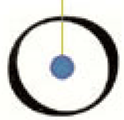
```
deferred class
    HANDLER [G]
...
feature -- Basic operation
    handle (a_request: G) is
            -- Handle a_request if can_handle otherwise forward it to next.
            -- If next is void, set handled to False.
        do
            if can_handle (a_request) then
                do_handle (a_request)
                handled := True
            else
                if next /= Void then
                    next.handle (a_request)
                    handled := next.handled
                else
                    handled := False
                end
            end
        ensure
            ...
        end
...
end
```

Would mean that a *HANDLER* that has handled a request cannot handle any other request; one would need to create another *HANDLER* object

⇒ Not very useful



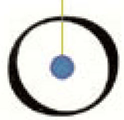
Command pattern



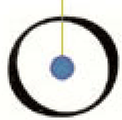
Command pattern: Intent

- Way to implement an undo-redo mechanism, e.g. in text editors. [OOSC, p 285-290]

- "*Way to encapsulate a request as an object, thereby letting you parameterize clients with different requests, queue or log requests, and support undoable operations.*" [GoF, p 233]



Command pattern (history-executable)

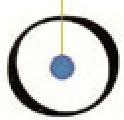


How to use the Command pattern

- Create a descendant of *COMMAND* and effect its features *execute*, *undo*, and *redo*

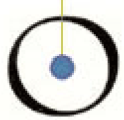
```
class
    COMMAND_1
inherit
    COMMAND
create
    make
feature {HISTORY} -- Command pattern
    execute (args: TUPLE) is do ... end
                -- Execute command with args.
feature {HISTORY} -- Undo
    undo (args: TUPLE) is do ... end
                -- Undo last action.
feature {HISTORY} -- Redo
    redo (args: TUPLE) is do ... end
                -- Redo last undone action.
end
```

To be completed



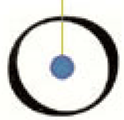
Example using the Command pattern (1/2)


```
class
    APPLICATION
create
    make
feature {NONE} -- Initialization
    make is
                -- Create a command and execute it.
                -- (Use the undo/redo mechanism.)
        local
                command_1: COMMAND_1
                command_2: COMMAND_2
        do
                create command_1.make (True)
                create command_2.make (False)
                history.execute (command_1, [])
                history.execute (command_2, [])
                history.undo
                history.redo
        end
```

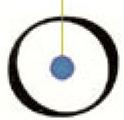


Example using the Command pattern (2/2)


```
feature {NONE} -- Implementation

    history: HISTORY is
                -- History of executed commands
        once
                create Result.make
        ensure
                history_not_void: Result /= Void
        end

end
```



Command pattern (self-executable)



Command: class *SHARED_HISTORY*

Common scheme in Eiffel: Inherit from a class containing the data to be shared among different objects

Not compulsory: *COMMAND* could have an attribute *history* initialized at creation and one would always pass the same *HISTORY* object as argument; hence sharing.

Advantage: enables having several histories; e.g. keep 2 histories of commands corresponding to 2 editor windows)