Object Oriented Programming in Java

3: Classes definitions. Visibility modifiers. Constructors. Variable number of arguments. Static class variables and methods.

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- The samples and slides are inspired by the Object Oriented Programming course at the University of Zagreb, Faculty of Electrical Engineering and Computing, Zagreb, Croatia.
  - Original materials in Croatian were created by (in alphabetical order): Ivica Botički, Marko Čupić, Mario Kušek, Boris Milašinović, and Krešimir Pripužić under CC-BY-NC-SA licence.
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Categorization

- Categorization: Placing things into classes or groups
- A program is developed for a (business) domain
- Each domain has
  - real life entities that must be categorized (divide in classes)
    - e.g. University: students, teachers, courses, exams, …
    - entities have attributes: name, surname, course name, grade, …
  - action related to identified categories (classes)
    - e.g. enroll, take exam, calculate grade, …
    - modelled as class methods
  - and “business” rules
    - e.g. “You have to have 90% for grade A”, …
    - rules as part of class methods

Abstraction in object-oriented programming

- Identified objects and actions must be abstracted in order to be modelled as classes and methods
- Model only relevant attributes and methods
- What is relevant for a student?
  - name, surname, student's id are probably relevant
  - what about date of birth, advisor’s name, height, weight, …
  - it depends what we model
    - Is it a system for administrative task?
    - Is it a system for tracking sports activities?

Encapsulation

- How TV works?
  - as long as it works and we have an interface to control it (remote control) it is not relevant
- Would students' grade would be stored inside an array or somewhere else? Do we have to know internal variable names and types?
  - allow someone to change the data directly or enforce using provided methods?

- Encapsulation
  - Bundles data with methods that operate on that data
  - Hides the implementation details and prevents unauthorized direct access

Access modifiers in Java

- Access modifiers controls visibility and access control
  - *public*
    - Access allowed from anywhere
  - *private*
    - Accessible only inside the same class
  - *protected*
    - Accessible only to classes in the same package and to the subclasses
      - More about subclasses later in *Topic 4 - Inheritance*
  - No modifier
    - called *package-private* visibility
    - Accessible to the classes in the same package
- Top level (e.g. classes) can be only public or package-private
  - members as variables, methods, nested classes (Topic 10) can have other modifiers

Differences between common OOP languages

- The main difference occurs for *protected* keyword and when no access modifier is specified

Access keyword	Java	C#	C++
public	(same meaning in Java, C# and C++)		
private	(same meaning in Java, C# and C++)		
protected	subclasses and classes from the same package	subclasses	subclasses
internal protected	-	subclasses and classes from the same assembly	-
private protected	-	subclasses if they are in the same assembly	-
internal	-	classes from the same assemly	-
no modifier	classes from the same package	(=private)	(=private)

2D Point abstraction

- A point in two-dimensional Euclidean space is represented by an ordered pair (x, y)
  - 2 class fields (attributes, variables) of *double* type
    - private fields and appropriate *getters* and *setters* to access current and set new value of encapsulated field
- Methods:
  - *print()* to write point's data to standard output
    - latter would be replaced with method *toString()*
  - *isEqualTo(Point other)* to compare a point with another one
    - Latter would be replaced with *equls(Object obj)*

Encapsulation for Point

- Getters and setter usually named as *[get/set]VariableName*
  - *camelCase* common for Java methods

03_Constructors/…/swu/oopj/constructors/Point.java

```
package swu.oopj.constructors
public class Point {
    private double x, y;
    public double getX(){
        return x;
    }
    public void setX(double x){
        this.x = x;
    }
    public double getY(){
        return y;
    }
    public void setY(double y){
        this.y = y;
    }   ...
```

Points equality (1)

- Two points are equal if they have same coordinates

03_Constructors/…/swu/oopj/constructors/Point.java

```
public class Point {
    ...
    public void print(){
       System.out.printf("(%.2f, %.2f)%n" , x , y);
    }

    public boolean isEqualTo(Point other) {
       return x == other.x && y == other.y;
    }
```

- Note: The solution above uses == to compare double numbers which can lead to errors due to differing precision of values
  - i.e. 3 * 0.1 is not equal to 0.3 using operator ==
  - 3 * 0.1 produces 0.3000000000000004 and 0.3 have infinite numbers of binary digits. Thus $3 * 0.1 - 0.3 \approx 5.55 * 10^{-17}$

Points equality (2)

- A better approach is to compare absolute value of the difference with acceptable relative margin (e.g. 0.001% of one of the values)
  - for further examples 10^{-8} would be quite fine

03_Constructors/…/swu/oopj/constructors/Point.java

```
public class Point {
    private double x, y;
    ... getters and setters ...

    public void print(){
       System.out.printf("(%.2f, %.2f)%n" , x , y);
    }

    public boolean isEqualTo(Point other) {
       return Math.abs(x-other.x) < 1E-8
              &&
            Math.abs(y-other.y) < 1E-8;
    }
```

How to create an object of Point type?

- New point (object) could be created using operator *new*

```
Point p = new Point();
```

  - In that case values for *x* and *y* would be 0 (default value for *double*)
  - Can be changed with setters *p.setX(new_value)* and *p.setY(value)*
- Can we assign some other values to x in y? Yes, by
  - providing initial value for a field in its declaration, e.g.

```
private int x = 5;
```

  - or/and by writing one or more constructors and setting variable to a value in a constructor

  - If both ways are used, variable first get the value from declaration, a then change its value to a value set in constructor

Constructor

- Special method used to prepare new object for use (i.e. to initialize member variables to the specific values)
  - The method name is same as the class name
  - Can have arguments, but does not have return type (not even void)
  - Cannot be directly invoked
    - Executed after the memory is allocated with operator *new*
- A class can have zero or more explicitly written constructors
  - If no constructors are written by a programmer, Java compiler creates a default one with zero parameters

A constructor for *Point*

- Constructor with two arguments: numbers that should be used as values for *x* and *y*.

```
public class Point {
  private double x, y;
  public Point(double newX, double newY){
        x = newX;
        y = newY;
  }
  ...
}
```

- A new point is created like

```
Point p = new Point(2.0, 5);
```

  - The following code is not correct anymore as there is no parameterless constructor

```
Point p = new Point();
```

    - Java compiler did not create default one because we explicitly wrote a constructor
    - We can write another one without arguments (if we want)

Variable hiding and *this* keyword

- What if an argument name is the same as class field name?
  - E.g. what if we change *newX* and *newY* to *x* and *y* in previous constructor
  - Common in constructors and setters
- Variable name refer to the argument (and hides class variable)
- *this* is a reference to current object
  - used for example to get reference to class variable

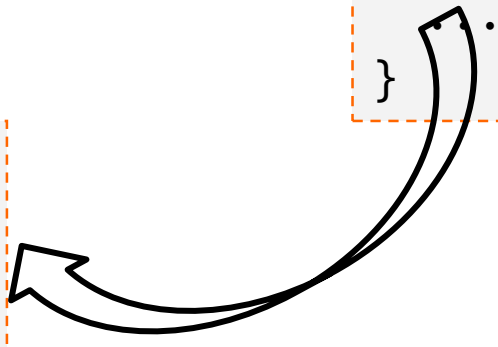
```
public class Point {
  private double x, y;
  public Point(double x, double y){
        this.x = x;
        this.y = y;
  }
  ...
}
```

this to call another constructor

- Additional constructor to initialize a point based on another point
  - Repeats (almost) same code
- More elegant solution using *this*
  - Run the code from another constructor (calls an existing constructor)
  - If used, *this* must be the first statement in a constructor

```
public class Point {
  private double x, y;
  public Point(Point p) {
        x = p.x;
        y = p.y;
  }
  ...
}
```

```
public class Point {
  private double x, y;
  public Point(Point p) {
        this(p.x, p.y);
  }
  ...
}
```



Note: *this* does not create new object

- New objects are created using operator *new*

Example using different constructors

- What is the output of the following program?

03_Constructors/…/swu/oopj/constructors/Point.java

```
package swu.oopj.constructors;
public class Main {
   public static void main(String[] args) {
       Point p1 = new Point(2, 5);
       Point p2 = new Point(p1);
       System.out.println("p1.isEqualTo(p2) : "
           + p1.isEqualTo(p2)); //true or false?
       p1.setX(1);
       p1.setY(2);
       System.out.println("p1.isEqualTo(p2) : "
           + p1.isEqualTo(p2)); //true or false?

       p1.print();
       p2.print();
     ...
```

```
(1.0, 2.0)  or  (1.0, 2.0)  or  (2.0, 5.0)
(2.0, 5.0)      (1.0, 2.0)      (2.0, 5.0)
```

Static methods

- Methods *print* and *isEqualTo* are instance methods
  - In order to invoke an instance method, an object must exist
    - invoked as `object.method(arguments)`
    - Uses object's data (x and y in this case) and other methods
- Methods could be marked as static.
  - Does not require an object to be invoked
    - does not belongs to particular object, but to a class
    - invoked as `ClassName.method(arguments)`
    - cannot use non-static fields and non-static methods of the class
  - Note: Java allows calling static methods using object of the class `object.method(arguments)`
    but it should not be practiced
    - makes no sense, and e.g. not allowed in C#

An example of static method

- Create a new point as a focus of three existing points referenced by variables *a, b, c*
- Suppose that we create this method as instance method
  - This would lead to method calls like *a.centerOf(b, c)* or some permutation of that call
  - Does not make sense because method is not intended to be part of an object, but to belong to all (three) objects, i.e. to belong to the class
    - Similarly *Integer.parseInt("12")* does not required that any integer exists before parsing the string
- Thus the method would be marked as static and called like

  Point.centerOf(a, b, c)

Static method for the focus of three points (1)

- Method *centerOf* is marked as *static*
  - It creates a new point

03_Constructors/…/swu/oopj/staticmethods/Point.java

```
package swu.oopj.staticmethods;
public class Point
  ...
  public static Point centerOf(Point a, Point b, Point c) {
       double x = (a.x + b.x + c.x) / 3.;
       double y = (a.y + b.y + c.y) / 3.;
       Point p = new Point(x, y);
       return p;
  }
  ...
```

Static method for the focus of three points (2)

- Method *centerOf* is static method in *Point*
- Method *print* is instance method in *Point*

03_Constructors/…/swu/oopj/staticmethods/Main.java

```
package swu.oopj.staticmethods;
public class Main {

      public static void main(String[] args) {
            Point a = new Point(0,0);
            Point b = new Point(6,0);
            Point c = new Point(3,5);
            Point center = Point.centerOf(a, b, c);
            center.print();
            ...
```

Focus of multiple points (1)

- Class can have more that one methods with the same name, as long arguments name or type is different
  - The concept is called ***overloading***
  - This version receives array of points

03_Constructors/…/swu/oopj/staticmethods/Point.java

```
package swu.oopj.staticmethods;
public class Point
  ...
  public static Point centerOf(Point[] points){
            double x = 0, y = 0;
            int len = points.length;
            for(int i=0; i<len; i++){
                  x += points[i].x;   y += points[i].y;
            }
            Point p = new Point(x / len, y / len);
            return p;
      }  ...
```

Focus of multiple points (2)

- Instead of classic for loop, for-each variant can be used
  - It iterates through the points array and in each pass assigns an address of next point to reference p

03_Constructors/…/swu/oopj/staticmethods/Point.java

```
package swu.oopj.staticmethods;
public class Point
  ...
  public static Point centerOf(Point[] points){
            double x = 0, y = 0;
            int len = points.length;
            for(Point p : points){
                  x += p.x;           y += p.y;
            }
            Point p = new Point(x / len, y / len);
            return p;
      }  ...
```

Focus of multiple points (3)

- An array of points must be created and filled before call
- What *new Point[] {a, b, c, d}* does?
  - creates an array of 4 elements where each element is a reference to an existing point

03_Constructors/…/swu/oopj/staticmethods/Main.java

```
package swu.oopj.staticmethods;
public class Main {

      public static void main(String[] args) {
            ...
            Point d = new Point(7, 3);
            Point[] points = new Point[] {a, b, c, d};
            center = Point.centerOf(points);
            center.print();
            ...
```

Focus of variables number of points (1)

- Previous solution can be used with any array size, but it is somehow inconvenient
  - Wouldn't be better to be able to call method just like in the example below?

03_Constructors/…/swu/oopj/staticmethods/Main.java

```
package swu.oopj.staticmethods;
public class Main {
  public static void main(String[] args) {
      Point a = new Point(0,0);
      ...
      Point.centerOf(a, b).print();
      Point.centerOf(a, b, c).print();
      Point.centerOf(a, b, c, d).print();
      Point.centerOf(a, b, c, d, new Point(4,8)).print();
            ...
```

Focus of variables number of points (2)

- Methods can have variable number of arguments by using *Type… variable* (only) as last argument
  - Internally stored as an array

03_Constructors/…/swu/oopj/staticmethods/Point.java

```
public class Point
  …
  public static Point centerOf(Point a, Point b, Point...points)
  {
      double x = a.x + b.x;
      double y = a.y + b.y;
      for(Point p : points){
            x += p.x;           y += p.y;
      }
      int len = points.length + 2;
      Point p = new Point(x / len, y / len);
      return p;
  } ...
```

Focus of variables number of points (3)

- What happens where there are more choices, e.g.

  public static Point centerOf(Point a, Point b, Point... points)

  public static Point centerOf(Point a, Point b, Point c)

  - Compiler will (if it is possible) prefer specific one to the method with variable number of arguments

```
package swu.oopj.staticmethods;
public class Main {

  public static void main(String[] args) {
      ...
      Point.centerOf(a, b).print();
      Point.centerOf(a, b, c).print();
      Point.centerOf(a, b, c, d).print();
      ...
```

03_Constructors/…/swu/oopj/staticmethods/Main.java

Using *Point* in another classes

- Vector in 2D could be defined using origin and a point
  - Point to be stored inside *Vector* can be create based on two double values, or based on an existing point

03_Constructors/…/swu/oopj/staticmethods/Vector.java

```
package swu.oopj.staticmethods;
public class Vector {
	private Point p;
	public Vector(Point p){
		this.p = new Point(p);
	}
	public Vector(double x, double y){
		this.p = new Point(x, y);
	}
	public void print() {
		p.print();
	}
}
```

Reference or a copy (1)?

"The [devil / beauty / thing] is in the details"

- What would happen if we change

```
public class Vector {
	private Point p;
	public Vector(Point p){
		this.p = new Point(p);
	}
```

to this?

```
public class Vector {
	private Point p;
	public Vector(Point p){
		this.p = p;
	}
```

Reference or a copy (2)?

- Try to change the code and run the following excerpt

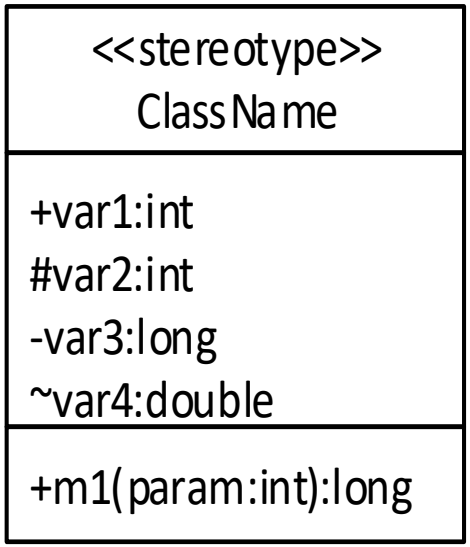
```
Point d = new Point(7, 3);
Vector v = new Vector(d);
v.print();
d.setX(17); d.setY(13);
v.print();
```

03_Constructors/…/swu/oopj/staticmethods/Main.java

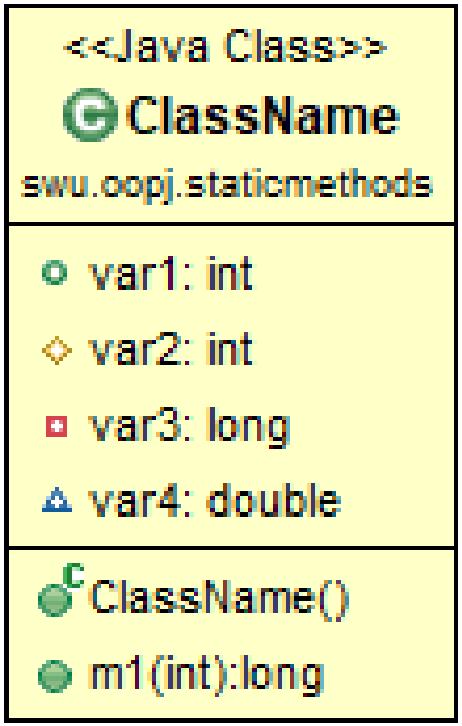
- The answer to the question depends on the problem
  - in our case, copy is more appropriate
  - Does not have to be case in future (e.g. lists, and collections in general keeps references)

UML class diagrams

- UML = Unified Modeling Language
- Class diagrams is a type of static structure diagram that describes the structure of a system by showing the system's classes, their attributes, operations (or methods), and the relationships among objects.

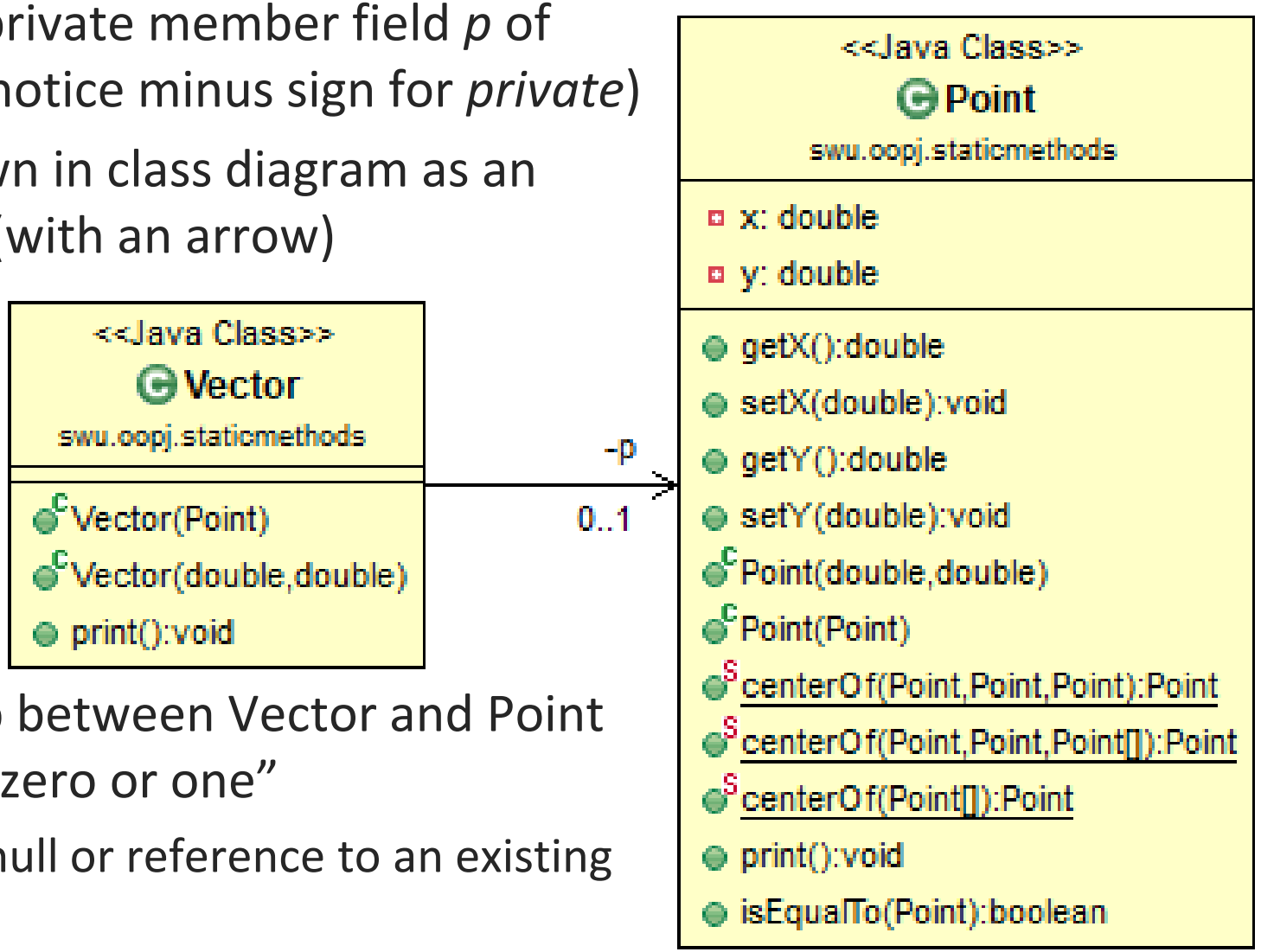


+ public
 # protected
- private
~ package-private



UML class diagram for *Vector* and *Point*

- Vector has private member field *p* of Point type (notice minus sign for *private*)
- Can be shown in class diagram as an association (with an arrow)



- Relationship between Vector and Point is “one” to “zero or one”
  - *p* can be null or reference to an existing point

Static variables

- Belong to a class
  - Available without existence of an object of the class
- Using syntax like for static methods

  ```
  ClassName.variableName
  ```
- Some notable examples:
  - Math.PI, Math.E
- Usually used for constants but (as will be shown) does not have to be

Keyword *final*

- Variables marked with *final* cannot change their value

```
final int x = 7;
...
x = 5;
```

```
final Point p = new Point(2.5, 3.0);
...
p = new Point(7.0, 4.2);
```

- However, it can change object on which refers!

```
final Point p = new Point(2.5, 3.0);
...
p.setX(7.0); p.setY(3.0)
```

- Could be static
- Final variables are initialized when declared or in constructor
  - Constant for class, or constant for an object
- Note: *final* is also used for stopping inheritance and overriding (more about that in slides T4 and T5)

Static variables for vector space basis

- Canonical basis for $\mathbb{R}^2$ e1=(1,0) and e2=(0,1).
  - α1=(1,1) and α2=(-1, 2) is also basis in $\mathbb{R}^2$
- Each vector in $\mathbb{R}^2$ is linear combination of basis vectors.

- Should be same for all vectors => make *static*
- Cannot change canonical basic => make *final static*
  - Note: Setting final for e1 and e2 means that references are constant (see previous slide). However, as *Vector* does not provide getter for *Point*, canonical base could not be changed in the program

Static variables initialization

- Initialization on declaration (e1, e2) or using static blocks
  - Note: C# have static constructors instead static blocks
  - Order of initialization (if both used) – on declaration then static blocks
- Static block is run before the first variable use or before first object of type Vector is created

```
package swu.oopj.staticblocks;
public class Vector {
   public final static Vector e1 = new Vector(new Point(1,0));
   public final static Vector e2 = new Vector(new Point(0,1));

   public static Vector alpha1, alpha2;
   static {
              alpha1 = e1; alpha2 = e2;
       }
  ...
```

03_Constructors/…/swu/oopj/staticblocks/Vector.java

An example of using static variables

- Method print uses *EquationSolver* class to find linear combination
  - Implementation details are not relevant for the course

03_Constructors/…/swu/oopj/staticblocks/Vector.java

```
package swu.oopj.staticblocks;
public class Vector {
  ...
  public void print() {
    System.out.format("(%.2f, %.2f) = %.2f * (%.2f, %.2f) + %.2f
* (%.2f, %.2f)", ... //details are not relevant!
```

03_Constructors/…/swu/oopj/staticblocks/Main.java

```
public class Main {
  Vector v = new Vector(new Point(3,4));
  v.print();
  Vector.alpha1 = new Vector(1,1);
  Vector.alpha2 = new Vector(-1,2);
  v.print();
```

```
(3,00, 4,00) = 3,00 * (1,00, 0,00) + 4,00 * (0,00, 1,00)
(3,00, 4,00) = 3,33 * (1,00, 1,00) + 0,33 * (-1,00, 2,00)
```

Class diagram of updated *Vector* and *Point*

- Associations removed for the sake clarity