Object-Oriented Programming In Mechatronic Systems

Summer School

Module 4
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Recap

Recap

```
public class IfElseDemo {
      public static void main(String[] args) {
        int testscore = 76;
        char grade;

        if (testscore >= 90) {
            grade = 'A';
        } else if (testscore >= 80) {
            grade = 'B';
        } else if (testscore >= 70) {
            grade = 'C';
        } else {
            grade = 'F';
        }
        System.out.println("Grade = " + grade);
    }
}
```

Recap

```
public class LoopDemo{

    public static void main(String[] args) {

        for (int i = 0; i < 15; i++){

            System.out.println("Loop " + i);

        }

}
```

i = i + 1

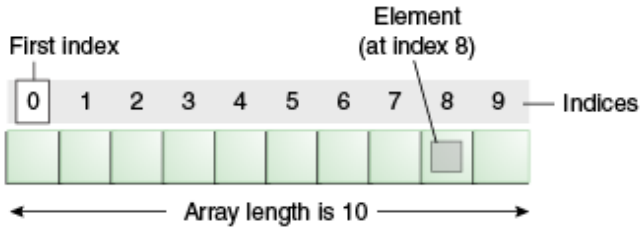
Output:
Loop 0
Loop 1
…
Loop 14

Recap and Motivation

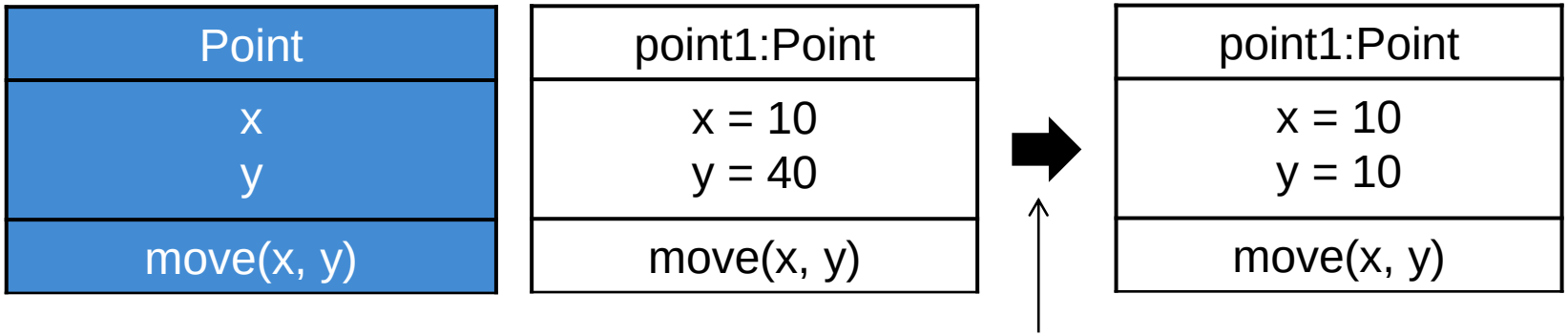
- Primitive data types (e.g. `int`) can only hold a single value
- E.g. `int val = 17;`

Array Features

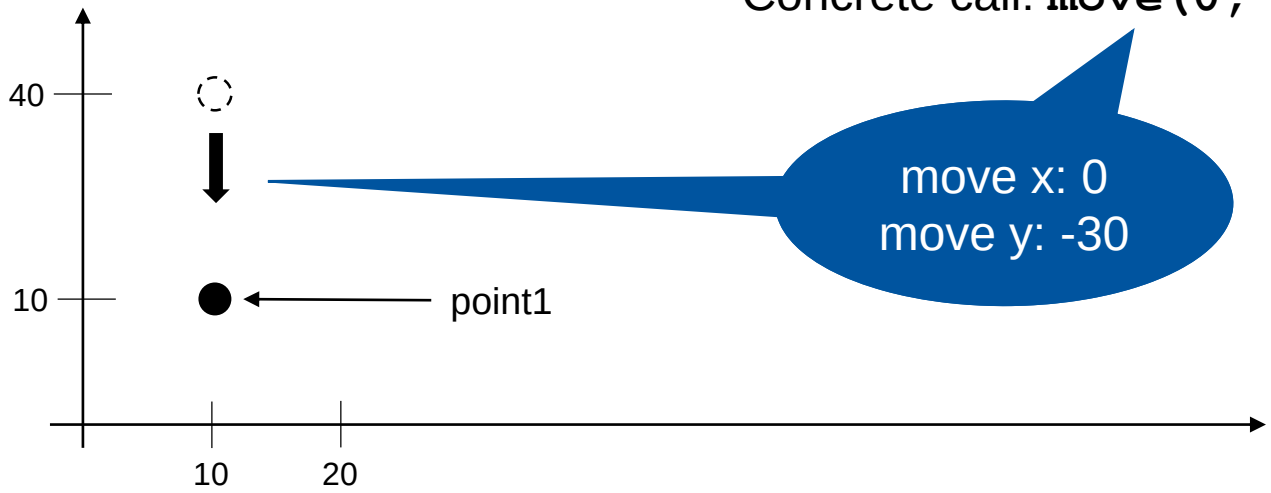
- Arrays can hold multiple values (or *elements*)!
- Can only hold one data type, i.e. no mixture of data types (e.g. `int` **and** `char`)
- Length is established upon creation: `int[] numbers = new int[10]`
- After that it's fixed!
- Access to elements via *index:* `numbers[0], numbers[5]`
- Index starts with 0. That is, the first array element has the index 0:



Example: Classes and Objects



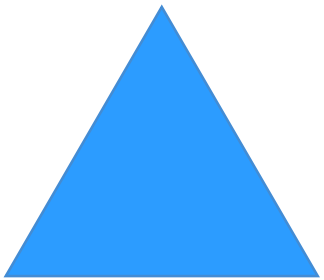
Concrete call: `move(0, -30)`



Instances: Example

```
public class Shape {

   public String color;

   public boolean filled;

}
```

This **Rectangle** is a **Shape** with color "red" and not filled



This **Triangle** is a **Shape** with color "blue" and filled

Constructors

- Constructors run *before* the object can be assigned to a reference
- It runs every time you invoke `new`
- If you don't write a constructor for your class the compiler writes one for you …
- … which is called the **default constructor**!

Example

```
public class Circle {
    private int radius;
    public Circle(){
    }

    public Circle(int r){
        this.radius = r;
    }
}
```

Default constructor

Constructor

Communication and Relations between Objects

Communication and Relations between Objects

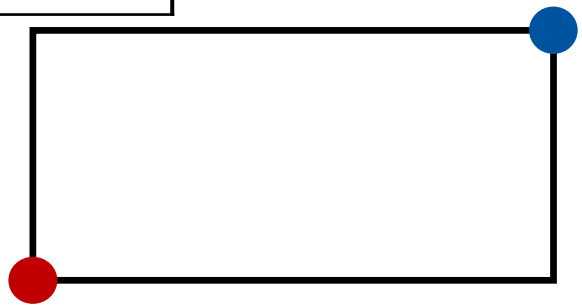
Point2D
-x:double -y:double
+Point2D(x:double, y:double) +getX():double +getY():double +move(delta_x:double, delta_y:double)

Every **rectangle** is defined by two **Point2Ds**:

- **First point** defines the lower left corner
- **Second point** defines the upper right corner

Communication and Relations between Objects

Rectangle
-lowerLeft:Point2D -upperRight:Point2D
+Rectangle(lowerLeft:Point2D, upperRight:Point2D) +setLowerLeft(lowerLeft:Point2D):void +getLowerLeft():Point2D +setUpperRight(upperRight:Point2D):void +getUpperRight():Point2D



Communication and Relations between Objects

```
public class Rectangle {

   private Point2D lowerLeft;
   private Point2D upperRight;

   public Rectangle(Point2D lowerLeft, Point2D upperRight) {
      this.lowerLeft = lowerLeft;
      this.upperRight = upperRight;
   }
   …
}
```

Constructor

lowerLeft and **upperRight** are names of **local and instance variables**!
Hence, we need a way to distinguish the variables ➔ `this`

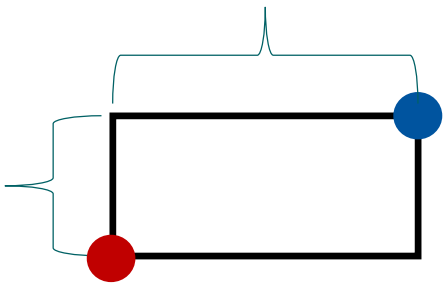
Communication and Relations between Objects

`this` represents a reference (a pointer) to the current object

```
public class Rectangle {
   private Point2D lowerLeft;

   private Point2D upperRight;
   …
   public void setLowerLeft(Point2D lowerLeft) {
      this.lowerLeft = lowerLeft;
   }

   public Point2D getLowerLeft() {
      return lowerLeft;
   }
   …
}
```

Communication and Relations between Objects

Rectangle
-lowerLeft:Point2D -upperRight:Point2D
… +calculateArea():double



```
public class Rectangle {
   …
   public double calculateArea() {
      return (upperRight.getX() - lowerLeft.getX()) *
         (upperRight.getY() - lowerLeft.getY());
   }
}
```

How can we ensure that this calculation works?

More precisely: How can we ensure that lower left and upper right represents these points and not others?

Communication and Relations between Objects

We have to check, if the following conditions are always satisfied:

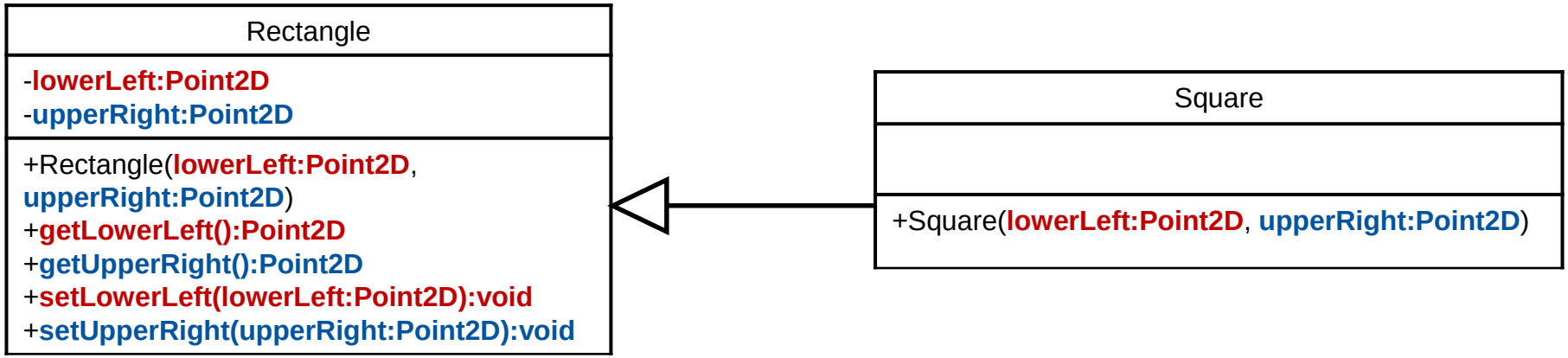
- lowerLeft.getX() < upperRight.getX() **and**
- lowerLeft.getY() < upperRight.getY()

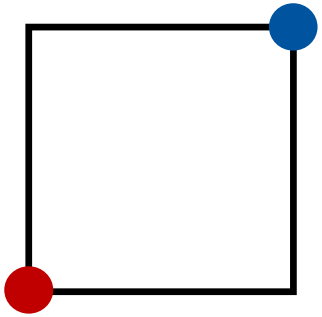
```
public class Rectangle {
   private Point2D lowerLeft;
   private Point2D upperRight;
   …
   public void setLowerLeft(Point2D lowerLeft) {
      if (lowerLeft.getX() < upperRight.getX() &&
         lowerLeft.getY() < upperRight.getY()) {

         this.lowerLeft = lowerLeft;
      }
      // else we do nothing (perhaps not the best solution!)
   }
}
```

Communication and Relations between Objects

```
public class Application {

   public static void main(String[] args) {
      Rectangle rect = new Rectangle(
         new Point2D(10,10),
         new Point2D(20,40)
      );
      System.out.println("The area of rect is: " +
         rect.calculateArea();
   }
}
```

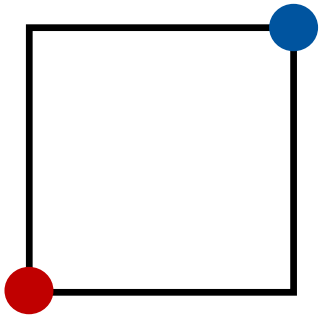
Communication and Relations between Objects





Communication and Relations between Objects

```
public class Square extends Rectangle {
        …
   public Square(Point2D lowerLeft, Point2D upperRight){
      super(lowerLeft, upperRight);

      if(this.upperRight.getX() - this.lowerLeft.getX()
         != this.upperRight.getY() - this.lowerLeft.getY())
      {
         throw new IllegalStateException();
      }
   }
}
```



A Square is a special case of a rectangle, where the sides have equal length

- Square extends and specializes Rectangle
- To save the two points needed to describe a rectangle, we need to call the constructor of Rectangle
- Use **super** to call the overridden method or constructor of a **superclass**

Exception Handling

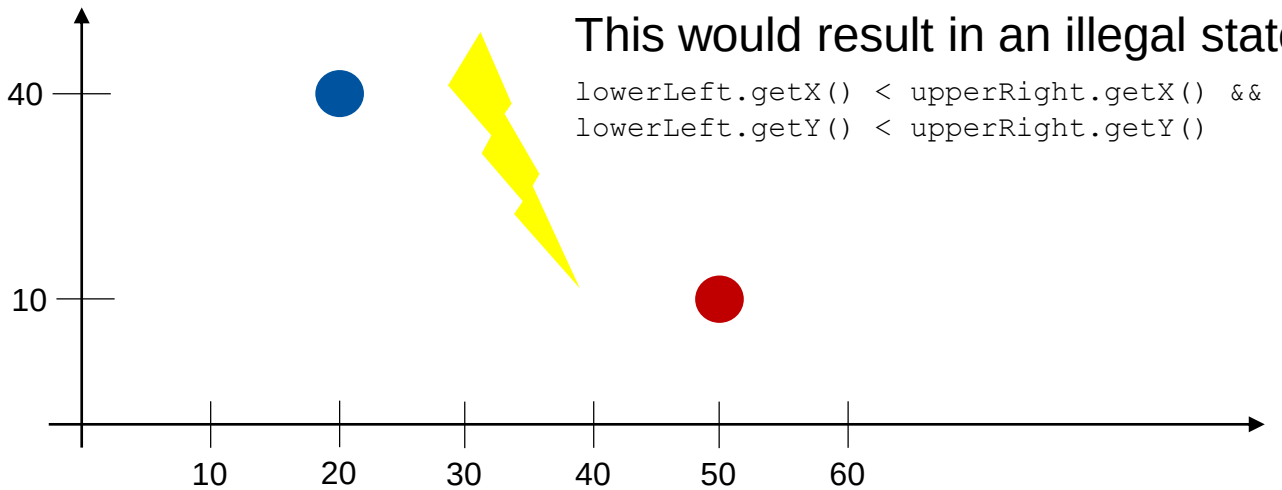
Exception Handling

How to handle unforeseen events during program execution?

- That is **during runtime**: Events like server down, file not found…
- Not everything is under your control! E.g., can you control an external server?
- Such events are called *Exception*
- Shorthand for exceptional event

Exception Handling

```
public class Application {

   public static void main(String[] args) {
      Rectangle r = new Rectangle(new Point2D(50,10), new
         Point2D(20,40));
      System.out.println("The area of r is: " +
         r.calculateArea();
   }
}
```



This would result in an illegal state!

```
lowerLeft.getX() < upperRight.getX() &&
lowerLeft.getY() < upperRight.getY()
```

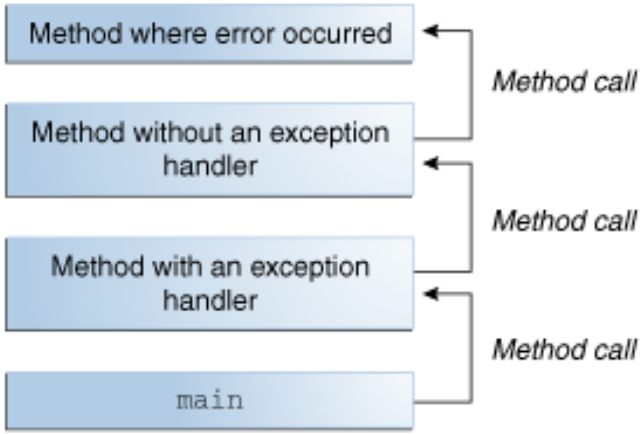
Exception Handling

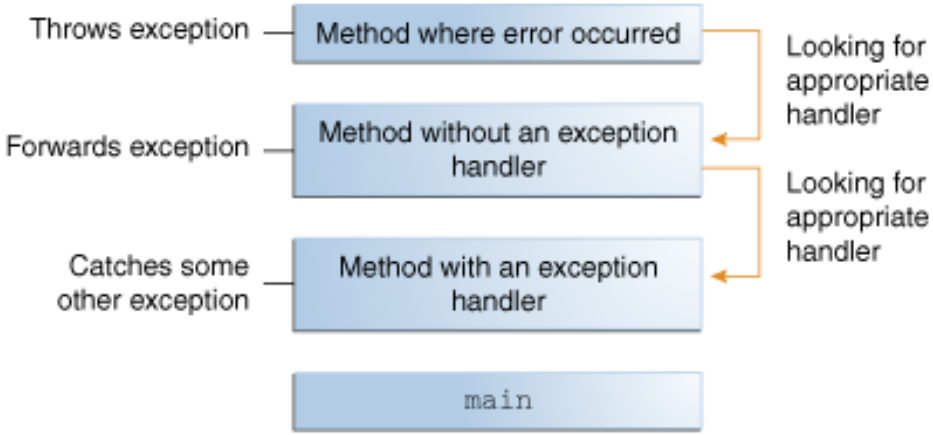
```
public class Application {

   public static void main(String[] args) {
      try {
         Rectangle r = new Rectangle(new Point2D(50,10), new
            Point2D(20,40));
         System.out.println("The area of r is: " +
            r.calculateArea();
      } catch (IllegalStateException e) {
         System.err.println("The initialization of rectangle
            failed. Reason: " + e.getMessage();
      }
   }
}
```

If the initialization fails (due to a created illegal state), an `IllegalStateException` is thrown: Now, we can react accordingly, by catching the `Exception`.

How are exceptions handled in Java?

- If exception occurs within a method, the method throws an *exception object*
- This object contains information about the error such as type and message
- The runtime tries to find something to handle it, by searching the method call stack for an *exception handler*!





The Catch or Specify Requirement

- Valid code must honor the *Catch or Specify* Requirement
- If code might throw certain exceptions, code **must** be enclosed by…
  - … a `try` statement that catches the exception **or**
  - … a method that is marked via the `throws` clause (telling the caller that the method can throw such exceptions)
- Code that does not honor the requirement doesn't compile!

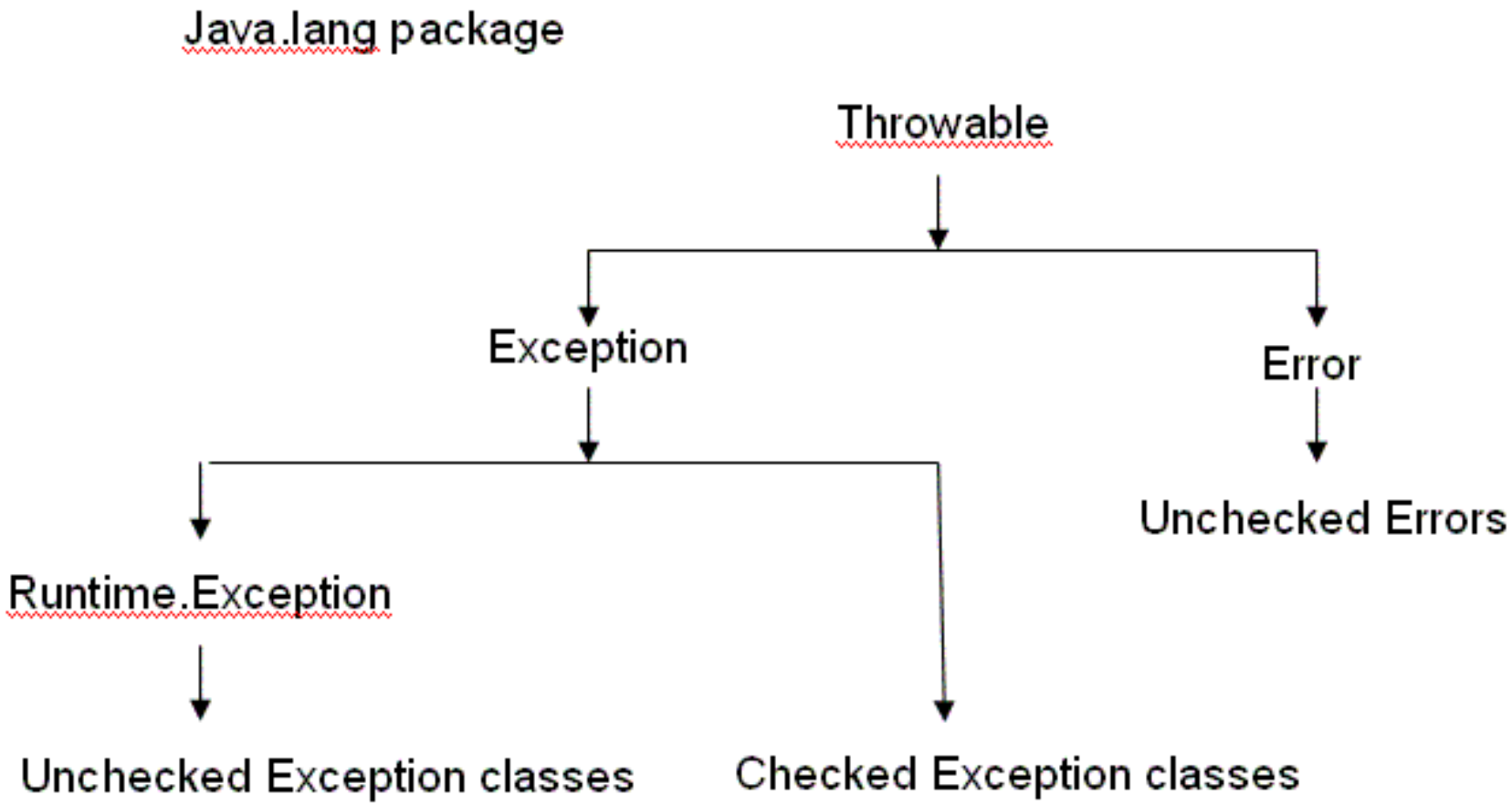
There are three types of exceptions in Java!

- Type 1: ***Checked exception***
  - Subject to the catch and specify requirement
  - **A well-written application should anticipate and recover from it!**

- Type 2: ***Errors***
  - Not a subject to catch and specify
  - **External** to the application
  - Applications usually cannot recover from it

- Type 3: ***Runtime exception***
  - Not a subject to catch and specify
  - **Internal** to the application
  - Applications usually cannot anticipate or recover from

Exception hierarchy



Catching and Handling Exceptions

Three exception handler components: `try`, `catch`, and `finally`

```
try
{
    statements that can throw exceptions
}
catch (exception-type identifier)
{
    statements executed when exception is thrown
}
finally // not mandatory!
{
    statements that are always executed
}
```

Exception Handling

```
public class Rectangle {
   private Point2D lowerLeft;
   private Point2D upperRight;
   …
   public void setUpperRight(Point2D upperRight)
      throws IllegalStateException {
      if (lowerLeft == null ||
            (lowerLeft.getX() < upperRight.getX() &&
             lowerLeft.getY() < upperRight.getY())
         ) {
         this.upperRight = upperRight;
      } else {
         throw new IllegalStateException("Upper right condition is
            not guaranteed");
      }
   }
   …
}
```

Exception Handling

```
public class Rectangle {
    private Point2D lowerLeft;
    private Point2D upperRight;
    …
    public void setUpperRight(Point2D upperRight)
        throws IllegalStateException, IllegalArgumentException {
        if (upperRight == null) {
            throw new IllegalArgumentException("The argument cannot be
                null");
        }
        if (lowerLeft == null ||
                (lowerLeft.getX() < upperRight.getX() &&
                 lowerLeft.getY() < upperRight.getY())
            ) {
            this.upperRight = upperRight;
        } else {
            throw new IllegalStateException("Upper right condition is
                not guaranteed");
        }
    }
    …
}
```

Now we can update our constructor using our setters (with the extended validation check)

```
public class Rectangle {

   private Point2D lowerLeft;

   private Point2D upperRight;

   // constructor
   public Rectangle(Point2D lowerLeft, Point2D upperRight)
       throws IllegalStateException, IllegalArgumentException {
      setLowerLeft(lowerLeft);
      setUpperRight(upperRight);
   }
   …
}
```

Finally, we get our application

```
public class Application {

   public static void main(String[] args) {
      try {
         Rectangle r = new Rectangle(new Point2D(50,10), new
            Point2D(20,40));
         System.out.println("The area of r is: " +
            r.calculateArea());
      } catch (IllegalStateException e1) {
         System.err.println("The initialization of rectangle
            failed. Reason: " + e1.getMessage());
      } catch (IllegalArgumentException e2) {
         System.err.println(e2.getMessage());
      }
   }
}
```

The Java API

The Java API

Java comes with hundreds of classes

- They are bundled in the Java API
- API is shorthand for ***A**pplication **P**rogramming **I**nterface*
- What's in it and how do we use the library?
- **In it**: Libs for mathematical operations or data structures like array list …
- **Use it**: You have to know which package the class is in!

Excursus: Packages I

- A *package* is a grouping of related types (e.g. classes or interfaces)
- Make stuff easier to find and use
- … to avoid naming conflicts
- … to control access.
- E.g. `java.util` (for utilities) or `javax.swing` (for creating GUIs)

Excursus: Packages II

- If we want to work with class `ArrayList` which is in package `java.util` …
- We have to **either import it** by using the `import` keyword
- E.g.: `import java.util.ArrayList`
- **Or type in the full name of the class everywhere in our code!**

Bad idea!
Why?

Excursus: Packages III

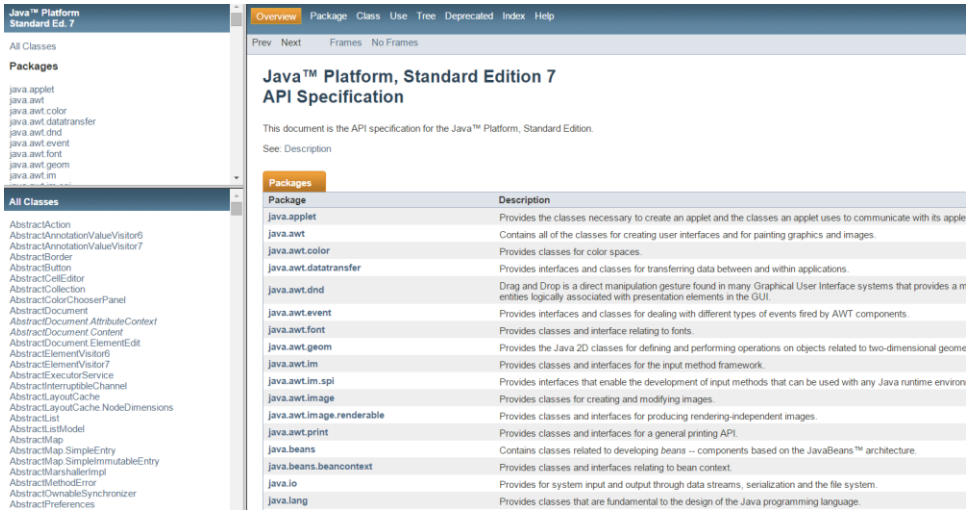
- **Of course you can bundle your own code in packages!**
- Use the `package` statement
- The package statement should be the first line in the source file
- There can be only one package statement in each source file
- If a package statement is not used in the class types go into the *default package*
- Name of package must match directory structure where bytecode resides

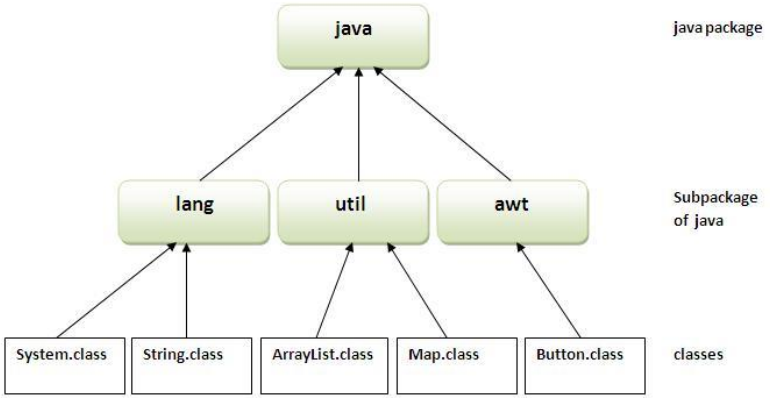
Excursus: Packages IV (Example)

```
// in the Rectangle.java file
package graphics;
public class Rectangle {
   // statements …
}
```

- Source file goes in a directory whose name reflects the name of the package
- *.....\graphics\Rectangle.java*
- **Qualified name** of package member and path name to the file are parallel
- Class name – `graphics.Rectangle`
- Pathname to file – `graphics\Rectangle.java`

Hundreds of packages and classes (Excerpt)



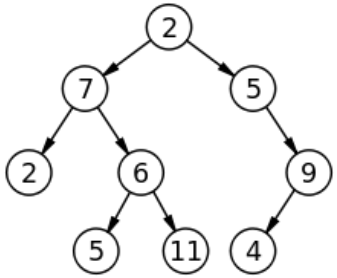


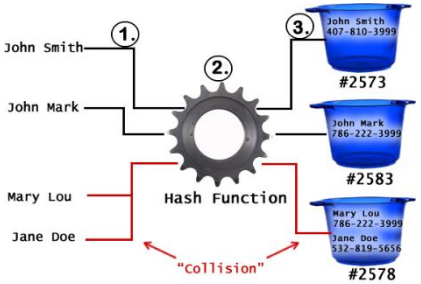
Thorough description: http://docs.oracle.com/javase/8/docs/api/

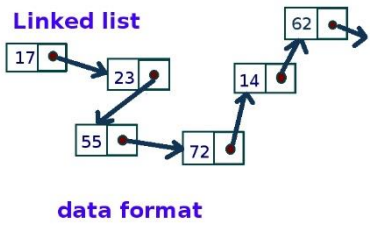
Data Structures

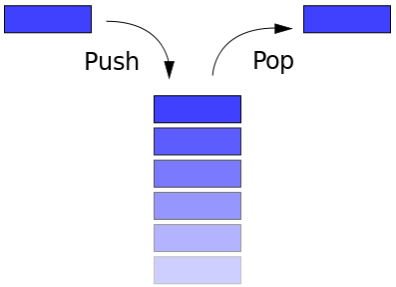
What are data structures?

- Informal: a container that provides storage for data items …
- and capabilities for storing and retrieving them.
- Examples: arrays, linked lists, trees, queues …







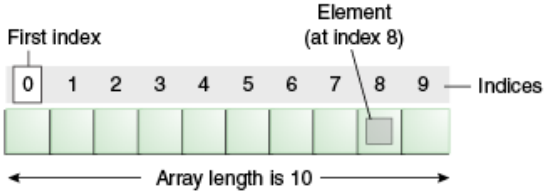


Data structures in Java

- **There are plenty of data structures in the Java API**
- We'll have a look on **array lists and maps**.

Recap: Arrays

- Arrays can hold multiple values (or *elements*)!
- Length is established upon creation, after that it's **fixed**!
- Access to elements via *index,* which starts with 0



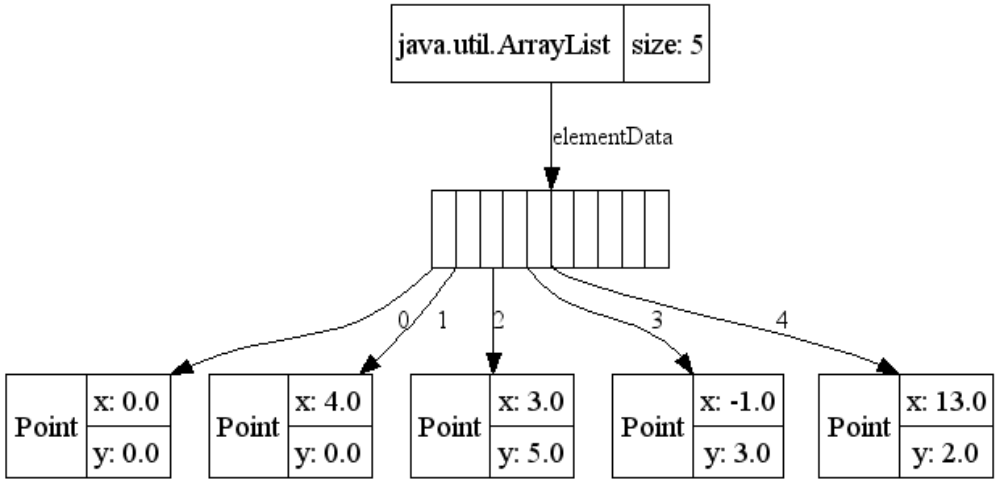
Example

```
public static void main(String[] args) {
        int[] ar = new int[3];
        ar[0] = 100;
        ar[1] = 200;
        ar[2] = 300;
        System.out.println("Array value on pos 1:" +ar[0]);
        System.out.println("Array value on pos 2:" +ar[1]);
        System.out.println("Array value on pos 3:" +ar[2]);
}
```

ArrayLists

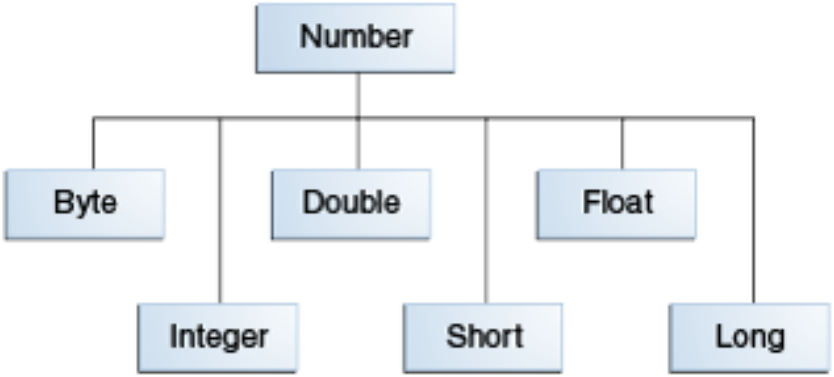
- Class `java.util.ArrayList`
- `ArrayList` class extends `AbstractList` and implements the `List` interface
- Are created with an initial size
- **Can hold objects** (e.g. class `Integer` or class `Point`)!
- **When this size is exceeded, the collection is automatically enlarged.**
- When objects are removed, the array may be shrunk.

Contrast to arrays!



Excursus: Wrapper Classes

- When working with numbers one can work with primitive types (e.g. `int`).
- There can be reasons to use objects in place of primitives
- Java provides *wrapper classes* for each of the primitive data types.
- Wrapping can be done by compiler (compiler *boxes* primitive in its wrapper class)
- Vice versa: if number object when a primitive is expected (compiler *unboxes*)
- Each wrapper class comes with methods, e.g. `Integer.parseInt("9")`



`ArrayList` Methods (Excerpt)

- **`void add(int index, Object element)`**
  Inserts the specified element at the specified position index in this list.

- **`void clear()`**
  Removes all of the elements from the ArrayList.

- **`int indexOf(Object o)`**
  Returns the index in this list of the first occurrence of the specified element, or -1 if the List does not contain this element.

- **`Object remove(int index)`**
  Removes the element at the specified position in this list.

- **`int size()`**
  Returns the number of elements in this list.

Example

```
import java.util.ArrayList;

public class Application {

   public static void main(String[] args) {

      // create new ArrayList to store rectangles
      ArrayList<Rectangle> rList = new ArrayList<>();

      // add three rectangle to list
      rList.add(new Rectangle(new Point2D(0,0), new Point2D(10,10)));
      rList.add(new Rectangle(new Point2D(5,3), new Point2D(6,7)));
      rList.add(new Rectangle(new Point2D(12,13),
         new Point2D(15,18)));

      // continue next slide
```

Example (cont'd)

```
        // get size and display.
        int count = rList.size();
        System.out.println("Number of rectangles: " + count);

        // loop through elements.
        for (int i = 0; i < rList.size(); i++) {
           double x1 = rList.get(i).getLowerLeft().getX();
           double x2 = rList.get(i).getUpperRight().getX();
           System.out.println("x-Range of rectangle " + i + " is "
              + (x2 - x1));
        }
    }
}
```

Maps

- Aka an *associative array*
- **It's a collection of (key, value) pairs**
- Each possible key appears just once in the collection
- Important operations are *add*, *remove* or *lookup*

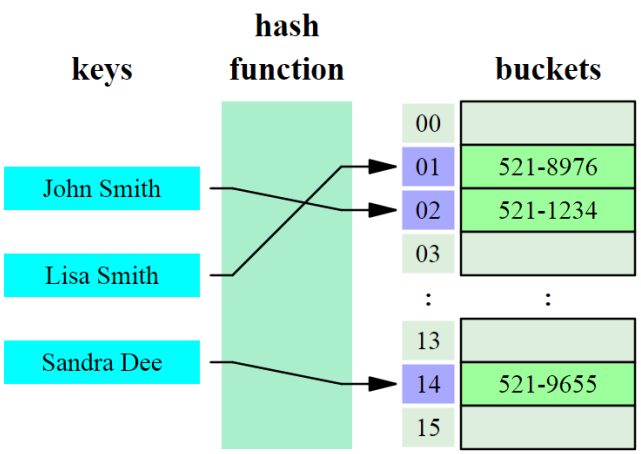
Aug →

KEYS	VALUES
Jan	327.2
Feb	368.2
Mar	197.6
Apr	178.4
May	100.0
Jun	69.9
Jul	32.3
Aug	37.3
Sep	19.0
Oct	37.0
Nov	73.2
Dec	110.9
Annual	1551.0

→ 37.3

Maps in Java

- In Java it's an **interface** called `Map` (`java.util.Map`)
- Map interface includes basic operations (e.g. `put`, `remove`, `containsKey` …)
- Bulk operations (`putAll` and `clear`)
- Collection views (e.g. `keySet` or `values`)
- Java contains three general-purpose implementations of the interface `Map` …
- **`HashMap`**, `TreeMap`, and `LinkedHashMap`.



Maps in Java (Example HashMap)

```
import java.util.HashMap;
public class Application {

   public static void main(String args[]) {

      // This is how to declare HashMap
      HashMap<Integer, String> hmap = new HashMap<Integer, String>();

      // Adding elements to HashMap
      hmap.put(12, "Tobias");
      hmap.put(2, "Christian");
      hmap.put(49, "Anna");
```

Maps in Java (Example HashMap)

```
        // Get values based on key
        String var= hmap.get(2);
        System.out.println("Value at key 2 is: " + var);

        hmap.remove(49);
        System.out.println("Value at key 49 is: " + hmap.get(49));
    }
}
```

Value at key 2 is: Christian
Value at key 49 is: null

Output

Thank you very much!