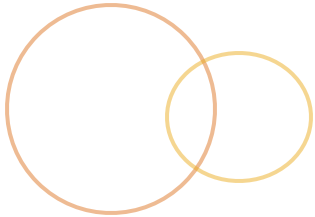
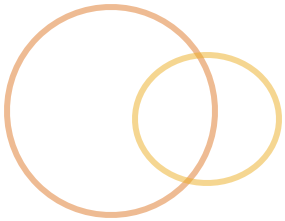
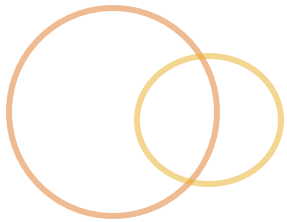
Introduction to Reflection





Presentation Topics



In this presentation, we will cover:

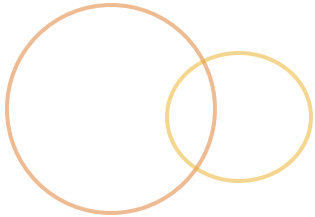
- What is Reflection?
- Working with the Reflection API
- Advanced Reflection

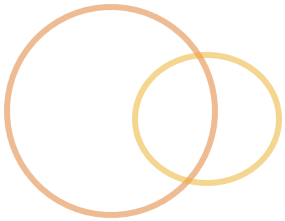
Objectives

When we are done, you should be able to:

- Define reflection
- Describe how reflection is implemented in Java
- Use reflection to perform dynamic discovery
- Use reflection to perform dynamic invocation
- Create a basic Java Reflection Example

What is Reflection?





What is Reflection? [part 1]

- "Process by which a computer program can be modified in the process of execution"
- Process typically referred to as *reflective programming*

What is Reflection? [part 2]

- API - Provides run-time information discovery for classes, fields, methods, and constructors for objects loaded into the VM
- Introduced in 1.1
- Released in concert with JavaBeans and Remote Method Invocation
- Updated to support new language features
- Performance enhancements made in 1.4

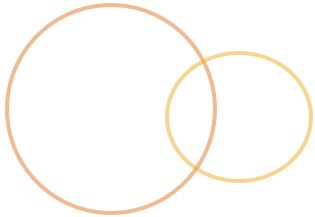
Motivations for using Reflection

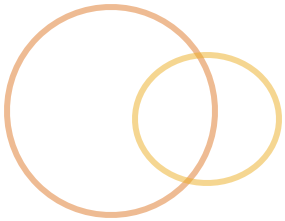
- Delegate decisions to run-time instead of compile-time
  - Instantiation of objects
  - Discovery of object's capabilities
  - Modification of capabilities
- Provides more decoupled source-code

Platform Support for Reflection

- Fundamental support provided by JVM
- Utilizes dynamic binding
  - Known as dynamic class loading
  - Provided through `ClassLoaders`
  - “Translates” .class files into `Class` objects
- Supported by two packages
  - `java.lang`
  - `java.lang.reflect`

Working with the Reflection API





Working with the Reflection API

- `Class` object is the starting point
- Accessed through `Class` literal
  - `Class clazz = Math.class;`
  - Abides by platform security rules
- Multiple ways to get `Class` object
  - Use dynamic class loading -

```
Class clazz =
Class.forName("java.lang.String");
```

  - Get class from an object -

```
String s = "Hello";
Class clazz = s.getClass();
```

- Once `Class` object is located; can start dynamic discovery process

Dynamic Class loading Example

```
1  package examples.reflection;
2
3  /**...*/
11 public class DynamicClassLoadingExample {
12
13   public static void main(String[] args) {
14     if(args.length == 0) {
15       System.out.println("Please specify a classname");
16       System.exit(0);
17     }
18
19     Class clazz = null;
20     try {
21       clazz = getClasss(args[0]);
22       System.out.println("Class name: " + clazz.getName());
23       System.out.println("Class simple name: " + clazz.getSimpleName());
24     } catch (ClassNotFoundException e) {
25       e.printStackTrace();
26       System.out.println("Could not load: " + args[0]);
27     }
28   }
29
30   private static Class getClasss(String className) throws ClassNotFoundException {
31     Class returnValue = null;
32     returnValue = Class.forName(className);
33     return returnValue;
34   }
35 }
36
```

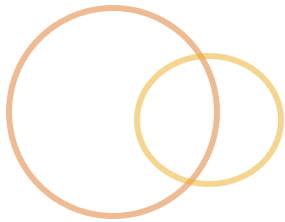
Discovery Class Type-Information

- Can be used to find information about the class
  - `Package` – supports further reflection
  - Modifiers
  - Name – simple or canonical
  - Hierarchy – supports further reflection
    - `getSuperclass : Class`
    - `getInterfaces : Class []`
- Can be used to find annotations

Discovery Class Contents

- Can be used to find contents of class
  - `Field` – named, public, or entire set
  - `Constructor` – named, typed, public, or entire set
  - `Method` – named and typed, public, or entire set
- All contents are considered `AccessibleObject`

Further Discovery



- Most discovered entities support further reflection
- Primitives are handled in special way
  - Denoted by wrapper class
  - Can test to determine if field is primitive
- Included support for
  - Generics
  - Enumerations

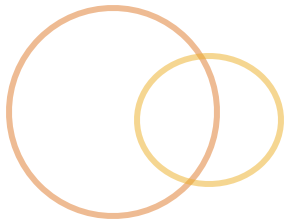
Basic Discovery Example

```
1  package examples.reflection;
2
3  import java.lang.reflect.Modifier;
4
5  /**...*/
9  public class BasicDiscoveryExample {
10
11     public static void main(String[] args) {
12       if (args.length == 0) {
13         System.out.println("Please specify a classname");
14         System.exit(0);
15       }
16
17       try {
18         //get the class
19         Class clazz = getClasss(args[0]);
20         //some class information
21         printBasicClassInfo(clazz);
22       } catch (ClassNotFoundException e) {
23         e.printStackTrace();
24         System.out.println("Could not load: " + args[0]);
25       }
26     }
27
28     private static Class getClasss(String className)
29                         throws ClassNotFoundException {...}
```

Basic Discovery Example [cont.]

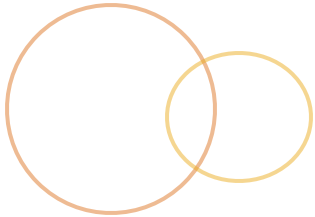
```
40    /**...*/
51    private static void printBasicClassInfo(Class clazz) {
52      Package containPkg = clazz.getPackage();
53      String className = clazz.getSimpleName();
54      boolean isInterface = clazz.isInterface();
55      boolean isEnum = clazz.isEnum();
56      String typeStructure = (isInterface ? "interface" :
57                              (isEnum ? "enumeration" : "class"));
58
59      String modifiers = Modifier.toString(clazz.getModifiers());
60      String pkgName = containPkg.getName();
61
62      System.out.println("Class simple name: " + className);
63      System.out.println(className + " is a " + typeStructure);
64      System.out.println(className + " is considered " + modifiers);
65      System.out.println(className + " belongs to " + pkgName);
66
67      //parent class
68      Class parent = clazz.getSuperclass();
69      if(parent != null) {
70        System.out.println(className + "'s parent : " + parent.getName());
71        System.out.println("\nParent information");
72        printBasicClassInfo(parent);
73      }
74
75    }
76
77  }
```

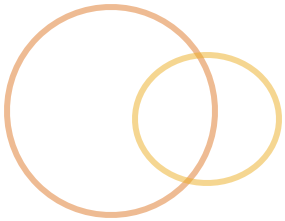
Reflection Lab 1



- **Description**: Use `BasicDiscoveryExample` as your starting point. Convert `BasicDiscoveryExample` into a replacement for the JDK command-line utility `javap`. `javap` provides a source-code like view of a class, showing class structure, fields, and methods. See `instructions.txt` for more details.
- **Duration**: 30 minutes

Advanced Reflection





What is Reflection? [part 3]

- API - Provides run-time invocation and modification on discovered fields, constructors, and methods
- Reflection is not just about discovery; also about execution

Run-time Modification Using Reflection

- `Class` object is still starting point
- Dynamically discover fields, constructors, or methods
- Perform appropriate invocation

Instantiation Using Reflection

- May need to convert `Class` object into `Object` object
- Two reflection based mechanisms
  - `newInstance` method on every `Class` object
    - Functions like new operator
    - Relies on public no-argument constructor
  - `newInstance` method on `Constructor` object
    - Discover `Constructor` from class
    - Functions like `new` operator
    - Relies on argument list associated with specific `Constructor` object
- Be sure to handle exceptions

Field Modification Using Reflection

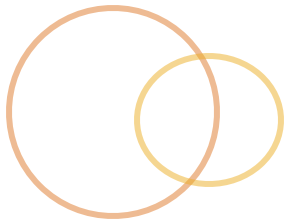
- Field modification requires an object instance
  - Could be `Class` object (static)
  - Or an `Object` object (instance)
- Object can be result of run-time instantiation, but not required
  - Discover `Field` from `Class`
  - Get / set `Field` using `Field`, `Object` instance, and field value
    - `public void set(Object instance, Object value)`
    - `public Object get(Object instance)`
    - `public void setInt(Object instance, int value)`
    - `public int getInt(Object instance)`

Method Invocation Using Reflection

- Method invocation requires an object instance
  - Could be `Class` object (static method)
  - Or an `Object` object (instance method)
- `Object` can be result of run-time instantiation
  - Discover method from `Class`
  - Invoke method using `Method`, `Object` instance, and method args

```
public Object invoke(Object instance, Object… args)
```

Run-time Example



```
1   package examples.reflection;
2
3   import java.lang.reflect.Method;
4   /**...*/
8   public class RuntimeInvocationExample {
9
10    public static void main(String[] args) {
11      if (args.length == 0) {
12        System.out.println("Please specify a classname");
13        System.exit(0);
14      }
15
16      try {
17        //get the class
18        Class clazz = getClasss(args[0]);
19        String className = clazz.getSimpleName();
20        //create the instance
```

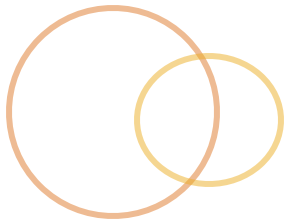
Run-time Example [cont.]

```
20          //create the instance
21          Object clazzInstance = clazz.newInstance();
22          //find the toString method
23          Method toString = clazz.getMethod("toString", null);
24          //invoke the method
25          Object result = toString.invoke(clazzInstance, null);
26          //print the results
27          System.out.println(className + ".toString result: " + result);
28        } catch(Exception e) {
29          e.printStackTrace();
30          System.out.println("Could not load: " + args[0]);
31        }
32    }
33
34    private static Class getClasss(String className)
35                            throws ClassNotFoundException {...}
40  }
```

Reflection best-practices

- At one point, goal was to use sparingly
- Things have changed
  - Significant performance improvements have helped
- Consider using Reflection to implement design patterns
- Make sure Security Manager is configured to support reflection

Reflection Lab 2



- **Description**: Use `RuntimeInvocationExample` as a starting point.The current `RunTimeInvocationExample` uses the `newInstance` method to create an instance of a class. In certain cases, this is fine. However, most classes have constructors that take arguments for their object initialization. Expand `RuntimeInvocationExample` to support constructor-based object instantiation for the primitive wrapper classes and `String`. See `instructions.txt` for more information.
- **Duration**: 30 minutes

Reflection Lab [Optional]

- **Description**: Create a basic unit-test framework using the Reflection API. The unit-test framework, UnitTester should dynamically load a class passed as a command line argument. Once the class is loaded, the UnitTester should inquirer the class for its test methods. All test methods should begin with the word test and should not take any arguments. They should return either a true or false. Test methods can generate exceptions if need be. The UnitTester should test static methods first and then proceed to instance methods. The UnitTester should keep track of the methods that passed (true), failed (false), or error (exception). Once all the methods have been tested, the UnitTester should generate a test report.
- **Duration**: 30 minutes.