INTERFACES
EXCEPTION HANDLING

18TH LECTURE

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Outline

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  - “Multiple Inheritance” in Java
  - Java “Multiple Inheritance”
- **Error Handling with Exceptions**
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  - What’s an exception?
  - Basic Exception / Catching an Exception
  - The Exception Specification
  - Creating your own exceptions
  - Catching any Exception
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  - Catching Base-Class Constructor Exceptions
  - “Inheritance” of Exceptions
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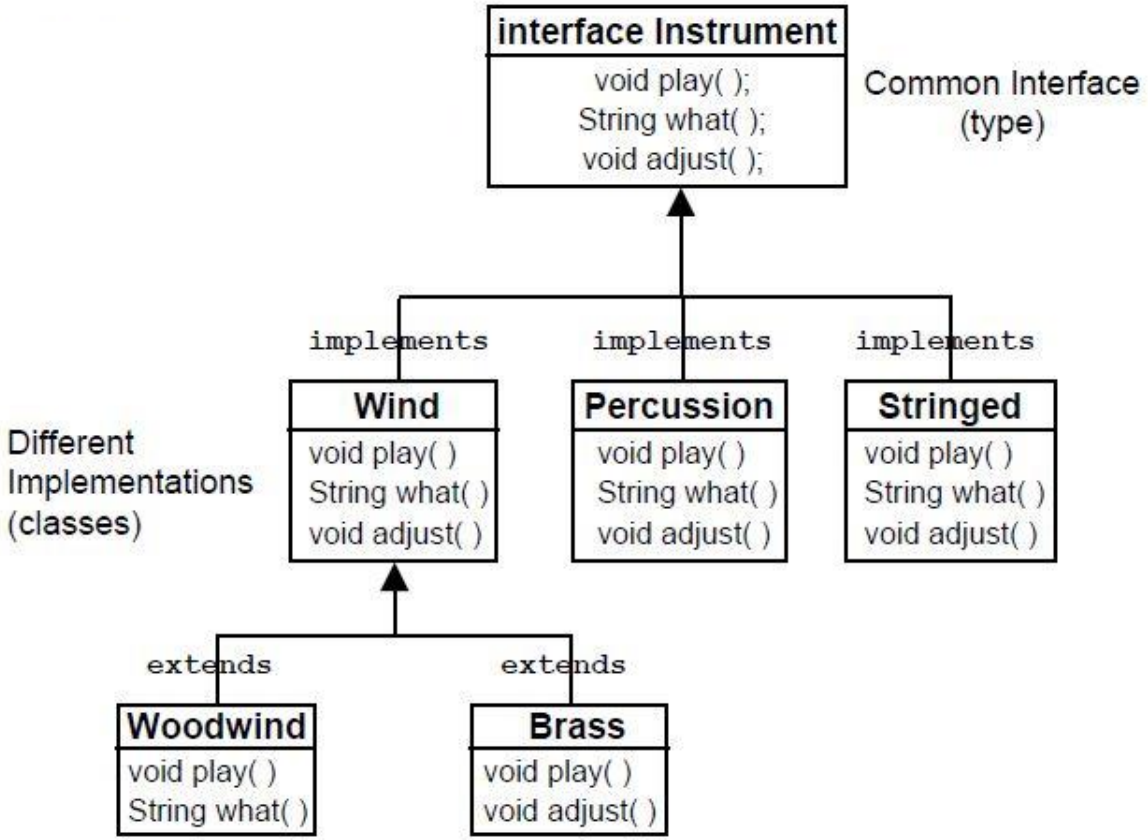
Interfaces

- Can't have any fields or method definitions



An Instrument interface

- No “concrete” elements in interface
- You don’t extend, you implement

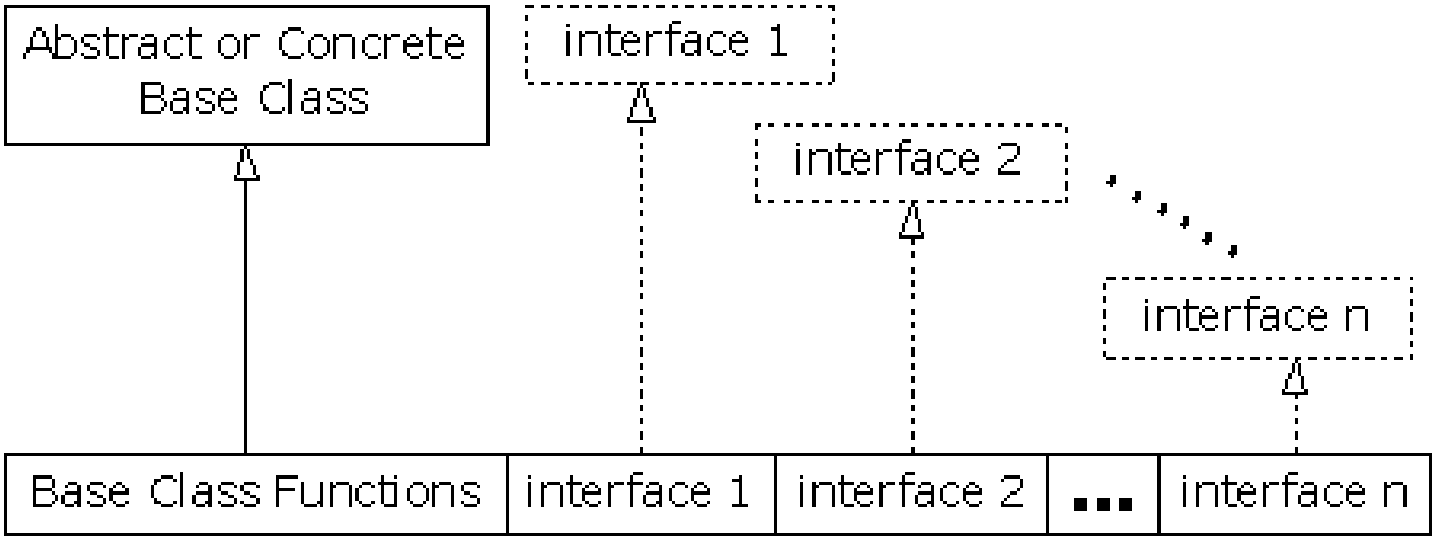
```
import java.util.*;

interface Instrument {
  // Compile-time constant:
  int i = 5; // static & final
  // Cannot have method definitions:
  void play(); // Automatically public
  String what();
  void adjust();
}

class Wind implements Instrument {
  public void play() {
    System.out.println("Wind.play()");
  }
  public String what() { return "Wind"; }
  public void adjust() {}
}
```

“Multiple Inheritance” in Java

- New class has combined interfaces of all types
  - But using only one physical implementation: that of the concrete base class



Java “Multiple Inheritance”

- To add extra interfaces
  - *Not* to combine implementations (using composition for that)
- Using it if you need to upcast to more than one base type
- Guideline
  - Using interfaces when possible, avoiding abstract classes
  - You never know when you’ll need to combine interfaces; any sort of concreteness prevents it

Error Handling with Exceptions

- Java
  - "Badly-formed code will not be run"
- Not all errors can be caught at compile time
- Run-time error handling integrated into the core of the language, enforced by the compiler
- Can't get too far learning the language without it

The problem

- Coping with errors during program execution
- Errors can be caused by
  - Program logic
    - I.e., exceeding array bounds
    - Can be prevented by the programmer
  - Status of the environment
    - I.e., network goes down
      - Cannot be prevented by the programmer

What's an exception?

- Exception
  - A type of object that signals an error condition and provides information about the error
- Once an exception is generated, control is passed *up the call stack* to a specific handler
  - You can have as many handlers as you want, for different exceptions and/or at different levels
- Java exceptions cannot be ignored

Basic Exception

- *Exceptional Condition*
  - not enough info in the current context to continue processing
- **throw** an exception:

```
if(t == null)
throw new NullPointerException();
```

- Exception arguments

```
if(t == null)
throw new NullPointerException("t=null");
```

  - Like any other constructor
  - Info can be extracted later

Catching an Exception

- **try** block
  - A guarded region

```
try {
// Code that may generate exceptions
} catch(Type1 id1) {
// Handle exceptions of Type1
} catch(Type2 id2) {
// Handle exceptions of Type2
} catch(Type3 id3) {
// Handle exceptions of Type3
}
// etc...
```

The Exception Specification

void f() throws TooBigException { //...

- If you say **void f() {}**
- It means that no exceptions (*except* for those derived from the special class **RuntimeException**) may be thrown
- Compiler verifies exception specifications!
- This guarantees that all (checked) exceptions will get caught somewhere

Creating your own exceptions

```
class MyException extends Exception {
  public MyException() {}
  public MyException(String msg) {
    super(msg);
  }
}
```

```
public class FullConstructors {
  public static void f() throws MyException {
    System.out.println(
      "Throwing MyException from f()");
    throw new MyException();
  }
  public static void g() throws MyException {
    System.out.println(
      "Throwing MyException from g()");
    throw new MyException("Originated in g()");
  }
  public static void main(String[] args) {
    try {
      f();
    } catch(MyException e) {
      e.printStackTrace(System.err);
    }
    try {
      g();
    } catch(MyException e) {
      e.printStackTrace(System.err);
    }
  }
} ///:~
```

```
>>
Throwing MyException from f()
MyException
        at
FullConstructors.f(FullConstructors.java:16)
        at
FullConstructors.main(FullConstructors.java:24)
Throwing MyException from g()
MyException: Originated in g()
        at
FullConstructors.g(FullConstructors.java:20)
        at
FullConstructors.main(FullConstructors.java:29)
```

Catching any Exception

- All the exceptions you need to worry about
- Being derived from **Exception**

```
catch(Exception e) {
System.out.println("Caught exception");
}
```

- Special system errors are derived from**Error**
- Program bugs: **RuntimeException**
  - These are thrown automatically for run-time programming errors

Rethrowing an Exception

```
catch(Exception e) {
    System.out.println("Exception was thrown");
    throw e;
}
```

- Performing anything you can locally, then letting a global handler perform more appropriate activities

What's in a name?

- Name of the exception is typically the most important thing about it
- Names tend to be long and descriptive
- Code for the exception class itself is usually minimal
- Once you catch the exception you are usually done with it

RuntimeException

- Name is confusing, since every exception is thrown at runtime
- Base class for all errors generated by programming mistakes that *appear* at runtime
  - **NullPointerException**,
  - **ArrayIndexOutOfBoundsException**,
  - **IllegalArgumentException**, etc.
- Do not need to include **RuntimeException** classes in the exception specification

One more factor: finally

- At least one catch or finally clause must be present

```
try {
  // The guarded region: Dangerous activities
  // that might throw A, B, or C
} catch(A a1) {
  // Handler for situation A
} catch(B b1) {
  // Handler for situation B
} catch(C c1) {
  // Handler for situation C
} finally {
  // Activities that happen every time
}
```

Try block (mandatory)

Catch clauses

Finally clause

What's "finally" For?

- Always getting called, regardless of what happens with the exception and where it's caught
- To set something *other* than memory back to its original state (GC handles memory) (close files, network connections, etc.)

```
class Switch {
    boolean state = false;
    boolean read() { return state; }
    void on() { state = true; }
    void off() { state = false; }
}
```

```
public class WithFinally {
  static Switch sw = new Switch();
  public static void main(String[] args) {
    try {
      sw.on();
      // Code that can throw exceptions...
      OnOffSwitch.f();
    } catch(OnOffException1 e) {
      System.err.println("OnOffException1");
    } catch(OnOffException2 e) {
      System.err.println("OnOffException2");
    } finally {
      sw.off();
    }
  }
} ///:~
```

```
class FourException extends Exception {}

public class AlwaysFinally {
  public static void main(String[] args) {
    System.out.println(
      "Entering first try block");
    try {
      System.out.println(
        "Entering second try block");
      try {
        throw new FourException();
      } finally {
        System.out.println(
          "finally in 2nd try block");
      }
    } catch(FourException e) {
      System.err.println(
        "Caught FourException in 1st try block");
    } finally {
      System.err.println(
        "finally in 1st try block");
    }
  }
} ///:~
```

```
>>
Entering first try block
Entering second try block
finally in 2nd try block
Caught FourException in 1st try block
finally in 1st try block
```

Exceptions in Constructors

```
import java.io.*;

class InputFile {
  private BufferedReader in;
  InputFile(String fname) throws Exception {
    try {
      in =
        new BufferedReader(
          new FileReader(fname));
      // Other code that might throw exceptions
    } catch(FileNotFoundException e) {
      System.err.println(
        "Could not open " + fname);
      // Wasn't open, so don't close it
      throw e;
    }
catch(Exception e) {
      // All other exceptions must
close it
      try {
        in.close();
      } catch(IOException e2) {
        System.err.println(
          "in.close() unsuccessful");
      }
      throw e; // Rethrow
    } finally {
      // Don't close it here!!!
    }
  }
```

Exception Matching

- Base-class handler will catch
- Derived-class object

```
class Annoyance extends Exception {}
class Sneeze extends Annoyance {}

public class Human {
  public static void main(String[] args) {
    try {
      throw new Sneeze();
    } catch(Sneeze s) {
      System.err.println("Caught Sneeze");
    } catch(Annoyance a) {
      System.err.println("Caught Annoyance");
    }
  }
} ///:~
```

Catching Base-Class Constructor Exceptions

- Cannot have *anything* before base-class constructor call, not even a **try** block
- Thus cannot catch base-class constructor exceptions in the derived-class constructor
- Must show exception in derived-class constructor exception specification

Code Example

```
class Base {
    Base() throws CloneNotSupportedException {
        throw new CloneNotSupportedException();
    }
}
class Derived extends Base {
    Derived() throws CloneNotSupportedException, RuntimeException {}
    public static void main(String[] args) {
        try {
            Derived d = new Derived();
        }
        catch(CloneNotSupportedException e) {
            e.printStackTrace();
        }
        catch(RuntimeException re) {}
    }
}
```

http://stackoverflow.com

Code Example (Cont'd)

```
class Derived extends Base {
    Derived() throws CloneNotSupportedException {
        try {
            super();
        } catch (CloneNotSupportedException e) {
            System.out.println("We have indeed caught an exception from the "+
              "base-class constructor! The book was wrong!");
        }
    }
    public static void main(String[] args) {
         try {
              Derived d = new Derived();
         }
         catch(CloneNotSupportedException e) {
              e.printStackTrace();
         }
    }
}
```

http://stackoverflow.com

“Inheritance” of Exceptions

- Base-class method throws an exception
  - Derived-class method may throw that exception or one derived from it
- Derived-class method
  - Throwing an exception that isn’t a type/subtype of an exception thrown by the base-class method

Overhead

- Exceptions are free as long as they don't get thrown
- If they are thrown, very expensive
- Not using exceptions for normal flow of control
- Only using exceptions to indicate abnormal conditions

Guidelines

- Handling an exception
  - Only if you have enough information in the current context to correct the error (partially or totally)
  - Otherwise, just letting the exception propagate up
- Separating error handling code (which almost never runs) from code that represents the normal path of execution
  - Making code more readable

Guidelines Cont'd

- Handling tasks, not statements
  - Not encompassing every single statement in a try block
  - Instead, putting tasks inside of a try block, then handling each exception that can occur
- Using loops to retry
  - Like C++, no *resumption* in Java
  - If you need to retry, putting the exception handling inside a **do**…**while** loop

Guidelines Cont'd

- Using exceptions in constructors
  - People assume construction succeeds
- If you catch an exception, doing something with it
  - Not "stubbing it out" by having an empty
- Handler
  - This discards the exception; not robust coding
- Cleaning up using **finally**

Summary

- You have no choice in Java
  - You *must* catch exceptions
  - You *must* use exception specifications
  - The compiler enforces exception use
- A clean, straightforward error-handling model
  - You don't have to decide how to handle errors
  - You don't have to figure out how someone else handles errors
  - You don't worry about whether errors get handled
- Seemingly more work at first
  - Only because you've been ignoring errors!