Interfaces & Types

Lecture 3

CS 2110 – Fall 2011

Interfaces

- What is an interface? Informally, it is a specification of how an agent interacts with the outside world
- Java has a construct called `interface` which is used formally for this purpose
  - an interface describes how a class interacts with its clients
  - method names, argument/return types, fields

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Java `interface`

```
interface IPuzzle {
    void scramble();
    int tile(int r, int c);
    boolean move(char d);
}
```

```
class IntPuzzle implements IPuzzle {
  public void scramble() {...}
  public int tile(int r, int c) {...}
  public boolean move(char d) {...}
}
```

- name of interface: `IPuzzle`
- a class implements this interface by implementing public instance methods as specified in the interface
- the class may implement other methods

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Notes

- An interface is not a class!
  - cannot be instantiated
  - incomplete specification
- class header must assert `implements I` for Java to recognize that the class implements interface `I`
- A class may implement several interfaces:
  `class X implements IPuzzle, IPod {...}`

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Why an `interface` construct?

- good software engineering
  - specify and enforce boundaries between different parts of a team project
- can use interface as a type
  - allows more generic code
  - reduces code duplication

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Why an `interface` construct?

- Lots of examples in Java

```
Map<String, Command> h
    = new HashMap<String, Command>();

List<Object> t = new ArrayList<Object>();

Set<Integer> s = new HashSet<Integer>();
```

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Example of code duplication

- Suppose we have two implementations of puzzles:
  - class `IntPuzzle` uses an `int` to hold state
  - class `ArrayPuzzle` uses an array to hold state
- Say the client wants to use both implementations
  - perhaps for benchmarking both implementations to pick the best one
  - client code has a `display` method to print out puzzles
- What would the `display` method look like?

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```
class Client{
  IntPuzzle p1 = new IntPuzzle();
  ArrayPuzzle p2 = new ArrayPuzzle();
    ...display(p1)...display(p2)...

  public static void display(IntPuzzle p){
    for (int r = 0; r < 3; r++)
      for (int c = 0; c < 3; c++)
        System.out.println(p.tile(r,c));
  }

  public static void display(ArrayPuzzle p){
    for (int r = 0; r < 3; r++)
      for (int c = 0; c < 3; c++)
        System.out.println(p.tile(r,c));
  }
}
```

Code duplicated because `IntPuzzle` and `ArrayPuzzle` are different

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Observation

- Two display methods are needed because `IntPuzzle` and `ArrayPuzzle` are different types, and parameter `p` must be one or the other
- but the code inside the two methods is identical!
  - code relies only on the assumption that the object `p` has an instance method `tile(int,int)`
- Is there a way to avoid this code duplication?

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One Solution — Abstract Classes

Puzzle code

```
abstract class Puzzle {
  abstract int tile(int r, int c);
  ...
}
class IntPuzzle extends Puzzle {
  public int tile(int r, int c) {...}
  ...
}
class ArrayPuzzle extends Puzzle {
  public int tile(int r, int c) {...}
  ...
}
```

Client code

```
public static void display(Puzzle p){
    for (int r = 0; r < 3; r++)
      for (int c = 0; c < 3; c++)
        System.out.println(p.tile(r,c));
}}
```

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Another Solution — Interfaces

Puzzle code

```
interface IPuzzle {
  int tile(int r, int c);
  ...
}
class IntPuzzle implements IPuzzle {
  public int tile(int r, int c) {...}
  ...
}
class ArrayPuzzle implements IPuzzle {
  public int tile(int r, int c) {...}
  ...
}
```

Client code

```
public static void display(IPuzzle p){
    for (int r = 0; r < 3; r++)
      for (int c = 0; c < 3; c++)
        System.out.println(p.tile(r,c));
}}
```

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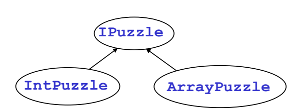

- interface names can be used in type declarations
  - `IPuzzle p1, p2;`
- a class that implements the interface is a subtype of the interface type
  - `IntPuzzle` and `ArrayPuzzle` are subtypes of `IPuzzle`
  - `IPuzzle` is a supertype of `IntPuzzle` and `ArrayPuzzle`

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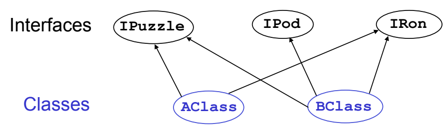

- Unlike classes, types do not form a tree!
  - a class may implement several interfaces
  - an interface may be implemented by several classes

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Extending a Class vs Implementing an Interface

- A class can
  - implement many interfaces, but
  - extend only one class
- To share code between two classes
  - put shared code in a common superclass
  - interfaces cannot contain code

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Static vs Dynamic Types

- Every variable (more generally, every expression that denotes some kind of data) has a static* or compile-time type
  - derived from declarations – you can see it
  - known at compile time, without running the program
  - does not change
- Every object has a dynamic or runtime type
  - obtained when the object is created using **`new`**
  - not known at compile time – you can't see it

* Warning! No relation to Java keyword **`static`**

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Example

```
int i = 3, j = 4;
Integer x = new Integer(i+3*j-1);
System.out.println(x.toString());
```

- static type of the variables **`i,j`** and the expression **`i+3*j-1`** is **`int`**
- static type of the variable **`x`** and the expression **`new Integer(i+3*j-1)`** is **`Integer`**
- static type of the expression **`x.toString()`** is **`String`** (because **`toString()`** is declared in the class **`Integer`** to have return type **`String`**)
- dynamic type of the object created by the execution of **`new Integer(i+3*j-1)`** is **`Integer`**

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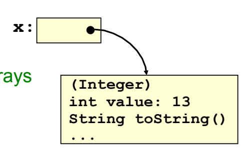
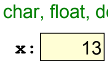
Reference vs Primitive Types

- Reference types
  - classes, interfaces, arrays
  - E.g.: **`Integer`**



- Primitive types
  - int, long, short, byte, boolean, char, float, double



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Why Both `int` and `Integer`?

- Some data structures work only with reference types (**`Hashtable, Vector, Stack, ...`**)
- Primitive types are more efficient

  `for (int i = 0; i < n; i++) {...}`

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Upcasting and Downcasting

- Applies to reference types only
- Used to assign the value of an expression of one (static) type to a variable of another (static) type
  - upcasting: subtype → supertype
  - downcasting: supertype → subtype
- A crucial invariant:

> If during execution, an expression *E* is ever evaluated and its value is an object *O*, then the dynamic type of *O* is a subtype of the static type of *E*.

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Upcasting

- Example of upcasting:

```
Object x = new Integer(13);
```

  - static type of expression on rhs is `Integer`
  - static type of variable `x` on lhs is `Object`
  - `Integer` is a subtype of `Object`, so this is an upcast
- static type of expression on rhs must be a subtype of static type of variable on lhs – compiler checks this
- upcasting is always type correct – preserves the invariant automatically

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Downcasting

- Example of downcasting:

```
Integer x = (Integer)y;
```

  - static type of `y` is `Object` (say)
  - static type of `x` is `Integer`
  - static type of expression `(Integer)y` is `Integer`
  - `Integer` is a subtype of `Object`, so this is a downcast
- In any downcast, dynamic type of object must be a subtype of static type of cast expression
- runtime check, `ClassCastException` if failure
- needed to maintain invariant (and only time it is needed)

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Is the Runtime Check Necessary?

Yes, because dynamic type of object may not be known at compile time

```
void bar() {
  foo(new ~~Integer(13)~~);
          String("x")
}

void foo(Object y) {
  int z = ((Integer)y).intValue();
  ...
}
```

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Upcasting with Interfaces

- Java allows up-casting:
  `IPuzzle p1 = new ArrayPuzzle();`
  `IPuzzle p2 = new IntPuzzle();`
- Static types of right-hand side expressions are `ArrayPuzzle` and `IntPuzzle`, resp.
- Static type of left-hand side variables is `IPuzzle`
- Rhs static types are subtypes of lhs static type, so this is ok

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Why Upcasting?

- Subtyping and upcasting can be used to avoid code duplication
- Puzzle example: you and client agree on interface `IPuzzle`

```
interface IPuzzle {
  void scramble();
  int tile(int r, int c);
  boolean move(char d);
}
```

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Solution

Puzzle code

```
interface IPuzzle {
  int tile(int r, int c);
  ...
}
class IntPuzzle implements IPuzzle {
  public int tile(int r, int c) {...}
  ...
}
class ArrayPuzzle implements IPuzzle {
  public int tile(int r, int c) {...}
  ...
}
```

Client code

```
public static void display(IPuzzle p){
    for (int r = 0; r < 3; r++)
      for (int c = 0; c < 3; c++)
        System.out.println(p.tile(r,c));
}}
```

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Method Dispatch

```
public static void display(IPuzzle p) {
  for (int row = 0; row < 3; row++)
    for (int col = 0; col < 3; col++)
      System.out.println(p.tile(row,col));
}
```

- Which `tile` method is invoked?
  - depends on dynamic type of object `p` (`IntPuzzle` or `ArrayPuzzle`)
  - we don't know what it is, but whatever it is, we know it has a `tile` method (since any class that implements `IPuzzle` must have a `tile` method)

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Method Dispatch

```
public static void display(IPuzzle p) {
  for (int row = 0; row < 3; row++)
    for (int col = 0; col < 3; col++)
      System.out.println(p.tile(row,col));
}
```

- Compile-time check: does the static type of `p` (namely `IPuzzle`) have a `tile` method with the right type signature? If not → error
- Runtime: go to object that is the value of `p`, find its dynamic type, look up its `tile` method
- The compile-time check guarantees that an appropriate `tile` method exists

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Note on Casting

- Up- and downcasting merely allow the object to be viewed at compile time as a different static type
- Important: when you do a cast, either up or down, nothing changes
  - not the dynamic type of the object
  - not the static type of the expression

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Another Use of Upcasting

Heterogeneous Data Structures

- Example:

```
IPuzzle[] pzls = new IPuzzle[9];
pzls[0] = new IntPuzzle();
pzls[1] = new ArrayPuzzle();
```

- expression `pzls[i]` is of type `IPuzzle`
- objects created on right hand sides are of subtypes of `IPuzzle`

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Java `instanceof`

- Example:
  `if (p instanceof IntPuzzle) {...}`
- true if dynamic type of `p` is a subtype of `IntPuzzle`
- usually used to check if a downcast will succeed

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Example

- suppose **`twist`** is a method implemented only in **`IntPuzzle`**

```
void twist(IPuzzle[] pzls) {
  for (int i = 0; i < pzls.length; i++) {
    if (pzls[i] instanceof IntPuzzle) {
      IntPuzzle p = (IntPuzzle)pzls[i];
      p.twist();
    }
  }
}
```

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Avoid Useless Downcasting

bad

```
void moveAll(IPuzzle[] pzls) {
  for (int i = 0; i < pzls.length; i++) {
    if (pzls[i] instanceof IntPuzzle)
      ((IntPuzzle)pzls[i]).move("N");
    else ((ArrayPuzzle)pzls[i]).move("N");
}}
```

good

```
void moveAll(IPuzzle[] pzls) {
  for (int i = 0; i < pzls.length; i++)
    pzls[i].move("N");
}
```

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Subinterfaces

- Suppose you want to extend the interface to include more methods
  - **`IPuzzle`**: **`scramble, move, tile`**
  - **`ImprovedPuzzle`**: **`scramble, move, tile, samLoyd`**
- Two approaches
  - start from scratch and write an interface
  - extend the **`IPuzzle`** interface

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```
interface IPuzzle {
   void scramble();
   int tile(int r, int c);
   boolean move(char d);
}

interface ImprovedPuzzle extends IPuzzle {
   void samLoyd();
}
```

- **`IPuzzle`** is a superinterface of **`ImprovedPuzzle`**
- **`ImprovedPuzzle`** is a subinterface of **`IPuzzle`**
- **`ImprovedPuzzle`** is a subtype of **`IPuzzle`**
- An interface can extend multiple superinterfaces
- A class that implements an interface must implement all methods declared in all superinterfaces

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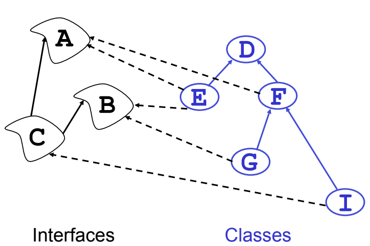


```
interface C extends A,B {...}
class F extends D implements A {...}
class E extends D implements A,B {...}
```

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Conclusion

- Interfaces have two main uses
  - software engineering: good fences make good neighbors
  - subtyping
- Subtyping is a central idea in modern programming languages
  - inheritance and interfaces are two methods for creating subtype relationships

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