The Composite Design Pattern

EECS3311 A & E: Software Design
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Learning Objectives

1. Motivating Problem: ***Recursive*** Systems
2. Two Design Attempts
3. Multiple Inheritance
4. Third Design Attempt: ***Composite Design Pattern***
5. Implementing and Testing the Composite Design Pattern

Motivating Problem (1)

- Many manufactured systems, such as computer systems or stereo systems, are composed of ***individual components*** and ***sub-systems*** that contain components.

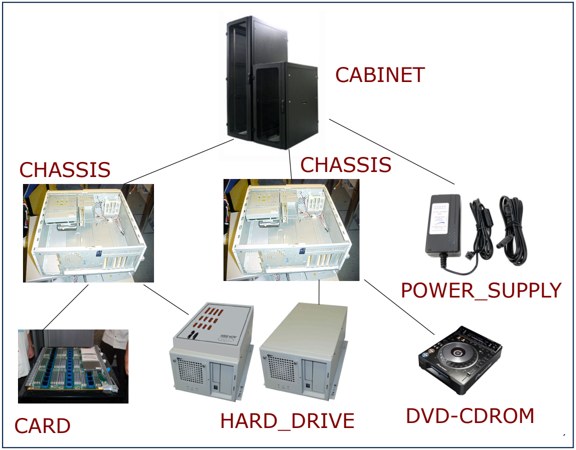
  e.g., A computer system is composed of:

  - Individual pieces of equipment (*hard drives*, *cd-rom drives*)
    Each equipment has *properties* : e.g., power consumption and cost.
  - Composites such as *cabinets*, *busses*, and *chassis*
    Each *cabinet* contains various types of *chassis*, each of which in turn containing components (*hard-drive*, *power-supply*) and *busses* that contain *cards*.

- Design a system that will allow us to easily *build* systems and *calculate* their total cost and power consumption.

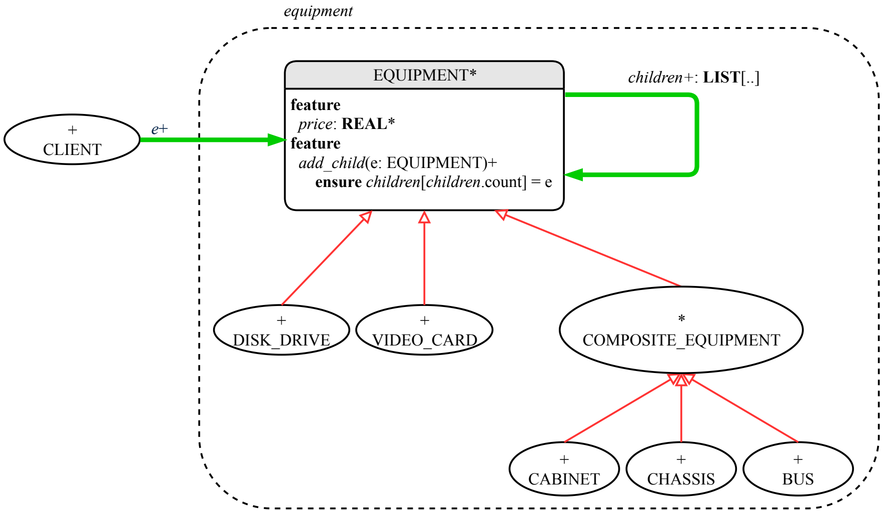
Motivating Problem (2)

Design for *tree structures* with whole-part *hierarchies*.



Challenge : There are ***base*** and ***recursive*** modelling artifacts.

Design Attempt 1: Architecture



Design Attempt 1: Flaw?

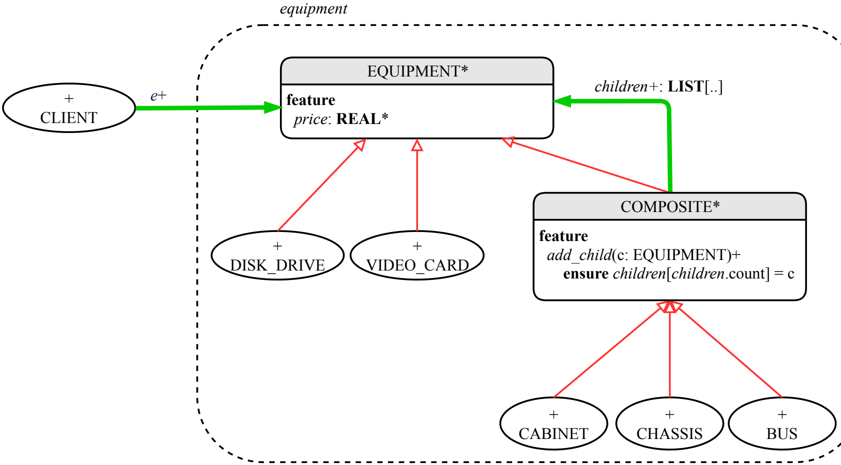
Q: Any flaw of this first design?

A: Two “composite” features defined at the `EQUIPMENT` level:

- `children: LIST[EQUIPMENT]`
- `add(child: EQUIPMENT)`

⇒ Inherited to all *base* equipments (e.g., `HARD_DRIVE`) that do not apply to such features.

Design Attempt 2: Architecture



Design Attempt 2: Flaw?

Q: Any flaw of this second design?

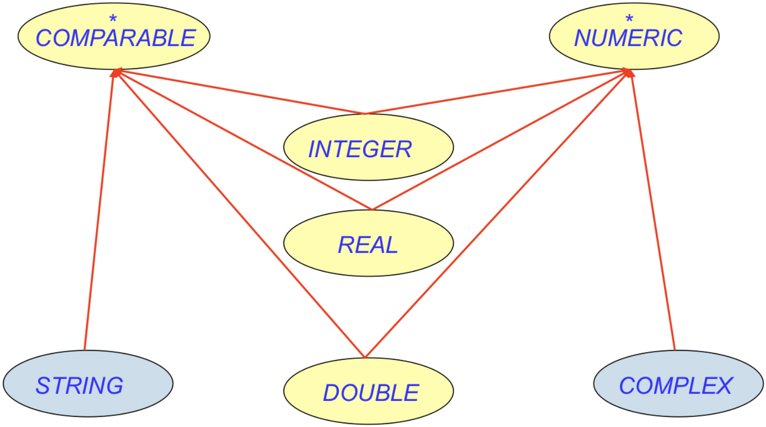
A: Two "composite" features defined at the `COMPOSITE` level:

- `children: LIST[EQUIPMENT]`
- `add(child: EQUIPMENT)`

⇒ Multiple instantiations of the composite architecture (e.g., equipments, furnitures) require duplicates of the `COMPOSITE` class.

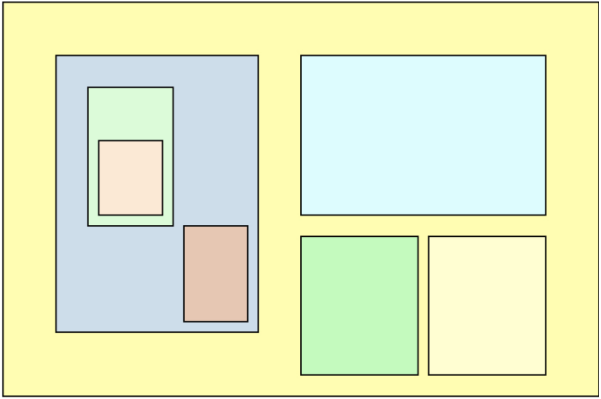
Multiple Inheritance: Combining Abstractions (1)

A class may have two more parent classes.



MI: Combining Abstractions (2.1)

Q: How do you design class(es) for nested windows?



Hints: height, width, xpos, ypos, change width, change height, move, parent window, descendant windows, add child window

MI: Combining Abstractions (2.2)

A: Separating *Graphical* features and *Hierarchical* features

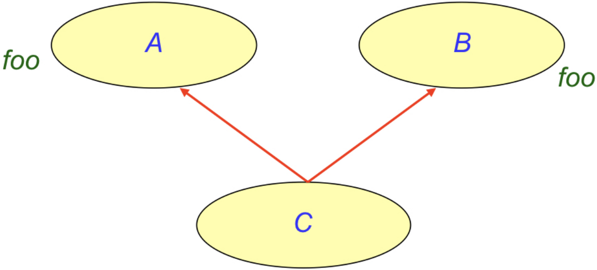
```
class RECTANGLE
  feature -- Queries
    width, height: REAL
    xpos, ypos: REAL
  feature -- Commands
    make (w, h: REAL)
    change_width
    change_height
    move
end
```

```
class TREE[G]
  feature -- Queries
    descendants: ITERABLE[G]
  feature -- Commands
    add (c: G)
          -- Add a child 'c'.
end
```

```
class WINDOW
  inherit
    RECTANGLE
    TREE[WINDOW]
end
```

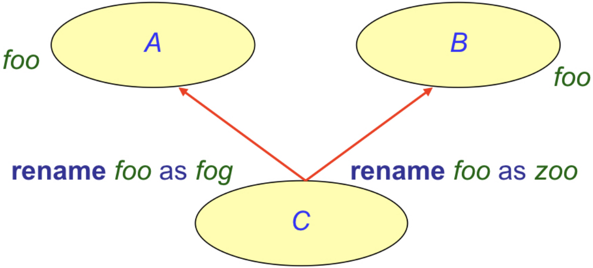
```
test_window: BOOLEAN
  local w1, w2, w3, w4: WINDOW
  do
    create w1.make(8, 6) ; create w2.make(4, 3)
    create w3.make(1, 1) ; create w4.make(1, 1)
    w2.add(w4) ; w1.add(w2) ; w1.add(w3)
    Result := w1.descendants.count = 2
  end
```

MI: Name Clashes



In class `C`, feature `foo` inherited from ancestor class `A` clashes with feature `foo` inherited from ancestor class `B`.

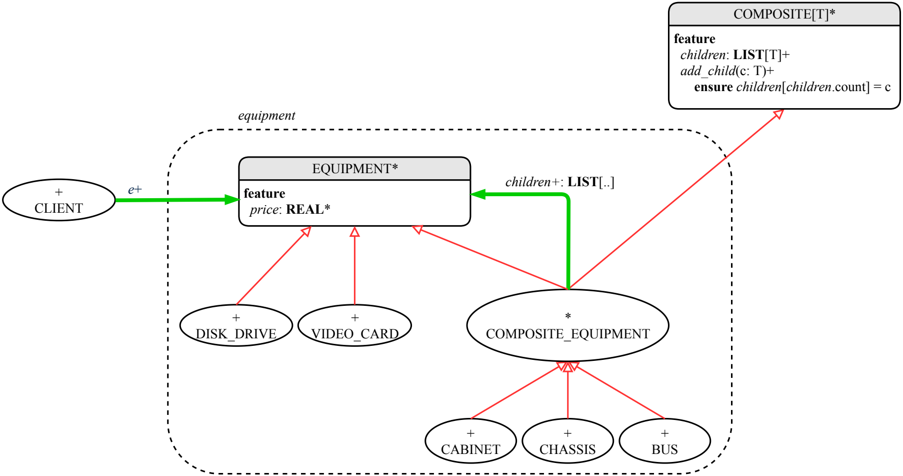
MI: Resolving Name Clashes



```
class C
  inherit
    A rename foo as fog end
    B rename foo as zoo end
  ...
```

	o.foo	o.fog	o.zoo
o: A	✓	×	×
o: B	✓	×	×
o: C	×	✓	✓

The Composite Pattern: Architecture



Implementing the Composite Pattern (1)

```
deferred class
  EQUIPMENT
feature
  name: STRING
  price: REAL deferred end -- uniform access principle
end
```

```
class
  CARD
inherit
  EQUIPMENT
feature {NONE}
  unit_price: REAL
feature
  make (n: STRING; p: REAL)
    do name := n ; unit_price := p end
  price
    do Result := unit_price end
end
```

Implementing the Composite Pattern (2.1)

```
deferred class
  COMPOSITE[T]
feature
  children: LINKED_LIST[T]

  add (c: T)
    do
      children.extend (c) -- Polymorphism
    end
end
```

Exercise: Make the `COMPOSITE` class *iterable*.

Implementing the Composite Pattern (2.2)

```
deferred class
  COMPOSITE_EQUIPMENT
inherit
  EQUIPMENT
  COMPOSITE [EQUIPMENT]
feature
  make (n: STRING)
      -- Child classes will declare this command as a constructor.
    do name := n ; create children.make end
  price : REAL -- price is a query
      -- Sum the net prices of all sub-equipments
    do
      across
        children is c
      loop
        Result := Result + c.price -- dynamic binding
      end
    end
end
```

Testing the Composite Pattern

```
test_composite_equipment: BOOLEAN
 local
  card, drive: EQUIPMENT
  cabinet: CABINET -- holds a CHASSIS
  chassis: CHASSIS -- contains a BUS and a DISK_DRIVE
  bus: BUS -- holds a CARD
 do
  create {CARD} card.make("16Mbs Token Ring", 200)
  create {DISK_DRIVE} drive.make("500 GB harddrive", 500)
  create bus.make("MCA Bus")
  create chassis.make("PC Chassis")
  create cabinet.make("PC Cabinet")

  bus.add(card)
  chassis.add(bus)
  chassis.add(drive)
  cabinet.add(chassis)
  Result := cabinet.price = 700
 end
```

Summay: The Composite Pattern

- **Design** : Categorize into *base* artifacts or *recursive* artifacts.
- **Programming** :

  Build a *tree structure* representing the whole-part *hierarchy* .
- **Runtime** :

  Allow clients to treat *base* objects (leafs) and *recursive* compositions (nodes) *uniformly* .

  ⇒ *Polymorphism* : *leafs* and *nodes* are "substitutable".

  ⇒ *Dynamic Binding* : Different versions of the same operation is applied on *individual objects* and *composites*.

  e.g., Given e: ***EQUIPMENT*** :

  - `e.price` may return the unit price of a ***DISK_DRIVE***.
  - `e.price` may sum prices of a ***CHASIS***' containing equipments.

Index (1)

Index (2)