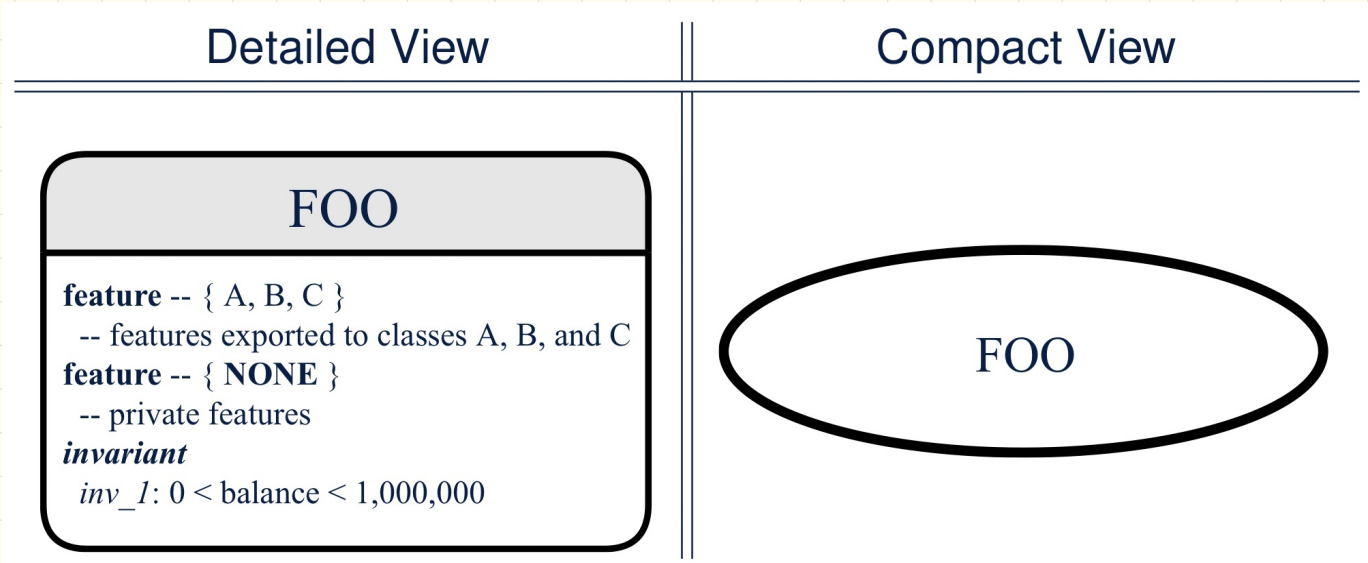
Lecture 4

Part 1

Architectural Design Diagrams

Classes: Detailed vs. Compact



Contracts: Mathematical vs Programming

ARRAYED_CONTAINER+

feature -- Queries
count+: **INTEGER**
-- *Number of items stored in the container*

feature -- Commands
assign_at+ (i: **INTEGER**; s: **STRING**)
-- *Change the value at position 'i' to 's'.*
require
valid_index: $1 \leq i \leq count$
ensure
size_unchanged: imp.count = (**old** imp.twin).count
item_assigned: $imp[i] \sim s$
others_unchanged: $\forall j : 1 \leq j \leq imp.count : j \neq i \Rightarrow imp[j] \sim$ (**old** imp.twin) [j]

feature -- { **NONE** }
imp+: **ARRAY**[**STRING**]
-- *Implementation of an arrayed-container*

invariant
consistency: imp.count = count

Generic Classes

- Type parameter(s) of a class may or may not be ***instantiated***:

HASH_TABLE[G, H]

MY_TABLE_1[STRING, INTEGER]

MY_TABLE_2[PERSON, INTEGER]

- If necessary, present a generic class in the detailed form:

DATABASE[G]+

feature
-- some public features here
feature -- { **NONE** }
-- imp: **ARRAY**[G]
invariant
-- some class invariant here

MY_DB_1[STRING]+

feature
-- some public features here
feature -- { **NONE** }
-- imp: **ARRAY**[**STRING**]
invariant
-- some class invariant here

MY_DB_2[PERSON]+

feature
-- some public features here
feature -- { **NONE** }
-- imp: **ARRAY**[PERSON]
invariant
-- some class invariant here

Programming Classes: Deferred vs. Effective

```
deferred class
  DATABASE[G]
feature -- Queries
  search (g: G): BOOLEAN
      -- Does item 'g' exist in database?
    deferred end
end
```

```
class
  DATABASE_V1[G]
inherit
  DATABASE
feature -- Queries
  search (g: G): BOOLEAN
      -- Perform a linear search on the database.
    do end
end
```

```
class
  DATABASE_V2[G]
inherit
  DATABASE_V1[G]
      redefine search end
feature -- Queries
  search (g: G): BOOLEAN
      -- Perform a binary search on the database.
    do end
end
```

Presenting Deferred/Effective Classes in Compact Form

Presenting Deferred/Effective Classes in Detailed Form

DATABASE[G]*

feature {**NONE**} -- Implementation
 data: **ARRAY**[G]

feature -- Commands
 add_item* (g: G)
  -- Add new item `g` into database.
  require
   non_existing_item: ¬ exists (g)
  ensure
   size_incremented: count = **old** count + 1
   item_added: exists (g)

feature -- Queries
 count+: **INTEGER**
  -- Number of items stored in database
  ensure
   correct_result: **Result** = data.count

 exists* (g: G): **BOOLEAN**
  -- Does item `g` exist in database?
  ensure
   correct_result: **Result** = (∃i : 1 ≤ i ≤ count : data[i] ~ g)

DATABASE_V1[G]+

feature {**NONE**} -- Implementation
 data: **ARRAY**[G]

feature -- Commands
 add_item+ (g: G)
  -- Append new item `g` into end of `data`.

feature -- Queries
 count+: **INTEGER**
  -- Number of items stored in database

 exists+ (g: G): **BOOLEAN**
  -- Perform a linear search on `data` array.

DATABASE_V2[G]+

feature {**NONE**} -- Implementation
 data: **ARRAY**[G]

feature -- Commands
 add_item++ (g: G)
  -- Insert new item `g` into the right slot of `data`.

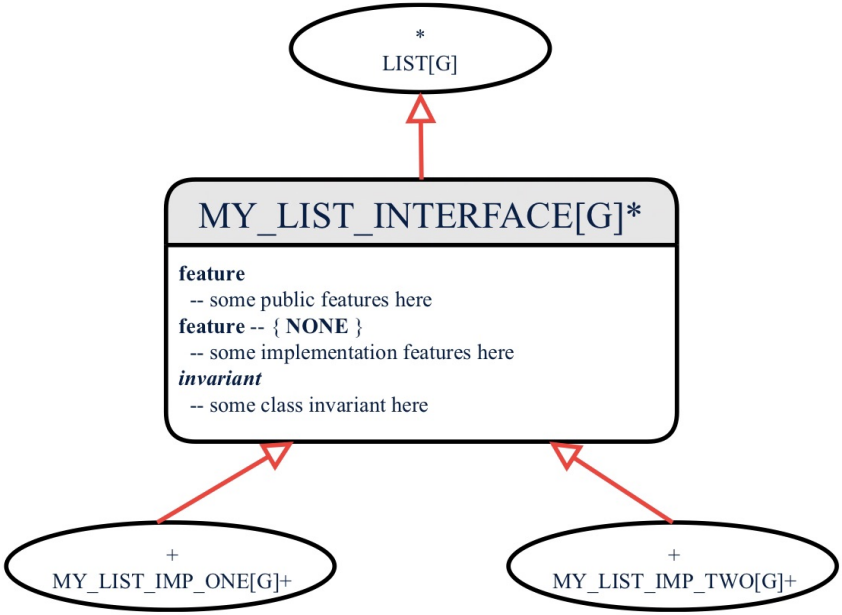
feature -- Queries
 count+: **INTEGER**
  -- Number of items stored in database

 exists++ (g: G): **BOOLEAN**
  -- Perform a binary search on `data` array.

 invariant
  sorted_data: ∀i : 1 ≤ i < count : data[i] < data[i + 1]

Inheritace (1)

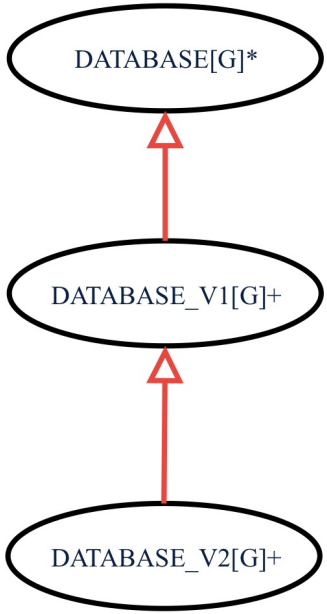
- You may choose to present each class in an inheritance hierarchy in either the detailed form or the compact form:



Inheritace (2)

More examples (emphasizing different aspects of DATABASE):

Inheritance Hierarchy	Features being (Re-)Implemented



DATABASE[G]*

feature {**NONE**} -- Implementation
data: **ARRAY**[G]

feature -- Commands
add_item* (g: G)
-- Add new item `g` into database.
require
non_existing_item: ¬ exists (g)
ensure
size_incremented: count = **old** count + 1
item_added: exists (g)

feature -- Queries
count+: **INTEGER**
-- Number of items stored in database
ensure
correct_result: **Result** = data.count

exists* (g: G): **BOOLEAN**
-- Does item `g` exist in database?
ensure
correct_result: **Result** = (∃i : 1 ≤ i ≤ count : data[i] ~ g)

DATABASE_V1[G]+

DATABASE_V2[G]+

feature {**NONE**} -- Implementation
data: **ARRAY**[G]

feature -- Commands
add_item++ (g: G)
-- Insert new item `g` into the right slot of `data`.

feature -- Queries
count+: **INTEGER**
-- Number of items stored in database

exists++ (g: G): **BOOLEAN**
-- Perform a binary search on `data` array.

invariant
sorted_data: ∀ i : 1 ≤ i < count : data[i] < data[i + 1]

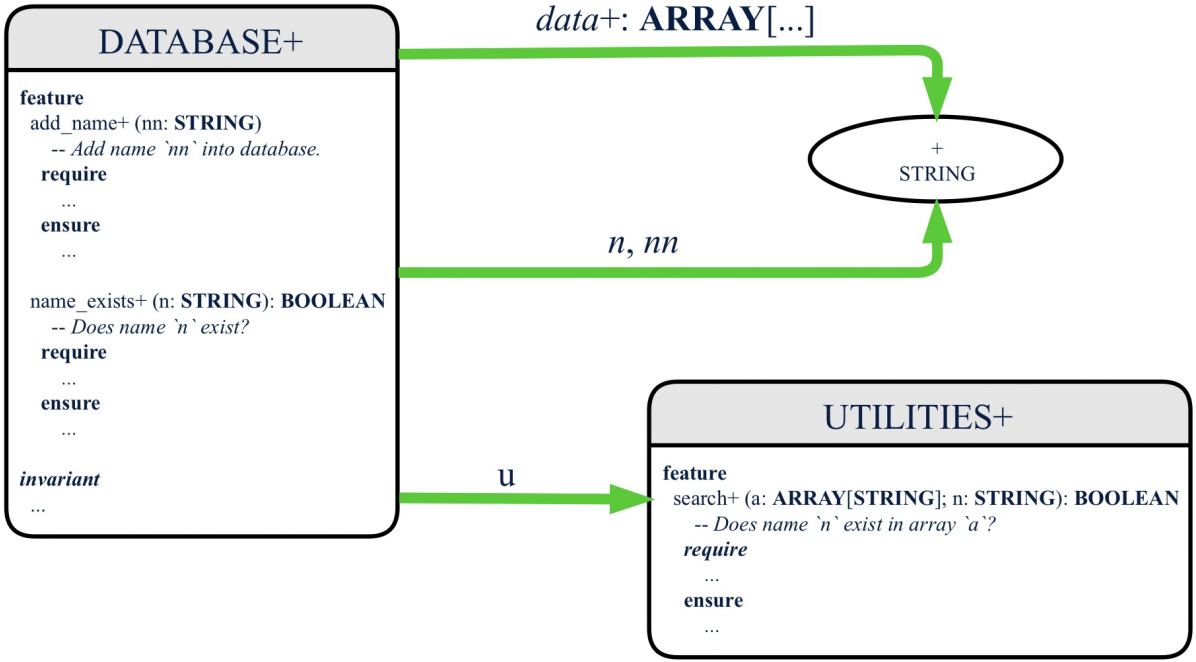
Programming Client-Supplier Relation

```
class DATABASE
feature {NONE} -- implementation
  data: ARRAY[STRING]
feature -- Commands
  add_name (nn: STRING)
      -- Add name 'nn' to database.
    require ... do ... ensure ... end

  name_exists (n: STRING): BOOLEAN
      -- Does name 'n' exist in database?
    require ...
    local
      u: UTILITIES
    do ... ensure ... end
invariant
  ...
end
```

```
class UTILITIES
feature -- Queries
  search (a: ARRAY[STRING]; n: STRING): BOOLEAN
      -- Does name 'n' exist in array 'a'?
    require ... do ... ensure ... end
end
```

Presenting CS Relation in Diagram: Approach 1

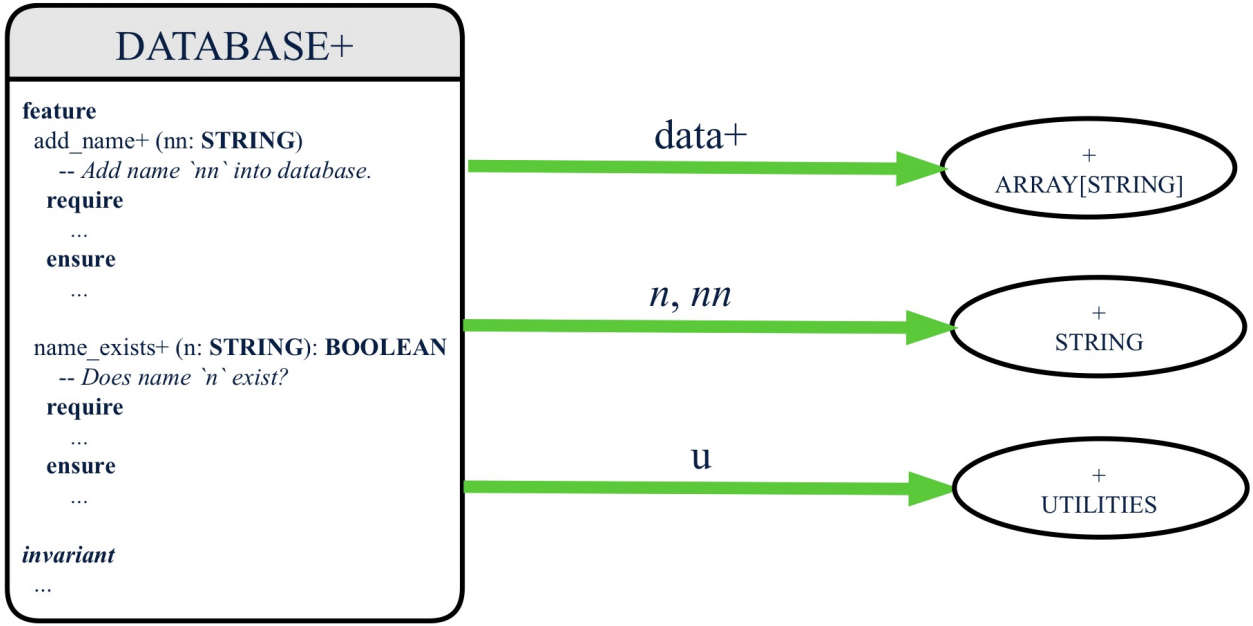
If `STRING` is to be emphasized, label is `data: ARRAY[...]`, where ... denotes the supplier class `STRING` being pointed to.



Presenting CS Relation in Diagram: Approach 2

If `ARRAY` is to be emphasized, label is `data`.

The supplier's name should be complete: `ARRAY[STRING]`



Programming Client-Supplier Relation

Design One:

```
class DATABASE_V1
feature {NONE} -- implementation
  imp: ARRAYED_LIST[PERSON]
... -- more features and contracts
end
```

Design Two:

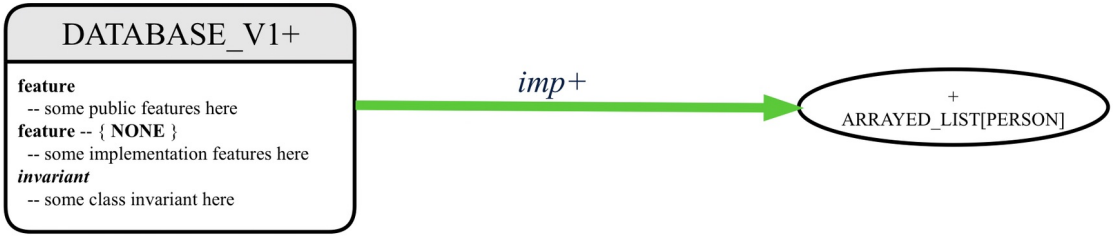
```
class DATABASE_V2
feature {NONE} -- implementation
  imp: LIST[PERSON]
... -- more features and contracts
end
```

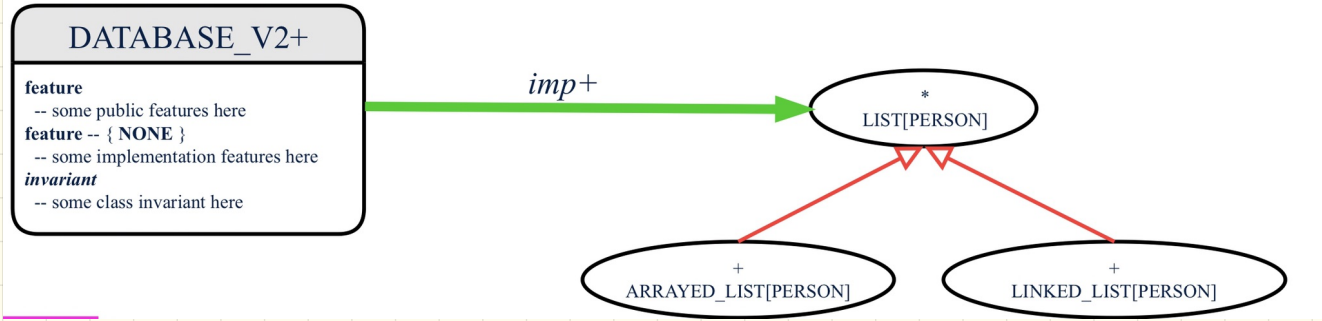
Presenting CS Relation in Diagram: Approach 1

We may focus on the `PERSON` supplier class, which may not help judge which design is better.

Presenting CS Relation in Diagram: Approach 2

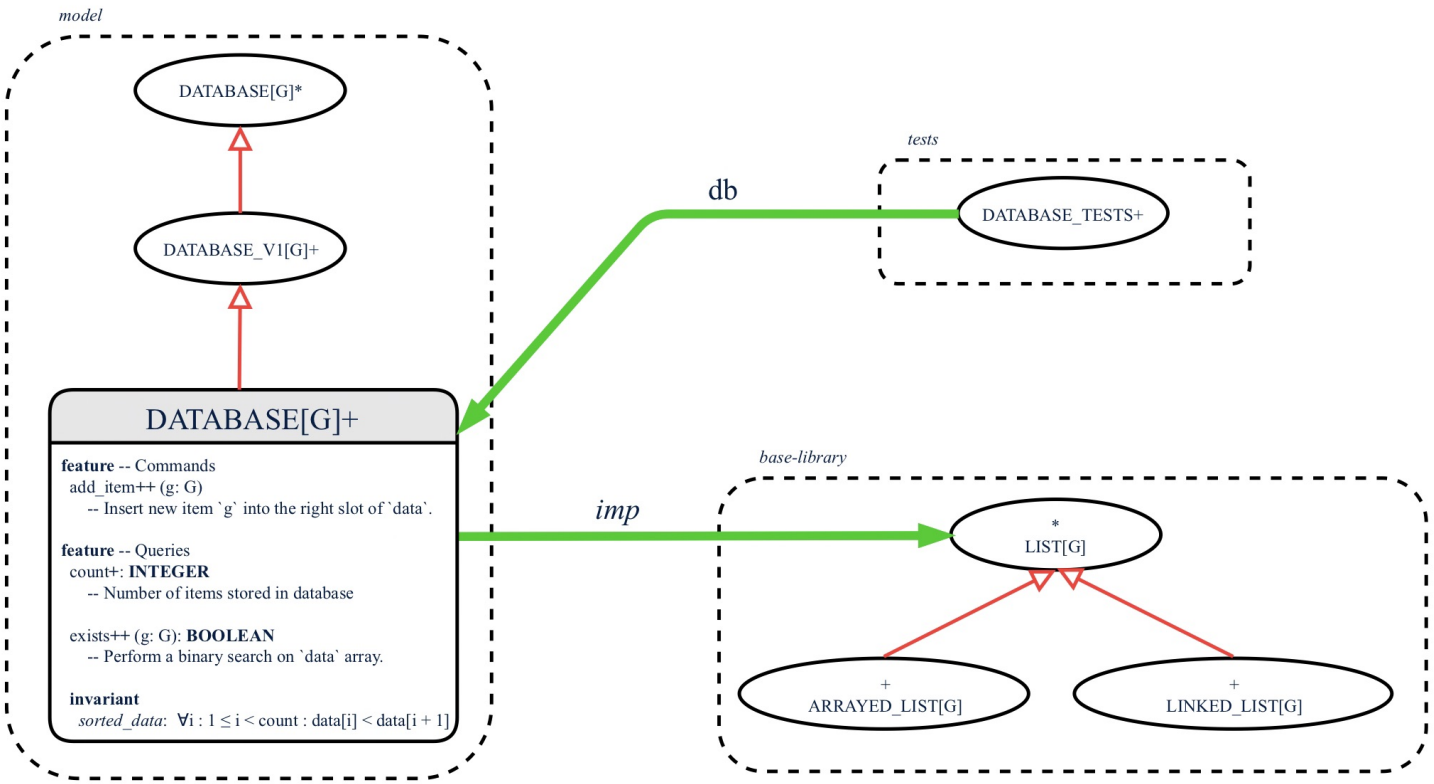
Alternatively, we may focus on the `LIST` supplier class, which in this case helps us judge which design is better.





Clusters

Use *clusters* to group classes into logical units.



Lecture 4

Part 2

Postcondition: Asserting Set Equality

Writing Postcondition: Exercise

Problem

```
all_positive_values (a: ARRAY[INTEGER]): ARRAY[INTEGER]
    require
      no_duplicates: ??
    ensure
      across Result is x
        all
          x > 0
        end
```

Writing Postcondition: Exercise

Solution

```
all_positive_values (a: ARRAY[INTEGER]): ARRAY[INTEGER]
    require
      no_duplicates: ??
    ensure
      across Result is x
        all
          x > 0
        end
```

Lecture 4

Part 3

Abstraction of a Birthday Book

Testing REL in MATHMODELS

Say $r = \{(a,1),(b,2),(c,3),(a,4),(b,5),(c,6),(d,1),(e,2),(f,3)\}$

r.domain
r.range
r.image(a)
r[g]

Say $r = \{(a,1),(b,2),(c,3),(a,4),(b,5),(c,6),(d,1),(e,2),(f,3)\}$

$$
\begin{aligned}
& r.\mathbf{overridden}(\underbrace{\{(a,3),(c,4)\}}_{t}) \\
= \; & \underbrace{\{(a,3),(c,4)\}}_{t} \cup \underbrace{\{(b,2),(b,5),(d,1),(e,2),(f,3)\}}_{r.\mathbf{domain\_subtracted}(\underbrace{t.\mathbf{domain}}_{\{a,c\}})} \\
= \; & \{(a,3),(c,4),(b,2),(b,5),(d,1),(e,2),(f,3)\}
\end{aligned}
$$

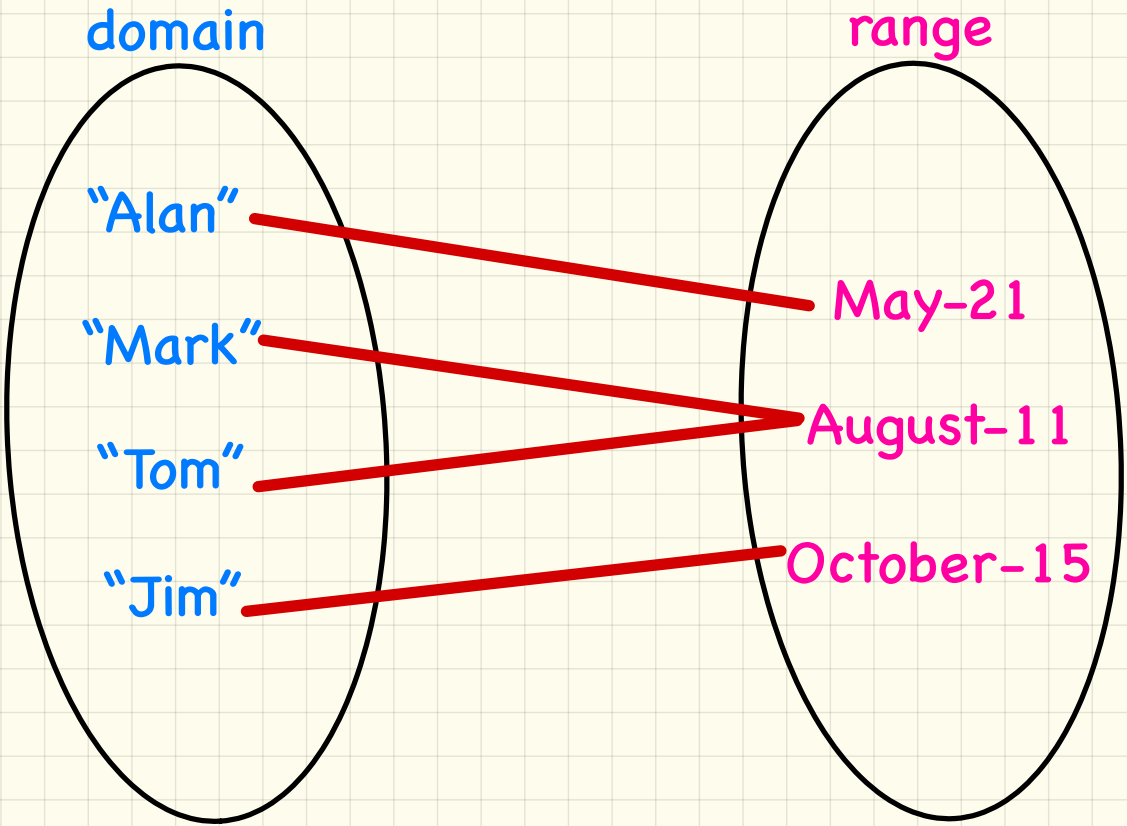
Testing REL in MATHMODELS

```
test_rel: BOOLEAN
 local
   r, t: REL[STRING, INTEGER]
   ds: SET[STRING]
 do
   create r.make_from_tuple_array (
     <<["a", 1], ["b", 2], ["c", 3],
       ["a", 4], ["b", 5], ["c", 6],
       ["d", 1], ["e", 2], ["f", 3]>>)
   create ds.make_from_array (<<"a">>)
   -- r is not changed by the query 'domain_subtracted'
   t := r.domain_subtracted (ds)
   Result :=
     t /~ r and not t.domain.has ("a") and r.domain.has ("a")
   check Result end
   -- r is changed by the command 'domain_subtract'
   r.domain_subtract (ds)
   Result :=
     t ~ r and not t.domain.has ("a") and not r.domain.has ("a")
 end
```

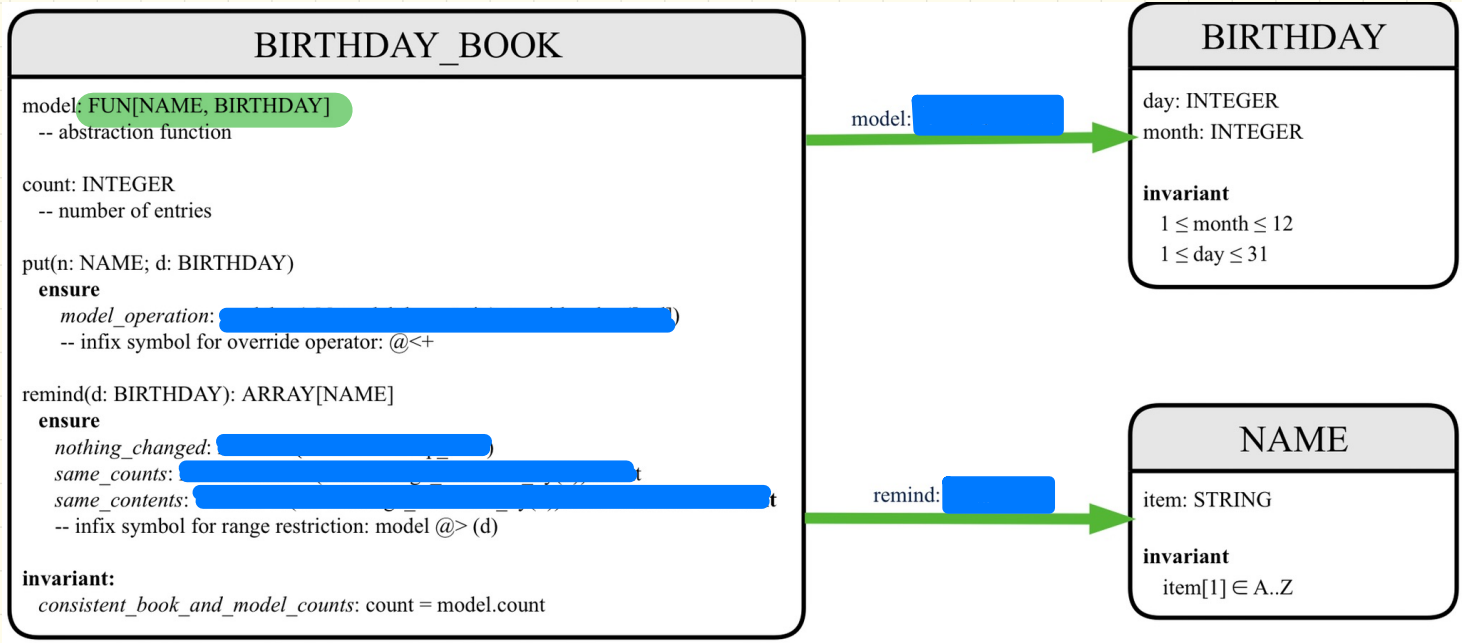
Say $r = \{(a,1),(b,2),(c,3),(a,4),(b,5),(c,6),(d,1),(e,2),(f,3)\}$

- r.***domain***: set of first-elements from r
  - r.**domain** = $\{ d \mid (d,r) \in r \}$
  - e.g., r.**domain** = $\{a,b,c,d,e,f\}$
- r.***range***: set of second-elements from r
  - r.**range** = $\{ r \mid (d,r) \in r \}$
  - e.g., r.**range** = $\{1,2,3,4,5,6\}$
- r.***inverse***: a relation like r except elements are in reverse order
  - r.**inverse** = $\{ (r,d) \mid (d,r) \in r \}$
  - e.g., r.**inverse** = $\{(1,a),(2,b),(3,c),(4,a),(5,b),(6,c),(1,d),(2,e),(3,f)\}$
- r.***domain_restricted***(ds): sub-relation of r with domain ds.
  - r.**domain_restricted**(ds) = $\{ (d,r) \mid (d,r) \in r \wedge d \in ds \}$
  - e.g., r.**domain_restricted**({a, b}) = $\{(\mathbf{a},1),(\mathbf{b},2),(\mathbf{a},4),(\mathbf{b},5)\}$
- r.***domain_subtracted***(ds): sub-relation of r with domain not ds.
  - r.**domain_subtracted**(ds) = $\{ (d,r) \mid (d,r) \in r \wedge d \notin ds \}$
  - e.g., r.**domain_subtracted**({a, b}) = $\{(\mathbf{c},6),(\mathbf{d},1),(\mathbf{e},2),(\mathbf{f},3)\}$
- r.***range_restricted***(rs): sub-relation of r with range rs.
  - r.**range_restricted**(rs) = $\{ (d,r) \mid (d,r) \in r \wedge r \in rs \}$
  - e.g., r.**range_restricted**({1, 2}) = $\{(a,\mathbf{1}),(b,\mathbf{2}),(d,\mathbf{1}),(e,\mathbf{2})\}$
- r.***range_subtracted***(ds): sub-relation of r with range not ds.
  - r.**range_subtracted**(rs) = $\{ (d,r) \mid (d,r) \in r \wedge r \notin rs \}$
  - e.g., r.**range_subtracted**({1, 2}) = $\{(c,\mathbf{3}),(a,\mathbf{4}),(b,\mathbf{5}),(c,\mathbf{6})\}$

Model of an Example Birthday Book

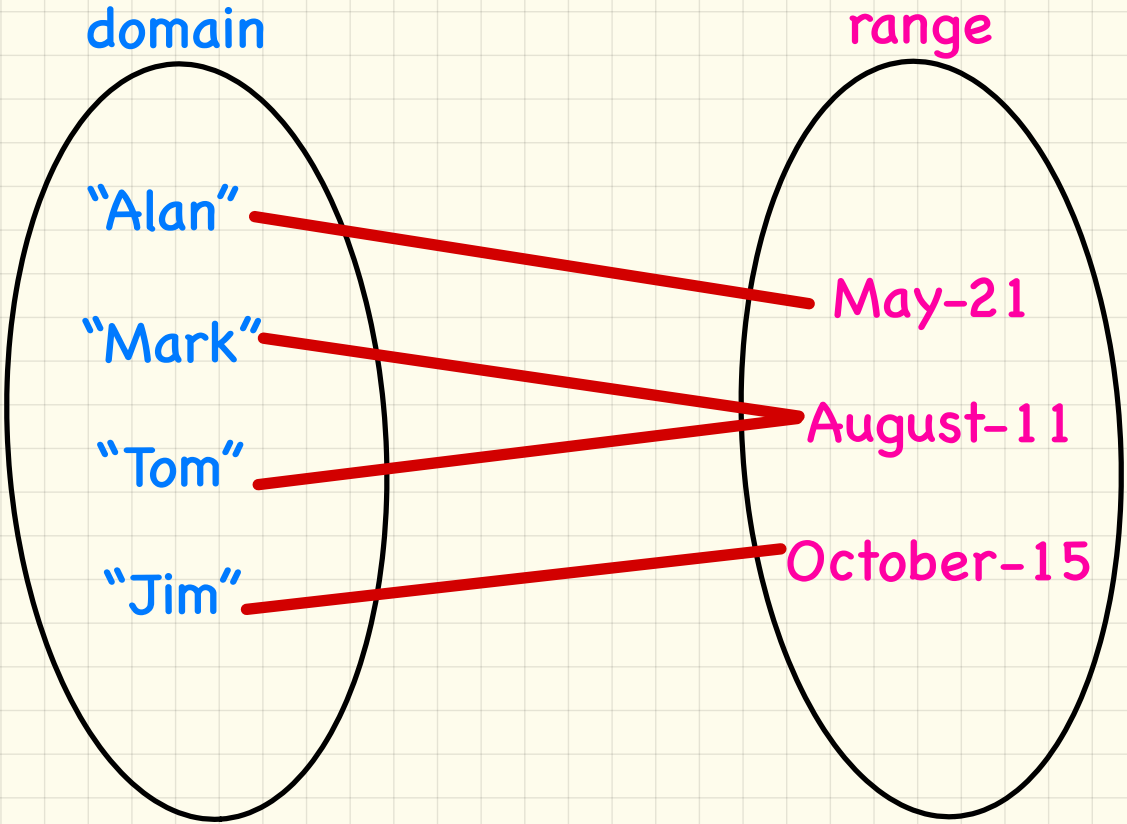


Birthday Book: Design



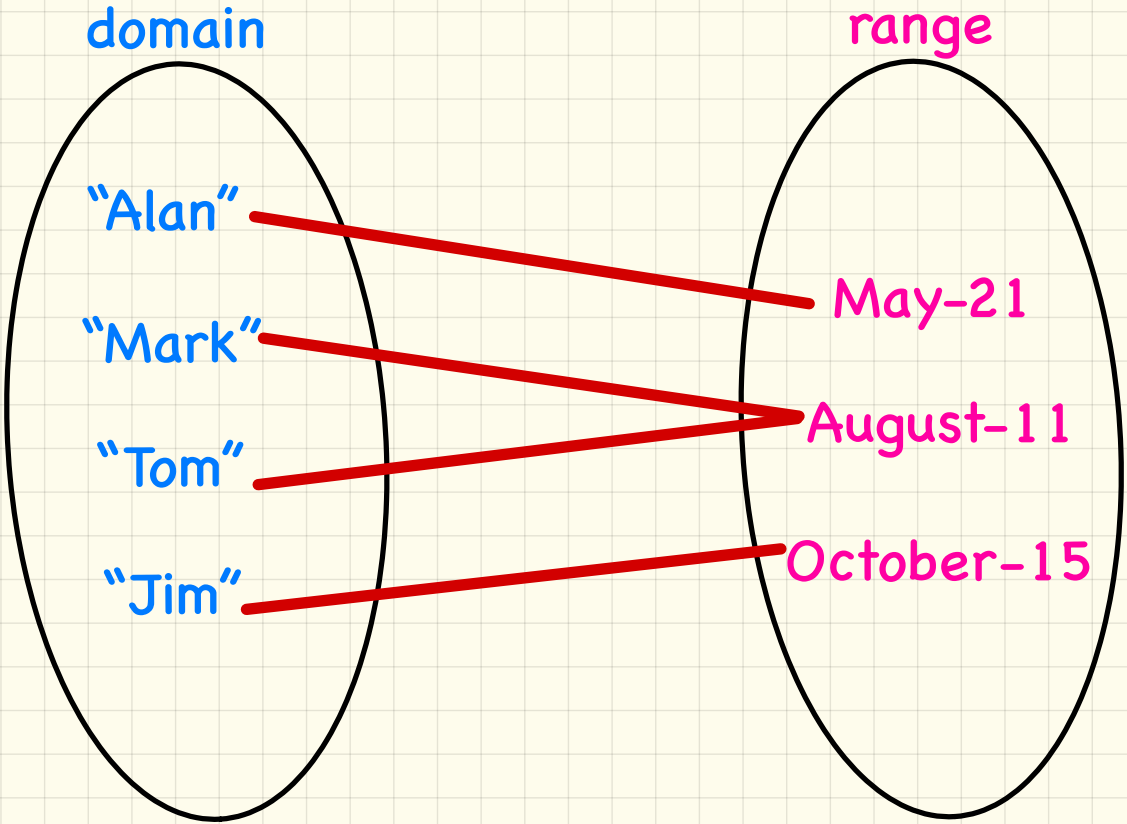
Birthday Book: Model Operation (1.1)

book.put("Heeyeon", October-15)



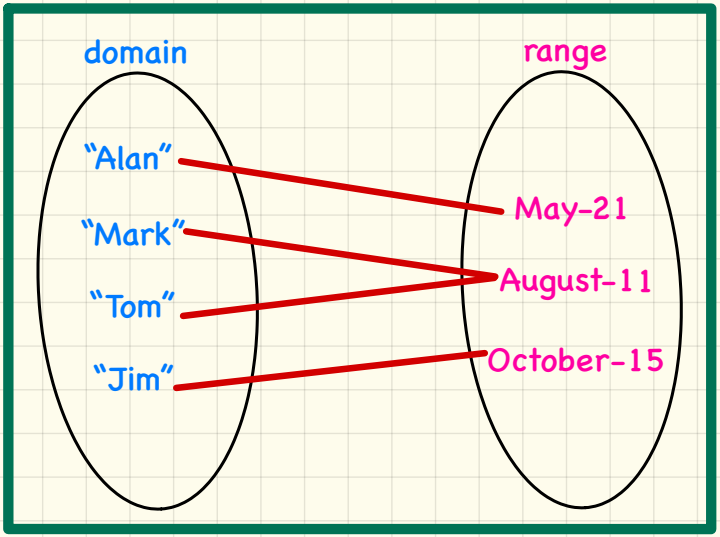
Birthday Book: Model Operation (1.2)

book.put("Tom", September-14)



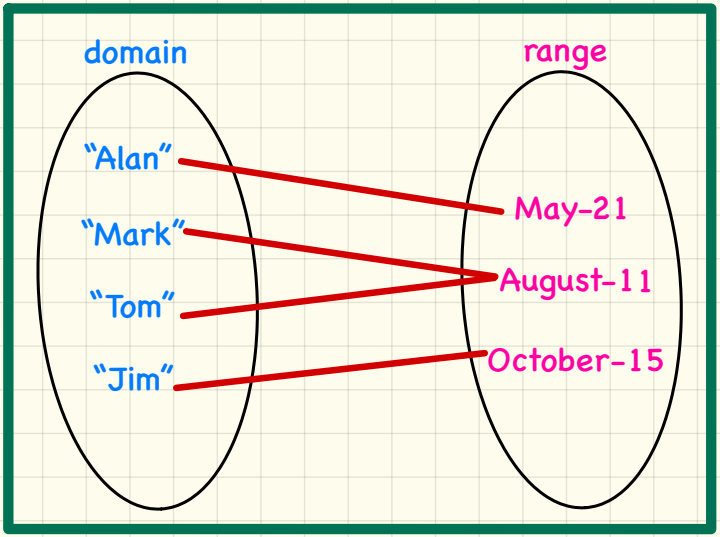
Birthday Book: Model Operation (2.1)

book.remind(August-11)

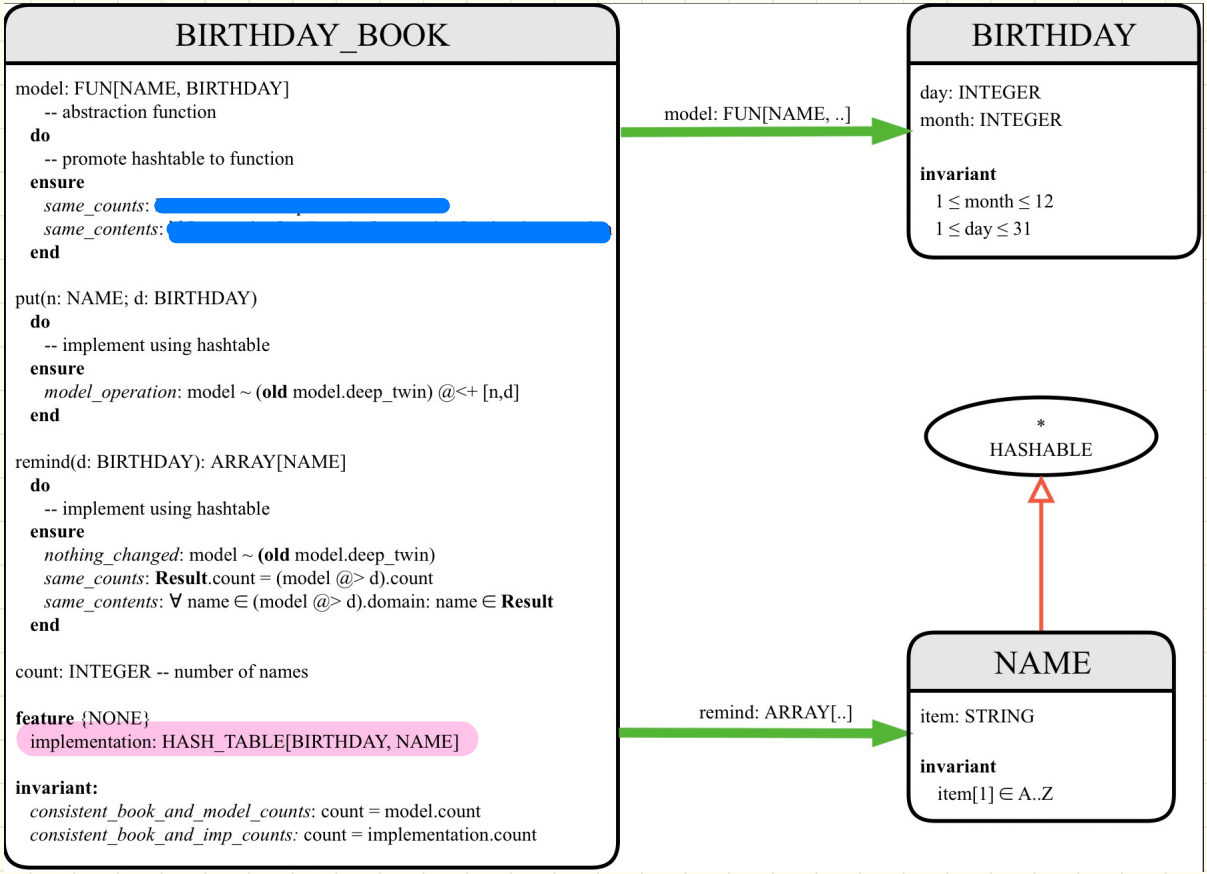


Birthday Book: Model Operation (2.2)

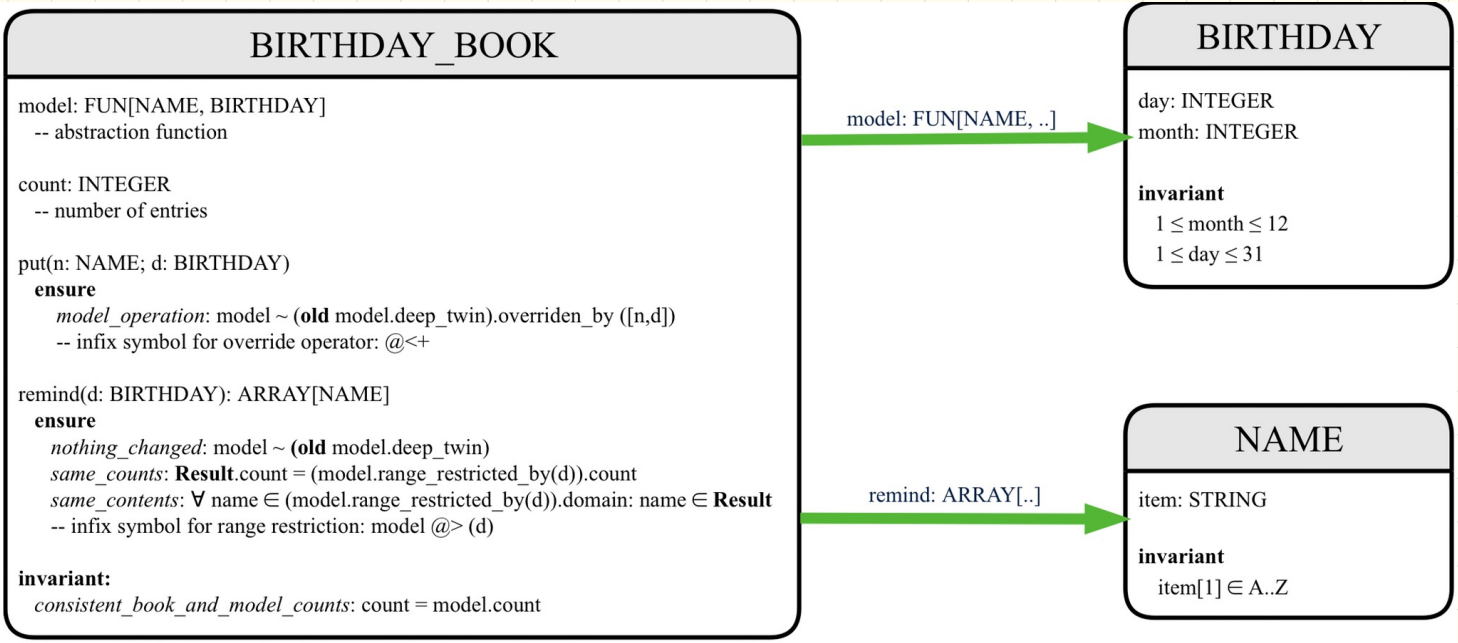
book.remind(November-29)



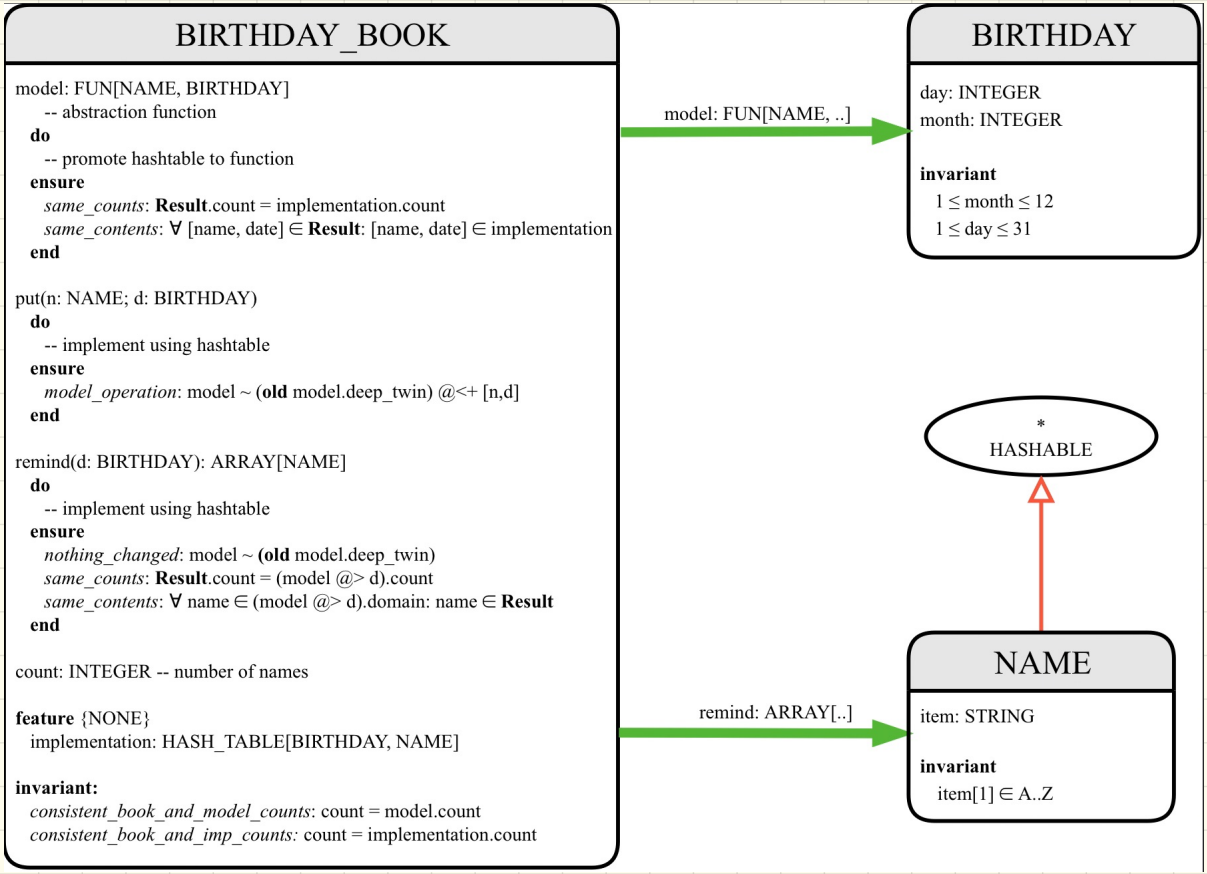
Birthday Book: Implementation



Birthday Book: Design



Birthday Book: Implementation



Lecture 4

Part 4

Design Pattern: Iterator

Principle of Information Hiding

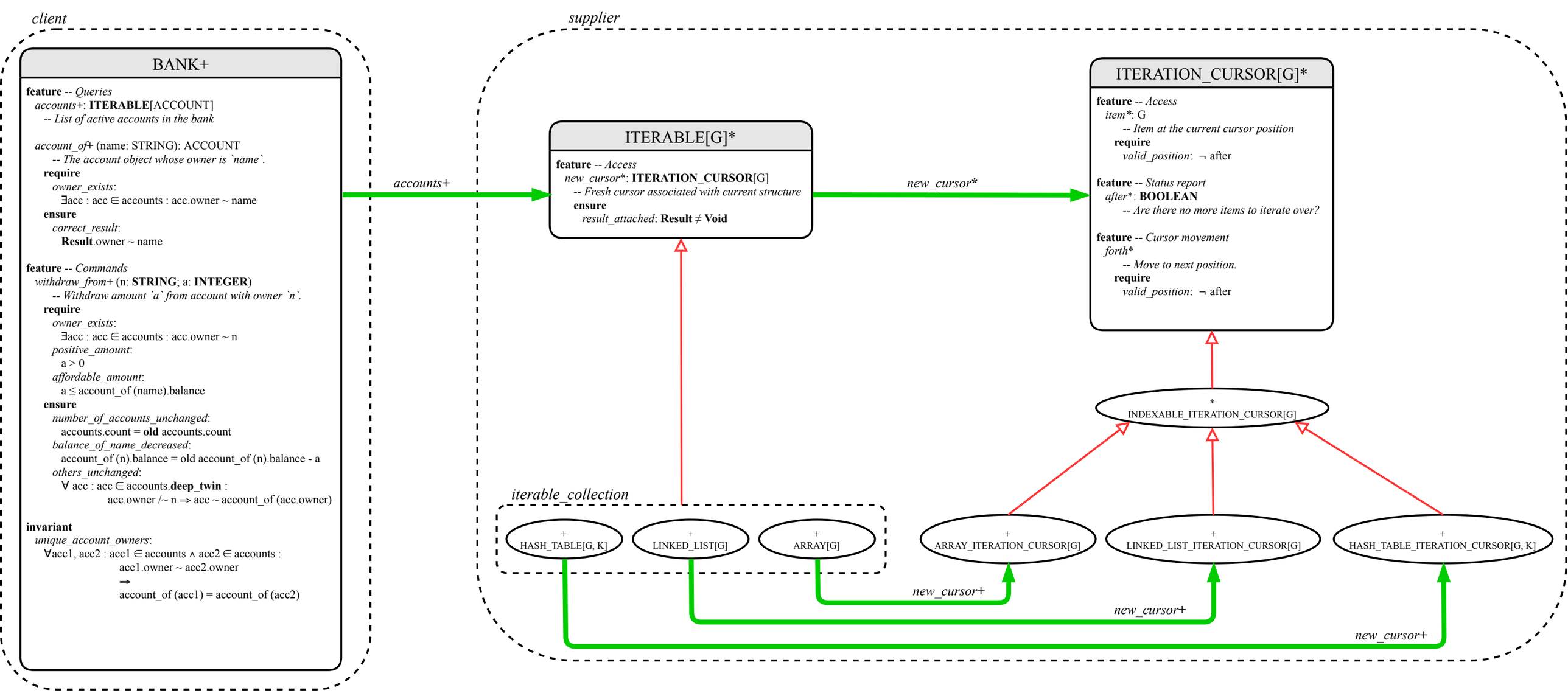
Supplier:

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

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

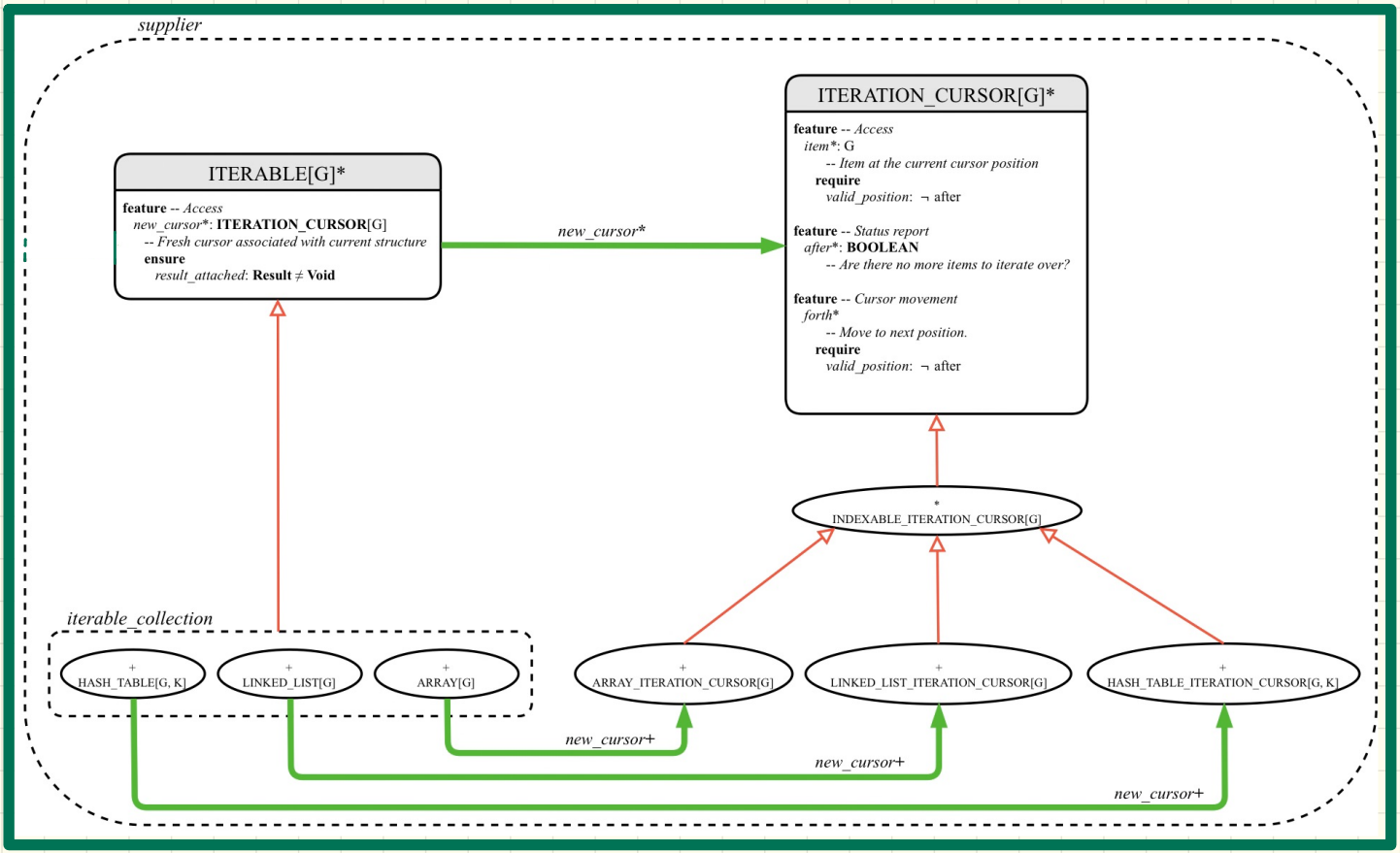
Problems?

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
```


client
supplier
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)
accounts+
ITERABLE[G]*
feature -- Access
new_cursor*: ITERATION_CURSOR[G]
-- Fresh cursor associated with current structure
ensure
result_attached: Result ≠ Void
new_cursor*
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
*
INDEXABLE_ITERATION_CURSOR[G]
iterable_collection
+
HASH_TABLE[G, K]
+
LINKED_LIST[G]
+
ARRAY[G]
+
ARRAY_ITERATION_CURSOR[G]
+
LINKED_LIST_ITERATION_CURSOR[G]
+
HASH_TABLE_ITERATION_CURSOR[G, K]
new_cursor+
new_cursor+
new_cursor+

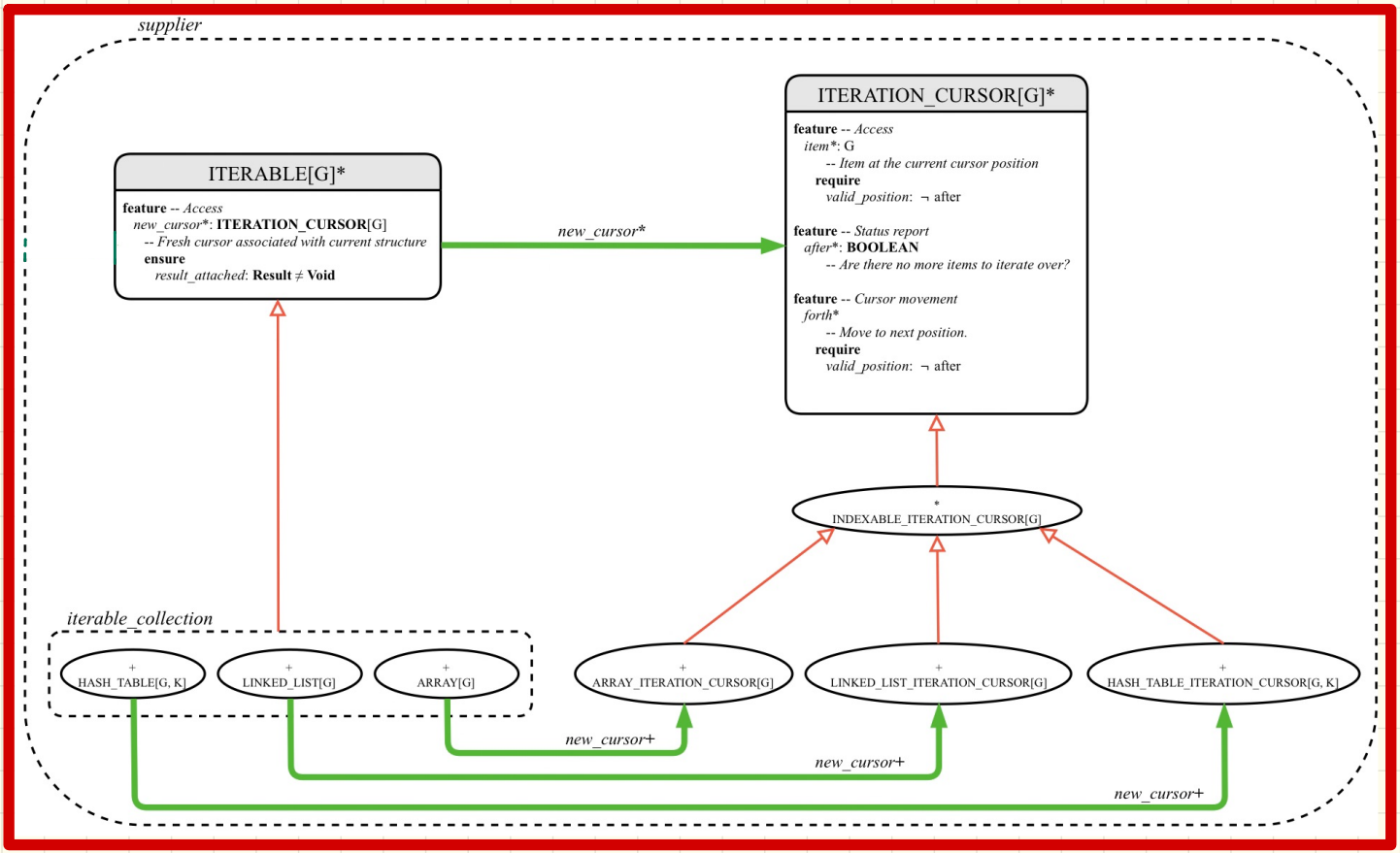
Implementing the Iterator Pattern: Easy Case



Implementing the Iterator Pattern: Easy Case

```
class
   CART


feature {NONE}
   orders: ARRAY[ORDER]









end
```

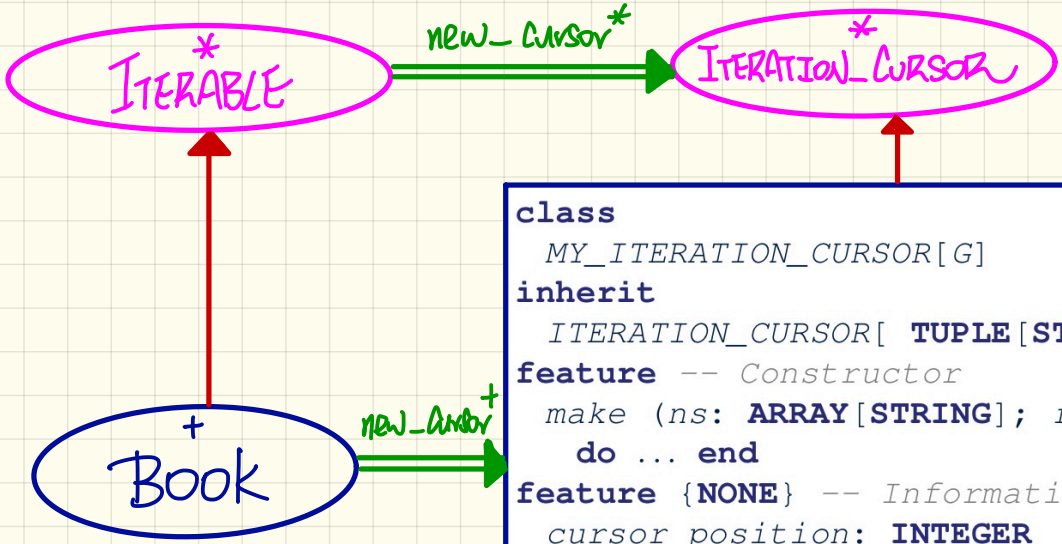
Implementing the Iterator Pattern: Hard Case



Implementing the Iterator Pattern: Hard Case

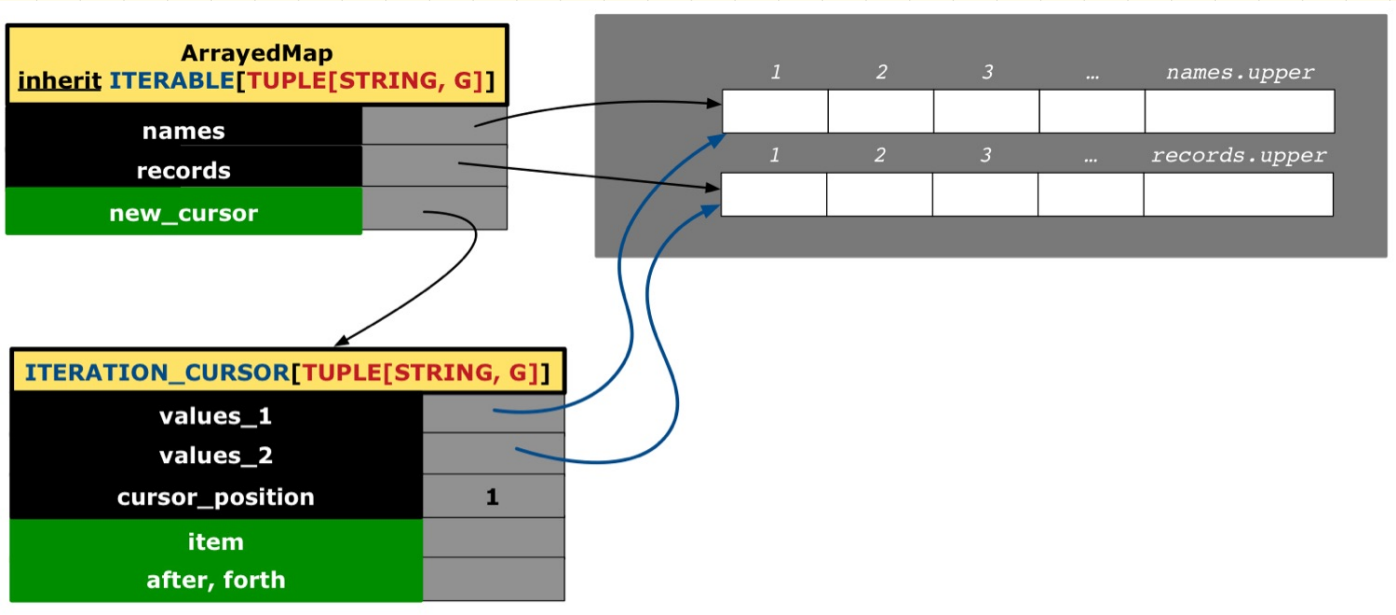
```
class
   BOOK[G]


feature {NONE}
   names: ARRAY[STRING]
   records: ARRAY[G]




end
```

Implementing the Iterator Pattern: Hard Case




```
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
```

Iterator Pattern at Runtime



Use of Iterable in Contracts

```
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
```

```
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
```

Use of Iterable in Contracts: Exercise

```
class BANK
...
  accounts: LIST [ACCOUNT]
  contains_duplicate: BOOLEAN
      -- Does the account list contain duplicate?
    do
      ...
    ensure
        ∀ i, j : INTEGER |
          1 ≤ i ≤ accounts.count ∧ 1 ≤ j ≤ accounts.count •
            accounts[i] ~ accounts[j] ⇒ i = j
    end
```

Use of Iterable in Implementation (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
```

Use of Iterable in Implementation (2)

```
class SHOP
  cart: CART
  checkout: INTEGER
      -- Total price calculated based on orders in the cart.
    require ??
    do
      across
        cart is order
      loop
        Result := Result + order.price * order.quantity
      end
    ensure ??
  end
```

```
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
```

Lecture 4

Part 5

Exercise: Generics in Iterator

Exercise

```
deferred class
  ITERABLE [G]
feature -- Access
  new_cursor: ITERATION_CURSOR [G]
    deferred end
end
```

new_cursor*

```
deferred class
  ITERATION_CURSOR [G]
feature -- Cursor features
  item: G
    deferred end

  after: BOOLEAN
    deferred end

  forth
    deferred end
```

```
test_database: BOOLEAN
  local
    db: DATABASE[STRING, INTEGER]
    tuples: LINKED_LIST[TUPLE[INTEGER, STRING]]
  do
    create db.make
    create tuples.make
    across
      db is t
    loop
      tuples.extend (t)
    end
end
```

db+

```
class
  DATABASE[G, H]
inherit
  ITERABLE[                ]
feature {NONE} -- Implementation
  gs: ARRAY[G]
  hs: ARRAY[H]
feature -- Iterable
  new_cursor: ITERATION_CURSOR[                ]
    local
      db_cursor: ITEM_ITERATION_CURSOR[H, G]
    do
      create db_cursor.make (      )
      Result := db_cursor
    end
end
```

new_cursor+

```
class
  ITEM_ITERATION_CURSOR[M, N]
inherit
  ITERATION_CURSOR[                ]
create
  make
feature {NONE} -- Implementation
  ms: ARRAY[M]
  ns: ARRAY[N]
feature -- Constructor
  make (new_ns: ARRAY[N]; new_ms: ARRAY[M])
    do ... end
feature -- Cursor features
  item:
    do ... end

  after: BOOLEAN
    do ... end

  forth
    do ... end
end
```