Aggregation and Composition

EECS2030 B: Advanced
Object Oriented Programming
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Aggregation vs. Composition: Terminology

Container object: an object that contains others.

Containee object: an object that is contained within another.

- e.g., Each course has a faculty member as its instructor.
  - ***Container***: `Course` ***Containee***: `Faculty`.
- e.g., Each student is registered in a list of courses; Each faculty member teaches a list of courses.
  - ***Container***: `Student`, `Faculty` ***Containees***: `Course`.

    e.g., `eecs2030` taken by `jim` (student) and taught by `tom` (faculty).

    ⇒ ***Containees*** **may** be *shared* by different instances of ***containers***.

    e.g., When EECS2030 is finished, `jim` and `jackie` still exist!

    ⇒ ***Containees*** **may** exist *independently* without their ***containers***.
- e.g., In a file system, each directory contains a list of files.
  - ***Container***: `Directory` ***Containees***: `File`.

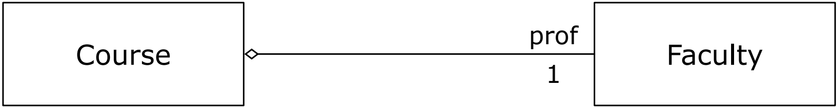
    e.g., Each file has exactly one parent directory.

    ⇒ A ***containee*** **may** be *owned* by only one ***container***.

    e.g., Deleting a directory also deletes the files it contains.

    ⇒ ***Containees*** **may** *co-exist* with their ***containers***.

Aggregation: Independent Containees Shared by Containers (1.1)




```
class Course {
  String title;
  Faculty prof;
  Course(String title) {
    this.title = title;
  }
  void setProf(Faculty prof) {
    this.prof = prof;
  }
  Faculty getProf() {
    return this.prof;
  }
}
```

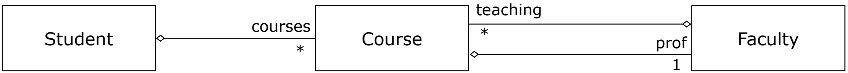
```
class Faculty {
  String name;
  Faculty(String name) {
    this.name = name;
  }
  void setName(String name) {
    this.name = name;
  }
  String getName() {
    return this.name;
  }
}
```

Aggregation: Independent Containees Shared by Containers (1.2)

```java
@Test
public void testAggregation1() {
  Course eecs2030 = new Course("Advanced OOP");
  Course eecs3311 = new Course("Software Design");
  Faculty prof = new Faculty("Jackie");
  eecs2030.setProf(prof);
  eecs3311.setProf(prof);
  assertTrue(eecs2030.getProf() == eecs3311.getProf());
  /* aliasing */
  prof.setName("Jeff");
  assertTrue(eecs2030.getProf() == eecs3311.getProf());
  assertTrue(eecs2030.getProf().getName().equals("Jeff"));

  Faculty prof2 = new Faculty("Jonathan");
  eecs3311.setProf(prof2);
  assertTrue(eecs2030.getProf() != eecs3311.getProf());
  assertTrue(eecs2030.getProf().getName().equals("Jeff"));
  assertTrue(eecs3311.getProf().getName().equals("Jonathan"));
}
```

Aggregation: Independent Containees Shared by Containers (2.1)




```
class Student {
  String id; ArrayList<Course> cs; /* courses */
  Student(String id) { this.id = id; cs = new ArrayList<>(); }
  void addCourse(Course c) { cs.add(c); }
  ArrayList<Course> getCS() { return cs; }
}
```

```
class Course { String title; Faculty prof; }
```

```
class Faculty {
  String name; ArrayList<Course> te; /* teaching */
  Faculty(String name) { this.name = name; te = new ArrayList<>(); }
  void addTeaching(Course c) { te.add(c); }
  ArrayList<Course> getTE() { return te; }
}
```

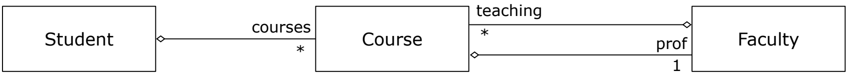
Aggregation: Independent Containees Shared by Containers (2.2)

```
@Test
public void testAggregation2() {
  Faculty p = new Faculty("Jackie");
  Student s = new Student("Jim");
  Course eecs2030 = new Course("Advanced OOP");
  Course eecs3311 = new Course("Software Design");
  eecs2030.setProf(p);
  eecs3311.setProf(p);
  p.addTeaching(eecs2030);
  p.addTeaching(eecs3311);
  s.addCourse(eecs2030);
  s.addCourse(eecs3311);

  assertTrue(eecs2030.getProf() == s.getCS().get(0).getProf());
  assertTrue(s.getCS().get(0).getProf()
             == s.getCS().get(1).getProf());
  assertTrue(eecs3311 == s.getCS().get(1));
  assertTrue(s.getCS().get(1) == p.getTE().get(1));
}
```

The Dot Notation (3.1)

In real life, the relationships among classes are sophisticated.




```java
class Student {
  String id;
  ArrayList<Course> cs;
}
```

```java
class Course {
  String title;
  Faculty prof;
}
```

```java
class Faculty {
  String name;
  ArrayList<Course> te;
}
```

Aggregation links between classes constrain how you can *navigate* among these classes.

e.g., In the context of class `Student`:

- Writing **`cs`** denotes the list of registered courses.
- Writing **`cs[i]`** (where `i` is a valid index) navigates to the class `Course`, which changes the context to class `Course`.

The Dot Notation (3.2)

```java
class Student {
  String id;
  ArrayList<Course> cs;
}
```

```java
class Course {
  String title;
  Faculty prof;
}
```

```java
class Faculty {
  String name;
  ArrayList<Course> te;
}
```

```java
class Student {
  ... /* attributes */
  /* Get the student's id */
  String getID() { return this.id; }
  /* Get the title of the ith course */
  String getCourseTitle(int i) {
    return this.cs.get(i).title;
  }
  /* Get the instructor's name of the ith course */
  String getInstructorName(int i) {
    return this.cs.get(i).prof.name;
  }
}
```

The Dot Notation (3.3)

```
class Student {
  String id;
  ArrayList<Course> cs;
}
```

```
class Course {
  String title;
  Faculty prof;
}
```

```
class Faculty {
  String name;
  ArrayList<Course> te;
}
```

```
class Course {
  ... /* attributes */
  /* Get the course's title */
  String getTitle() { return this.title; }
  /* Get the instructor's name */
  String getInstructorName() {
    return this.prof.name;
  }
  /* Get title of ith teaching course of the instructor */
  String getCourseTitleOfInstructor(int i) {
    return this.prof.te.get(i).title;
  }
}
```

The Dot Notation (3.4)

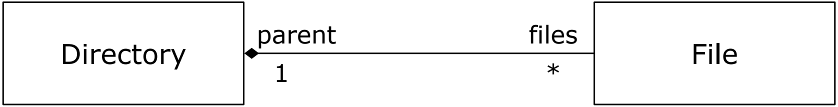
```
class Student {
  String id;
  ArrayList<Course> cs;
}
```

```
class Course {
  String title;
  Faculty prof;
}
```

```
class Faculty {
  String name;
  ArrayList<Course> te;
}
```

```
class Faculty {
  ... /* attributes */
  /* Get the instructor's name */
  String getName() {
    return this.name;
  }
  /* Get the title of ith teaching course */
  String getCourseTitle(int i) {
    return this.te.get(i).title;
  }
}
```

Composition: Dependent Containees Owned by Containers (1.1)

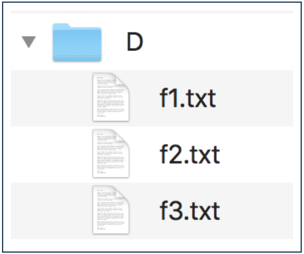


Assumption: Files are not shared among directories.

```
class File {
  String name;
  File(String name) {
    this.name = name;
  }
}
```

```
class Directory {
  String name;
  File[] files;
  int nof; /* num of files */
  Directory(String name) {
    this.name = name;
    files = new File[100];
  }
  void addFile(String fileName) {
    files[nof] = new File(fileName);
    nof ++;
  }
}
```

Composition: Dependent Containees Owned by Containers (1.2.1)

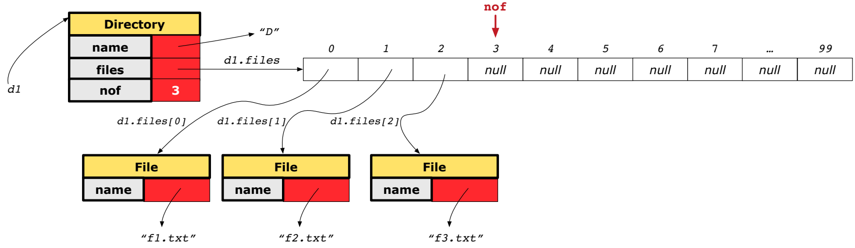



```
1 @Test
2 public void testComposition() {
3   Directory d1 = new Directory("D");
4   d1.addFile("f1.txt");
5   d1.addFile("f2.txt");
6   d1.addFile("f3.txt");
7   assertTrue(
8     d1.files[0].name.equals("f1.txt"));
9 }
```

- **L4**: 1st `File` object is created and ***owned exclusively*** by `d1`. No other directories are sharing this `File` object with `d1`.
- **L5**: 2nd `File` object is created and ***owned exclusively*** by `d1`. No other directories are sharing this `File` object with `d1`.
- **L6**: 3rd `File` object is created and ***owned exclusively*** by `d1`. No other directories are sharing this `File` object with `d1`.

Composition: Dependent Containees Owned by Containers (1.2.2)

Right before test method `testComposition` terminates:



Composition: Dependent Containees Owned by Containers (1.3)

Problem: Implement a *copy constructor* for `Directory`.

A ***copy constructor*** is a constructor which initializes attributes from the argument object `other`.

```
class Directory {
  Directory(Directory other) {
    /* Initialize attributes via attributes of 'other'. */
  }
}
```

Hints:

- The implementation should be consistent with the effect of copying and pasting a directory.
- Separate copies of files are created.

Composition: Dependent Containees Owned by Containers (1.4.1)

Version 1: *Shallow Copy* by copying all attributes using =.

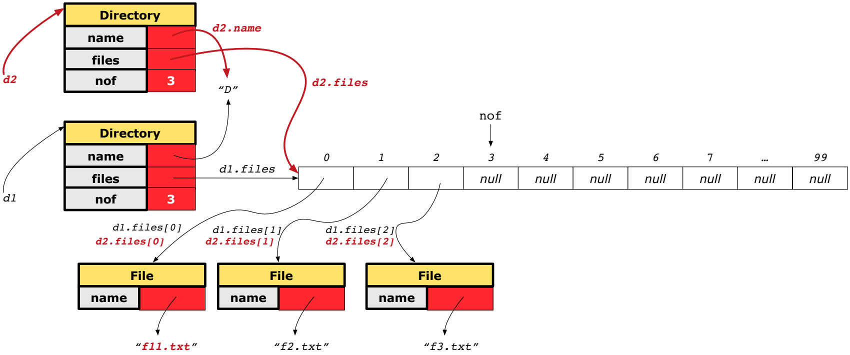
```
class Directory {
  Directory(Directory other) {
    /* value copying for primitive type */
    nof = other.nof;
    /* address copying for reference type */
    name = other.name; files = other.files; } }
```

Is a shallow copy satisfactory to support composition?
i.e., Does it still forbid sharing to occur? [***NO***]

```
@Test
void testShallowCopyConstructor() {
  Directory d1 = new Directory("D");
  d1.addFile("f1.txt"); d1.addFile("f2.txt"); d1.addFile("f3.txt");
  Directory d2 = new Directory(d1);
  assertTrue(d1.files == d2.files); /* violation of composition */
  d2.files[0].changeName("f11.txt");
  assertFalse(d1.files[0].name.equals("f1.txt")); }
```

Composition: Dependent Containees Owned by Containers (1.4.2)

Right before test method `testShallowCopyConstructor` terminates:



Composition: Dependent Containees Owned by Containers (1.5.1)

Version 2: a *Deep Copy*

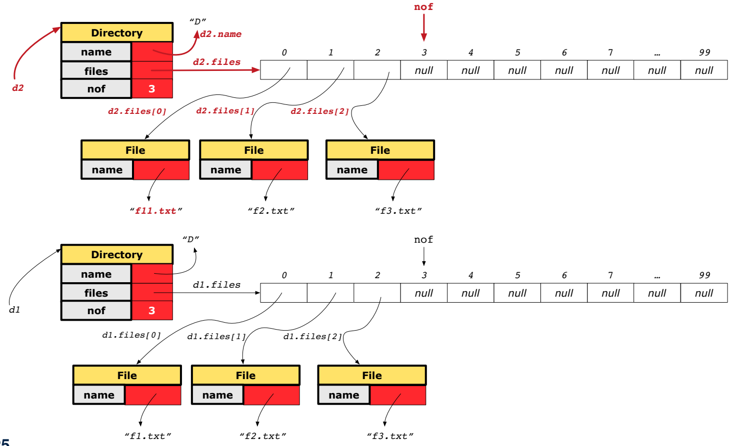
```
class File {
  File(File other) {
    this.name =
      new String(other.name);
  }
}
```

```
class Directory {
  Directory(String name) {
    this.name = new String(name);
    files = new File[100]; }
  Directory(Directory other) {
    this (other.name);
    for(int i = 0; i < nof; i ++) {
      File src = other.files[i];
      File nf = new File(src);
      this.addFile(nf); } }
  void addFile(File f) { ... } }
```

```
@Test
void testDeepCopyConstructor() {
  Directory d1 = new Directory("D");
  d1.addFile("f1.txt"); d1.addFile("f2.txt"); d1.addFile("f3.txt");
  Directory d2 = new Directory(d1);
  assertTrue(d1.files != d2.files); /* composition preserved */
  d2.files[0].changeName("f11.txt");
  assertTrue(d1.files[0].name.equals("f1.txt")); }
```

Composition: Dependent Containees Owned by Containers (1.5.2)

Right before test method `testDeepCopyConstructor` terminates:



Composition: Dependent Containees Owned by Containers (1.5.3)

Q: Composition Violated?

```
class File {
  File(File other) {
    this.name =
      new String(other.name);
  }
}
```

```
class Directory {
  Directory(String name) {
    this.name = new String(name);
    files = new File[100]; }
  Directory(Directory other) {
    this (other.name);
    for(int i = 0; i < nof; i ++) {
      File src = other.files[i];
      this.addFile(src); } }
  void addFile(File f) { ... } }
```

```
@Test
void testDeepCopyConstructor() {
  Directory d1 = new Directory("D");
  d1.addFile("f1.txt"); d1.addFile("f2.txt"); d1.addFile("f3.txt");
  Directory d2 = new Directory(d1);
  assertTrue(d1.files != d2.files); /* composition preserved */
  d2.files[0].changeName("f11.txt");
  assertTrue(d1.files[0] == d2.files[0]); /* composition violated! */
```

Composition: Dependent Containees Owned by Containers (1.6)

Exercise: Implement the accessor in class `Directory`

```
class Directory {
  File[] files;
  int nof;
  File[] getFiles() {
    /* Your Task */
  }
}
```

so that it ***preserves composition***, i.e., does not allow references of files to be shared.

Aggregation vs. Composition (1)

Terminology:

- **Container** object: an object that contains others.
- **Containee** object: an object that is contained within another.

Aggregation :

- Containees (e.g., `Course`) may be *shared* among containers (e.g., `Student`, `Faculty`).
- Containees *exist independently* without their containers.
- When a container is destroyed, its containees still exist.

Composition :

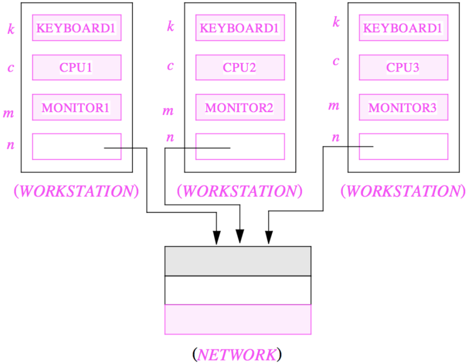
- Containers (e.g, `Directory`, `Department`) *own* exclusive access to their containees (e.g., `File`, `Faculty`).
- Containees cannot exist without their containers.
- Destroying a container destroys its containeees *cascadingly*.

Aggregation vs. Composition (2)

Aggregations and *Compositions* may exist at the same time!

e.g., Consider a workstation:

- Each workstation owns CPU, monitor, keyword. [***compositions***]
- All workstations share the same network. [***aggregations***]



Index (1)

Index (2)

Index (3)