Inheritance

Readings: OOSCS2 Chapters 14 – 16

EECS3311 A & E: Software Design
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Learning Objectives

Upon completing this lecture, you are expected to understand:

1. Design Attempts without Inheritance (w.r.t. Cohesion, SCP)
2. Using Inheritance for Code Reuse
3. Static Type & Polymorphism
4. Dynamic Type & Dynamic Binding
5. Type Casting
6. Polymorphism & Dynamic Binding:
   Routine Arguments, Routine Return Values, Collections

Aspects of Inheritance

- ***Code Reuse***
- Substitutability
  - ***Polymorphism*** and ***Dynamic Binding***
    [compile-time type checks]
  - *Sub-contracting*
    [runtime behaviour checks]

Why Inheritance: A Motivating Example

Problem: A *student management system* stores data about students. There are two kinds of university students: *resident* students and *non-resident* students. Both kinds of students have a *name* and a list of *registered courses*. Both kinds of students are restricted to *register* for no more than 30 courses. When *calculating the tuition* for a student, a base amount is first determined from the list of courses they are currently registered (each course has an associated fee). For a non-resident student, there is a *discount rate* applied to the base amount to waive the fee for on-campus accommodation. For a resident student, there is a *premium rate* applied to the base amount to account for the fee for on-campus accommodation and meals.

Tasks: Design classes that satisfy the above problem statement. At runtime, each type of student must be able to register a course and calculate their tuition fee.

The COURSE Class

```
class
  COURSE

create -- Declare commands that can be used as constructors
  make

feature -- Attributes
  title: STRING
  fee: REAL

feature -- Commands
  make (t: STRING; f: REAL)
      -- Initialize a course with title ’t’ and fee ’f’.
    do
      title := t
      fee := f
    end
end
```

No Inheritance: RESIDENT_STUDENT Class

```
class RESIDENT_STUDENT
create make
feature -- Attributes
  name: STRING
  courses: LINKED_LIST[COURSE]
  premium_rate: REAL
feature -- Constructor
  make (n: STRING)
    do name := n ; create courses.make end
feature -- Commands
  set_pr (r: REAL) do premium_rate := r end
  register (c: COURSE) do courses.extend (c) end
feature -- Queries
  tuition: REAL
    local base: REAL
    do base := 0.0
      across courses as c loop base := base + c.item.fee end
      Result := base * premium_rate
    end
end
```

No Inheritance: NON_RESIDENT_STUDENT Class

```
class NON_RESIDENT_STUDENT
create make
feature -- Attributes
  name: STRING
  courses: LINKED_LIST[COURSE]
  discount_rate: REAL
feature -- Constructor
  make (n: STRING)
    do name := n ; create courses.make end
feature -- Commands
  set_dr (r: REAL) do discount_rate := r end
  register (c: COURSE) do courses.extend (c) end
feature -- Queries
  tuition: REAL
    local base: REAL
    do base := 0.0
      across courses as c loop base := base + c.item.fee end
      Result := base * discount_rate
    end
end
```

No Inheritance: Testing Student Classes

```
test_students: BOOLEAN
  local
    c1, c2: COURSE
    jim: RESIDENT_STUDENT
    jeremy: NON_RESIDENT_STUDENT
  do
    create c1.make ("EECS2030", 500.0)
    create c2.make ("EECS3311", 500.0)
    create jim.make ("J. Davis")
    jim.set_pr (1.25)
    jim.register (c1)
    jim.register (c2)
    Result := jim.tuition = 1250
    check Result end
    create jeremy.make ("J. Gibbons")
    jeremy.set_dr (0.75)
    jeremy.register (c1)
    jeremy.register (c2)
    Result := jeremy.tuition = 750
  end
```

No Inheritance: Issues with the Student Classes

- Implementations for the two student classes seem to work. But can you see any potential problems with it?
- The code of the two student classes share a lot in common.
- *Duplicates of code make it hard to maintain your software!*
- This means that when there is a change of policy on the common part, we need modify *more than one places*.

  ⇒ This violates the *Single Choice Principle* :

  when a ***change*** is needed, there should be ***a single place*** (or ***a minimal number of places***) where you need to make that change.

No Inheritance: Maintainability of Code (1)

What if a ***new*** way for course registration is to be implemented?

e.g.,

```
register(Course c)
  do
    if courses.count >= MAX_CAPACITY then
      -- Error: maximum capacity reached.
    else
      courses.extend (c)
    end
  end
```

We need to change the `register` commands in ***both*** student classes!

⇒ ***Violation*** of the *Single Choice Principle*

No Inheritance: Maintainability of Code (2)

What if a ***new*** way for base tuition calculation is to be implemented?

e.g.,

```
tuition: REAL
   local base: REAL
 do base := 0.0
    across courses as c loop base := base + c.item.fee end
    Result := base * inflation_rate * ...
 end
```

We need to change the `tuition` query in ***both*** student classes.

⇒ ***Violation*** of the *Single Choice Principle*

No Inheritance: A Collection of Various Kinds of Students

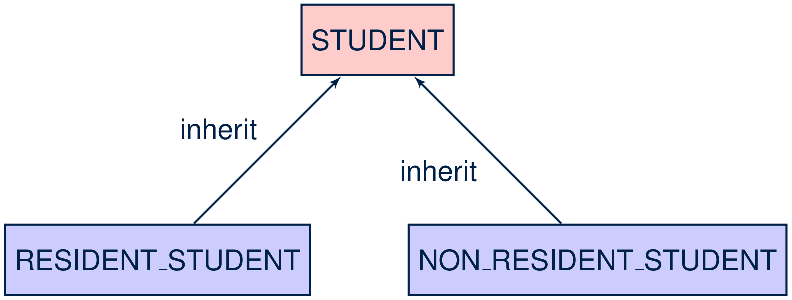
How do you define a class `StudentManagementSystem` that contains a list of *resident* and *non-resident* students?

```
class STUDENT_MANAGEMENT_SYSETM
  rs : LINKED_LIST[RESIDENT_STUDENT]
  nrs : LINKED_LIST[NON_RESIDENT_STUDENT]
  add_rs (rs: RESIDENT_STUDENT) do ... end
  add_nrs (nrs: NON_RESIDENT_STUDENT) do ... end
  register_all (Course c) -- Register a common course 'c'.
    do
      across rs as c loop c.item.register (c) end
      across nrs as c loop c.item.register (c) end
    end
end
```

But what if we later on introduce *more kinds of students*?

Inconvenient to handle each list of students, in pretty much the ***same*** manner, *separately*!

Inheritance Architecture



Inheritance: The STUDENT Parent Class

```
class STUDENT
create make
feature -- Attributes
  name: STRING
  courses: LINKED_LIST[COURSE]
feature -- Commands that can be used as constructors.
  make (n: STRING) do name := n ; create courses.make end
feature -- Commands
  register (c: COURSE) do courses.extend (c) end
feature -- Queries
  tuition: REAL
    local base: REAL
    do base := 0.0
      across courses as c loop base := base + c.item.fee end
      Result := base
    end
end
```

Inheritance:
The RESIDENT_STUDENT Child Class

```
1  class
2    RESIDENT_STUDENT
3  inherit
4    STUDENT
5      redefine tuition end
6  create make
7  feature -- Attributes
8    premium_rate : REAL
9  feature -- Commands
10   set_pr (r: REAL) do premium_rate := r end
11 feature -- Queries
12   tuition: REAL
13     local base: REAL
14     do base := Precursor ;  Result := base * premium_rate end
15 end
```

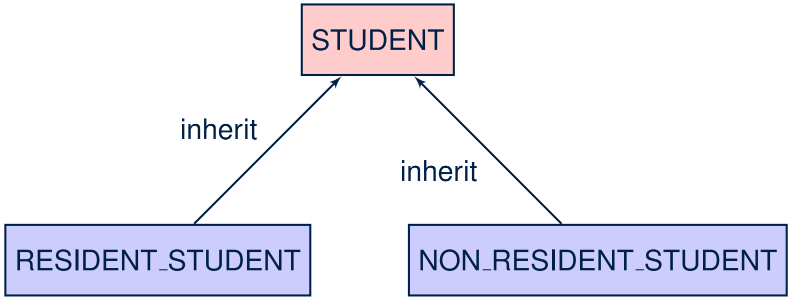
- **L3**: RESIDENT_STUDENT inherits all features from STUDENT.
- There is no need to repeat the register command
- **L14**: *Precursor* returns the value from query tuition in STUDENT.

Inheritance:
The NON_RESIDENT_STUDENT Child Class

```
1  class
2    NON_RESIDENT_STUDENT
3  inherit
4    STUDENT
5      redefine tuition end
6  create make
7  feature -- Attributes
8    discount_rate : REAL
9  feature -- Commands
10   set_dr (r: REAL) do discount_rate := r end
11 feature -- Queries
12   tuition: REAL
13     local base: REAL
14     do base := Precursor ;  Result := base * discount_rate end
15 end
```

- **L3**: NON_RESIDENT_STUDENT inherits all features from STUDENT.
- There is no need to repeat the register command
- **L14**: *Precursor* returns the value from query tuition in STUDENT.

Inheritance Architecture Revisited



- The class that defines the common features (attributes, commands, queries) is called the *parent*, *super*, or *ancestor* class.
- Each "specialized" class is called a *child*, *sub*, or *descendent* class.

Using Inheritance for Code Reuse

Inheritance in Eiffel (or any OOP language) allows you to:

- Factor out *common features* (attributes, commands, queries) in a separate class.
  e.g., the `STUDENT` class
- Define an "specialized" version of the class which:
  - *inherits* definitions of all attributes, commands, and queries
    e.g., attributes `name`, `courses`
    e.g., command `register`
    e.g., query on base amount in `tuition`
    This means code reuse and elimination of code duplicates!
  - *defines* **new** features if necessary
    e.g., `set_pr` for `RESIDENT_STUDENT`
    e.g., `set_dr` for `NON_RESIDENT_STUDENT`
  - *redefines* features if necessary
    e.g., compounded tuition for `RESIDENT_STUDENT`
    e.g., discounted tuition for `NON_RESIDENT_STUDENT`

Testing the Two Student Sub-Classes

```
test_students: BOOLEAN
 local
  c1, c2: COURSE
  jim: RESIDENT_STUDENT ; jeremy: NON_RESIDENT_STUDENT
 do
  create c1.make ("EECS2030", 500.0); create c2.make ("EECS3311", 500.0)
  create jim.make ("J. Davis")
  jim.set_pr (1.25) ; jim.register (c1); jim.register (c2)
  Result := jim.tuition = 1250
  check Result end
  create jeremy.make ("J. Gibbons")
  jeremy.set_dr (0.75); jeremy.register (c1); jeremy.register (c2)
  Result := jeremy.tuition = 750
 end
```

- The software can be used in exactly the same way as before (because we did not modify *feature signatures*).
- But now the internal structure of code has been made *maintainable* using *inheritance*.

Index (1)

Index (2)