SWEN20003
Object Oriented Software Development

Exceptions

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The Road So Far

- Java Foundations
  - A Quick Tour of Java
- Object Oriented Programming Foundations
  - Classes and Objects
  - Arrays and Strings
  - Input and Output
  - *Software Tools and Bagel*
  - Inheritance and Polymorphism
  - Interfaces and Polymorphism
- Advanced Object Oriented Programming and Software Design
  - Modelling Classes and Relationships
  - Generics
  - Collections and Maps
  - Design Patterns

Lecture Objectives

After this lecture you will be able to:

- Understand what **exceptions** are
- Appropriately handle **exceptions** in Java
- Define and utilise **exceptions** in Java

Errors

It is common to make mistakes (errors) while developing as well as typing a program.

Such mistakes can be categorised as:

- Syntax errors
- Semantic errors
- Runtime errors

Errors

Keyword

Syntax: Errors where what you write isn't legal code; identified by the editor/compiler.

Keyword

Semantic: Code runs to completion, but results in *incorrect* output/operation; identified through software testing (coming soon).

Keyword

Runtime: An error that causes your program to end prematurely (crash and burn); identified through execution.

Common Runtime Errors

- Dividing a number by zero
- Accessing an element that is out of bounds of an array.
- Trying to store incompatible data elements.
- Using negative value as array size
- Trying to convert from string data to another type (e.g., converting string abc to integer value)
- File errors:
  - Opening a file in read mode that does not exist or no read permission
  - Opening a file in write/update mode which has read only permission
- Many more ...

Runtime Error - Example

```
1  class NoErrorHandling {
2      public static void main(String[] args){
3          int n1 = 1, n2 = 0;
4          System.out.println("The result is " + divide(n1, n2));
5          System.out.println("The program reached this line");
6      }
7      public static  int divide(int n1, int n2) {
8          return n1/n2;
9      }
10 }
```

What happens if `n2 == 0`?

```
1  Exception in thread "main" java.lang.ArithmeticException: ...
```

Solution 1: Do nothing and hope for the best. Obviously less than ideal.

Runtime Errors

How can we protect against the error?

```
1  public int divide(int n1, double n2) {
2      if (n2 != 0) {
3          return n1/n2;
4      } else {
5          ???
6      }
7  }
```

```
1  if (n2 != 0) {
2      divide(n1, n2);
3  } else {
4      // Print error message and exit or continue
5  }
```

Solution 2: Explicitly guard yourself against dangerous or invalid conditions, known as *defensive programming*.

Runtime Errors

What are some downsides of solution 2?

- Need to explicitly protect against every possible error condition
- Some conditions don't have a "backup" or alternate path, they're just failures
- Not very nice to read
- Poor abstraction (bloated code)

Runtime Errors

```
1   class WithExceptionHandling {
2       public static void main(String[] args){
3           int n1 = 1, n2 = 0;
4
5           try {
6               System.out.println("The result is " + divide(n1, n2));
7           } catch (ArithmeticException e) {
8               System.out.println("Cannot divide - n2 is zero");
9           }
10          System.out.println("The program reached this line");
11      }
12
13      public static int divide(int n1, int n2) {
14          return n1/n2;
15      }
16  }
```

Solution 3: Use exceptions to catch error states, then recover from them, or gracefully end the program.

Exceptions

Keyword

Exception: An *error state* created by a *runtime error* in your code; an exception.

Keyword

Exception: An object created by Java to *represent* the error that was encountered.

Keyword

Exception Handling: Code that actively protects your program in the case of exceptions.

Exception Handling

```
1  public void method(...) {
2      try {
3          <block of code to execute,
4                                  which may cause an exception>
5      } catch (<ExceptionClass> varName) {
6          <block of code to execute to recover from exception,
7                                  or end the program>
8      } finally {
9          <block of code that executes whether an exception
10                                 happened or not>
11     }
12 }
```

Exception Handling

Keyword

try: *Attempt* to execute some code that may result in an error state (exception).

Keyword

catch: Deal with the exception. This could be recovery (ask the user to input again, adjust an index) or failure (output an error message and exit).

Keyword

finally: Perform clean up (like closing files) assuming the code didn't exit.

Exception Handling

```
1   class WithExceptionCatchThrowFinally {
2       public static void main(String[] args){
3           int n1 = 1, n2 = 0;
4
5           try {
6               System.out.println("The result is " + divide(n1, n2));
7           } catch (ArithmeticException e) {
8               System.out.println("Cannot divide - n2 is zero");
9           } finally {
10              System.out.println("The program reached this line");
11          }
12      }
13
14      public static int divide(int n1, int n2) {
15          return n1/n2;
16      }
17  }
```

Exception Handling - Chaining Exceptions

```
1  public void processFile(String filename) {
2      try {
3          ...
4      } catch (FileNotFoundException e) {
5          e.printStackTrace();
6      } catch (IOException e) {
7          e.printStackTrace();
8      }
9  }
```

We can also *chain* catch blocks to deal with different exceptions *separately*. The most "specific" exception (subclasses) come first, with "broader" exceptions (superclasses) listed lower.

Assess Yourself

Write a method that has the potential to create an `ArithmeticException` and an `ArrayIndexOutOfBoundException`, and implement appropriate exception handling for these cases.

Assess Yourself

```
1   public class AverageDifference {
2     public static void main(String[] args) {
3       int[] n1 = {1, 2, 3};
4       int[] n2 = {2, 3, 4};
5
6       try {
7         System.out.println("Answer = " + averageDifference(n1, n2));
8       } catch (ArithmeticException e) {
9         System.out.println("Caught an arithmetic exception");
10      } catch (ArrayIndexOutOfBoundsException e) {
11        System.out.println("Caught an index exception");
12      }
13    }
14
15    public static int averageDifference(int n1[], int n2[]) {
16      int sumDifference = 0;
17      for (int i = 0; i < n1.length; i++) {
18         sumDifference += n1[i] - n2[i];
19      }
20      return sumDifference/n1.length;
21    }
22  }
```

Generating Exceptions

Keyword

throw: Respond to an error state by creating an exception object, either already existing or one defined by you.

Keyword

throws: Indicates a method has the potential to create an exception, and can't be bothered to deal with it, or that the exact response varies by application.

Assess Yourself

Write a method that has the potential to create a `NullPointerException`, and throws an exception if its argument is null.

```
1   public class Person {
2       private String name;
3       private int age;
4
5       public Person(int age, String name) {
6           if (name == null) {
7               throw new NullPointerException("Creating person with null name");
8           }
9           this.age = age;
10          this.name = name;
11      }
12
13      public static void main(String[] args) {
14          Person p1 = new Person(10, "Sarah");
15          System.out.println("Created object p1");
16          Person p2 = new Person(12, null);
17          System.out.println("Created object p2");
18      }
19  }
```

Assess Yourself

Can we improve the previous program so that it does not die on the exception (exit gracefully)?

```
1   public class PersonWithExcpHandling {
2       private String name;
3       private int age;
4       public PersonWithExcpHandling(int age, String name) {
5           if (name == null) {
6               throw new NullPointerException("Creating person with null name");
7           }
8           this.age = age;
9           this.name = name;
10      }
11      public static void main(String[] args) {
12          try {
13              Person p1 = new Person(10, "Sarah");
14              System.out.println("Created object p1");
15              Person p2 = new Person(12, null);
16              System.out.println("Created object p2");
17          } catch(NullPointerException e) {
18              System.out.println("Failed to create object");
19          }
20      }
21  }
```

Defining Exceptions

What if we discover a new "type" of problem?

We can define our own exceptions!

- Exceptions are classes!
- Most exceptions inherit from an `Exception` class
- All exceptions should have two constructors, but we can add whatever else we like

Defining Exceptions

Write a class `Circle`, which has attributes centre and radius, initialized at creation. Your must ensure that the radius is greater than zero.

Defining Exceptions

Step 1: Write the exception class.

```
1  import java.lang.Exception;
2
3  public class InvalidRadiusException extends Exception {
4      public InvalidRadiusException() {
5          super("Radius is not valid");
6      }
7
8      public InvalidRadiusException(double radius){
9          super("Radius [" +  radius + "] is not valid");
10     }
11 }
```

Defining Exceptions - Throwing

Step 2: Write the Circle class.

```
1  public class Circle {
2      private double centreX, centreY;
3      private double radius;
4
5      public Circle (double centreX, double centreY, double radius)
6              throws InvalidRadiusException {
7          if (r <= 0 ) {
8              throw new InvalidRadiusException(radius);
9          }
10         this.centreX = centreX;
11         this.centreY = centreY;
12         this.radius = radius;
13     }
14 }
```

Defining Exceptions - Handling

Step 3: Test your class.

```
1  public class TestCircle {
2      public static void main(String[] args)  {
3          try {
4              Circle c1 = new Circle(10, 10, 100);
5              System.out.println("Circle 1 created");
6
7              Circle c2 = new Circle(10, 10, -1);
8              System.out.println("Circle 2 created");
9          } catch(InvalidRadiusException e) {
10             System.out.println(e.getMessage());
11         }
12     }
13 }
```

```
1  "Circle 1 created"
2  "Radius [-1] is not valid"
```

Defining Exceptions - Handling

Following is another way you handle the exception, but it is better to handle specific exceptions!

```
1  public class TestCircle5 {
2      public static void main(String[] args)  {
3          try{
4              Circle c1 = new Circle(10, 10, 100);
5              System.out.println("Circle 1 created");
6              Circle c2 = new Circle(10, 10, -1);
7              System.out.println("Circle 2 created");
8          } catch(Exception e) {
9              System.out.println(e.getMessage());
10         }
11     }
12 }
```

```
1  "Circle 1 created"
2  "Radius [-1] is not valid"
```

Defining Exceptions - Handling

A better way to do this is:

```
1  public class TestCircle6 {
2      public static void main(String[] args)  {
3          try{
4              Circle c1 = new Circle(10, 10, 100);
5              System.out.println("Circle 1 created");
6              Circle c2 = new Circle(10, 10, -1);
7              System.out.println("Circle 2 created");
8          } catch(InvalidRadiusException e) {
9              System.out.println(e.getMessage() + " error 1");
10         } catch(Exception e) {
11             System.out.println(e.getMessage() + " error 2");
12         }
13     }
14 }
```

```
1  "Circle 1 created"
2  "Radius [-1] is not valid error 1"
```

Types of Exceptions

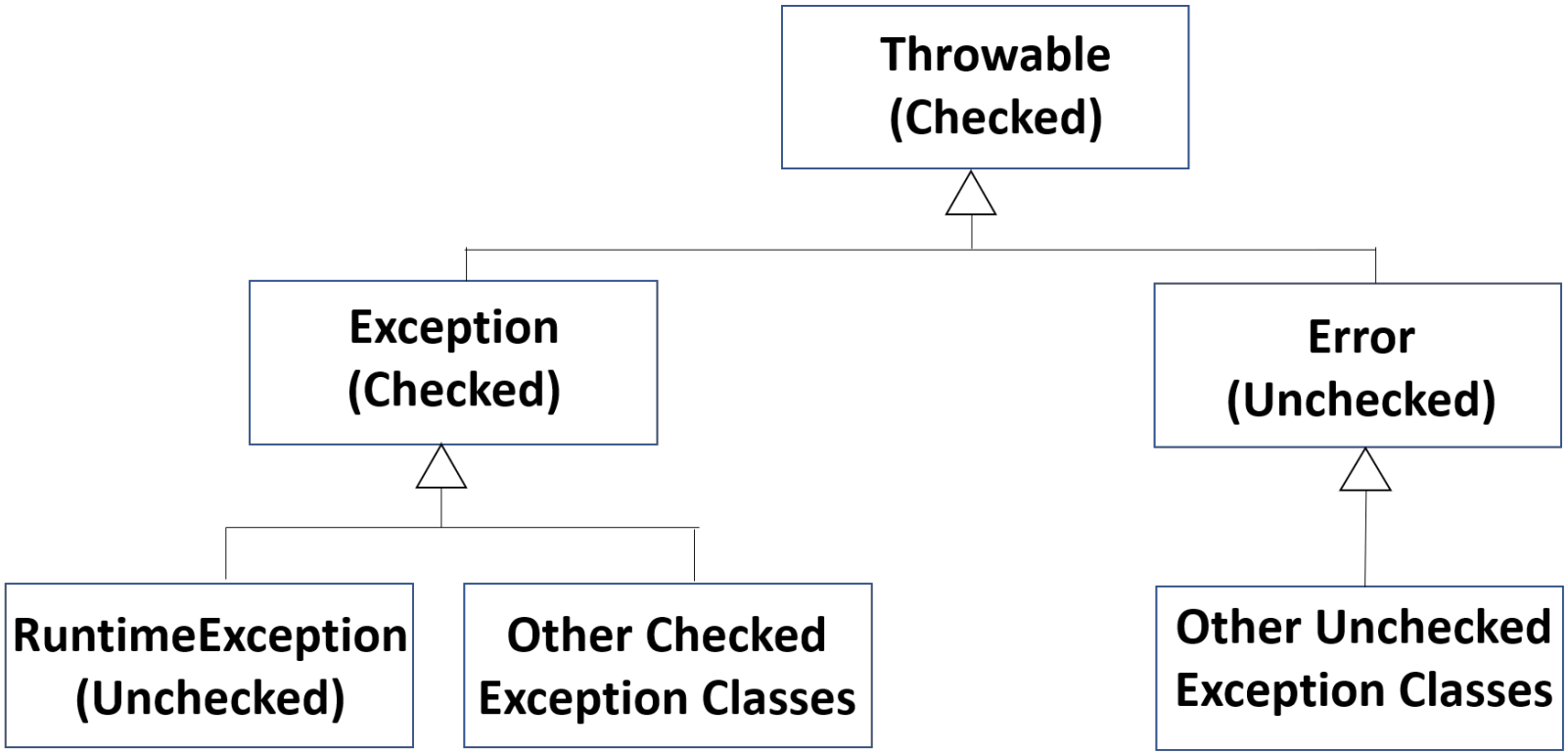
Keyword

Unchecked: Can be safely ignored by the programmer; most (inbuilt) Java exceptions are *unchecked*, because you aren't forced to protect against them.

Keyword

Checked: Must be explicitly handled by the programmer in some way; the compiler gives an error if a checked exception is ignored.

Checked and Unchecked Exceptions



Exception Handling

Catch or Declare

- All checked exceptions must be handled by
  - Enclosing code that can generate exceptions in a try-catch block
  - Declaring that a method may create an exception using the `throws` clause
- Both techniques can be used in the same method, for different exceptions

Using Exceptions

- Should be reserved for when a method encounters an *unusual* or *unexpected* case that cannot be handled easily in some other way

Try With

```
1  public void processFile(String filename) {
2      try (BufferedReader reader = ...) {
3          ...
4      } catch (FileNotFoundException e) {
5          e.printStackTrace();
6      } catch (IOException e) {
7          e.printStackTrace();
8      }
9  }
```

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