Generics with Type Bounds

Computer Science and Engineering ■ College of Engineering ■ The Ohio State University

Lecture 27

Generic Methods

- Like classes, *methods* can be generic

```
class ArrayOps { //ordinary nongeneric class
  static <T> T midpoint(T[] A);
  <T> int nonNullLength(T[] A);
}
```

- Scope of type parameter limited to method
- Instantiation with a specific parameter type *not* needed when invoking method
  - Parameter type is inferred from arguments

    ```
    String s = ArrayOps.midpoint(args);
    Date d = ArrayOps.midpoint(timeline);
    int c = arrayWorker.nonNullLength(args);
    ```

  - (Can also use return type, when assigned)
  - But explicit type invocation is legal too

    ```
    i = MathUtilities.<Integer>max(42, 34);
    ```

Example: Generic Methods


```
class ArrayOps {
  public static <T> T midpoint(T[] A) {
    assert A.length >= 1;
    return A[A.length/2];
  }
  public <T> int nonNullLength(T[] A) {
    int count = 0;
    for (T t : A)
      if (t != null) count++;
    return count;
}

public static void main(String[] args) {
  ArrayOps arrayWorker = new ArrayOps();
  String s1 = ArrayOps.midpoint(args);
  String s2 = ArrayOps.<String>midpoint(args);
  int x = arrayWorker.nonNullLength(args);
  int y = arrayWorker.<String>nonNullLength(args);
}
```

Type Bounds

- Ordinary parameters have 2 parts: *name* and *type*

```
void someMethod(Person p)
```

  - Inside method, know p refers to a Person (or below)

```
SSN id = p.getSSN(); //ok, p is Person (or Student)
```

- Generics have only 1 part: a *name*, like “T”
  - Inside method, know only that T is Object (or below)

```
<T> void genericMethod(T t) {
  t.hashCode(); //ok, all Objects have hashCode
```

  - So generic code must be applicable to all objects?
- What if we want to restrict type arguments?

```
<T> void genericMethod(T t) {
  SSN id = t.getSSN(); //error: no getSSN for Object
```

- Solution: *Bound* type argument above by Person

```
<T extends Person> void genericMethod(T t) {
  SSN id = t.getSSN();
```

Example: Type Bounds


```
class Filter {
  static <T>
      T max(T t1, T t2) {
    return (t1.compareTo(t2) <= 0 ? t2 : t1);
  }
}

BigNatural nat1 = ...
BigNatural nat2 = ...
System.out.println(Filter.max(nat1, nat2));
```

Question: Why not This Way?


```
class Filter {
  static <T>
      Comparable<T> max(Comparable<T> t1,
                        Comparable<T> t2) {
    return (t1.compareTo(t2) <= 0 ? t2 : t1);
  }
}

BigNatural nat1 = ...
BigNatural nat2 = ...
System.out.println(Filter.max(nat1, nat2));
```

Example: Type Bounds


```
class Filter {
  static <T extends Comparable<T>>
      T max(T t1, T t2) {
    return (t1.compareTo(t2) <= 0 ? t2 : t1);
  }
}

BigNatural nat1 = ...
BigNatural nat2 = ...
System.out.println(Filter.max(nat1, nat2));
```

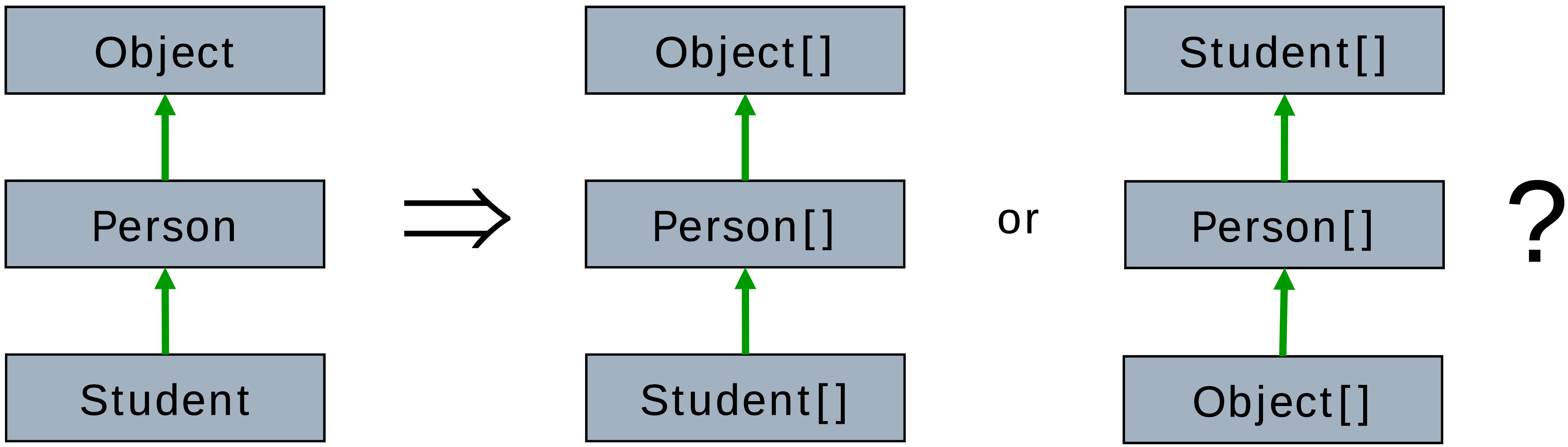
Arrays and Inheritance

- Consider 3 types: Student, Person, Object
  - Student extends Person, Person extends Object
- Subtyping: a Student "is a" Person
  - A Student can do everything a Person can do
    - Client would rather have Student to use
    - Implementer would rather write Person
  - Code expecting a Person, can be given a Student

    `boolean older (int age, Person p);`
- Question: a Student[] "is a" Person[]?
  - Can a Student[] do everything a Person[] can do?
  - Can code expecting a Person[] be given a Student[] instead?

    `boolean allOlder(int age, Person[] ps);`

Arrays and Co/Contra-Variance



Covariance

Contravariance

Strawman 1: Covariance

- Student[] is a Person[], Person[] is an Object[]

```
boolean allOlder (int age, Person[] ps) {
  boolean result = true;
  for (Person p : ps)
    if (p.getAge() < age) result = false;
  return result; //ok for arrays of Students too
}
```

- Counter-example

```
void clobberFirst (Person[] ps) {
  ps[0] = new Infant(“Baby Doe”);
    //ok since Infant extends Person
}

Student[] roster = ...
  //assert: roster contains only Students
clobberFirst(roster);
  //trouble: Dynamic type of roster[0] is Infant
roster[0].grantDegree();
```

Strawman 2: Contravariance

- Object[] is a Person[], Person[] is a Student[]

```
void populateClass(Student[] roster) {
  for (int i=0; i<roster.length; i++)
    roster[i] = new Student();
} //ok for an array of Persons too

void formJury(Person[] panel) {
  populateClass(panel);
}
```

- Counter-example

```
void graduate (Student[] roster) {
  for (Student s : roster)
   //trouble: dynamic type of s is Person
   s.grantDegree();
}

Person[] ps = ...
graduate(ps);
```

Java's Choice

- Neither is right!
  - A Student[] *can not* do everything a Person[] can do!
    - e.g. it can not contain an Infant
  - A Person[] *can not* do everything a Student[] can do!
    - e.g. it can not calculate a max GPA
- Java's choice: Covariance
  - Student[] is a Person[]!
- Consequence: We live dangerously
  - If the wrong type of object is assigned to an array element, ArrayStoreException is thrown

Generics and Wildcards

- Wildcard ?: Refers to stack of *any* kind

```
Stack<?>
```

- Example

```
boolean largeSize(int limit, Stack<?> s) {
  if (s.size() > limit) return true;
  else return false;
}
```

- Subtyping: Every Stack is a Stack<?>

```
Stack<String> args = . . .
Stack<People> crew = . . .
flag = largeSize(3, args);   //ok
flag = largeSize(32, crew);  //ok
```

Generics and Inheritance

- Is a Stack<Student> a Stack<Person>?
  - Can a Stack<Student> do everything a Stack<Person> can do?
  - Can code expecting a Stack<Person> be given a Stack<Student> instead?
- Java's choice:
  - No!
  - For a generic class G, there is no implicit subtyping relationship between G<A> and G<B>
  - *Neither* covariance nor contravariance
  - Regardless of any subtyping relationship between A and B

Generics: Co/Contra-variance

- Similar to arrays
  - Sometimes covariance is ok
  - Sometimes contravariance is ok
- Consider code written for Stack<Person>

```
boolean someMethod(Stack<Person> s);
```

- Questions:
  - Can a Stack<Student> be passed in instead?
  - Can a Stack<Object> be passed in instead?
- Answer:
  - It depends on what client code does with s!
  - Some code works fine for Stack<Student>
  - Some code works fine for Stack<Object>

Both Forms

- Example 1: Getting from stack

```
int firstAge(Stack<Person> s) {
  Person p = s.pop();
  return p.getAge();
}
```

  - Works when argument is a Stack<Student>
  - Does not work when given a Stack<Object>
- Example 2: Putting into stack

```
void addChild(Stack<Person> s) {
  s.push(new Person(3));
}
```

  - Works when argument is a Stack<Object>
  - Does not work when given a Stack<Student>

Upper Type Bounds: Covariance

- Combine wildcard with type bound

```
Stack<? extends Person>
```

  - Person is an upper bound on type parameter
- Reflects covariant relationship

```
int firstAge(Stack<? extends Person> s) {
  Person p = s.pop();
  return p.getAge();
}

List<? extends Number> figures =
    new ArrayList<Number>();
figures = new ArrayList<Integer>();
```

- Use when code “gets” from generic

Lower Type Bounds: Contravariance

- Combine wildcard with type bound

```
Stack<? super Person>
```

  - Person is a lower bound on type parameter
- Reflects contravariant relationship

```
void addChild(Stack<? super Person> s) {
  s.push(new Person(3));
}

List<? super Integer> figures =
    new ArrayList<Integer>();
figures = new ArrayList<Number>();
```

- Use when client code “puts” to generic

Summary

- Generic methods
  - Type parameter applied to individual methods
- Inheritance and arrays
  - Java arrays are covariant in their base type
  - This is not type safe (wrong stores cause exception)
- Inheritance and generics: type bounds
  - Use upper type bound when getting
  - Use lower type bound when putting
  - Use exact type when doing both