CS2030 Lecture 6

SOLID Principles
Packaging and Exception Handling

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Outline and Learning Outcome

- Understand the **SOLID principles** and their application in the design of object-oriented software
- Be able to create packages and use the appropriate access modifiers
- Be able to employ exception handling to deal with "exceptional" events
  - Understand the use of `try–catch–finally` clauses
  - Able to distinguish the different types of exceptions
  - Able to appreciate exception control flow

SOLID Principles in OO Design

- **Single responsibility principle**:

  a class should have only one reason to change

  — *Robert C. Martin (Uncle Bob)*

- **Liskov substitution principle**:

  Let $\phi(x)$ be a property provable about objects x of type T. Then $\phi(y)$ should be true for objects y of type S where S is a subtype of T.

  — *Barbara Liskov*

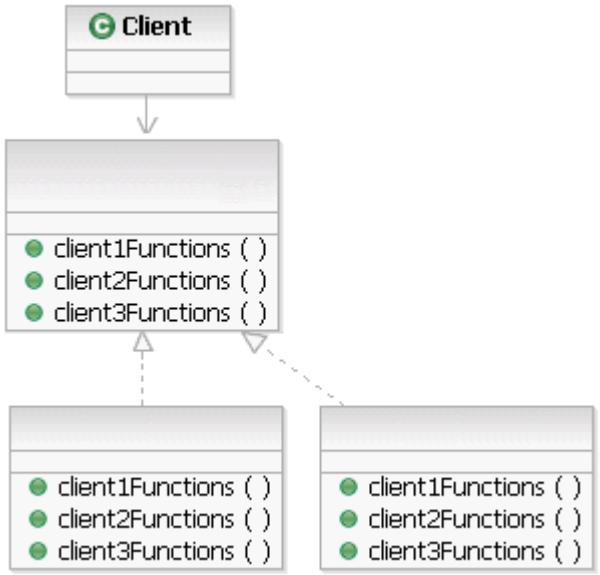
  - If S is a *subtype* of T (denoted `S <: T`), then an object of type T can be replaced by that of type S *without changing the desirable property* of the program

SOLID Principles in OO Design

- **Open–closed principle**:

  classes should be *open for extension, but closed for modification* — *Bertrand Meyer*

```
jshell> class A { void foo() { } }
|  created class A

jshell> void client(A a) { a.foo(); }
|  created method client(A)

jshell> client(new A())

jshell> class B extends A { }
|  created class B

jshell> class C extends A { @Override void foo() { } }
|  created class C

jshell> class D extends B { @Override void foo() { } }
|  created class D

jshell> client(new B()) // client does not need modification

jshell> client(new C()) // C:foo() invoked

jshell> client(new D()) // D:foo() invoked
```



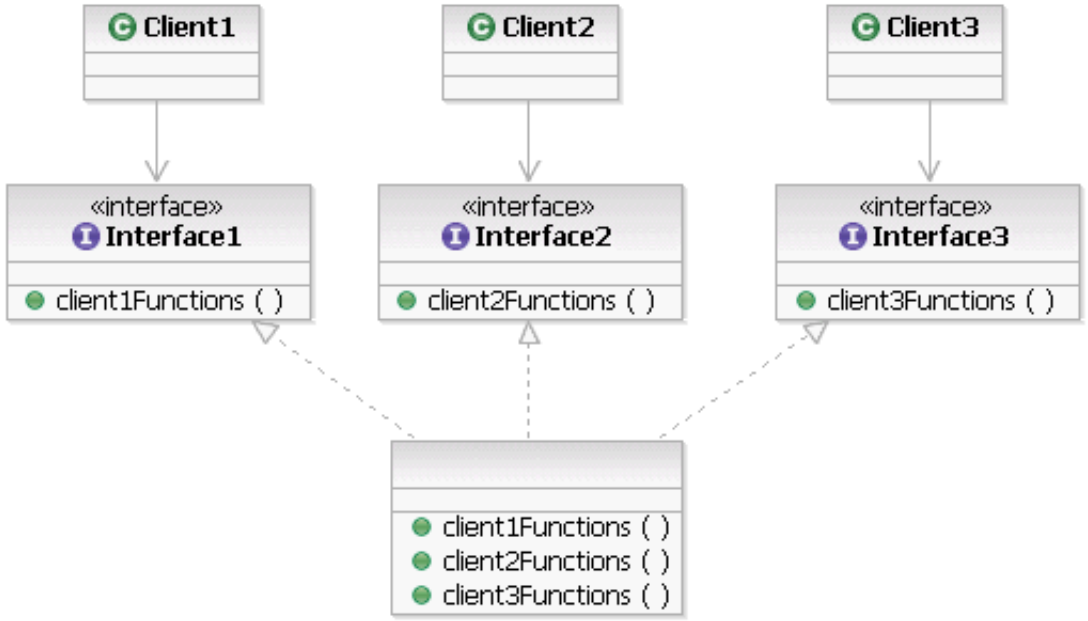
SOLID Principles in OO Design

- **Interface segregation principle**:

  no client should be forced to depend on methods it does not use.

  — *Uncle Bob*

```
jshell> Circle circle = new Circle(1)
circle ==> Circle with radius 1

jshell> void client1(Shape s) {
   ...>     s.getArea();
   ...> }
|  created method client1(Shape)

jshell> void client2(Scalable k) {
   ...>     k.scale(2);
   ...> }
|  created method client2(Scalable)

jshell> client1(circle)

jshell> client2(circle)

jshell> void client3(Scalable k) {
   ...>     k.getArea(); // ???
   ...> }
```



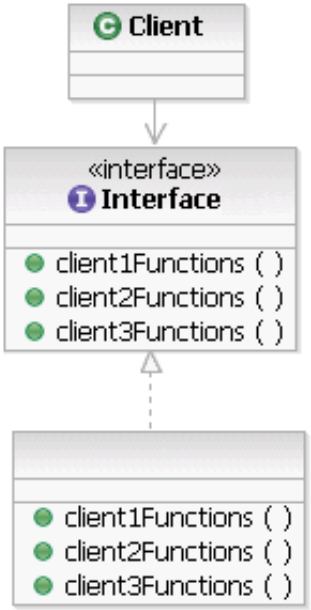
SOLID Principles in OO Design

- **Dependency inversion principle**:

  Program to an interface, not an implementation.

  — *GoF*

```
jshell> /list Shape

   1 : interface Shape { // Shape is the contract
           double getArea();
       }
jshell> Shape s = new Circle(1)
s ==> Area 3.14 and perimeter 6.28

jshell> class Circle implements Shape { // Circle follows contract specs
   ...>    private final int radius;
   ...>    public double getArea() {
   ...>       return Math.PI * this.radius * this.radius;
   ...>    }
   ...> }
|  created class Circle

jshell> void client(Shape s) { // client codes according to contract
   ...>     double area = s.getArea();
   ...> }
|  created method client(Shape)

jshell> client(circle)
```



Creating Packages

- Include the **`package`** statement at the top of all source files that reside within the package, e.g.

  ```
  package cs2030.test;
  ```

- Include the **`import`** statement to source files outside the package, e.g.

  ```
  import cs2030.test.SomeClass;
  ```

- Compile the Java files using

  ```
  $ javac -d . *.java
  ```

- `cs2030/test` directory created with same-package class files stored within

Most Restrictive ⟷ Least Restrictive

Access Modifiers ->	private	Default/no-access	protected	public
Inside class	Y	Y	Y	Y
Same Package Class	N	Y	Y	Y
Same Package Sub-Class	N	Y	Y	Y
Other Package Class	N	N	N	Y
Other Package Sub-Class	N	N	Y	Y

Access Modifiers and Their Accessibility

```
==> Base.java <==
package cs2030.test;
public class Base {
    private void foo() { } // -
    protected void bar() { } // #
    void baz() { } // ~
    public void qux() { } // +
    private void test() {
        this.foo();
        this.bar();
        this.baz();
        this.qux();
    }

==> InsidePackageClient.java <==
package cs2030.test;
class InsidePackageClient {
    private void test() {
        Base b = new Base();
        b.bar();
        b.baz();
        b.qux();
    }
}
```

```
==> InsidePackageSubClass.java <==
package cs2030.test;
class InsidePackageSubClass extends Base {
    private void test() {
        super.bar();
        super.baz();
        super.qux();
    }
}

==> OutsidePackageClient.java <==
import cs2030.test.Base;
class OutsidePackageClient {
    private void test() {
        Base b = new Base();
        b.qux();
    }
}

==> OutsidePackageSubClass.java <==
import cs2030.test.Base;
class OutsidePackageSubClass extends Base {
    private void test() {
        super.bar();
        super.qux();
    }
}
```

Preventing Inheritance and Overriding

- The **final** keyword can be applied to methods or classes
  - Use the **final** keyword to explicitly prevent inheritance

```
final class Circle {
    :
}
```

  - To allow inheritance but prevent overriding

```
class Circle implements Shape {
    :
    @Override
    final double getArea() {
        :
    }
    :
    @Override
    final double getPerimeter() {
        :
    }
}
```

Error Handling

- Use exceptions to track reasons for program failure, e.g.

```
public static void main(String[] args) {
    FileReader file = new FileReader(args[0]);
    Scanner sc = new Scanner(file);
    List<Point> points = new ArrayList<Point>();
    while (sc.hasNext()) {
        points.add(new Point(sc.nextDouble(), sc.nextDouble()));
    }
    DiscCoverage maxCoverage = new DiscCoverage(points);
    System.out.println(maxCoverage);
}
```

  - Filename missing or misspelt
  - The file contains a non-numerical value
  - The file provided contains insufficient numerical values

- Compiling the above gives the following compilation error:

```
Main1.java:12: error: unreported exception FileNotFoundException;
must be caught or declared to be thrown
        FileReader file = new FileReader(args[0]);
                          ^
```

Handling Exceptions

- Method #1: **throws** the exception out of the method

```
public static void main(String[] args) throws FileNotFoundException {
```

- Method #2: **handle** the exception within the method

```
try {
    FileReader file = new FileReader(args[0]);
    Scanner sc = new Scanner(file);
    List<Point> points = new ArrayList<Point>();
    while (sc.hasNext()) {
        points.add(new Point(sc.nextDouble(), sc.nextDouble()));
    }
    DiscCoverage maxCoverage = new DiscCoverage(points);
    System.out.println(maxCoverage);
} catch (FileNotFoundException ex) {
    System.err.println("Unable to open file " + args[0] + "\n" + ex);
}
```

  - **try** block encompasses the business logic
  - **catch** block encompasses exception handling logic

Catching Multiple Exceptions

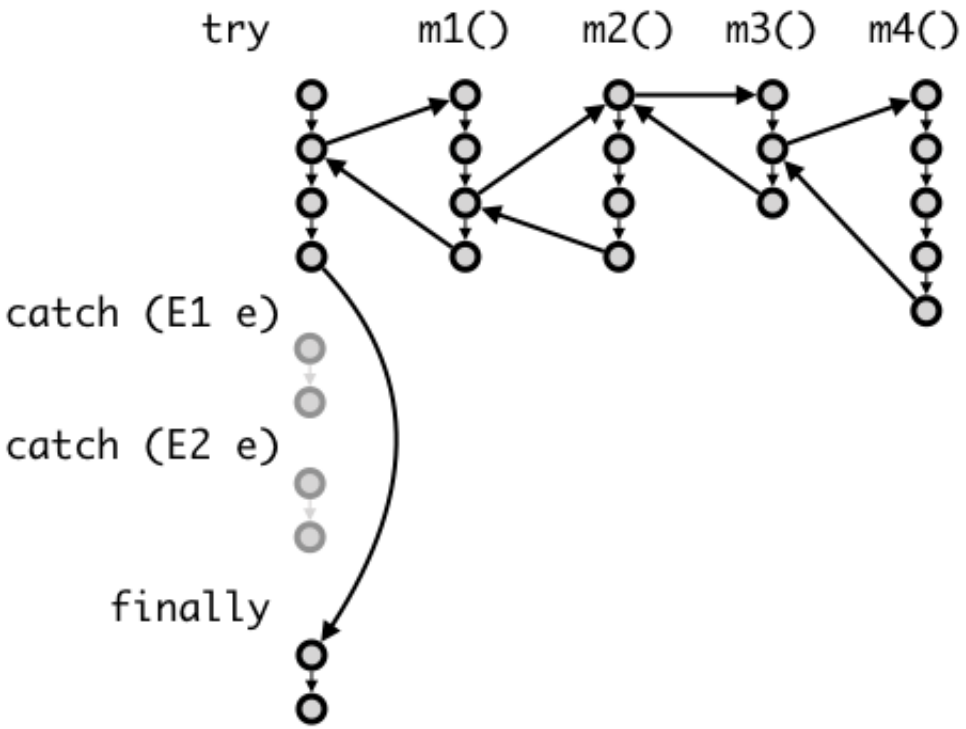
- Multiple catch blocks ordered by *most specific exceptions first*

```
try {
    FileReader file = new FileReader(args[0]);
    Scanner sc = new Scanner(file);
    List<Point> points = new ArrayList<Point>();
    while (sc.hasNext()) {
        points.add(new Point(sc.nextDouble(), sc.nextDouble()));
    }
    DiscCoverage maxCoverage = new DiscCoverage(points);
    System.out.println(maxCoverage);
} catch (FileNotFoundException ex) {
    System.err.println("Unable to open file " + args[0] + "\n" + ex);
} catch (ArrayIndexOutOfBoundsException ex) {
    System.err.println("Missing filename");
} catch (NoSuchElementException ex) { // includes InputMismatchException
    System.err.println("Incorrect file format\n");
} finally {
    System.out.println("Program Terminated\n");
}
```

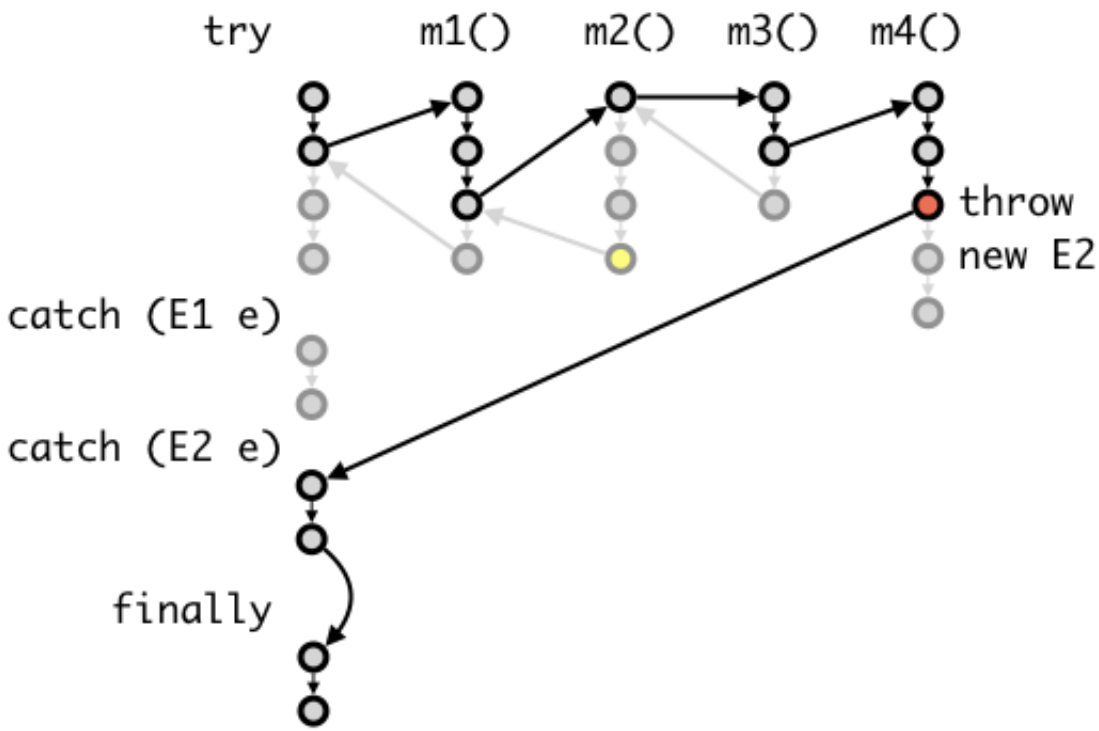
- Optional **`finally`** block used for house-keeping tasks
- Multiple exceptions (no sub-classing) in a single catch using `|`

Normal vs Exception Control Flow

- E.g. **`try`–`catch`–`finally`** block (`m1` is called, `m1` calls `m2`, `m2` calls `m3`, `m3` calls `m4`), and catching two exceptions `E1`, `E2`



Normal Control Flow



Exception Control Flow

Throwing an Exception

- An exception can be created and thrown using **throw**

```
Circle createUnitCircle(Point p, Point q) {
    double distPQ = p.distanceTo(q);
    if (distPQ < EPSILON || distPQ > 2.0 + EPSILON) {
        throw new IllegalArgumentException("Distance pq not within (0, 2]");
    }
    ...
    return new Circle(...);
}
```

- Creating a user defined exception to be thrown

```
class IllegalCircleException extends IllegalArgumentException {
    IllegalCircleException(String message) {
        super(message);
    }
    @Override
    public String toString() {
        return "IllegalCircleException:" + getMessage();
    }
}
```

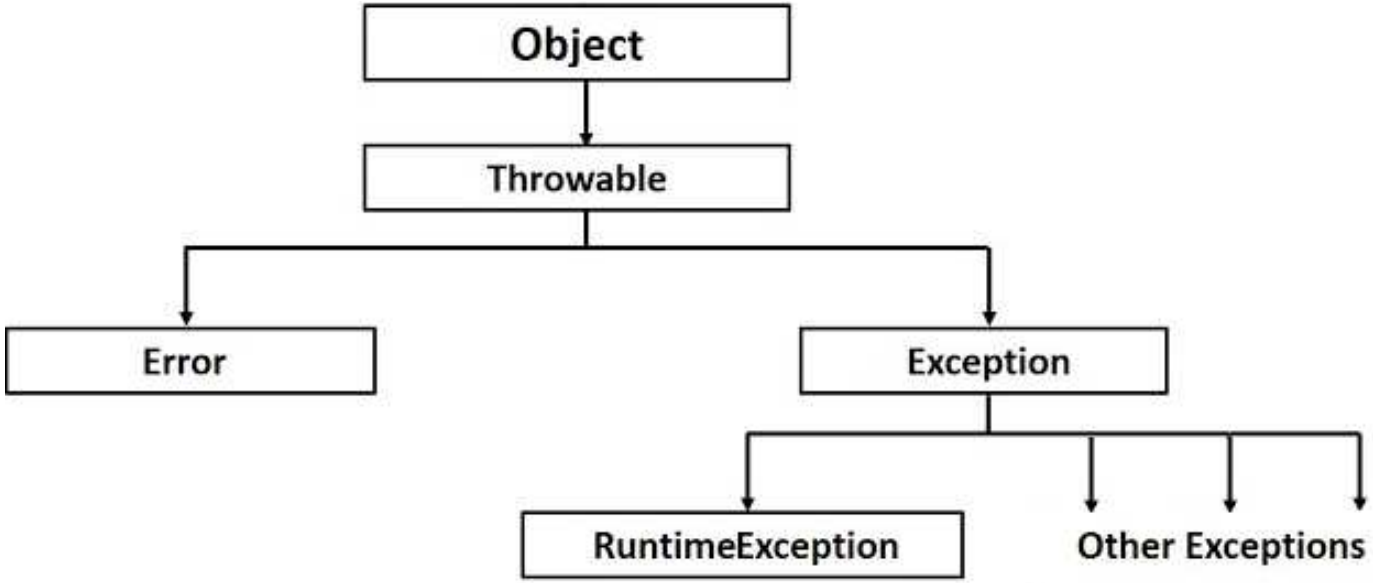
- Only create your own exceptions if there is a good reason to do so, else just find one that suits your needs

Types of Exceptions

- There are two types of exceptions:
  - A **checked exception** is one that the programmer is expected to actively anticipate and handle
    - all checked exceptions should be caught (`catch`) or propagated (`throw`)
    - e.g. when opening a file, `FileNotFoundException` should be explicitly handled
  - An **unchecked exception** is one that is unanticipated, usually the result of a bug in the program
    - e.g. `ArithmeticException` surfaces when trying to divide by zero

Exception Hierarchy

- Unchecked exceptions are sub-classes of `RuntimeException`



- When overriding a method that throws a checked exception, the overriding method cannot throw a more general exception
- Avoid *Pokemon Exception Handling*, `catch (Exception ex)`
- Handle exceptions at the appropriate abstraction level, do not just throw and break the abstraction barrier