

Use of Generic Parameters

Iterator and Singleton Patterns



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Generic Collection Class: Motivation (1)

```
class STRING_STACK
feature {NONE} -- Implementation
  imp: ARRAY[STRING] ; i: INTEGER
feature -- Queries
  count: INTEGER do Result := i end
    -- Number of items on stack.
  top: STRING do Result := imp [i] end
    -- Return top of stack.
feature -- Commands
  push (v: STRING) do imp[i] := v; i := i + 1 end
    -- Add 'v' to top of stack.
  pop do i := i - 1 end
    -- Remove top of stack.
end
```

- Does how we implement integer stack operations (e.g., top, push, pop) depends on features specific to element type **STRING** (e.g., at, append)? [**NO!**]
- How would you implement another class **ACCOUNT_STACK**?

Generic Collection Class: Motivation (2)

```
class ACCOUNT_STACK
feature {NONE} -- Implementation
  imp: ARRAY[ACCOUNT] ; i: INTEGER
feature -- Queries
  count: INTEGER do Result := i end
  -- Number of items on stack.
  top: ACCOUNT do Result := imp [i] end
  -- Return top of stack.
feature -- Commands
  push (v: ACCOUNT) do imp[i] := v; i := i + 1 end
  -- Add 'v' to top of stack.
  pop do i := i - 1 end
  -- Remove top of stack.
end
```

- Does how we implement integer stack operations (e.g., top, push, pop) depends on features specific to element type ACCOUNT (e.g., deposit, withdraw)? [**NO!**]
- A **collection** (e.g., table, tree, graph) is meant for the **storage** and **retrieval** of elements, not how those elements are manipulated.

Generic Collection Class: Supplier

- Your design “*smells*” if you have to create an *almost identical* new class (hence *code duplicates*) for every stack element type you need (e.g., INTEGER, CHARACTER, PERSON, etc.).
- Instead, as **supplier**, use **G** to *parameterize* element type:

```
class STACK [G]
feature {NONE} -- Implementation
  imp: ARRAY[G] ; i: INTEGER
feature -- Queries
  count: INTEGER do Result := i end
  -- Number of items on stack.
  top: G do Result := imp [i] end
  -- Return top of stack.
feature -- Commands
  push (v: G) do imp[i] := v; i := i + 1 end
  -- Add 'v' to top of stack.
  pop do i := i - 1 end
  -- Remove top of stack.
end
```

Generic Collection Class: Client (1.1)

As **client**, declaring `ss: STACK [STRING]` instantiates every occurrence of `G` as `STRING`.

```
class STACK [STRING]  
feature {NONE} -- Implementation  
  imp: ARRAY [STRING] ; i: INTEGER  
feature -- Queries  
  count: INTEGER do Result := i end  
    -- Number of items on stack.  
  top: STRING do Result := imp [i] end  
    -- Return top of stack.  
feature -- Commands  
  push (v: STRING) do imp[i] := v; i := i + 1 end  
    -- Add 'v' to top of stack.  
  pop do i := i - 1 end  
    -- Remove top of stack.  
end
```

Generic Collection Class: Client (1.2)

As **client**, declaring `ss: STACK [ACCOUNT]` instantiates every occurrence of `G` as `ACCOUNT`.

```
class STACK [G ACCOUNT]
feature {NONE} -- Implementation
  imp: ARRAY [G ACCOUNT] ; i: INTEGER
feature -- Queries
  count: INTEGER do Result := i end
  -- Number of items on stack.
  top: G ACCOUNT do Result := imp [i] end
  -- Return top of stack.
feature -- Commands
  push (v: G ACCOUNT) do imp[i] := v; i := i + 1 end
  -- Add 'v' to top of stack.
  pop do i := i - 1 end
  -- Remove top of stack.
end
```

Generic Collection Class: Client (2)

As **client**, instantiate the type of **G** to be the one needed.

```

1 test_stacks: BOOLEAN
2   local
3     ss: STACK[STRING] ; sa: STACK[ACCOUNT]
4     s: STRING ; a: ACCOUNT
5   do
6     ss.push("A")
7     ss.push(create {ACCOUNT}.make ("Mark", 200))
8     s := ss.top
9     a := ss.top
10    sa.push(create {ACCOUNT}.make ("Alan", 100))
11    sa.push("B")
12    a := sa.top
13    s := sa.top
14  end

```

- **L3** commits that `ss` stores `STRING` objects only.
 - **L8** and **L10** *valid*; **L9** and **L11** *invalid*.
- **L4** commits that `sa` stores `ACCOUNT` objects only.
 - **L12** and **L14** *valid*; **L13** and **L15** *invalid*.

What are design patterns?

- Solutions to *recurring problems* that arise when software is being developed within a particular *context*.
 - Heuristics for structuring your code so that it can be systematically maintained and extended.
 - **Caveat**: A pattern is only suitable for a particular problem.
 - Therefore, always understand *problems* before *solutions*!

Iterator Pattern: Motivation (1)

Supplier:

```
class
  CART
feature
  orders: ARRAY[ORDER]
end

class
  ORDER
feature
  price: INTEGER
  quantity: INTEGER
end
```

Problems?

Client:

```
class
  SHOP
feature
  cart: CART
  checkout: INTEGER
  do
    from
      i := cart.orders.lower
    until
      i > cart.orders.upper
    do
      Result := Result +
        cart.orders[i].price
        *
        cart.orders[i].quantity
      i := i + 1
    end
  end
end
end
```

Iterator Pattern: Motivation (2)

Supplier:

```
class
  CART
feature
  orders: LINKED_LIST[ORDER]
end

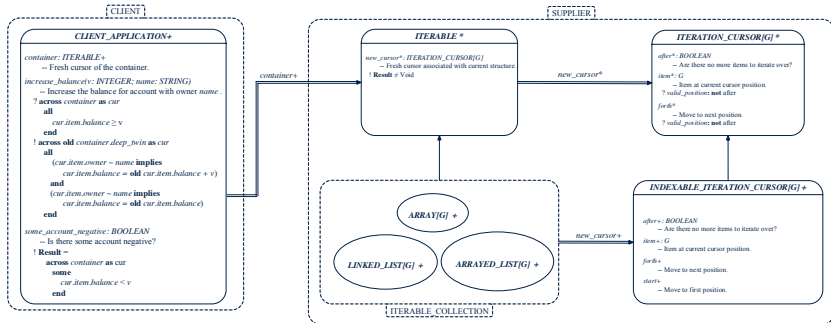
class
  ORDER
feature
  price: INTEGER
  quantity: INTEGER
end
```

Client's code must be modified to adapt to the supplier's *change on implementation*.

Client:

```
class
  SHOP
feature
  cart: CART
  checkout: INTEGER
  do
    from
      cart.orders.start
    until
      cart.orders.after
    do
      Result := Result +
        cart.orders.item.price
        *
        cart.orders.item.quantity
    end
  end
end
```

Iterator Pattern: Architecture



Iterator Pattern: Supplier's Side

- **Information Hiding Principle** :
 - Hide design decisions that are *likely to change* (i.e., *stable* API).
 - *Change of secrets* does not affect clients using the existing API.
e.g., changing from *ARRAY* to *LINKED_LIST* in the *CART* class
- Steps:
 1. Let the supplier class inherit from the deferred class *ITERABLE[G]*.
 2. This forces the supplier class to implement the inherited feature: *new_cursor: ITERATION_CURSOR [G]*, where the type parameter *G* may be instantiated (e.g., *ITERATION_CURSOR[ORDER]*).
 - 2.1 If the internal, library data structure is already *iterable* e.g., *imp: ARRAY[ORDER]*, then simply return *imp.new_cursor*.
 - 2.2 Otherwise, say *imp: MY_TREE[ORDER]*, then create a new class *MY_TREE_ITERATION_CURSOR* that inherits from *ITERATION_CURSOR[ORDER]*, then implement the 3 inherited features *after*, *item*, and *forth* accordingly.

Iterator Pattern: Supplier's Implementation (1)



```
class
  CART
inherit
  ITERABLE [ORDER]

...

feature {NONE} -- Information Hiding
  orders: ARRAY [ORDER]

feature -- Iteration
  new_cursor: ITERATION_CURSOR [ORDER]
  do
    Result := orders.new_cursor
  end
```

When the secrete implementation is already *iterable*, reuse it!

Iterator Pattern: Supplier's Imp. (2.1)

```
class
  GENERIC_BOOK[G]
inherit
  ITERABLE[ TUPLE[STRING, G] ]
...
feature {NONE} -- Information Hiding
  names: ARRAY[STRING]
  records: ARRAY[G]
feature -- Iteration
  new_cursor: ITERATION_CURSOR[ TUPLE[STRING, G] ]
  local
    cursor: MY_ITERATION_CURSOR[G]
  do
    create cursor.make (names, records)
    Result := cursor
  end
```

No Eiffel library support for iterable arrays ⇒ Implement it yourself!

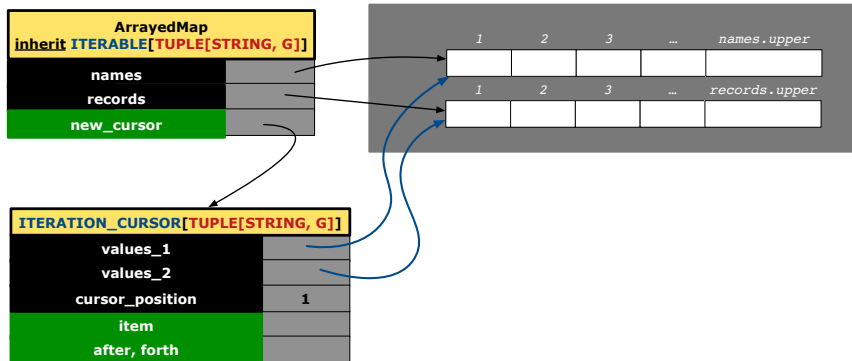
Iterator Pattern: Supplier's Imp. (2.2)

```
class
  MY_ITERATION_CURSOR[G]
inherit
  ITERATION_CURSOR[ TUPLE[STRING, G] ]
feature -- Constructor
  make (ns: ARRAY[STRING]; rs: ARRAY[G])
    do ... end
feature {NONE} -- Information Hiding
  cursor_position: INTEGER
  names: ARRAY[STRING]
  records: ARRAY[G]
feature -- Cursor Operations
  item: TUPLE[STRING, G]
    do ... end
  after: Boolean
    do ... end
  forth
    do ... end
```

You need to implement the three inherited features:
item, *after*, and *forth*.

Iterator Pattern: Supplier's Imp. (2.3)

Visualizing iterator pattern at runtime:



1. Draw the BON diagram showing how the iterator pattern is applied to the *CART* (supplier) and *SHOP* (client) classes.
2. Draw the BON diagram showing how the iterator pattern is applied to the supplier classes:
 - *GENERIC_BOOK* (a descendant of *ITERABLE*) and
 - *MY_ITERATION_CURSOR* (a descendant of *ITERATION_CURSOR*).

- Tutorial Videos on Generic Parameters and the Iterator Pattern
- Tutorial Videos on Information Hiding and the Iterator Pattern

Iterator Pattern: Client's Side

Information hiding: the clients do not at all depend on *how* the supplier implements the collection of data; they are only interested in iterating through the collection in a linear manner.

Steps:

1. Obey the **code to interface, not to implementation** principle.
2. Let the client declare an attribute of **interface** type **ITERABLE[G]** (rather than **implementation** type **ARRAY**, **LINKED_LIST**, or **MY_TREE**).
e.g., `cart: CART`, where **CART** inherits **ITERABLE[ORDER]**
3. Eiffel supports, in both implementation and **contracts**, the **across** syntax for iterating through anything that's *iterable*.

Iterator Pattern: Clients using across for Contracts (1)

```
class
  CHECKER
  feature -- Attributes
    collection: ITERABLE [INTEGER]
  feature -- Queries
    is_all_positive: BOOLEAN
      -- Are all items in collection positive?
    do
      ...
    ensure
      across
        collection as cursor
      all
        cursor.item > 0
      end
    end
end
```

- Using **all** corresponds to a universal quantification (i.e., \forall).
- Using **some** corresponds to an existential quantification (i.e., \exists).

Iterator Pattern:

Clients using across for Contracts (2)

```
class BANK
...
  accounts: LIST [ACCOUNT]
  binary_search (acc_id: INTEGER): ACCOUNT
    -- Search on accounts sorted in non-descending order.
    require
      across
        1 |..| (accounts.count - 1) as cursor
      all
        accounts [cursor.item].id <= accounts [cursor.item + 1].id
      end
    do
      ...
    ensure
      Result.id = acc_id
    end
end
```

This precondition corresponds to:

$\forall i: \text{INTEGER} \mid 1 \leq i < \text{accounts.count} \bullet \text{accounts}[i].\text{id} \leq \text{accounts}[i+1].\text{id}$

Iterator Pattern: Clients using across for Contracts (3)

```
class BANK
...
  accounts: LIST [ACCOUNT]
  contains_duplicate: BOOLEAN
    -- Does the account list contain duplicate?
  do
    ...
  ensure
     $\forall i, j: \text{INTEGER} \mid$ 
       $1 \leq i \leq \text{accounts.count} \wedge 1 \leq j \leq \text{accounts.count} \bullet$ 
       $\text{accounts}[i] \sim \text{accounts}[j] \Rightarrow i = j$ 
  end
```

- **Exercise:** Convert this mathematical predicate for postcondition into Eiffel.
- **Hint:** Each **across** construct can only introduce one dummy variable, but you may nest as many **across** constructs as necessary.

Iterator Pattern: Clients using Iterable in Imp. (1)

```
class BANK
  accounts: ITERABLE [ACCOUNT]
  max_balance: ACCOUNT
  -- Account with the maximum balance value.
  require ??
  local
    cursor: ITERATION_CURSOR[ACCOUNT]; max: ACCOUNT
  do
    from max := accounts [1]; cursor := accounts.new_cursor
  until cursor.after
  do
    if cursor.item.balance > max.balance then
      max := cursor.item
    end
    cursor.forth
  end
ensure ??
end
```

Iterator Pattern: Clients using Iterable in Imp. (2)

```
1 class SHOP
2   cart: CART
3   checkout: INTEGER
4   -- Total price calculated based on orders in the cart.
5   require ??
6   local
7     order: ORDER
8   do
9     across
10    cart as cursor
11    loop
12      order := cursor.item
13      Result := Result + order.price * order.quantity
14    end
15  ensure ??
16 end
```

- Class *CART* should inherit from *ITERABLE[ORDER]*.
- **L10** implicitly declares `cursor: ITERATION_CURSOR[ORDER]` and does `cursor := cart.new_cursor`

Iterator Pattern: Clients using Iterable in Imp. (3)

```
class BANK
  accounts: ITERABLE [ACCOUNT]
  max_balance: ACCOUNT
  -- Account with the maximum balance value.
  require ??
  local
    max: ACCOUNT
  do
    max := accounts [1]
  across
    accounts as cursor
  loop
    if cursor.item.balance > max.balance then
      max := cursor.item
    end
  end
  ensure ??
end
```

Singleton Pattern: Motivation

Consider two problems:

1. **Bank accounts** share a set of data.
e.g., interest and exchange rates, minimum and maximum balance, *etc.*
2. **Processes** are regulated to access some shared, limited resources.
e.g., printers

Shared Data via Inheritance

Client:

```
class DEPOSIT inherit SHARED_DATA
  -- 'maximum_balance' relevant
end

class WITHDRAW inherit SHARED_DATA
  -- 'minimum_balance' relevant
end

class INT_TRANSFER inherit SHARED_DATA
  -- 'exchange_rate' relevant
end

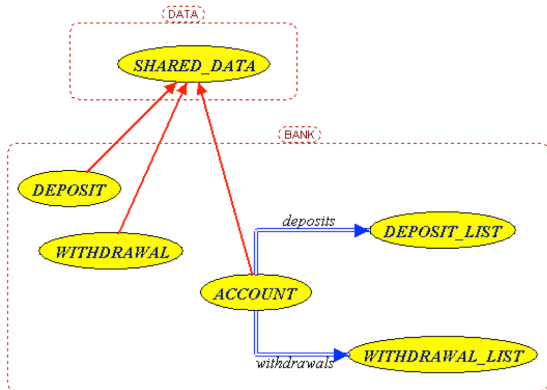
class ACCOUNT inherit SHARED_DATA
feature
  -- 'interest_rate' relevant
  deposits: DEPOSIT_LIST
  withdraws: WITHDRAW_LIST
end
```

Supplier:

```
class
  SHARED_DATA
feature
  interest_rate: REAL
  exchange_rate: REAL
  minimum_balance: INTEGER
  maximum_balance: INTEGER
  ...
end
```

Problems?

Sharing Data via Inheritance: Architecture



- *Irreverent* features are inherited.
⇒ Descendants' **cohesion** is broken.
- Same set of data is *duplicated* as instances are created.
⇒ Updates on these data may result in **inconsistency**.

Sharing Data via Inheritance: Limitation

- Each descendant instance at runtime owns a separate copy of the shared data.
- This makes inheritance *not* an appropriate solution for both problems:
 - What if the interest rate changes? Apply the change to all instantiated account objects?
 - An update to the global lock must be observable by all regulated processes.

Solution:

- Separate notions of *data* and its *shared access* in two separate classes.
- *Encapsulate* the shared access itself in a separate class.

Introducing the Once Routine in Eiffel (1.1)

```
1 class A
2 create make
3 feature -- Constructor
4   make do end
5 feature -- Query
6   new_once_array (s: STRING): ARRAY[STRING]
7     -- A once query that returns an array.
8     once
9       create {ARRAY[STRING]} Result.make_empty
10      Result.force (s, Result.count + 1)
11    end
12   new_array (s: STRING): ARRAY[STRING]
13     -- An ordinary query that returns an array.
14     do
15       create {ARRAY[STRING]} Result.make_empty
16       Result.force (s, Result.count + 1)
17     end
18 end
```

L9 & L10 executed **only once** for initialization.

L15 & L16 executed **whenever** the feature is called.

Introducing the Once Routine in Eiffel (1.2)

```
1 test_query: BOOLEAN
2   local
3     a: A
4     arr1, arr2: ARRAY[STRING]
5   do
6     create a.make
7
8     arr1 := a.new_array ("Alan")
9     Result := arr1.count = 1 and arr1[1] ~ "Alan"
10    check Result end
11
12    arr2 := a.new_array ("Mark")
13    Result := arr2.count = 1 and arr2[1] ~ "Mark"
14    check Result end
15
16    Result := not (arr1 = arr2)
17    check Result end
18  end
```

Introducing the Once Routine in Eiffel (1.3)

```
1 test_once_query: BOOLEAN
2   local
3     a: A
4     arr1, arr2: ARRAY[STRING]
5   do
6     create a.make
7
8     arr1 := a.new_once_array ("Alan")
9     Result := arr1.count = 1 and arr1[1] ~ "Alan"
10    check Result end
11
12    arr2 := a.new_once_array ("Mark")
13    Result := arr2.count = 1 and arr2[1] ~ "Alan"
14    check Result end
15
16    Result := arr1 = arr2
17    check Result end
18  end
```


Introducing the Once Routine in Eiffel (2)

```
r (...): T
  once
    -- Some computations on Result
    ...
  end
```

- The ordinary **do ... end** is replaced by **once ... end**.
- The first time the **once** routine *r* is called by some client, it executes the body of computations and returns the computed result.
- From then on, the computed result is “*cached*”.
- In every subsequent call to *r*, possibly by different clients, the body of *r* is not executed at all; instead, it just returns the “*cached*” result, which was computed in the very first call.
- **How does this help us?**

Cache the reference to the same shared object !

Approximating Once Routine in Java

We may encode Eiffel once routines in Java:

```
class BankData {  
    BankData() { }  
    double interestRate;  
    void setIR(double r);  
    ...  
}
```

```
class Account {  
    BankData data;  
    Account() {  
        data = BankDataAccess.getData();  
    }  
}
```

```
class BankDataAccess {  
    static boolean initOnce;  
    static BankData data;  
    static BankData getData() {  
        if(!initOnce) {  
            data = new BankData();  
            initOnce = true;  
        }  
        return data;  
    }  
}
```

Problem?

Multiple **BankData** objects may be created in Account, breaking the singleton!

```
Account() {  
    data = new BankData();  
}
```

Singleton Pattern in Eiffel (1)

Supplier:

```
class DATA
create {DATA_ACCESS} make
feature {DATA_ACCESS}
  make do v := 10 end
feature -- Data Attributes
  v: INTEGER
  change_v (nv: INTEGER)
    do v := nv end
end
```

```
expanded class
  DATA_ACCESS
feature
  data: DATA
  -- The one and only access
  once create Result.make end
invariant data = data
```

Client:

```
test: BOOLEAN
  local
    access: DATA_ACCESS
    d1, d2: DATA
  do
    d1 := access.data
    d2 := access.data
    Result := d1 = d2
    and d1.v = 10 and d2.v = 10
  check Result end
  d1.change_v (15)
  Result := d1 = d2
  and d1.v = 15 and d2.v = 15
end
end
```

Writing `create d1.make` in test feature does not compile. Why?

Singleton Pattern in Eiffel (2)

Supplier:

```
class BANK_DATA
  create {BANK_DATA_ACCESS} make
  feature {BANK_DATA_ACCESS}
    make do ... end
  feature -- Data Attributes
    interest_rate: REAL
    set_interest_rate (r: REAL)
    ...
end
```

```
expanded class
  BANK_DATA_ACCESS
  feature
    data: BANK_DATA
    -- The one and only access
    once create Result.make end
  invariant data = data
```

Client:

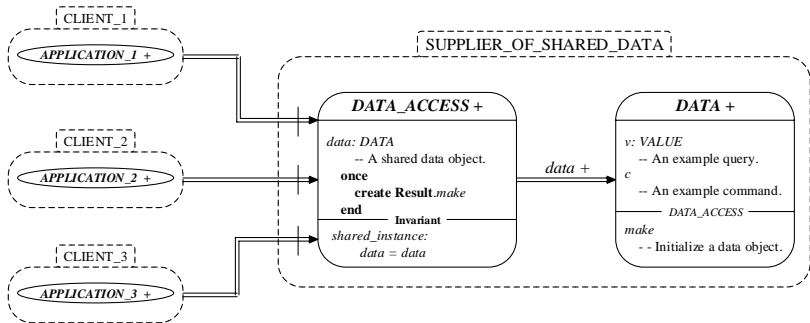
```
class
  ACCOUNT
  feature
    data: BANK_DATA
    make (...)
    -- Init. access to bank data.
  local
    data_access: BANK_DATA_ACCESS
  do
    data := data_access.data
    ...
  end
end
```

Writing `create data.make` in client's `make` feature does not compile. Why?

Testing Singleton Pattern in Eiffel

```
test_bank_shared_data: BOOLEAN
  -- Test that a single data object is manipulated
  local acc1, acc2: ACCOUNT
  do
    comment("t1: test that a single data object is shared")
    create acc1.make ("Bill")
    create acc2.make ("Steve")
    Result := acc1.data = acc2.data
    check Result end
    Result := acc1.data ~ acc2.data
    check Result end
    acc1.data.set_interest_rate (3.11)
    Result :=
      acc1.data.interest_rate = acc2.data.interest_rate
      and acc1.data.interest_rate = 3.11
    check Result end
    acc2.data.set_interest_rate (2.98)
    Result :=
      acc1.data.interest_rate = acc2.data.interest_rate
      and acc1.data.interest_rate = 2.98
  end
```

Singleton Pattern: Architecture



Important Exercises: Instantiate this architecture to both problems of shared bank data and shared lock. Draw them in

draw.io.

Index (1)

Generic Collection Class: Motivation (1)

Generic Collection Class: Motivation (2)

Generic Collection Class: Supplier

Generic Collection Class: Client (1.1)

Generic Collection Class: Client (1.2)

Generic Collection Class: Client (2)

What are design patterns?

Iterator Pattern: Motivation (1)

Iterator Pattern: Motivation (2)

Iterator Pattern: Architecture

Iterator Pattern: Supplier's Side

Iterator Pattern: Supplier's Implementation (1)

Iterator Pattern: Supplier's Imp. (2.1)

Iterator Pattern: Supplier's Imp. (2.2)

Index (2)

Iterator Pattern: Supplier's Imp. (2.3)

Exercises

Resources

Iterator Pattern: Client's Side

Iterator Pattern:

Clients using `across` for Contracts (1)

Iterator Pattern:

Clients using `across` for Contracts (2)

Iterator Pattern:

Clients using `across` for Contracts (3)

Iterator Pattern:

Clients using `Iterable` in Imp. (1)

Iterator Pattern:

Clients using `Iterable` in Imp. (2)

Index (3)

Iterator Pattern:

Clients using Iterable in Imp. (3)

Singleton Pattern: Motivation

Shared Data via Inheritance

Sharing Data via Inheritance: Architecture

Sharing Data via Inheritance: Limitation

Introducing the Once Routine in Eiffel (1.1)

Introducing the Once Routine in Eiffel (1.2)

Introducing the Once Routine in Eiffel (1.3)

Introducing the Once Routine in Eiffel (2)

Approximating Once Routines in Java

Singleton Pattern in Eiffel (1)

Singleton Pattern in Eiffel (2)

Testing Singleton Pattern in Eiffel

Index (4)

Singleton Pattern: Architecture