Polymorphism (generics)

CSE 331

University of Washington

Varieties of abstraction

- Abstraction over computation: procedures

```
int x1, y1, x2, y2;
Math.sqrt(x1*x1 + y1*y1);
Math.sqrt(x2*x2 + y2*y2);
```

- Abstraction over data: ADTs (classes, interfaces)

```
Point p1, p2;
```

- Abstraction over types: polymorphism (generics)

```
Point<Integer>, Point<Double>
```

  – Applies to both computation and data

Why we ♥ abstraction

- Hide details
  - Avoid distraction
  - Permit the details to change later
- Give a meaningful name to a concept
- Permit reuse in new contexts
  - Avoid duplication: error-prone, confusing
  - Programmers hate to repeat themselves

A collection of related abstractions

```
interface ListOfNumbers {
  boolean add(Number elt);
  Number get(int index);
}
interface ListOfIntegers {
  boolean add(Integer elt);
  Integer get(int index);
}
```

… and many, many more

```
interface List<E> {
  boolean add(E elt);
  E get(int index);
}
```

Declares a new **variable**, called a **formal parameter**

Instantiate by passing an `Integer`:
`l.add(7);`
`myList.add(myInt);`

The type of `add` is Integer → boolean

Declares a new **type variable**, called a **type parameter**

Instantiate by passing a type:
`List<Float>`
`List<List<String>>`
`List<T>`

The type of `List` is Type → Type

Restricting instantiation by clients

```
boolean add1(Object elt);
boolean add2(Number elt);
add1(new Date());  // OK
add2(new Date());  // compile-time error

interface MyList1<E extends Object> {…}
interface MyList2<E extends Number> {…}
MyList1<Date>      // OK
MyList2<Date>      // compile-time error
```

Using type variables

Code can perform any operation permitted by the bound

```
interface MyList1<E extends Object> {
  void m(E arg) {
    arg.asInt();  // compiler error
  }
}

interface MyList2<E extends Number> {
  void m(E arg) {
    arg.asInt();  // OK
  }
}
```

Another example

```
public class Graph<N> implements Iterable<N> {
  private final Map<N, Set<N>> node2neighbors;
  public Graph(Set<N> nodes, Set<Tuple<N,N>> edges) {
    ...
  }
}

public interface Path<N, P extends Path<N,P>>
  extends Iterable<N>, Comparable<Path<?, ?>> {
  public Iterator<N> iterator();
}
```

Type variables are types

Declaration

```
class MySet<T> {
  // rep invariant:
  //   non-null, contains no duplicates
  List<T> theRep;
}
```

Use

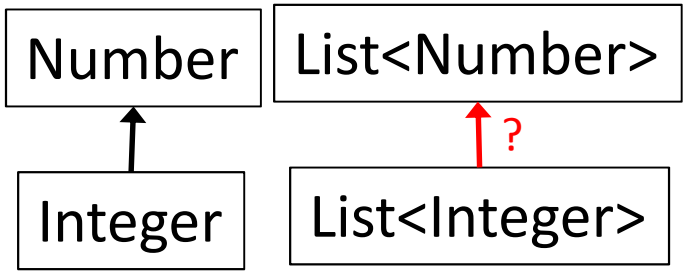
```
class MySet<T> implements Set<T> {
  // rep invariant:
  //   non-null, contains no duplicates
  List<T> theRep;
}
```

Generics and subtyping

Integer is a subtype of Number

Is **`List<Integer>`** a subtype of **`List<Number>`**?

Use our subtyping rules to find out



List<Number> and List<Integer>

```
interface List<Number> {
  boolean add(Number elt);
  Number get(int index);
}
interface List<Integer> {
  boolean add(Integer elt);
  Integer get(int index);
}
```

Java subtyping is covariant with respect to generics

Immutable lists

```
interface ImmutableList<Number> {
  Number get(int index);
}
interface ImmutableList<Integer> {
  Integer get(int index);
}
```

Why would we want this?

Write-only lists

```
interface WriteOnlyList<Number> {
  boolean add(Number elt);
}
interface WriteOnlyList<Integer> {
  boolean add(Integer elt);
}
WriteOnlyList<Eagle> hotelCalifornia;
```

Why would we want this?

Covariant subtyping is restrictive
Solution: wildcards

```
interface Set<E> {
  // Adds all of the elements in c to this set
  // if they're not already present (optional operation).
  void addAll(Set<E> c);
}

interface Set<E> {
  void addAll(Collection<E> c);
}

interface Set<E> {
  void addAll(Collection<? extends E> c);
}
```

Problem 1:

```
Set<Number> s;
List<Number> l;
s.addAll(l);
```

Problem 2:

```
Set<Number> s;
List<Integer> l;
s.addAll(l);
```

Using wildcards

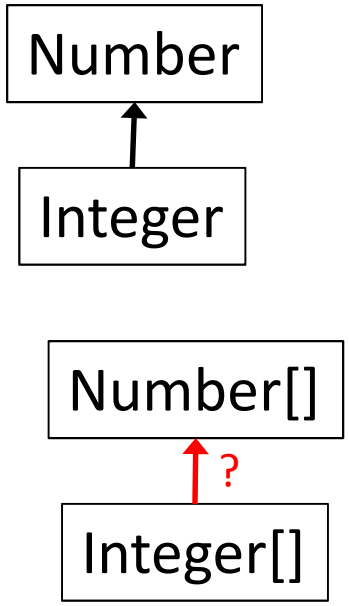
```
class HashSet<E> implements Set<E> {
  void addAll(Collection<? extends E> c) {
    // What can this code assume about c?
    // What operations can this code invoke on c?
    ...
  }
}
```

Wildcards are writteen at declarations, not uses

A missing extends clause means **`extends Object`**

There is also "**`? super E`**"

Arrays and subtyping



Integer is a subtype of Number

Is **`Integer[]`** a subtype of **`Number[]`**?

Use our subtyping rules to find out

(Same question as with Lists)

Same answer with respect to true subtyping

Different answer in Java!

- **`Integer[]`** is a Java subtype of **`Number[]`**
- Java subtyping disagrees with true subtyping

Integer[] is a Java subtype of Number[]

```
Number n;
Number[] na;
Integer i;
Integer[] ia;

na[0] = n;
na[1] = i;
n = na[0];
i = na[1];
ia[0] = n;
ia[1] = i;
n = ia[0];
i = ia[1];
```

```
ia = na;

Double d = 3.14;

na = ia;
na[2] = d;
i = ia[2];
```

Why did the Java designers do this?

Not all generics are for collections

```
class MyUtils {
  static Number sumList(List<Number> l) {
    Number result = 0;
    for (Number n : l) {
      result += n;
    }
    return result;
  }
}
```

Not all generics are for collections

```
class MyUtils {
  static T sumList(Collection<T> l) {
    // ... black magic within ...
  }
}
```

Where is this type variable declared?

Not all generics are for collections

```
class MyUtils {
  static
  <T extends Number> T sumList(Collection<T> l) {
    // ... black magic within ...
  }
}
```

How to declare a type parameter to a method

Sorting

```
public static
<T extends Comparable<T>>
void sort(List<T> list) {
 // … use list.get() and T.compareTo(T)
}
```

Actually:

```
<T extends Comparable<? super T>>
```

Tips when writing a generic class

1. Start by writing a concrete instantiation
2. Get it correct (testing, reasoning, etc.)
3. Consider writing a second concrete version
4. Generalize it by adding type parameters
   - Think about which types are the same & different
   - Not all `int`s are the same, nor are all `String`s
   - The compiler will help you find errors

Eventually, it will be easier to write the code generically from the start

- but maybe not yet

Generics clarify your code

```
interface Map {
  Object put(Object key, Object value);
  equals(Object other);
}

interface Map<Key,Value> {
  Value put(Key key, Value value);
  equals(Object other);
}
```

Generics usually clarify the implementation

- sometimes ugly: wildcards, arrays, instantiation

Generics always make the client code prettier and safer