Design Pattern: Iterator

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Learning Objectives

Upon completing this lecture, you are expected to understand:

1. Motivating Problem of the Iterator Design Pattern
2. Supplier: Implementing the Iterator Design Pattern
3. Client: Using the Iterator Design Pattern
4. A Challenging Exercise (architecture & generics)

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:

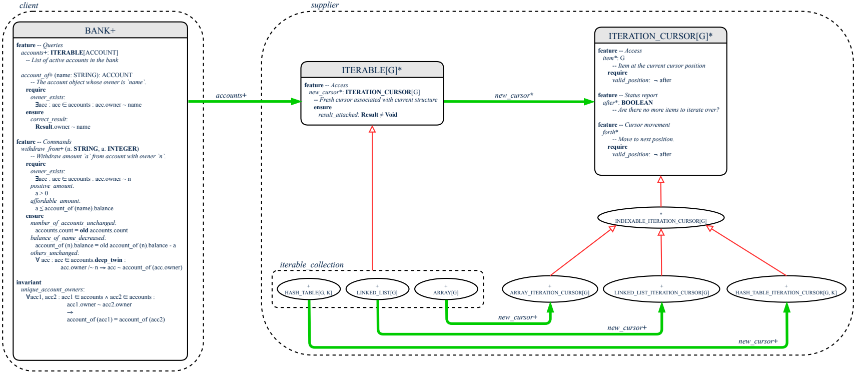
```
class
  CART
feature
  orders: LINKED_LIST[ORDER]
end

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



```
BANK+
feature -- Queries
  accounts+: ITERABLE[ACCOUNT]
    -- List of active accounts in the bank

  account_of+ (name: STRING): ACCOUNT
      -- The account object whose owner is `name`.
    require
      owner_exists:
        ∃acc : acc ∈ accounts : acc.owner ~ name
    ensure
      correct_result:
        Result.owner ~ name

feature -- Commands
  withdraw_from+ (n: STRING; a: INTEGER)
      -- Withdraw amount `a` from account with owner `n`.
    require
      owner_exists:
        ∃acc : acc ∈ accounts : acc.owner ~ n
      positive_amount:
        a > 0
      affordable_amount:
        a ≤ account_of (name).balance
    ensure
      number_of_accounts_unchanged:
        accounts.count = old accounts.count
      balance_of_name_decreased:
        account_of (n).balance = old account_of (n).balance - a
      others_unchanged:
        ∀ acc : acc ∈ accounts.deep_twin :
                  acc.owner /~ n → acc ~ account_of (acc.owner)

invariant
  unique_account_owners:
    ∀acc1, acc2 : acc1 ∈ accounts ∧ acc2 ∈ accounts :
                  acc1.owner ~ acc2.owner
                  →
                  account_of (acc1) = account_of (acc2)
```

```
ITERABLE[G]*
feature -- Access
  new_cursor*: ITERATION_CURSOR[G]
    -- Fresh cursor associated with current structure
    ensure
      result_attached: Result ≠ Void
```

```
ITERATION_CURSOR[G]*
feature -- Access
  item*: G
      -- Item at the current cursor position
    require
      valid_position: ¬ after

feature -- Status report
  after*: BOOLEAN
      -- Are there no more items to iterate over?

feature -- Cursor movement
  forth*
      -- Move to next position.
    require
      valid_position: ¬ after
```

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!

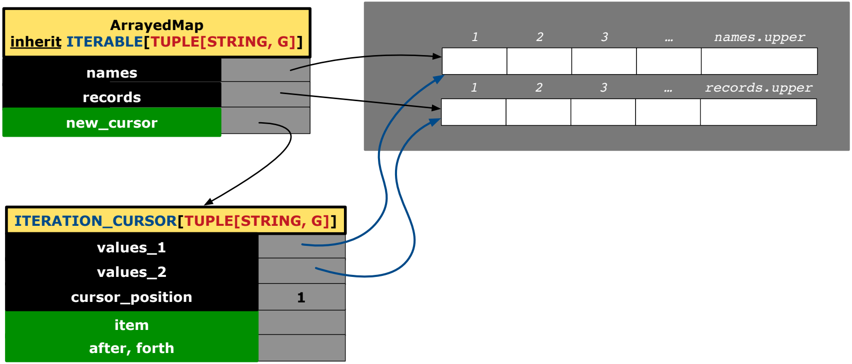
Iterator Pattern: Supplier’s Imp. (2.2)

```
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
- Tutorial on Making a Birthday Book (implemented using HASH_TABLE) ITERABLE

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:

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

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

```
class BANK
...
  accounts: LIST [ACCOUNT]
  contains_duplicate: BOOLEAN
      -- Does the account list contain duplicate?
    do
      ...
    ensure
      $\forall i, j : INTEGER \mid$
        $1 \leq i \leq accounts.count \land 1 \leq j \leq accounts.count \bullet$
          $accounts[i] \sim accounts[j] \Rightarrow i = j$
    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 cursor := accounts. new_cursor ; max := cursor. item
      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: LIST[ACCOUNT] -- Q: Can ITERABLE[ACCOUNT] work?
 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
```

Beyond this lecture . . .

- Tutorial Videos on Iterator Pattern
- Exercise: Architecture & Generics

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Learning Objectives

What are design patterns?

Iterator Pattern: Motivation (1)

Iterator Pattern: Motivation (2)

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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)

Iterator Pattern: Supplier's Imp. (2.3)

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

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

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

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

Beyond this lecture . . .