Classes and Objects

EECS2030 B: Advanced Object Oriented Programming
Fall 2019

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Tutorial Videos to Help You Review

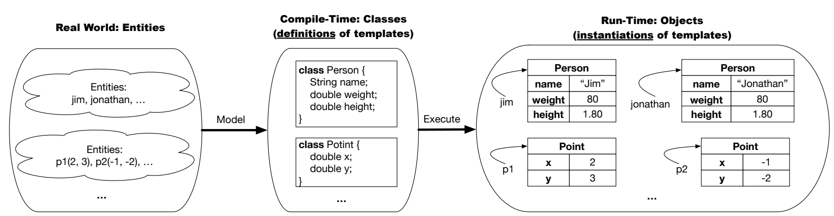
- **Link to Tutorial Series**: `https://www.youtube.com/playlist?list=PL5dxAmCmjv_5NRNPG3OiWZWAqmvCjiLfG`
  - **Videos 1 to 8**: Basics of Programming and **Eclipse**
  - **Videos 9 to 19**: Programming/Debugging **If-Statements**
  - **Videos 20 to 33**: Programming/Debugging **Arrays** and **Loops**
  - **Videos 34 to 38**: Basics of **Classes** and **Objects**
  - **Videos 39 to 46**: A Complete Example – `Student`, `Faculty`, `CourseRecord`, `StudentManagementSystem`
- **iPad Notes**: `https://www.eecs.yorku.ca/~jackie/teaching/tutorials/notes/EECS1021%20Tutorial%20on%20Java.pdf`

Separation of Concerns: App/Tester vs. Model

- In EECS1022:
  - ***Model Component***: One or More Java Classes
    e.g., `Person` vs. `SMS`, `Student`, `CourseRecord`
  - Another Java class that "manipulates" the model class (by creating instances and calling methods):
    - ***Controller*** (e.g., `BMIActivity`, `BankActivity`). Effects? Visualized (via a GUI) at connected tablet
    - ***Tester*** with `main` (e.g., `PersonTester`, `BankTester`). Effects? Seen (as textual outputs) at console
- In Java:
  - We may define more than one *classes*.
  - Each class may contain more than one *methods*.

  object-oriented programming in Java:
  - Use *classes* to define templates
  - Use *objects* to instantiate classes
  - At *runtime*, *create* objects and *call* methods on objects, to *simulate interactions* between real-life entities.

Object Orientation: Observe, Model, and Execute



- Study this tutorial video that walks you through the idea of *object orientation*.
- We *observe* how real-world *entities* behave.
- We *model* the common *attributes* and *behaviour* of a set of entities in a single *class*.
- We *execute* the program by creating *instances* of classes, which interact in a way analogous to that of real-world *entities*.

Object-Oriented Programming (OOP)

- In real life, lots of *entities* exist and interact with each other.
  e.g., *People* gain/lose weight, marry/divorce, or get older.
  e.g., *Cars* move from one point to another.
  e.g., *Clients* initiate transactions with banks.
- Entities:
  - Possess *attributes*;
  - Exhibit *bebaviour*; and
  - Interact with each other.
- Goals: Solve problems *programmatically* by
  - *Classifying* entities of interest
    Entities in the same class share *common* attributes and bebaviour.
  - *Manipulating* data that represent these entities
    Each entity is represented by *specific* values.

OO Thinking: Templates vs. Instances (1.1)

A person is a being, such as a human, that has certain attributes and behaviour constituting personhood: a person ages and grows on their heights and weights.

- A template called `Person` defines the common
  - *attributes* (e.g., `age`, `weight`, `height`) [≈ nouns]
  - *behaviour* (e.g., get older, gain weight) [≈ verbs]

OO Thinking: Templates vs. Instances (1.2)

- Persons share these common *attributes* and *behaviour*.
  - Each person possesses an age, a weight, and a height.
  - Each person's age, weight, and height might be *distinct*
    e.g., `jim` is 50-years old, 1.8-meters tall and 80-kg heavy
    e.g., `jonathan` is 65-years old, 1.73-meters tall and 90-kg heavy
- Each person, depending on the *specific values* of their attributes, might exhibit *distinct* behaviour:
  - When `jim` gets older, he becomes 51
  - When `jonathan` gets older, he becomes 66.
  - `jim`'s BMI is based on his own height and weight [$\frac{80}{1.8^2}$]
  - `jonathan`'s BMI is based on his own height and weight [$\frac{90}{1.73^2}$]

OO Thinking: Templates vs. Instances (2.1)

Points on a two-dimensional plane are identified by their signed distances from the X- and Y-axises. A point may move arbitrarily towards any direction on the plane. Given two points, we are often interested in knowing the distance between them.

- A template called `Point` defines the common
  - *attributes* (e.g., `x`, `y`) [≈ nouns]
  - *behaviour* (e.g., move up, get distance from) [≈ verbs]

OO Thinking: Templates vs. Instances (2.2)

- Points share these common *attributes* and *behaviour*.
  - Each point possesses an x-coordinate and a y-coordinate.
  - Each point's location might be *distinct*
    e.g., `p1` is located at $(3, 4)$
    e.g., `p2` is located at $(-4, -3)$
- Each point, depending on the *specific values* of their attributes (i.e., locations), might exhibit *distinct* behaviour:
  - When `p1` moves up for 1 unit, it will end up being at $(3, 5)$
  - When `p2` moves up for 1 unit, it will end up being at $(-4, -2)$
  - Then, `p1`'s distance from origin: $[\sqrt{3^2 + 5^2}]$
  - Then, `p2`'s distance from origin: $[\sqrt{(-4)^2 + (-2)^2}]$

OO Thinking: Templates vs. Instances (3)

- A *template* defines what's **shared** by a set of related entities.
  - Common *attributes* (`age` in `Person`, `x` in `Point`)
  - Common *behaviour* (get older for `Person`, move up for `Point`)
- Each template may be *instantiated* into multiple instances.
  - `Person` instances: `jim` and `jonathan`
  - `Point` instances: `p1` and `p2`
- Each *instance* may have *specific values* for the attributes.
  - Each `Person` instance has an age:
    `jim` is 50-years old, `jonathan` is 65-years old
  - Each `Point` instance has a location:
    `p1` is at $(3, 4)$, `p2` is at $(-3, -4)$
- Therefore, instances of the same template may exhibit *distinct behaviour*.
  - Each `Person` instance can get older: `jim` getting older from 50 to 51; `jonathan` getting older from 65 to 66.
  - Each `Point` instance can move up: `p1` moving up from $(3, 3)$ results in $(3, 4)$; `p1` moving up from $(-3, -4)$ results in $(-3, -3)$.

OOP: Classes ≈ Templates

In Java, you use a *class* to define a *template* that enumerates *attributes* that are common to a set of *entities* of interest.

```
public class Person {
  int age;
  String nationality;
  double weight;
  double height;
}
```

```
public class Point {
  double x;
  double y;
}
```


OOP: Define Constructors for Creating Objects (1.1)

- Within class `Point`, you define *constructors*, specifying how instances of the `Point` template may be created.

```
public class Point {
  ... /* attributes: x, y */
  Point(double newX, double newY) {
    x = newX;
    y = newY; } }
```

- In the corresponding tester class, each *call* to the `Point` constructor creates an instance of the `Point` template.

```
public class PointTester {
  public static void main(String[] args) {
    Point p1 = new Point(2, 4);
    println(p1.x + " " + p1.y);
    Point p2 = new Point(-4, -3);
    println(p2.x + " " + p2.y); } }
```

OOP: Define Constructors for Creating Objects (1.2)

```
Point p1 = new Point(2, 4);
```

1. **RHS (Source) of Assignment**: `new Point(2, 4)` creates a new *Point object* in memory.

Point	
x	2.0
y	4.0

2. **LHS (Target) of Assignment**: `Point p1` declares a *variable* that is meant to store the *address* of *some Point object*.
3. **Assignment**: Executing `=` stores new object's address in `p1`.

p1 →

Point	
x	2.0
y	4.0

OOP: Define Constructors for Creating Objects (2.1)

- Within class `Person`, you define *constructors*, specifying how instances of the `Person` template may be created.

```
public class Person {
  ... /* attributes: age, nationality, weight, height */
  Person(int newAge, String newNationality) {
    age = newAge;
    nationality = newNationality; } }
```

- In the corresponding tester class, each *call* to the `Person` constructor creates an instance of the `Person` template.

```
public class PersonTester {
  public static void main(String[] args) {
    Person jim = new Person(50, "British");
    println(jim.nationlaity + " " + jim.age);
    Person jonathan = new Person(60, "Canadian");
    println(jonathan.nationlaity + " " + jonathan.age); } }
```


OOP: Define Constructors for Creating Objects (2.2)

```
Person jim = new Person(50, "British");
```

1. **RHS (Source) of Assignment**: `new Person(50, "British")` creates a new *Person object* in memory.

Person	
age	50
nationality	"British"
weight	0.0
height	0.0

2. **LHS (Target) of Assignment**: `Point jim` declares a *variable* that is meant to store the *address* of *some Person object*.
3. **Assignment**: Executing `=` stores new object's address in `jim`.

jim →

Person	
age	50
nationality	"British"
weight	0.0
height	0.0

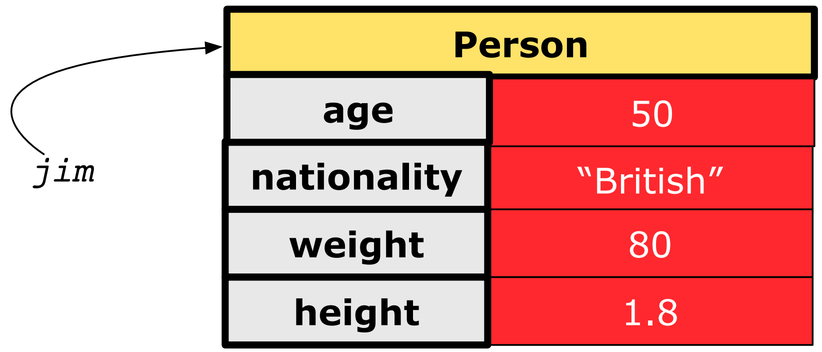
Visualizing Objects at Runtime (1)

- To trace a program with sophisticated manipulations of objects, it's critical for you to visualize how objects are:
  - Created using *constructors*
    `Person jim = new Person(50, "British", 80, 1.8);`
  - Inquired using *accessor methods*
    `double bmi = jim.getBMI();`
  - Modified using *mutator methods*
    `jim.gainWeightBy(10);`
- To visualize an object:
  - Draw a rectangle box to represent *contents* of that object:
    - Title indicates the *name of class* from which the object is instantiated.
    - Left column enumerates *names of attributes* of the instantiated class.
    - Right column fills in *values* of the corresponding attributes.
  - Draw arrow(s) for *variable(s)* that store the object's *address*.

Visualizing Objects at Runtime (2.1)

After calling a *constructor* to create an object:

```
Person jim = new Person(50, "British", 80, 1.8);
```

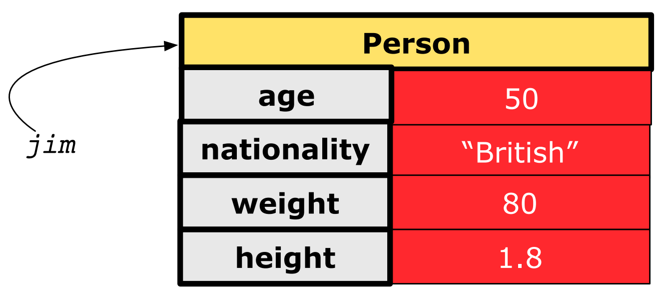


Visualizing Objects at Runtime (2.2)

After calling an *accessor* to inquire about context object `jim`:

```
double bmi = jim.getBMI();
```

- Contents of the object pointed to by `jim` remain intact.
- Retuned value $\frac{80}{(1.8)^2}$ of `jim.getBMI()` stored in variable `bmi`.

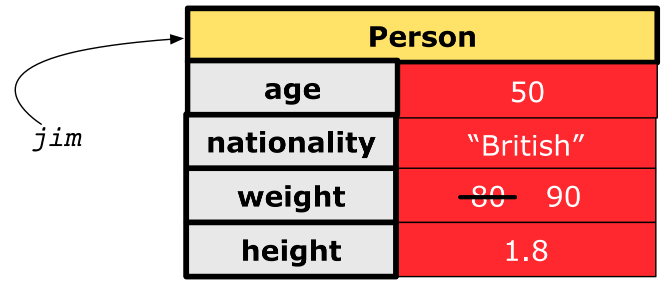


Visualizing Objects at Runtime (2.3)

After calling a *mutator* to modify the state of context object `jim`:

```
jim.gainWeightBy(10);
```

- *Contents* of the object pointed to by `jim` change.
- *Address* of the object remains unchanged.
  ⇒ `jim` points to the same object!

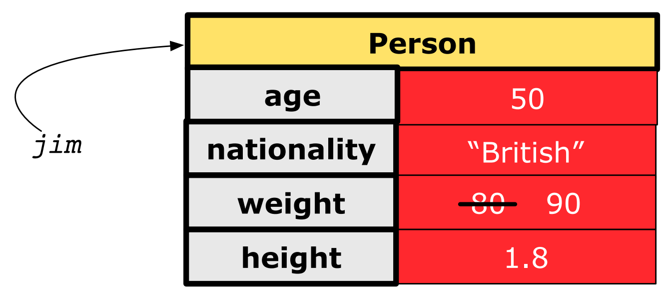


Visualizing Objects at Runtime (2.4)

After calling the same *accessor* to inquire the *modified* state of context object `jim`:

```
bmi = p.getBMI();
```

- Contents of the object pointed to by `jim` remain intact.
- Retuned value $\frac{90}{(1.8)^2}$ of `jim.getBMI()` stored in variable `bmi`.



The `this` Reference (1)

- Each *class* may be instantiated to multiple *objects* at runtime.

```
class Point {
  double x; double y;
  void moveUp(double units) { y += units; }
}
```

- Each time when we call a method of some class, using the dot notation, there is a specific *target*/*context* object.

```
1 Point p1 = new Point(2, 3);
2 Point p2 = new Point(4, 6);
3 p1.moveUp(3.5);
4 p2.moveUp(4.7);
```

  - `p1` and `p2` are called the *call targets* or *context objects*.
  - **Lines 3 and 4** apply the same definition of the `moveUp` method.
  - But how does Java distinguish the change to `p1.y` versus the change to `p2.y`?

The `this` Reference (2)

- In the *method* definition, each *attribute* has an *implicit* `this` which refers to the *context object* in a call to that method.

```
class Point {
  double x;
  double y;
  Point(double newX, double newY) {
    this.x = newX;
    this.y = newY;
  }
  void moveUp(double units) {
    this.y = this.y + units;
  }
}
```

- Each time when the *class* definition is used to create a new `Point` *object*, the `this` reference is substituted by the name of the new object.

The `this` Reference (3)

- After we create `p1` as an instance of `Point`

```
Point p1 = new Point(2, 3);
```

- When invoking `p1.moveUp(3.5)`, a version of `moveUp` that is specific to `p1` will be used:

```
class Point {
  double x;
  double y;
  Point(double newX, double newY) {
    p1.x = newX;
    p1.y = newY;
  }
  void moveUp(double units) {
    p1.y = p1.y + units;
  }
}
```


The `this` Reference (4)

- After we create `p2` as an instance of `Point`

```
Point p2 = new Point(4, 6);
```

- When invoking `p2.moveUp(4.7)`, a version of `moveUp` that is specific to `p2` will be used:

```
class Point {
  double x;
  double y;
  Point(double newX, double newY) {
    p2.x = newX;
    p2.y = newY;
  }
  void moveUp(double units) {
    p2.y = p2.y + units;
  }
}
```

The `this` Reference (5)

The `this` reference can be used to *disambiguate* when the names of *input parameters* clash with the names of *class attributes*.

```
class Point {
  double x;
  double y;
  Point(double x, double y) {
    this.x = x;
    this.y = y;
  }
  void setX(double x) {
    this.x = x;
  }
  void setY(double y) {
    this.y = y;
  }
}
```


The `this` Reference (6.1): Common Error

The following code fragment compiles but is problematic:

```
class Person {
  String name;
  int age;
  Person(String name, int age) {
    name = name;
    age = age;
  }
  void setAge(int age) {
    age = age;
  }
}
```

Why? Fix?

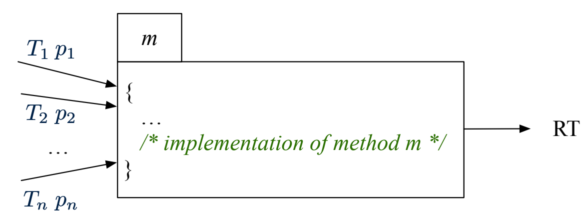
The `this` Reference (6.2): Common Error

Always remember to use `this` when *input parameter* names clash with *class attribute* names.

```
class Person {
  String name;
  int age;
  Person(String name, int age) {
    this.name = name;
    this.age = age;
  }
  void setAge(int age) {
    this.age = age;
  }
}
```


OOP: Methods (1.1)

- A *method* is a named block of code, *reusable* via its name.



- The *header* of a method consists of: [see here]
  - Return type [*RT* (which can be `void`)]
  - Name of method [*m*]
  - Zero or more *parameter names* [$p_1, p_2, \ldots, p_n$]
  - The corresponding *parameter types* [$T_1, T_2, \ldots, T_n$]
- A call to method *m* has the form: $m(a_1, a_2, \ldots, a_n)$
  Types of *argument values* $a_1, a_2, \ldots, a_n$ must match the the corresponding parameter types $T_1, T_2, \ldots, T_n$.

OOP: Methods (1.2)

- In the body of the method, you may
  - Declare and use new *local variables*
    Scope of local variables is only within that method.
  - Use or change values of *attributes*.
  - Use values of *parameters*, if any.

```
class Person {
  String nationality;
  void changeNationality(String newNationality) {
    nationality = newNationality; } }
```

- *Call* a *method*, with a *context object*, by passing *arguments*.

```
class PersonTester {
  public static void main(String[] args) {
    Person jim = new Person(50, "British");
    Person jonathan = new Person(60, "Canadian");
    jim.changeNationality("Korean");
    jonathan.changeNationality("Korean"); } }
```


OOP: Methods (2)

- Each *class* `C` defines a list of methods.
  - A *method* `m` is a named block of code.
- We *reuse* the code of method `m` by calling it on an *object* `obj` of class `C`.
  For each *method call* `obj.m(...)`:
  - `obj` is the *context object* of type `C`
  - `m` is a method defined in class `C`
  - We intend to apply the *code effect of method* `m` to object `obj`.
    e.g., `jim.getOlder()` vs. `jonathan.getOlder()`
    e.g., `p1.moveUp(3)` vs. `p2.moveUp(3)`
- All objects of class `C` share *the same definition* of method `m`.
- However:
  ∵ Each object may have *distinct attribute values*.
  ∴ Applying *the same definition* of method `m` has *distinct effects*.

OOP: Methods (3)

1. *Constructor*
   - Same name as the class. No return type. *Initializes* attributes.
   - Called with the **new** keyword.
   - e.g., `Person jim = new Person(50, "British");`
2. *Mutator*
   - *Changes* (re-assigns) attributes
   - `void` return type
   - Cannot be used when a value is expected
   - e.g., `double h = jim.setHeight(78.5)` is illegal!
3. *Accessor*
   - *Uses* attributes for computations (without changing their values)
   - Any return type other than `void`
   - An explicit *`return` statement* (typically at the end of the method) returns the computation result to where the method is being used.
     e.g., `double bmi = jim.getBMI();`
     e.g., `println(p1.getDistanceFromOrigin());`

OOP: The Dot Notation (1.1)

A binary operator:
- `LHS` stores an address (which denotes an object)
- `RHS` the name of an attribute or a method
- `LHS.RHS` means:
  Locate the context object whose address is stored in **LHS**, then apply `RHS`.
  What if `LHS` stores `null`? [`NullPointerException`]

OOP: The Dot Notation (1.2)

- Given a *variable* of some *reference type* that is **not** `null`:
  - We use a dot to retrieve any of its *attributes*.
    Analogous to 's in English
    e.g., `jim.nationality` means `jim`'s nationality
  - We use a dot to invoke any of its *mutator methods*, in order to *change* values of its attributes.
    e.g., `jim.changeNationality("CAN")` changes the `nationality` attribute of `jim`
  - We use a dot to invoke any of its *accessor methods*, in order to *use* the result of some computation on its attribute values.
    e.g., `jim.getBMI()` computes and returns the BMI calculated based on `jim`'s weight and height
  - Return value of an *accessor method* must be stored in a variable.
    e.g., `double jimBMI = jim.getBMI()`

OOP: Method Calls

```
1 Point p1 = new Point(3, 4);
2 Point p2 = new Point(-6, -8);
3 System.out.println(p1.getDistanceFromOrigin());
4 System.out.println(p2.getDistanceFromOrigin());
5 p1.moveUp(2);
6 p2.moveUp(2);
7 System.out.println(p1.getDistanceFromOrigin());
8 System.out.println(p2.getDistanceFromOrigin());
```

- **Lines 1 and 2** create two different instances of `Point`
- **Lines 3 and 4:** invoking the same accessor method on two different instances returns *distinct* values
- **Lines 5 and 6:** invoking the same mutator method on two different instances results in *independent* changes
- **Lines 3 and 7:** invoking the same accessor method on the same instance *may* return *distinct* values, why? **Line 5**

OOP: Class Constructors (1)

- The purpose of defining a *class* is to be able to create *instances* out of it.
- To *instantiate* a class, we use one of its *constructors*.
- A constructor
  - declares input *parameters*
  - uses input parameters to *initialize* *some or all* of its *attributes*

OOP: Class Constructors (2)

```
public class Person {
  int age;
  String nationality;
  double weight;
  double height;
  Person(int initAge, String initNat) {
    age = initAge;
    nationality = initNat;
  }
  Person (double initW, double initH) {
    weight = initW;
    height = initH;
  }
  Person(int initAge, String initNat,
         double initW, double initH) {
    ... /* initialize all attributes using the parameters */
  }
}
```

OOP: Class Constructors (3)

```
public class Point {
  double x;
  double y;

  Point(double initX, double initY) {
    x = initX;
    y = initY;
  }

  Point(char axis, double distance) {
    if (axis == 'x') { x = distance; }
    else if (axis == 'y') { y = distance; }
    else { System.out.println("Error: invalid axis.") }
  }
}
```


OOP: Class Constructors (4)

- For each *class*, you may define *one or more* *constructors* :
  - *Names* of all constructors must match the class name.
  - *No return types* need to be specified for constructors.
  - Each constructor must have a *distinct* list of *input parameter types*.
  - Each *parameter* that is used to initialize an attribute must have a *matching type*.
  - The *body* of each constructor specifies how *some or all* *attributes* may be *initialized*.

OOP: Object Creation (1)

```
Point p1 = new Point(2, 4);
System.out.println(p1);
```

```
Point@677327b6
```

By default, the address stored in `p1` gets printed.
Instead, print out attributes separately:

```
System.out.println("(" + p1.x + ", " + p1.y + ")");
```

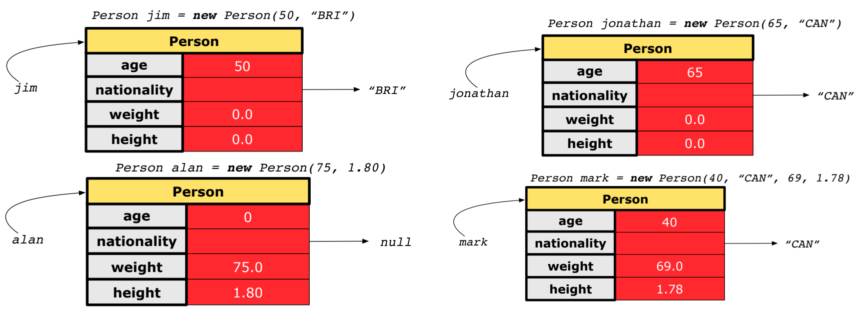
```
(2.0, 4.0)
```


OOP: Object Creation (2)

A constructor may only *initialize* some attributes and leave others *uninitialized*.

```
public class PersonTester {
  public static void main(String[] args) {
    /* initialize age and nationality only */
    Person jim = new Person(50, "BRI");
    /* initialize age and nationality only */
    Person jonathan = new Person(65, "CAN");
    /* initialize weight and height only */
    Person alan = new Person(75, 1.80);
    /* initialize all attributes of a person */
    Person mark = new Person(40, "CAN", 69, 1.78);
  }
}
```

OOP: Object Creation (3)

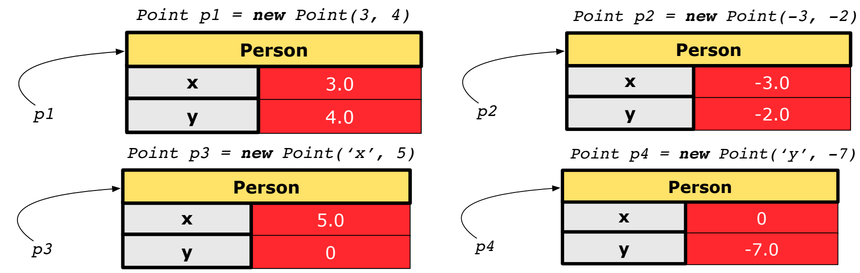


OOP: Object Creation (4)

A constructor may only *initialize* some attributes and leave others *uninitialized*.

```
public class PointTester {
  public static void main(String[] args) {
    Point p1 = new Point(3, 4);
    Point p2 = new Point(-3 -2);
    Point p3 = new Point('x', 5);
    Point p4 = new Point('y', -7);
  }
}
```


OOP: Object Creation (5)



OOP: Object Creation (6)

- When using the constructor, pass *valid* *argument values*:
  - The type of each argument value must match the corresponding parameter type.
  - e.g., `Person(50, "BRI")` matches `Person(int initAge, String initNationality)`
  - e.g., `Point(3, 4)` matches `Point(double initX, double initY)`
- When creating an instance, *uninitialized* attributes implicitly get assigned the *default values*.
  - Set *uninitialized* attributes properly later using **mutator** methods

```
Person jim = new Person(50, "British");
jim.setWeight(85);
jim.setHeight(1.81);
```

OOP: Mutator Methods

- These methods *change* values of attributes.
- We call such methods *mutators* (with `void` return type).

```
public class Person {
  ...
  void gainWeight(double units) {
    weight = weight + units;
  }
}
```

```
public class Point {
  ...
  void moveUp() {
    y = y + 1;
  }
}
```


OOP: Accessor Methods

- These methods *return* the result of computation based on attribute values.
- We call such methods *accessors* (with non-`void` return type).

```
public class Person {
  ...
  double getBMI() {
    double bmi = height / (weight * weight);
    return bmi;
  }
}
```

```
public class Point {
  ...
  double getDistanceFromOrigin() {
    double dist = Math.sqrt(x*x + y*y);
    return dist;
  }
}
```


OOP: Use of Mutator vs. Accessor Methods

- Calls to *mutator methods* *cannot* be used as values.
  - e.g., `System.out.println(jim.setWeight(78.5));` ×
  - e.g., `double w = jim.setWeight(78.5);` ×
  - e.g., `jim.setWeight(78.5);` ✓
- Calls to *accessor methods* *should* be used as values.
  - e.g., `jim.getBMI();` ×
  - e.g., `System.out.println(jim.getBMI());` ✓
  - e.g., `double w = jim.getBMI();` ✓

OOP: Method Parameters

- **Principle 1:** A *constructor* needs an *input parameter* for every attribute that you wish to initialize.

  e.g., `Person(double w, double h)` vs.
  `Person(String fName, String lName)`
- **Principle 2:** A *mutator* method needs an *input parameter* for every attribute that you wish to modify.

  e.g., In `Point`, `void moveToXAxis()` vs.
  `void moveUpBy(double unit)`
- **Principle 3:** An *accessor method* needs *input parameters* if the attributes alone are not sufficient for the intended computation to complete.

  e.g., In `Point`, `double getDistFromOrigin()` vs.
  `double getDistFrom(Point other)`

OOP: Object Alias (1)

```
1 int i = 3;
2 int j = i;  System.out.println(i == j);  /* true */
3 int k = 3;  System.out.println(k == i && k == j);  /* true */
```

- **Line 2** copies the number stored in `i` to `j`.
- After **Line 4**, `i`, `j`, `k` refer to three separate integer placeholder, which happen to store the same value `3`.

```
1 Point p1 = new Point(2, 3);
2 Point p2 = p1;  System.out.println(p1 == p2);  /* true */
3 Point p3 = new Point(2, 3);
4 Systme.out.println(p3 == p1 || p3 == p2);  /* false */
5 Systme.out.println(p3.x == p1.x && p3.y == p1.y);  /* true */
6 Systme.out.println(p3.x == p2.x && p3.y == p2.y);  /* true */
```

- **Line 2** copies the *address* stored in `p1` to `p2`.
- Both `p1` and `p2` refer to the same object in memory!
- `p3`, whose *contents* are same as `p1` and `p2`, refer to a different object in memory.

OO Program Programming: Object Alias (2.1)

Problem: Consider assignments to *primitive* variables:

```
int i1 = 1;
int i2 = 2;
int i3 = 3;
int[] numbers1 = {i1, i2, i3};
int[] numbers2 = new int[numbers1.length];
for(int i = 0; i < numbers1.length; i ++) {
  numbers2[i] = numbers1[i];
}
numbers1[0] = 4;
System.out.println(numbers1[0]);
System.out.println(numbers2[0]);
```


OO Program Programming: Object Alias (2.2)

Problem: Consider assignments to *reference* variables:

```
Person alan = new Person("Alan");
Person mark = new Person("Mark");
Person tom = new Person("Tom");
Person jim = new Person("Jim");
Person[] persons1 = {alan, mark, tom};
Person[] persons2 = new Person[persons1.length];
for(int i = 0; i < persons1.length; i ++) {
  persons2[i] = persons1[(i + 1) % persons1.length]; }
persons1[0].setAge(70);
System.out.println(jim.age);  /* 0 */
System.out.println(alan.age);  /* 70 */
System.out.println(persons2[0].age);  /* 0 */
persons1[0] = jim;
persons1[0].setAge(75);
System.out.println(jim.age);  /* 75 */
System.out.println(alan.age);  /* 70 */
System.out.println(persons2[0].age);  /* 0 */
```


OO Program Programming: Object Alias (3)

```
Person tom = new Person("TomCruise");
Person ethanHunt = tom;
Person spy = ethanHunt;
tom.setWeight(77);  print(tom.weight);  /* 77 */
ethanHunt.gainWeight(10);  print(tom.weight);  /* 87 */
spy.loseWeight(10);  print(tom.weight);  /* 77 */
Person prof = new Person("Jackie"); prof.setWeight(80);
spy = prof;  prof = tom;  tom = spy;
print(prof.name+" teaches 2030");/*TomCruise teaches 2030*/
print("EthanHunt is "+ethanHunt.name);/*EthanHunt is TomCruise*/
print("EthanHunt is "+spy.name);/*EthanHunt is Jackie*/
print("TomCruise is "+tom.name);/*TomCruise is Jackie*/
print("Jackie is "+prof.name);/*Jackie is TomCruise*/
```

- An *object* at runtime may have *more than one identities*. Its *address* may be stored in multiple *reference variables*.
- Calling a *method* on one of an object's identities has the *same effect* as calling the same method on any of its other identities.

Java Data Types (1)

A (data) type denotes a set of related *runtime values*.

1. *Primitive Types*
   - *Integer* Type
     - `int` [set of 32-bit integers]
     - `long` [set of 64-bit integers]
   - *Floating-Point Number* Type
     - `double` [set of 64-bit FP numbers]
   - *Character* Type
     - `char` [set of single characters]
   - *Boolean* Type
     - `boolean` [set of `true` and `false`]
2. *Reference Type* : *Complex Type with Attributes and Methods*
   - *String* [set of references to character sequences]
   - *Person* [set of references to Person objects]
   - *Point* [set of references to Point objects]
   - *Scanner* [set of references to Scanner objects]

Java Data Types (2)

- A variable that is declared with a *type* but *uninitialized* is implicitly assigned with its *default value*.
  - **Primitive Type**
    - `int i;` [`0` is implicitly assigned to `i`]
    - `double d;` [`0.0` is implicitly assigned to `d`]
    - `boolean b;` [`false` is implicitly assigned to `b`]
  - **Reference Type**
    - `String s;` [`null` is implicitly assigned to `s`]
    - `Person jim;` [`null` is implicitly assigned to `jim`]
    - `Point p1;` [`null` is implicitly assigned to `p1`]
    - `Scanner input;` [`null` is implicitly assigned to `input`]
- You *can* use a primitive variable that is *uninitialized*. Make sure the *default value* is what you want!
- Calling a method on a *uninitialized* reference variable crashes your program. [*NullPointerException*] Always initialize reference variables!

Java Data Types (3.1)

- An attribute may store the reference to some object.

```
class Person { Person spouse; }
```

- Methods may take as *parameters* references to other objects.

```
class Person {
  void marry(Person other) { ... } }
```

- *Return values* from methods may be references to other objects.

```
class Point {
  void moveUpBy(int i) { y = y + i; }
  Point movedUpBy(int i) {
    Point np = new Point(x, y);
    np.moveUp(i);
    return np;
  }
}
```


Java Data Types (3.2.1)

An attribute may be of type `Point[]`, storing references to `Point` objects.

```
class PointCollector {
  Point[] points; int nop; /* number of points */
  PointCollector() { points = new Point[100]; }
  void addPoint(double x, double y) {
    points[nop] = new Point(x, y); nop++; }
  Point[] getPointsInQuadrantI() {
    Point[] ps = new Point[nop];
    int count = 0; /* number of points in Quadrant I */
    for(int i = 0; i < nop; i ++) {
      Point p = points[i];
      if(p.x > 0 && p.y > 0) { ps[count] = p; count ++; } }
    Point[] q1Points = new Point[count];
    /* ps contains null if count < nop */
    for(int i = 0; i < count; i ++) { q1Points[i] = ps[i] }
    return q1Points ;
  } }
```

Required Reading: Point and PointCollector

Java Data Types (3.2.2)

```java
class PointCollectorTester {
 public static void main(String[] args) {
  PointCollector pc = new PointCollector();
  System.out.println(pc.nop); /* 0 */
  pc.addPoint(3, 4);
  System.out.println(pc.nop); /* 1 */
  pc.addPoint(-3, 4);
  System.out.println(pc.nop); /* 2 */
  pc.addPoint(-3, -4);
  System.out.println(pc.nop); /* 3 */
  pc.addPoint(3, -4);
  System.out.println(pc.nop); /* 4 */
  Point[] ps = pc.getPointsInQuadrantI();
  System.out.println(ps.length); /* 1 */
  System.out.println("(" + ps[0].x + ", " + ps[0].y + ")");
  /* (3, 4) */
 }
}
```


Anonymous Objects (1)

- What's the difference between these two fragments of code?

```java
1 double square(double x) {
2  double sqr = x * x;
3  return sqr; }
```

```java
1 double square(double x) {
2  return x * x; }
```

After **L2**, the result of `x * x`:
  - LHS: it can be reused (without recalculating) via the name `sqr`.
  - RHS: it is not stored anywhere and returned right away.
- Same principles applies to objects:

```java
1 Person getP(String n) {
2  Person p = new Person(n);
3  return p; }
```

```java
1 Person getP(String n) {
2  return new Person(n); }
```

***new** Person(n)* denotes an object without a name reference.
  - LHS: **L2** stores the address of this anonymous object in `p`.
  - RHS: **L2** returns the address of this anonymous object directly.

Anonymous Objects (2.1)

Anonymous objects can also be used as *assignment sources* or *argument values*:

```java
class Member {
 Order[] orders;
 int noo;
 /* constructor ommitted */
 void addOrder(Order o) {
  orders[noo] = o;
  noo ++;
 }
 void addOrder(String n, double p, double q) {
  addOrder(new Order(n, p, q));
  /* Equivalent implementation:
   * orders[noo] = new Order(n, p, q);
     noo ++; */
 }
}
```


Anonymous Objects (2.2)

One more example on using anonymous objects:

```java
class MemberTester {
 public static void main(String[] args) {
  Member m = new Member("Alan");
  Order o = new Order("Americano", 4.7, 3);
  m.addOrder(o);
  m.addOrder(new Order("Cafe Latte", 5.1, 4));
 }
}
```

Static Variables (1)

```
class Account {
  int id;
  String owner;
  Account(int id, String owner) {
    this.id = id;
    this.owner = owner;
  }
}
```

```
class AccountTester {
  Account acc1 = new Account(1, "Jim");
  Account acc2 = new Account(2, "Jeremy");
  System.out.println(acc1.id != acc2.id);
}
```

But, managing the unique id's *manually* is *error-prone* !

Static Variables (2)

```
class Account {
  static int globalCounter = 1;
  int id; String owner;
  Account(String owner) {
    this.id = globalCounter; globalCounter ++;
    this.owner = owner; } }
```

```
class AccountTester {
  Account acc1 = new Account("Jim");
  Account acc2 = new Account("Jeremy");
  System.out.println(acc1.id != acc2.id); }
```

- Each instance of a class (e.g., `acc1`, `acc2`) has a *local* copy of each attribute or instance variable (e.g., `id`).
  - Changing `acc1.id` does not affect `acc2.id`.
- A ***static*** variable (e.g., `globalCounter`) belongs to the class.
  - All instances of the class share a *single* copy of the ***static*** variable.
  - Change to `globalCounter` via `c1` is also visible to `c2`.

Static Variables (3)

```
class Account {
  static int globalCounter = 1;
  int id; String owner;
  Account(String owner) {
    this.id = globalCounter;
    globalCounter ++;
    this.owner = owner;
  } }
```

- *Static* variable `globalCounter` is not instance-specific like *instance* variable (i.e., attribute) `id` is.
- To access a *static* variable:
  - ***No*** context object is needed.
  - Use of the class name suffices, e.g., `Account.globalCounter`.
- Each time `Account`'s constructor is called to create a new instance, the increment effect is *visible to all existing objects* of `Account`.

Static Variables (4.1): Common Error

```
class Client {
  Account[] accounts;
  static int numberOfAccounts = 0;
  void addAccount(Account acc) {
    accounts[numberOfAccounts] = acc;
    numberOfAccounts ++;
  } }
```

```
class ClientTester {
  Client bill = new Client("Bill");
  Client steve = new Client("Steve");
  Account acc1 = new Account();
  Account acc2 = new Account();
  bill.addAccount(acc1);
    /* correctly added to bill.accounts[0] */
  steve.addAccount(acc2);
    /* mistakenly added to steve.accounts[1]! */
}
```

Static Variables (4.2): Common Error

- Attribute `numberOfAccounts` should **not** be declared as `static` as its value should be specific to the client object.
- If it were declared as `static`, then every time the `addAccount` method is called, although on different objects, the increment effect of `numberOfAccounts` will be visible to all `Client` objects.
- Here is the correct version:

```
class Client {
  Account[] accounts;
  int numberOfAccounts = 0;
  void addAccount(Account acc) {
    accounts[numberOfAccounts] = acc;
    numberOfAccounts ++;
  }
}
```


Static Variables (5.1): Common Error

```
1 public class Bank {
2    public string branchName;
3    public static int nextAccountNumber = 1;
4    public static void useAccountNumber() {
5       System.out.println (branchName + ...);
6       nextAccountNumber ++;
7    }
8 }
```

- *Non-static method cannot be referenced from a static context*
- **Line 4** declares that we *can* call the method `userAccountNumber` without instantiating an object of the class `Bank`.
- However, in **Lined 5**, the *static* method references a *non-static* attribute, for which we *must* instantiate a `Bank` object.

Static Variables (5.2): Common Error

```
1 public class Bank {
2    public string branchName;
3    public static int nextAccountNumber = 1;
4    public static void useAccountNumber() {
5       System.out.println (branchName + ...);
6       nextAccountNumber ++;
7    }
8 }
```

- To call `useAccountNumber()`, no instances of `Bank` are required:

```
Bank.useAccountNumber();
```

- *Contradictorily*, to access `branchName`, a *context object* is required:

```
Bank b1 = new Bank(); b1.setBranch("Songdo IBK");
System.out.println(b1.branchName);
```


Static Variables (5.3): Common Error

There are two possible ways to fix:

1. Remove all uses of *non-static* variables (i.e., `branchName`) in the *static* method (i.e., `useAccountNumber`).
2. Declare `branchName` as a *static* variable.
   - This does not make sense.
     ∵ `branchName` should be a value specific to each `Bank` instance.

Non-Static Context vs. Static Context (1)

- A Recap of Rules:
  - Use of **static** variables in a **non-static** method is ***allowed***.
    e.g., `static int globalCounter` [see this slide]
  - Use if **non-static** variables in a **static** method is ***forbidden***.
    e.g., `String branchName` [see this slide]
- Principles of Judgement:
  - Using a **non-static** variable/method requires a *context object*.

```
Person jim = new Person(50, "British", 80, 1.8);
System.out.println("Jim's BMI: " + jim.getBMI());
```

  - To use a **static** variable/method, a *class name* is sufficient.

```
class Counter { static int gc = 1; /* global counter */ }
class CounterTester {
  static void main(String[] args) {
    System.out.println("Global value: " + Counter.gc);
  } }
```

  - Warning if accessing a **static** variable/method via a *context object*.

Non-Static Context vs. Static Context (2)

```
1  class MyClass {
2    int i; /* a non-static attribute */
3    static int si = 2; /* a static attribute */
4    void changeOne () { /* a non-static method */
5      i ++;
6      si ++;
7    }
8    static void changeTwo () { /* a static method */
9      i ++; /* Error: Use of non-static in static context.  */
10     si ++;
11   }
12 }
```

- Say we already created an object: `MyClass o = new MyClass()`
- **L5** & **L6** are *valid*.
  - Calling `o.changeOne()` means `o.i ++` and `o.si ++`
- **L9** is *invalid*.
  - Allowing `MyClass.changeTwo()` would allow `MyClass.i ++`.
  - But `MyClass.i ++` is *invalid* ∵ non-static `i` needs a context object

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