CS/ENGRD 2110
Object-Oriented Programming and Data Structures

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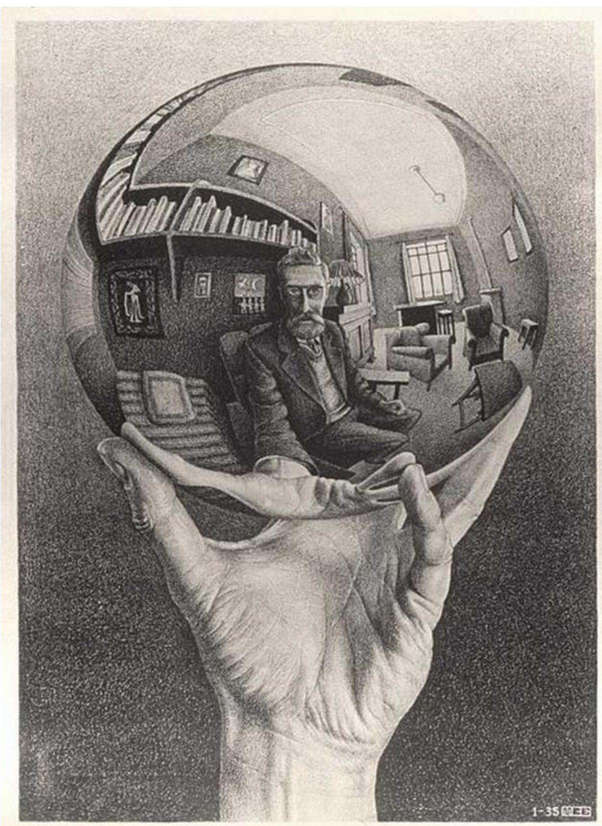


Lecture 4: Interfaces and Types

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

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

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 Ipod, Ipad {...}`**

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
- Examples

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

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

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

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?

```
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

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?

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));
}
```

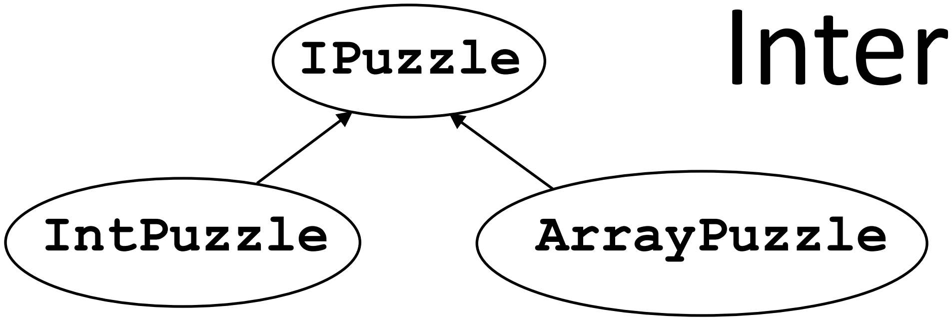
Another Solution — Interfaces

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));
}
```

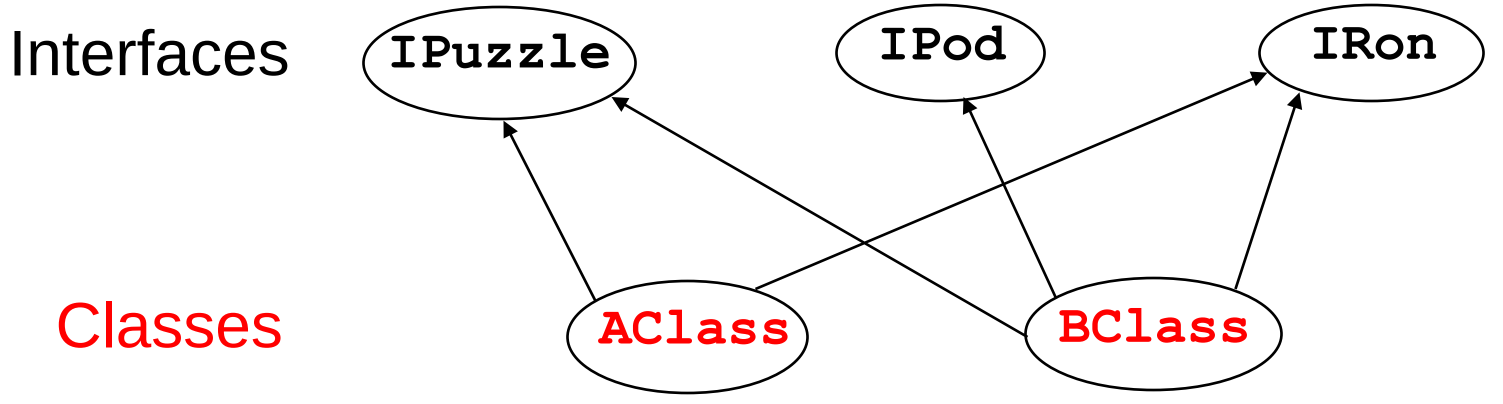


Interfaces and Types

- Interface names can be used in type declarations
  - IPuzzle p1, p2;

- When a class implements an interface:
  - **`IntPuzzle`** and **`ArrayPuzzle`** are subtypes of **`IPuzzle`**
  - **`IPuzzle`** is a supertype of **`IntPuzzle`** and **`ArrayPuzzle`**

Multiple "Inheritance"



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

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

Subinterfaces

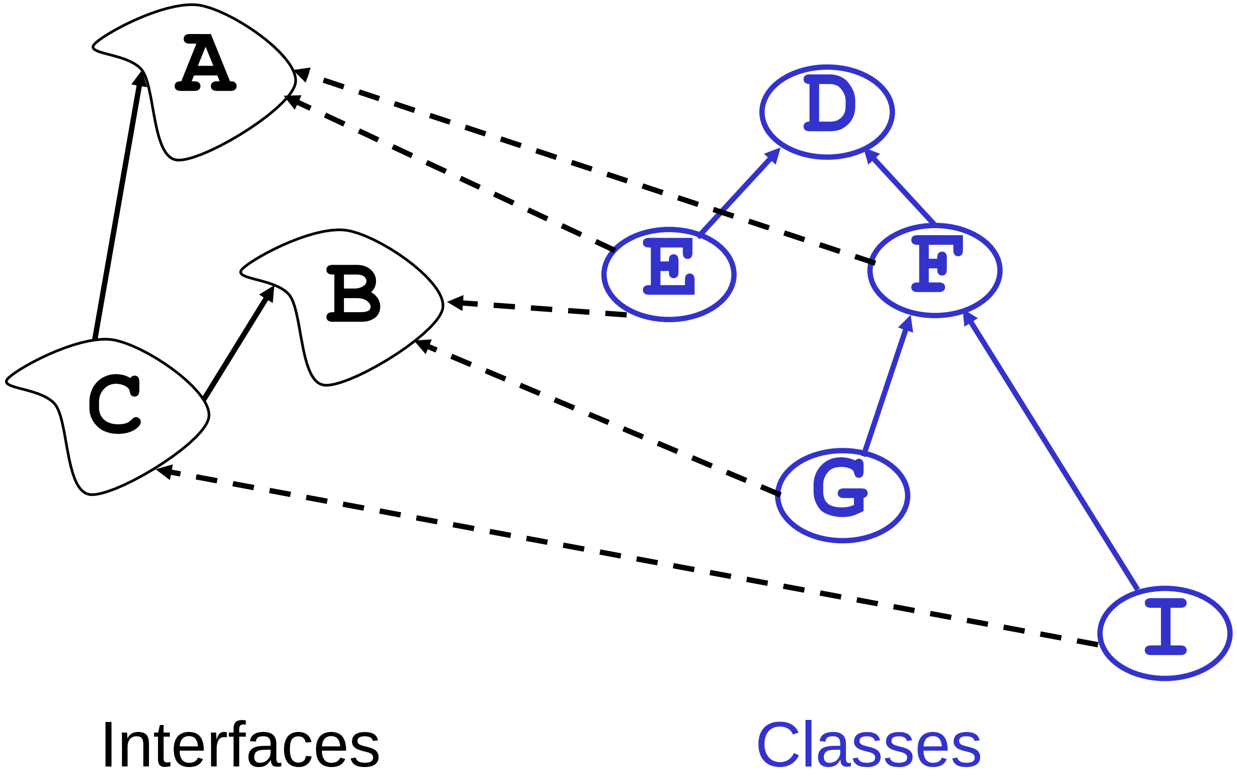
- Suppose you want to extend the interface to include more methods
  - **`IPuzzle`**: **`scramble, move, tile`**
  - **`ImprovedPuzzle`**: **`scramble, move, tile, hint`**

- Two approaches
  - start from scratch and write an interface
  - extend the **`IPuzzle`** interface

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

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

- Example:
  - **`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




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

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`**

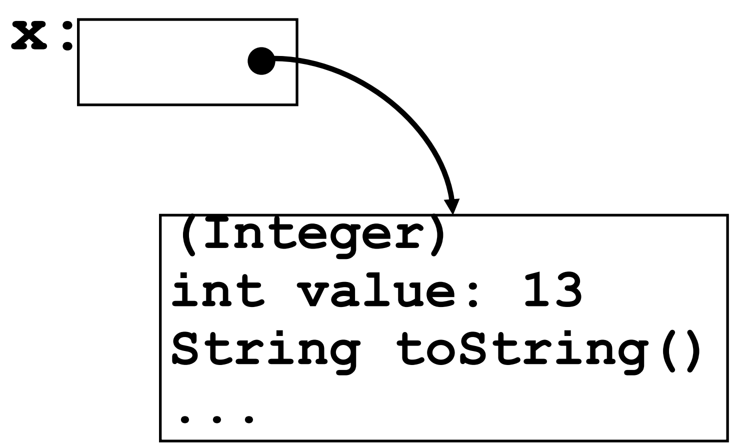
Example

```
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`

Reference vs Primitive Types

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



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

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++) {...}
```

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*.

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

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)

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();
   ...
}
```

Upcasting with Interfaces

- Java allows up-casting for types from interfaces:

```
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

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);
}
```

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));
}
```

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)

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 → compile 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!

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

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`**

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

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();
    }
  }
}
```

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");
}
```

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