Use of Generic Parameters
Iterator and Singleton Patterns

EECS3311 A: Software Design
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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 [G̸ STRING]
feature {NONE} -- Implementation
  imp: ARRAY[ G̸ STRING ] ; i: INTEGER
feature -- Queries
  count: INTEGER do Result := i end
      -- Number of items on stack.
  top: G̸ STRING do Result := imp [i] end
      -- Return top of stack.
feature -- Commands
  push (v: G̸ 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 [G̸ ACCOUNT]
feature {NONE} -- Implementation
  imp: ARRAY[ G̸ ACCOUNT ] ; i: INTEGER
feature -- Queries
  count: INTEGER do Result := i end
    -- Number of items on stack.
  top: G̸ ACCOUNT do Result := imp [i] end
    -- Return top of stack.
feature -- Commands
  push (v: G̸ 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
```

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
```

Problems?

Iterator Pattern: Motivation (2)

Supplier:

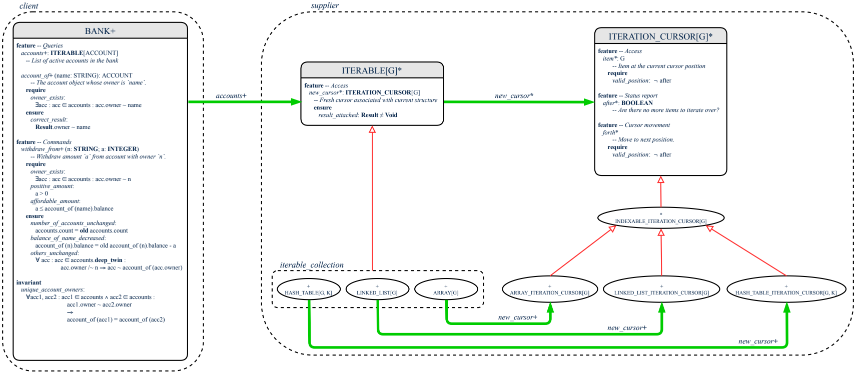
```
class
  CART
feature
  orders: LINKED_LIST[ORDER]
end

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!

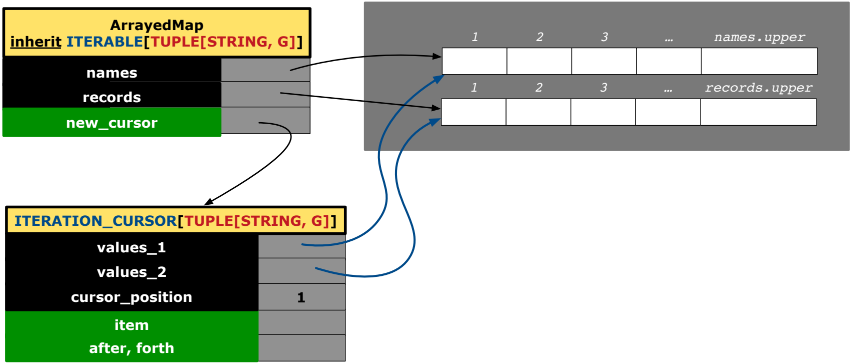
Iterator Pattern: Supplier's Imp. (2.2)

```
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:



Exercises

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*).

Resources

- 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 `ITERATBLE[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 is item
      all
        item > 0
      end
  end
```

- Using **all** corresponds to a universal quantification (i.e., ∀).
- Using **some** corresponds to an existential quantification (i.e., ∃).

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) is i
      all
        accounts [i].id <= accounts [i + 1].id
      end
    do
      ...
    ensure
      Result.id = acc_id
    end
```

This precondition corresponds to:

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

Iterator Pattern: Clients using `across` for Contracts (3)

```
class BANK
...
  accounts: LIST [ACCOUNT]
  contains_duplicate: BOOLEAN
      -- Does the account list contain duplicate?
    do
      ...
    ensure
```

$$\forall i, j : INTEGER \mid 1 \leq i \leq accounts.count \wedge 1 \leq j \leq accounts.count \bullet accounts[i] \sim accounts[j] \Rightarrow i = j$$

```
    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      do
7        across
8          cart is order
9        loop
10         Result := Result + order.price * order.quantity
11       end
12     ensure ??
13   end
```

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

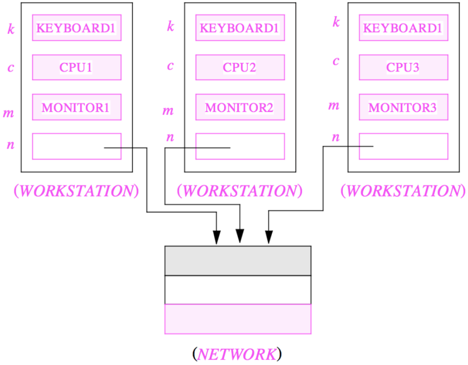
Iterator Pattern:
Clients using Iterable in Imp. (3)

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

Expanded Class: Modelling

- We may want to have objects which are:
  - Integral parts of some other objects
  - ***Not*** shared among objects

  e.g., Each workstation has its own CPU, monitor, and keyword.
  All workstations share the same network.



Expanded Class: Programming (2)

```
class KEYBOARD ... end class CPU ... end
class MONITOR ... end class NETWORK ... end
class WORKSTATION
  k: expanded KEYBOARD
  c: expanded CPU
  m: expanded MONITOR
  n: NETWORK
end
```

Alternatively:

```
expanded class KEYBOARD ... end
expanded class CPU ... end
expanded class MONITOR ... end
class NETWORK ... end
class WORKSTATION
  k: KEYBOARD
  c: CPU
  m: MONITOR
  n: NETWORK
end
```

Expanded Class: Programming (3)

```
expanded class
  B
feature
  change_i (ni: INTEGER)
    do
      i := ni
    end
feature
  i: INTEGER
end
```

```
1  test_expanded: BOOLEAN
2    local
3      eb1, eb2: B
4    do
5      Result := eb1.i = 0 and eb2.i = 0
6      check Result end
7      Result := eb1 = eb2
8      check Result end
9      eb2.change_i (15)
10     Result := eb1.i = 0 and eb2.i = 15
11     check Result end
12     Result := eb1 /= eb2
13     check Result end
14   end
```

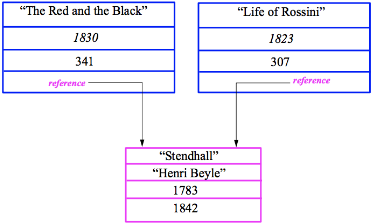
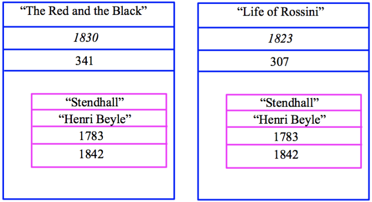
- **L5**: object of expanded type is automatically initialized.
- **L9 & L10**: no sharing among objects of expanded type.
- **L7 & L12**: = between expanded objects compare their contents.

Reference vs. Expanded (1)

- Every entity must be declared to be of a certain type (based on a class).
- Every type is either ***referenced*** or ***expanded***.
- In ***reference*** types:
  - `y` denotes ***a reference*** to some object
  - `x := y` attaches `x` to same object as does `y`
  - `x = y` compares references
- In ***expanded*** types:
  - `y` denotes ***some object*** (of expanded type)
  - `x := y` copies contents of `y` into `x`
  - `x = y` compares contents [`x ~ y`]

Reference vs. Expanded (2)

Problem: Every published book has an author. Every author may publish more than one books. Should the author field of a book ***reference***-typed or ***expanded***-typed?

reference-typed author	***expanded***-typed author
	
Hyperlinked author page	Physical printed copies

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

Descendant:

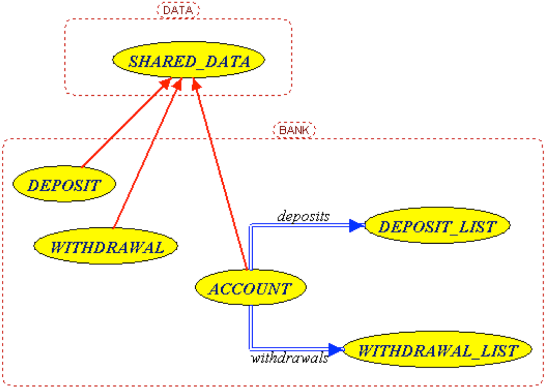
```
class DEPOSIT inherit SHARED_DATA
      -- 'maximum_balance' relevant
end

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
```

Ancestor:

```
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)

```
test_query: BOOLEAN
  local
    a: A
    arr1, arr2: ARRAY[STRING]
  do
    create a.make

    arr1 := a.new_array ("Alan")
    Result := arr1.count = 1 and arr1[1] ~ "Alan"
    check Result end

    arr2 := a.new_array ("Mark")
    Result := arr2.count = 1 and arr2[1] ~ "Mark"
    check Result end

    Result := not (arr1 = arr2)
    check Result end
  end
```

Introducing the Once Routine in Eiffel (1.3)

```
test_once_query: BOOLEAN
  local
    a: A
    arr1, arr2: ARRAY[STRING]
  do
    create a.make

    arr1 := a.new_once_array ("Alan")
    Result := arr1.count = 1 and arr1[1] ~ "Alan"
    check Result end

    arr2 := a.new_once_array ("Mark")
    Result := arr2.count = 1 and arr2[1] ~ "Alan"
    check Result end

    Result := arr1 = arr2
    check Result end
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 (1)

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();
}
```

Approximating Once Routine in Java (2)

We may encode Eiffel once routines in Java:

```
class BankData {
  private BankData() { }
  double interestRate;
  void setIR(double r);
  static boolean initOnce;
  static BankData data;
  static BankData getData() {
    if(!initOnce) {
      data = new BankData();
      initOnce = true;
    }
    return data;
  }
}
```

Problem?

Loss of Cohesion: ***Data*** and ***Access to Data*** are two separate concerns, so should be decoupled into two different classes!

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:

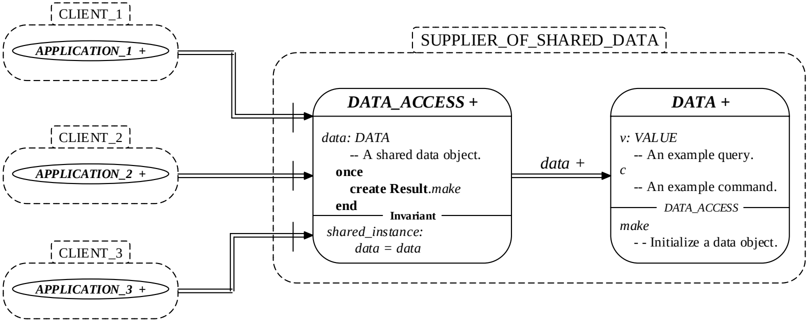
```
class
  ACCOUNT
feature
  data: BANK_DATA
  make (...)
    -- Init. access to bank data.
   local
     data_access: BANK_DATA_ACCESS
   do
     data := data_access.data
     ...
   end
end
```

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`.

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