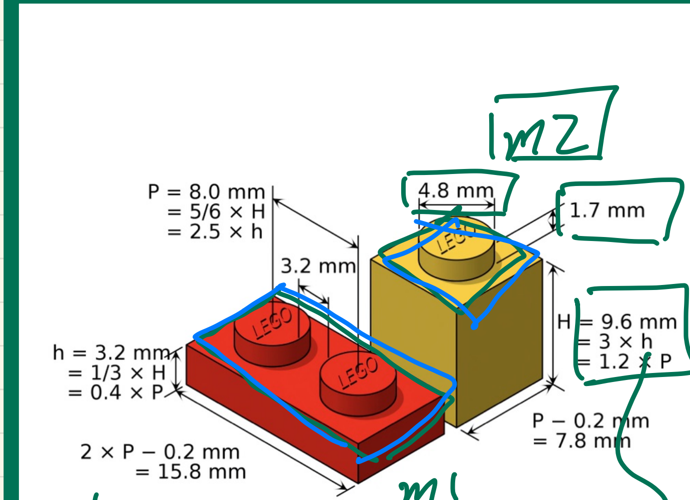
Lecture 2

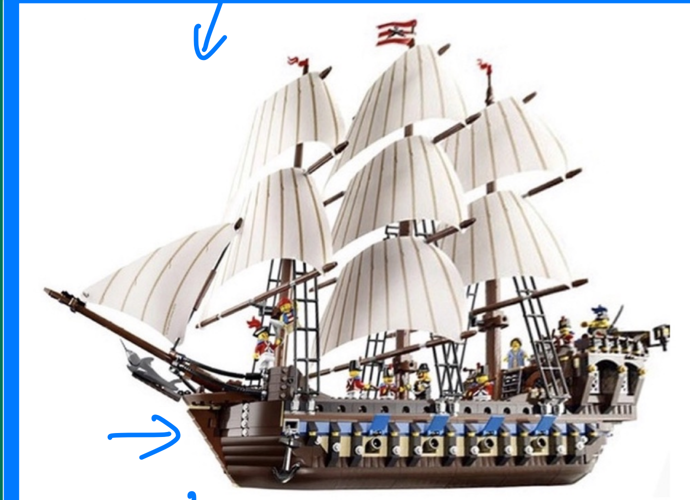
Part 1

Modularity & Modular Design
Abstract Data Types (ADTs)

Modularity: Childhood Activities

assembly of modules.



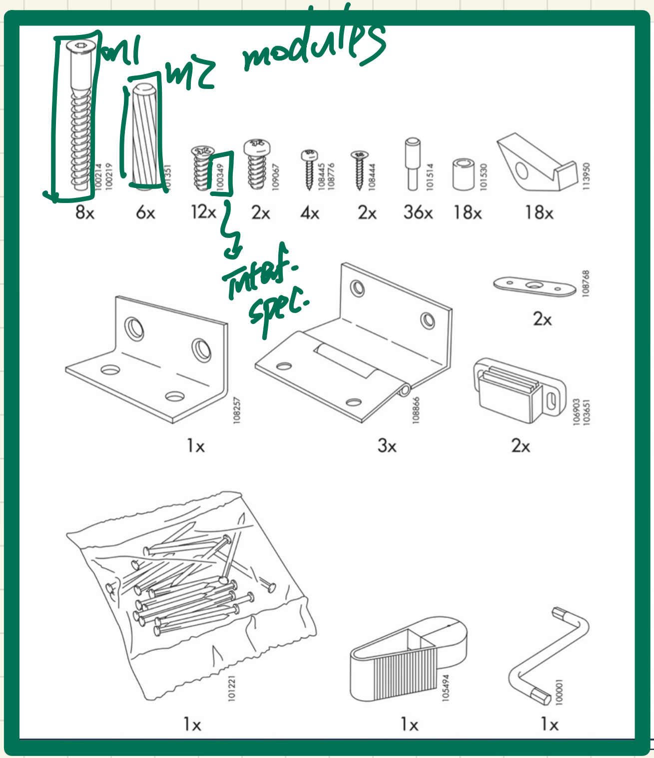


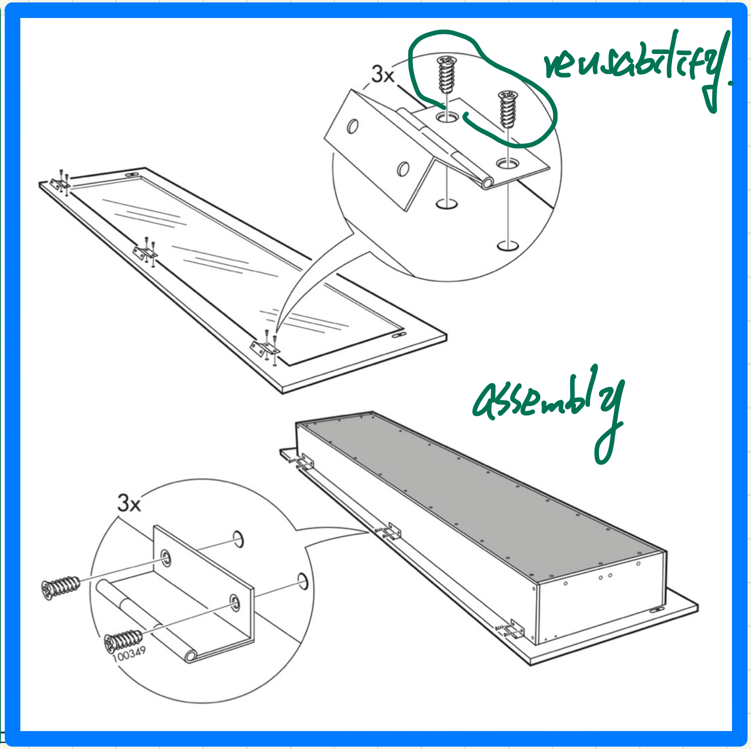
modules

interface specification

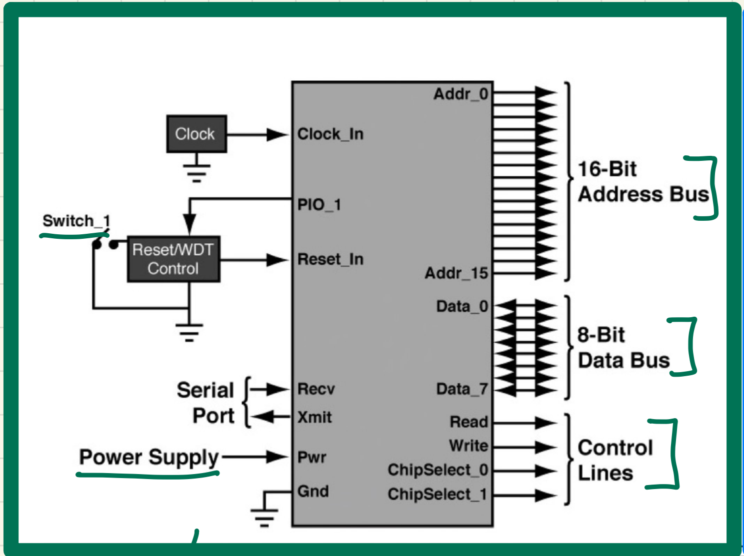
reusable

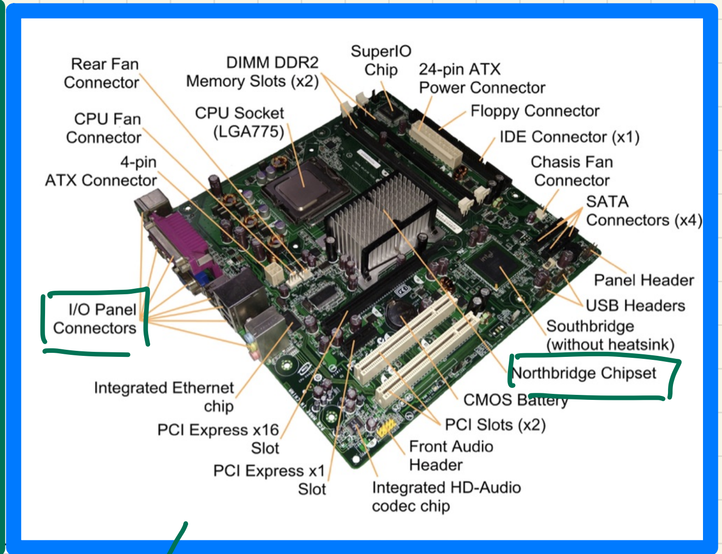
Modularity: Daily Constructions





Modularity: Computer Architectures

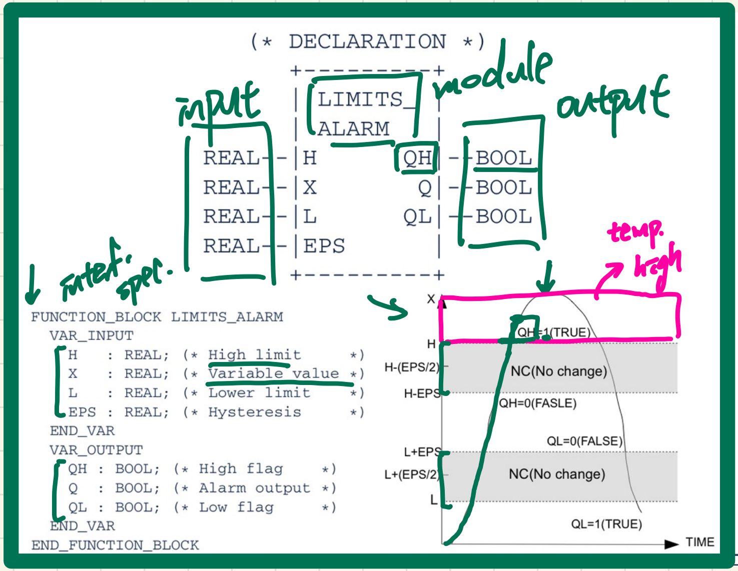


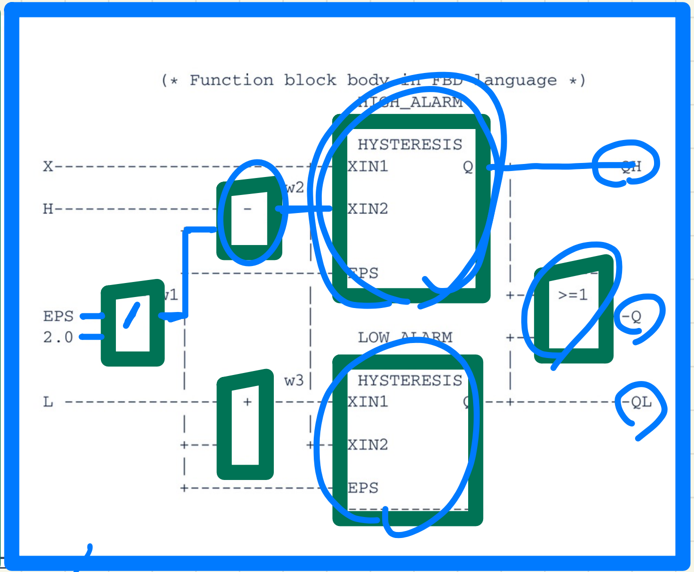


↳ spec.

↳ assembly.

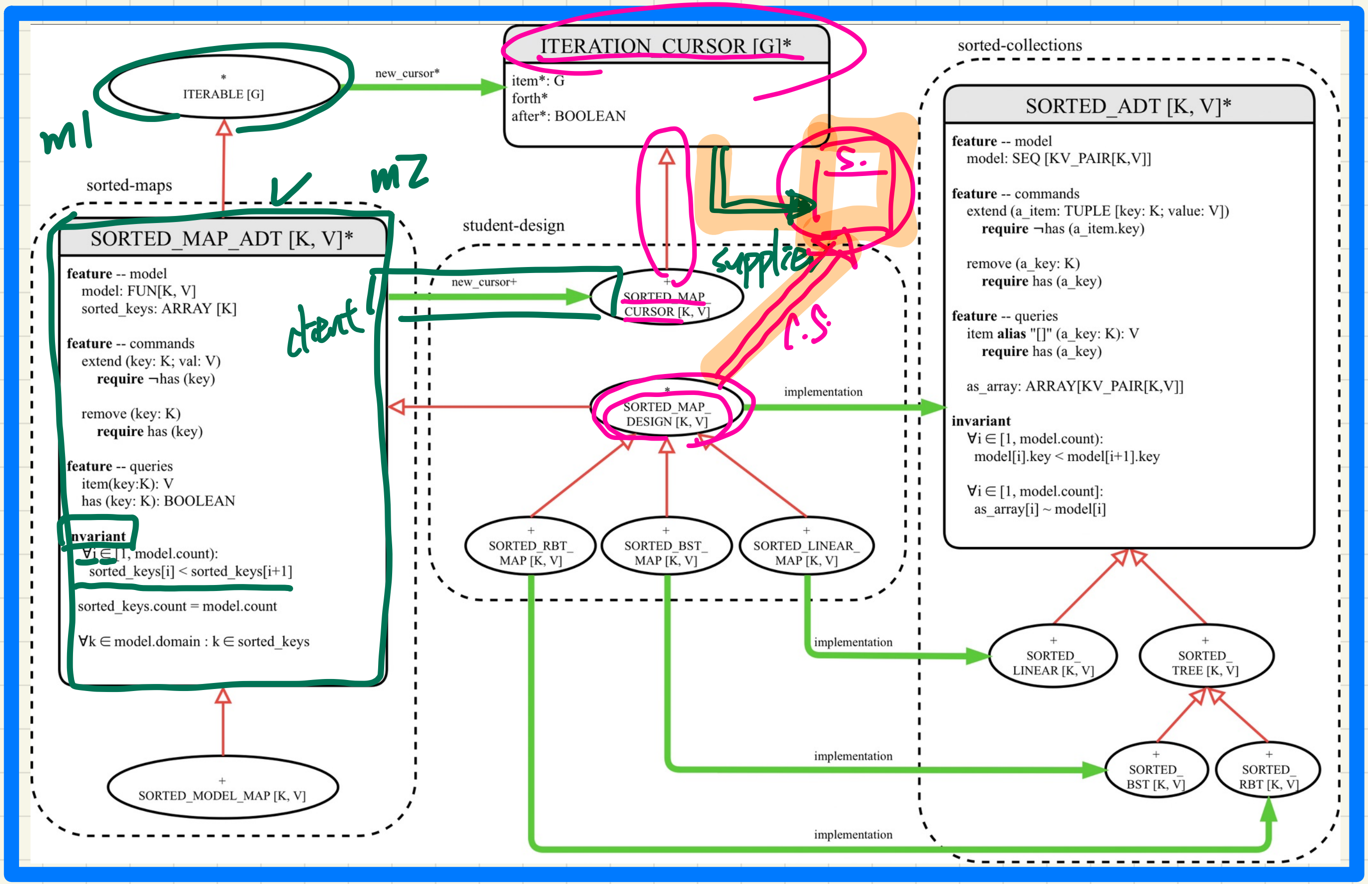
Modularity: System Developments





assembly.

Modularity: Software Design



Java Classes: Abstract Data Types? No.

E	set(int index, E element) Replaces the element at the specified position in this list with the specified element (optional operation).

set

```
E set(int index,
      E element)
```

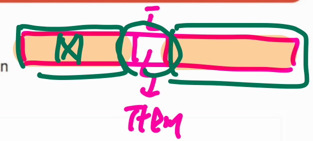
set(i, item)

Replaces the element at the specified position in this list with the specified element (optional operation).

Parameters:

index - index of the element to replace

element - element to be stored at the specified position



Returns:

the element previously at the specified position

Throws:

UnsupportedOperationException - if the set operation is not supported by this list

ClassCastException - if the class of the specified element prevents it from being added to this list

NullPointerException - if the specified element is null and this list does not permit null elements

IllegalArgumentException - if some property of the specified element prevents it from being added to this list

IndexOutOfBoundsException - if the index is out of range (index < 0 || index >= size()) ≠ precond.

gen. param.

Interface List<E>

Type Parameters:

E - the type of elements in this list

All Superinterfaces:

Collection<E>, Iterable<E>

All Known Implementing Classes:

AbstractList, AbstractSequentialList, ArrayList, AttributeList, CopyOnWriteArrayList, LinkedList, RoleList, RoleUnresolvedList, Stack, Vector

---

```
public interface List<E>
extends Collection<E>
```

An ordered collection (also known as a *sequence*). The user of this interface has precise control over where in the list each element is inserted. The user can access elements by their integer index (position in the list), and search for elements in the list.

Eiffel Classes: Abstract Data Types?

Contract View

```
class interface ARRAYED_CONTAINER
feature -- Commands
  assign_at (i: INTEGER; s: STRING)
    -- Change the value at position 'i'
    require
     valid_index: 1 <= i and i <= count
    ensure
     size_unchanged:
       imp.count = (old imp.twin).count
     item_assigned:
       imp [i] ~ s
     others_unchanged:
       across
         1 |..| imp.count as j
       all
         j.item /= i implies imp [j.item] ~ (old imp.twin) [j.item]
       end
  count: INTEGER
invariant
  consistency: imp.count = count
end -- class ARRAYED_CONTAINER
```

∀

Design Diagram

ARRAYED_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] ~ s
others_unchanged: $\forall j : 1 \leq j \leq imp.count : j \neq i \Rightarrow imp[j]$ ~ (**old** imp.twin) [j]

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

invariant
consistency: imp.count = count

spec.

Lecture 2

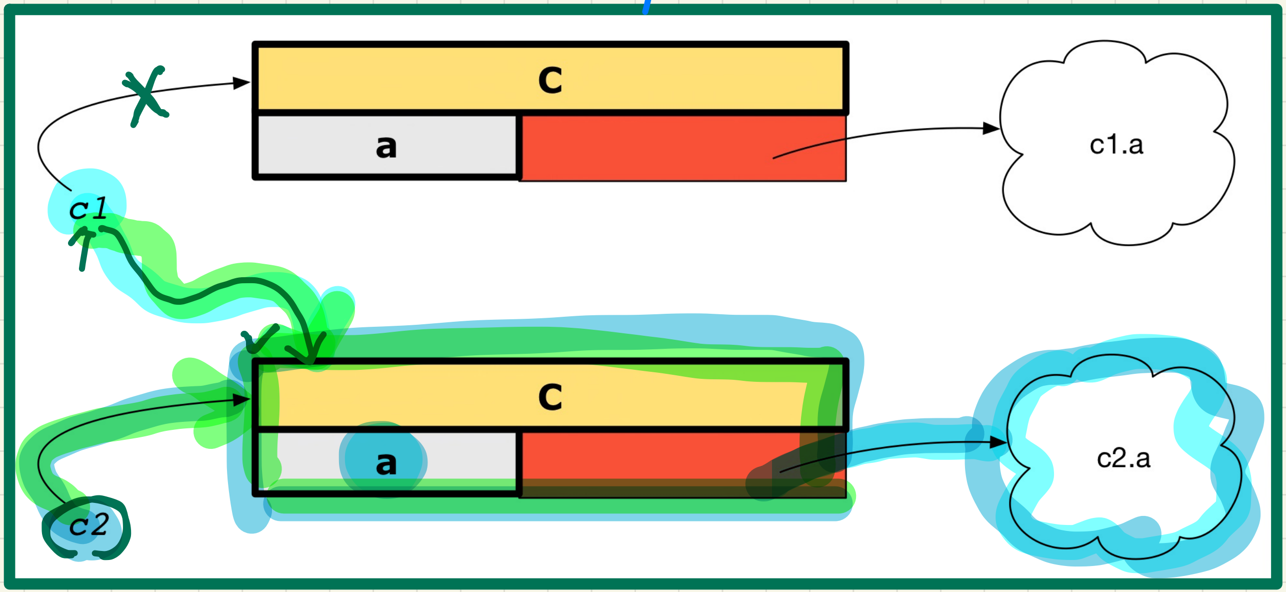
Part 2

Copying Objects:
Reference vs. Shallow vs. Deep

Reference Copy: c1 := c2

ref. copy

↳ cheapest!



c1 = c2 T.

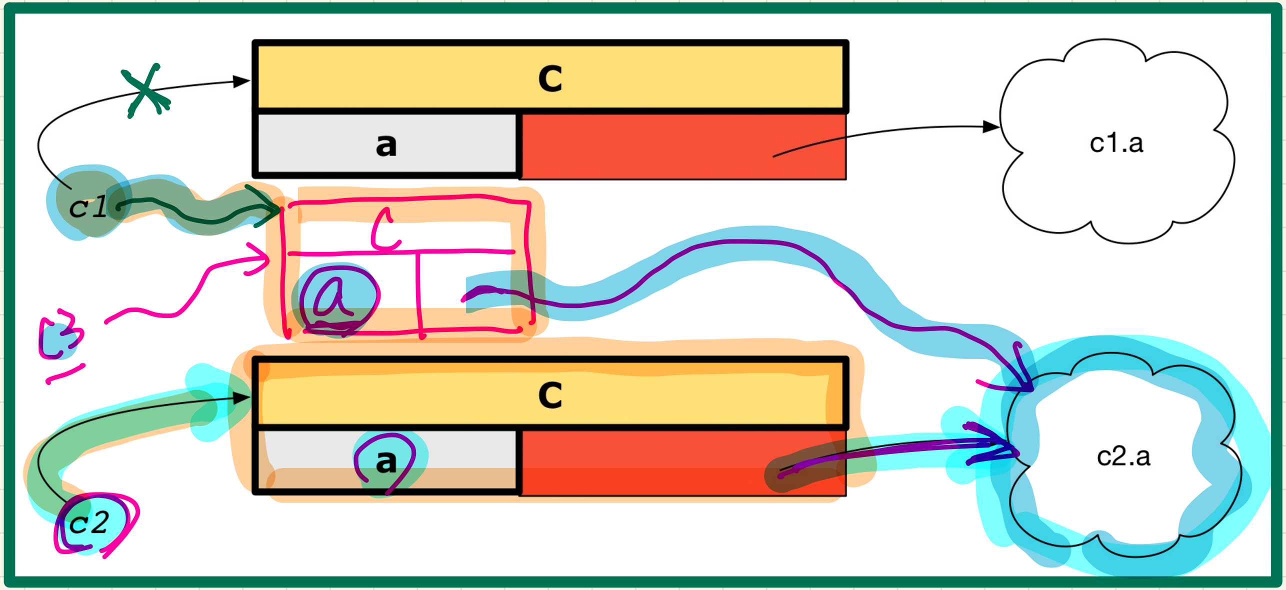
↳ equality

c1.a = c2.a T.

Shallow Copy: c1 := c2.twin

shallow copy

c3



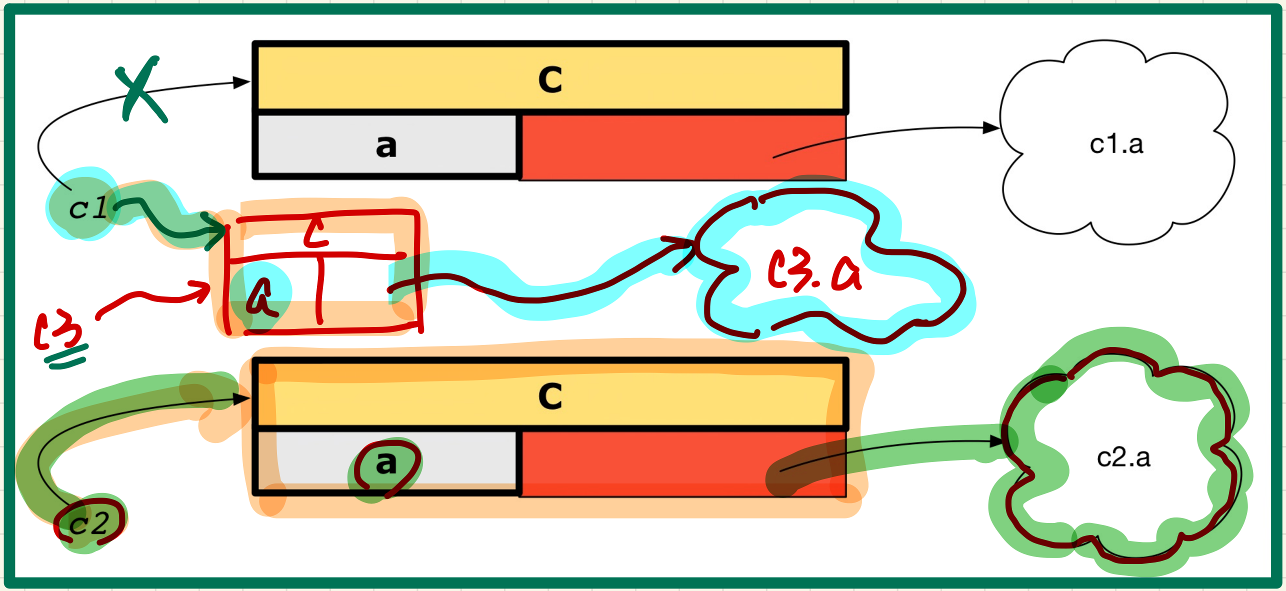
c3.a := c2.a

- c1 = c2 (F)

c1.a = c2.a (T)

Deep Copy: c1 := c2.deep_twin

deep copy.



c3.a := c2.a.deep_twin

c1 = c2 (F)

c1.a = c2.a (F)

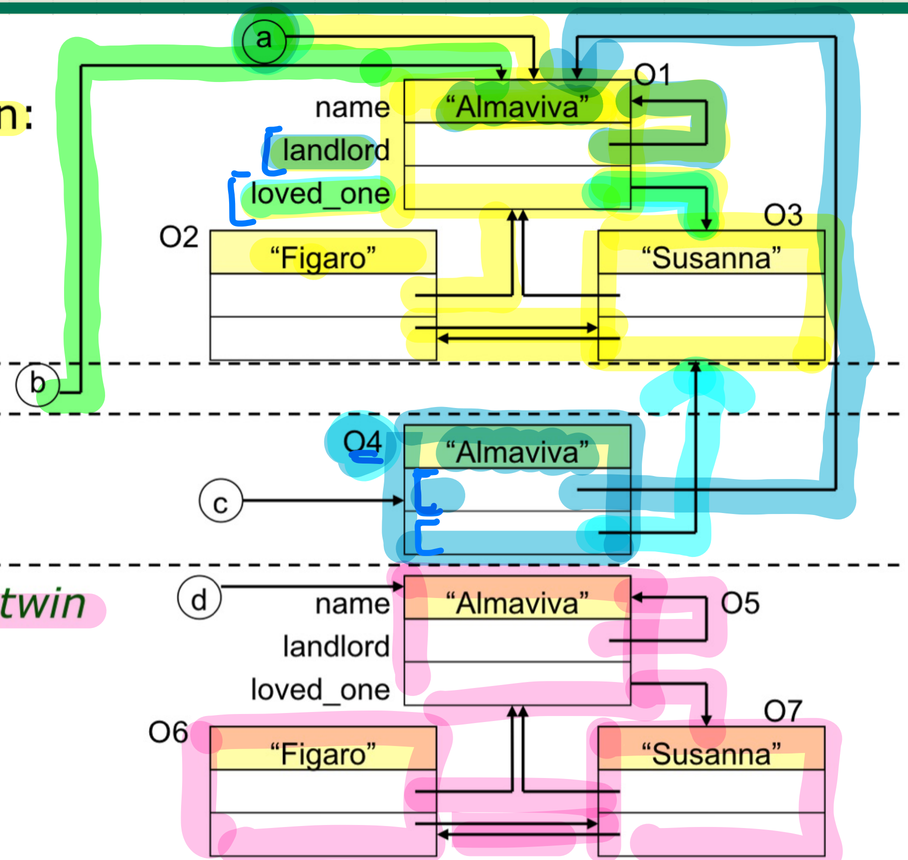
Reference vs. Shallow vs. Deep Copies

- Initial situation:
- Result of:

b := *a*

c := *a.twin*

d := *a.deep_twin*

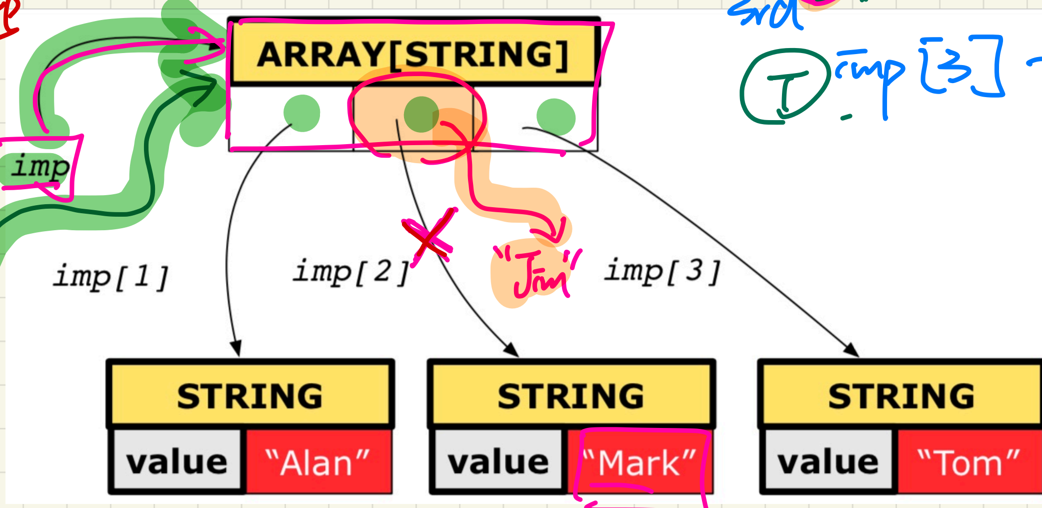


o4.ld := a.ld

o4.lo := a.lo

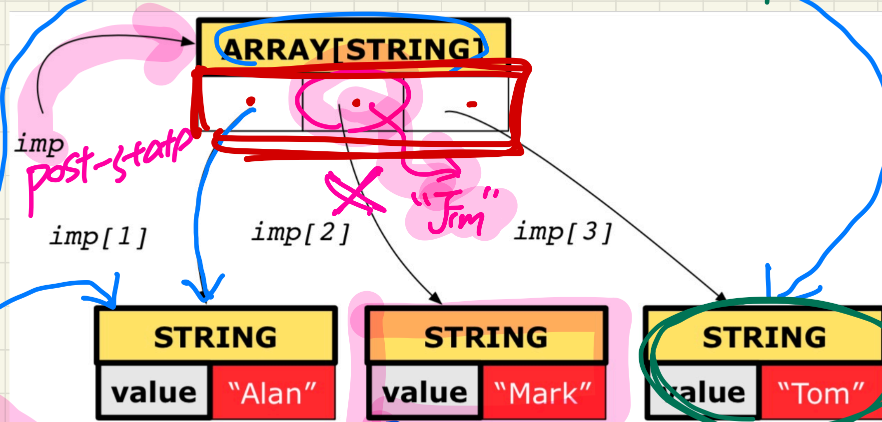
Collection Objects: Reference Copy & Make Changes

```
old_imp := imp
Result := old_imp = imp  -- Result = true
imp[2] := "Jim"
Result :=
  across 1 |..| imp.count is j
  all imp [j] ~ old_imp [j]
  end -- Result = true
```



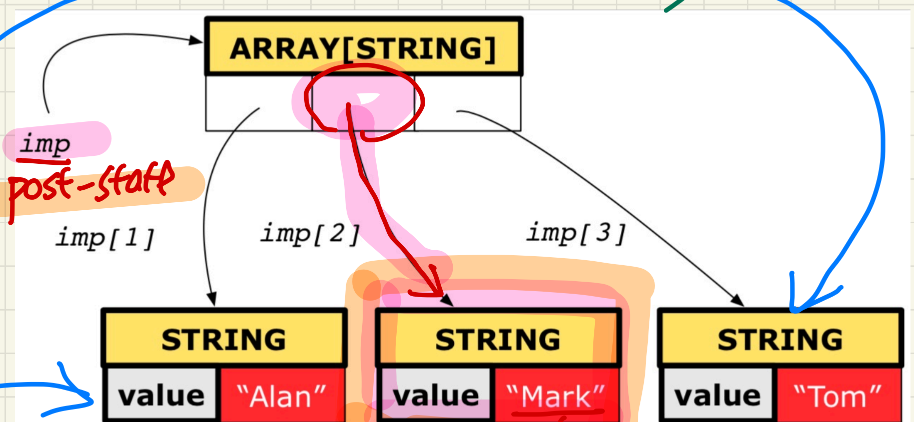
Collection Objects: Shallow Copy & Make 1st-Level Changes

```
old_imp := imp.twin
Result := old_imp = imp  -- Result = false
imp[2] := "Jim"
Result :=
  across 1 |..| imp.count is j
  all imp [j] ~ old_imp [j]
  end -- Result = false
```



Collection Objects: Shallow Copy & Make 2nd-Level Changes

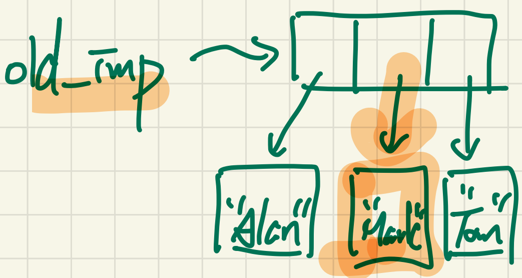
```
old_imp := imp.twin
Result := old_imp = imp   -- Result = false
imp[2].append ("***")
Result :=
  across 1 |..| imp.count is j
  all imp [j] ~ old_imp [j]
  end -- Result = true
```

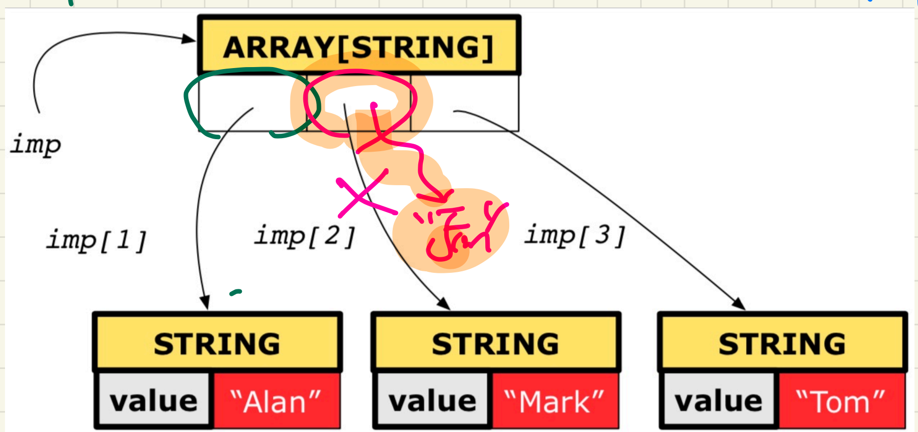


Collection Objects: Deep Copy & Make 1st-Level Changes

```
old_imp := imp.deep_twin
Result := old_imp = imp  -- Result = false
imp[2] := "Jim"
Result :=
  across 1 |..| imp.count is j
  all imp [j] ~ old_imp [j] end -- Result = false
```

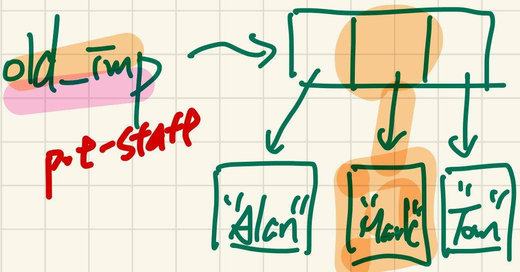
old_imp[1] := imp[1].deep_twin

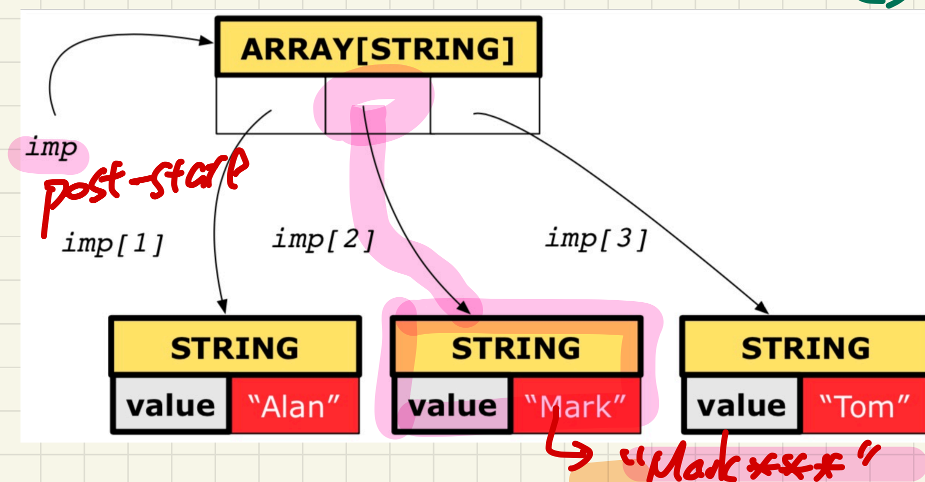




Collection Objects: Deep Copy & Make 2nd-Level Changes

```
old_imp := imp.deep_twin
Result := old_imp = imp   -- Result = [redacted]
imp[2].append ("***")
Result :=
  across 1 |..| imp.count is j
  all imp [j] ~ old_imp [j] end   -- Result = false
```





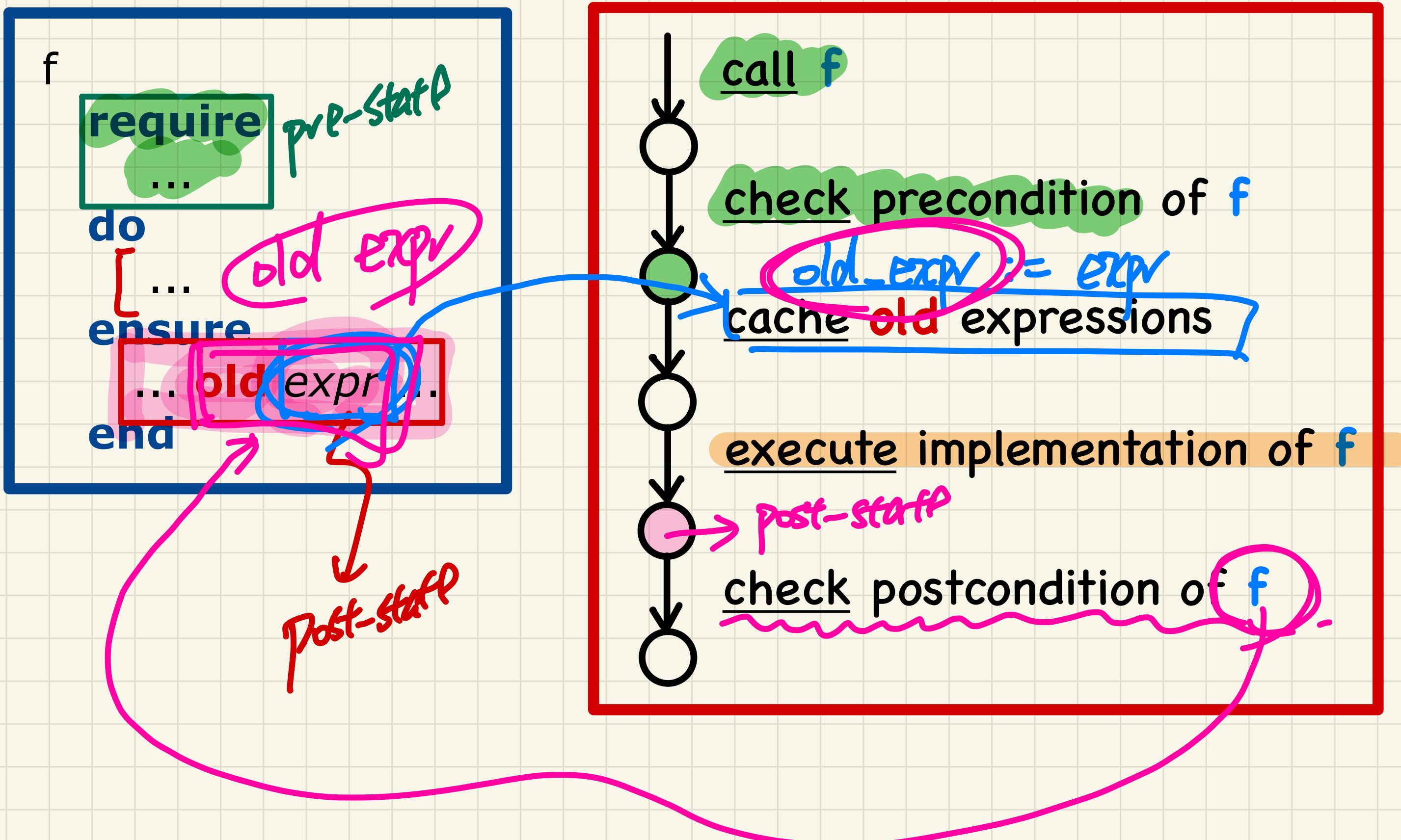
Lecture 2

Part 3

Writing Complete Postconditions

Contract View

Runtime Contract Checks



Caching Values for old Expressions in Postconditions

```
class BANK
  accounts: ARRAY[ACCOUNT]

  some_feature
    require
      ...
    do
      ...
    ensure
      ... old expr ...
    end
end
```

```
class ACCOUNT
  id: INTEGER
end
```

cache old exp.

supplier

Current
accounts
accounts[i]
accounts[i].id

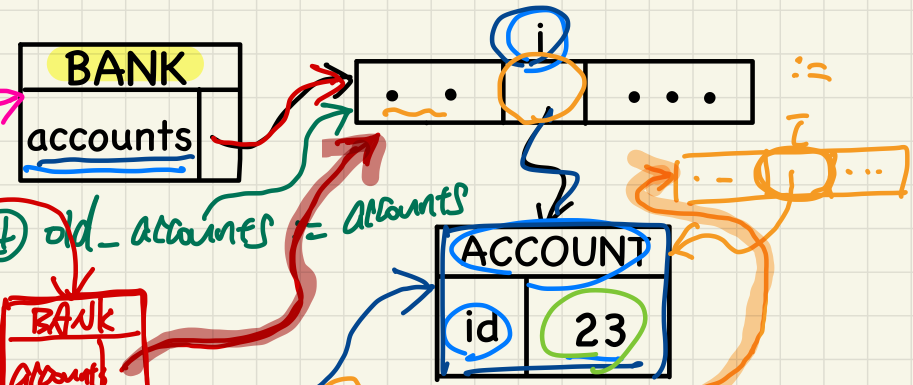
Caching Values for old Expressions in Postconditions

Lecture 1
↳ DbC Java
Postcond.

ensure (in context of **BANK**)

1. **old** accounts[i].id
2. (**old** accounts[i]).id
3. (**old** accounts[i].**twin**).id
4. (**old** accounts)[i].id
5. (**old** accounts.**twin**)[i].id
6. (**old** **Current**).accounts[i].id
7. (**old** **Current**.**twin**).accounts[i].id

How to cache at runtime?



⑥ old_C_twin := Current

⑦ Current_twin := Current.twin

④ old_accounts := accounts

⑤ accounts_twin := accounts.twin

② old_accs_i := accounts[i]

③ old_accs_i_twin := accounts[i].twin

① old_accs_i_id := accounts[i].id

|23|

Revisit: Bank Accounts in Java V5

```java
public class AccountV5 {
  public void withdraw(int amount) throws
      WithdrawAmountNegativeException, WithdrawAmountTooLargeException {
    int oldBalance = this.balance;
    if(amount < 0) { /* negated precondition */
      throw new WithdrawAmountNegativeException(); }
    else if (balance < amount) { /* negated precondition */
      throw new WithdrawAmountTooLargeException(); }
    else { this.balance = this.balance - amount; }
    assert this.getBalance() > 0 :"Invariant: positive balance";
    assert this.getBalance() == oldBalance - amount :
      "Postcondition: balance deducted"; }
```

How does the corresponding **Eiffel design** look like (with **automatic** caching of **pre-state** values)?

Use of old in across Expression in Postcondition

```
class LINEAR_CONTAINER
create make
feature -- Attributes
  a: ARRAY[STRING]
feature -- Queries
  count: INTEGER do Result := a.count end
  get (i: INTEGER): STRING do Result := a[i] end
feature -- Commands
  make do create a.make_empty end
  update (i: INTEGER; v: STRING)
  do ...
  ensure -- Others Unchanged
    across
      1 |..| count as j
    all
      j.item /= i implies old get(j.item) ~ get(j.item)
    end
  end
end
```

Hint: What value will be cached at runtime
before executing the implementation of update?

```
class BANK
create make
feature
  accounts: ARRAY[ACCOUNT]
  make do create accounts.make_empty end
  account_of (n: STRING): ACCOUNT
    require -- the input name exists
      existing: across accounts is acc some acc.owner ~ n end
        -- not (across accounts is acc all acc.owner /~ n end)
    do ... ensure Result.owner ~ n end
  add (n: STRING)
    require -- the input name does not exist
      non_existing: across accounts is acc all acc.owner /~ n end
        -- not (across accounts is acc some acc.owner ~ n end)
    local new_account: ACCOUNT
    do
      create new_account.make (n)
      accounts.force (new_account, accounts.upper + 1)
    end
end
```

```
class
 ACCOUNT

inherit
  ANY
    redefine is_equal end

create
  make

feature -- Attributes
  owner: STRING
  balance: INTEGER

feature -- Commands
  make (n: STRING)
    do
      owner := n
      balance := 0
    end
```

```
  deposit(a: INTEGER)
    do
      balance := balance + a
    ensure
      balance = old balance + a
    end

  is_equal(other: ACCOUNT): BOOLEAN
    do
      Result :=
           owner ~ other.owner
        and balance = other.balance
    end
end
```

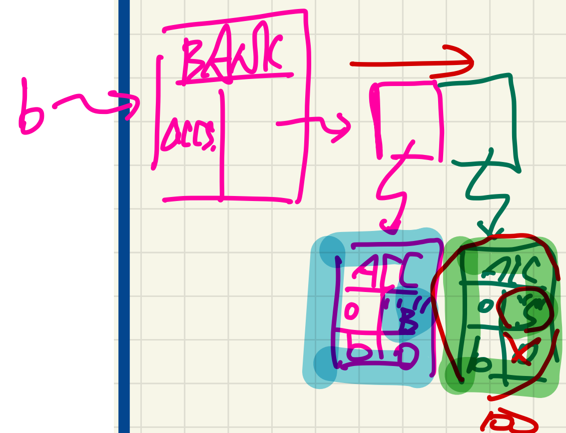
$$\forall x \mid R(x) \cdot P(x)$$

$$\neg(\exists x \mid R(x) \cdot \neg P(x))$$

Unit Test for All 5 Versions

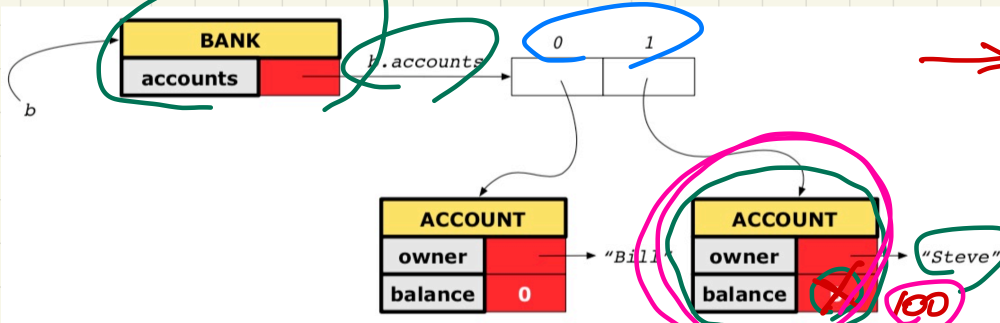
```
class TEST_BANK
  test_bank_deposit_correct_imp_incomplete_contract: BOOLEAN
    local
      b: BANK
    do
      comment("t1: correct imp and incomplete contract")
      create b.make
      b.add ("Bill")
      b.add ("Steve")

      -- deposit 100 dollars to Steve's account
      b.deposit_on_v1 ("Steve", 100)
      Result :=
           b.account_of("Bill").balance = 0
        and b.account_of("Steve").balance = 100
      check Result end
  end
end
```



Version 1: Incomplete Contracts, Correct Implementation

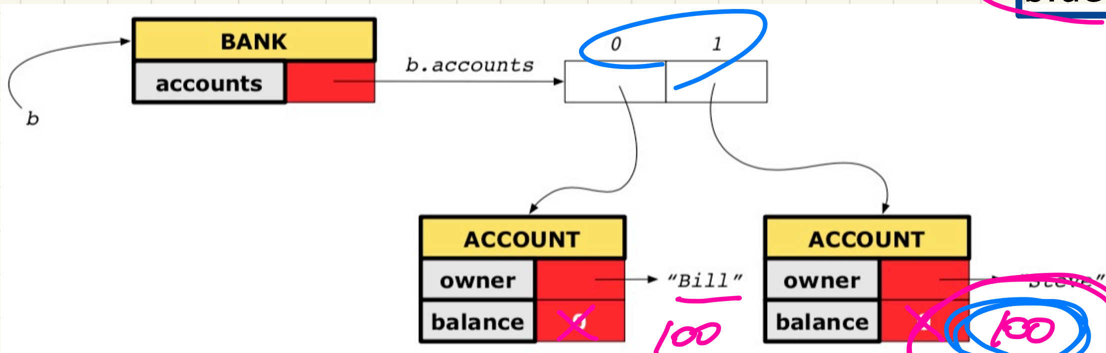
b.deposit("Steve", 100)




```
class BANK
  deposit_on_v1 (n: STRING; a: INTEGER)
  require across accounts is acc some acc.owner ~ n end
   local i: INTEGER
   do
     from i := accounts.lower
     until i > accounts.upper
     loop
       if accounts[i].owner ~ n then accounts[i].deposit(a) end
       i := i + 1
     end
   ensure
     num_of_accounts_unchanged:
       accounts.count = old accounts.count
     balance_of_n_increased:
       Current.account_of(n).balance =
         old Current.account_of(n).balance + a
   end
end
```

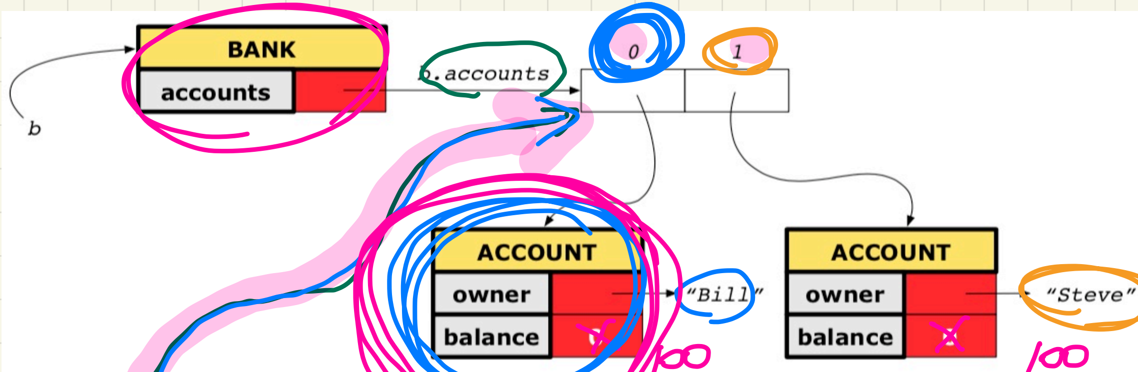
Version 2: Incomplete Contracts, Wrong Implementation

b.deposit("Steve", 100)




```
class BANK
  deposit_on_v2 (n: STRING; a: INTEGER)
   require across accounts is acc some acc.owner ~ n end
   local i: INTEGER
   do ...
    -- imp. of version 1, followed by a deposit into 1st account
    accounts[accounts.lower].deposit(a)
   ensure
    num_of_accounts_unchanged:
     accounts.count = old accounts.count
    balance_of_n_increased:
     Current.account_of(n).balance =
      old Current.account_of(n).balance + a
   end
end
```

Version 3: Complete Contracts (Ref. Copy), Correct Implementation



b.deposit("Steve", 100)

```
class BANK
  deposit_on_v3 (n: STRING; a: INTEGER)
    require across accounts is acc some acc.owner ~ n end
    local i: INTEGER
    do ...
      -- imp. of version 1, followed by a deposit into 1st account
      accounts[accounts.lower].deposit(a)
    ensure
      num_of_accounts_unchanged: accounts.count = old accounts.count
      balance_of_n_increased:
        Current.account_of(n).balance =
          old Current.account_of(n).balance + a
      others_unchanged :
        across old accounts is acc
        all
          acc.owner /~ n implies acc ~ Current.account_of(acc.owner
        end
end
```

1st Iteration

acc.owner /~ n **implies** acc ~ **Current**.account_of (acc.owner)

2nd Iteration

acc.owner /~ n **implies** acc ~ **Current**.account_of (acc.owner)

Use of across in Postcondition

$T \Rightarrow P \equiv P$
$F \Rightarrow P \equiv T$

```
across old accounts is acc
all
   acc.owner /~ n
   implies
   acc ~ Current.account_of (acc.owner)
end
```

pre-state

pre-state "value" for each account

ACCOUNT

post-state

Acc → post-state

pre-state

For each iteration:

Case 1: acc.owner is not n

acc.owner /~ n implies acc ~ Current.account_of (acc.owner)

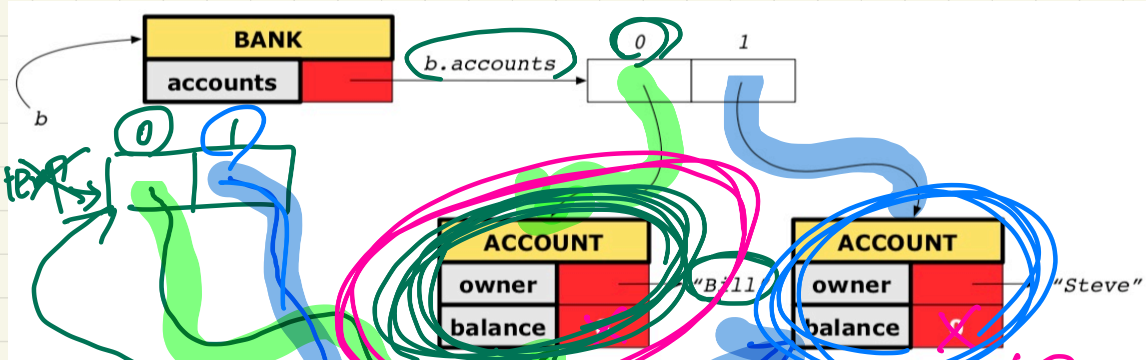
Case 2: acc.owner is n

acc.owner /~ n implies acc ~ Current.account_of (acc.owner)

F

T

Version 4: Complete Contracts (Shallow Copy), Correct Implementation



b.deposit("Steve", 100)

```
class BANK
  deposit_on_v4 (n: STRING; a: INTEGER)
    require across accounts is acc some acc.owner ~ n end
    local i: INTEGER
    do ...
      -- imp. of version 1, followed by a deposit into 1st account
      accounts[accounts.lower].deposit(a)
    ensure
      num_of_accounts_unchanged: accounts.count = old accounts.count
      balance_of_n_increased:
        Current.account_of(n).balance =
          old Current.account_of(n).balance + a
      others_unchanged :
        across old accounts.twin is acc
        all
          acc.owner /~ n implies acc ~ Current.account_of(acc.owner)
        end
    end
end
```

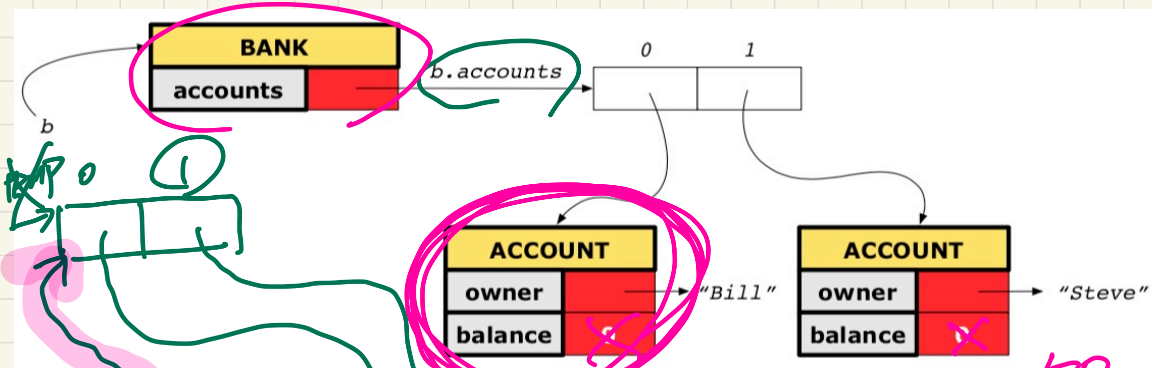
1st Iteration

acc.owner /~ n implies acc ~ **Current**.account_of (acc.owner)

2nd Iteration

acc.owner /~ n implies acc ~ **Current**.account_of (acc.owner)

Version 5: Complete Contracts (Deep Copy), Correct Implementation



b.deposit("Steve", 100)

```
class BANK
  deposit_on_v5 (n: STRING; a: INTEGER)
    require across accounts is acc some acc.owner ~ n end
    local i: INTEGER
    do ...
      -- imp. of version 1, followed by a deposit into 1st account
      accounts[accounts.lower].deposit(a)
    ensure
      num_of_accounts_unchanged: accounts.count = old accounts.count
      balance_of_n_increased:
        Current.account_of(n).balance =
          old Current.account_of(n).balance + a
      others_unchanged :
        across old accounts.deep_twin is acc
        all
          acc.owner /~ n implies acc ~ Current.account_of(acc.owner)
        end
    end
end
```

1st Iteration

acc.owner /~ n implies acc ~ **Current**.account_of (acc.owner)

2nd Iteration

acc.owner /~ n implies acc ~ **Current**.account_of (acc.owner)

Complete Postcondition: Exercise

[redacted]

Consider the query *account_of (n: STRING)* of *BANK*.

How do we specify (part of) its postcondition to assert that the state of the bank remains unchanged:

- `accounts = old accounts` [redacted]
- `accounts = old accounts.twin` [redacted]
- `accounts = old accounts.deep_twin` [redacted]
- `accounts ~ old accounts` [redacted]
- `accounts ~ old accounts.twin` [redacted]
- `accounts ~ old accounts.deep_twin` [redacted]