Java Generics

Slides derived from the work of
Dr. Amy McGovern and Dr. Deborah Trytten
Arrays Class

Provides, among other things, static methods for sorting primitive arrays of different types (byte, char, int, double)

• Problems with this?
Arrays Class

Problems with this?
• Separate implementation for each type
• Each new type needs a new implementation

Solutions?
Arrays Class

Solutions?

• Could provide a static method that sorts an array of Objects

• But what does it mean to compare two arbitrary Objects so that we can establish an ordering between them?
  • For example a String and an Integer?

We really need a way of talking generically about a homogeneous array of Objects
Java Generics

• A type becomes a parameter to a class and/or a method:

```java
public ClassName<T>{{
    :
}
```  

• $T$ is the variable type that is assigned when we use the class

• Within the class definition, we can “pretend” that it is a real type (parameters, variable declarations and return types)
GenericQueue example ...
Standard Generic Type Names

• E - Element (used extensively by the Java Collections Framework)
• K - Key
• N - Number
• T - Type
• V – Value
Notes

• Lab 7 deadline is Sunday
• No office hours on Friday
  • We are still available for appointments and for email
• Exam II: now on Nov 4 (from Nov 2)
• Project 3 deadline: now Nov 2 (from Nov 4)
Advantages of Generics

• Code reuse
  • ArrayList, Java Collections Framework

• Specific types are checked at compile time (as opposed to everything having to be an Object)
  • Reduces runtime errors

• Easier to read and understand code when we can be very explicit about types
Notes

• Primitive types cannot be used as generic types
  • Must use the wrapper classes

• Type erasure: generics are checked at compile time, not at runtime
  • This decision was driven to maintain backward compatibility
  • Not a serious issue most of the time
Implications of Type Erasure

• Cannot construct objects of type \(E\)
  
  \[E\text{ myData} = \text{new } E();\] // illegal code

• Cannot construct arrays of type \(E\)
  
  \[E[\text{]}\text{ elements} = \text{new } E[\text{capacity}];\] // illegal

• Solution to the latter: create an array of objects and then cast to array of \(E\)
Implications of Type Erasure

• `instanceof()` cannot distinguish same class with different generic, because it is done at run time
  • `ArrayList<Integer>` and `ArrayList<String>` are the same type using `instanceof`
• Exception classes cannot be generic
• Static data cannot be of a generic type
Inheritance and Generics

• In many situations, we might have more than one generic type as part of a class or method definition

• These could be arbitrary types or we might want them to have some specific relationship
  • For example: we might want T1 to be a superclass of T2
Class Hierarchies

```
Object

Number

Integer  Double
```
Class Hierarchies

Object

Number

Integer  Double

Integer i = new Integer(42);
Number n = new Integer(1138);
Class Hierarchies

Object

Number

Integer

Double

ArrayList<Number>

ArrayList<Integer>
Class Hierarchies

Arraylist\<Number\>
Class Hierarchies

The only common ancestor is Object...
GenericTest example
Class Hierarchies

The only common ancestor is Object...

Andrew H. Fagg: CS 2334: Inheritance and Polymorphism
Wildcards

But, there is a hierarchy that we can use...

![](image-url)

```java
ArrayList<? extends Number>
```

- `ArrayList<Integer>`
- `ArrayList<Double>`
- `ArrayList<Number>`
Wildcards

ArrayList<Integer> list1 = new ArrayList<Integer>();
ArrayList<? extends Number> list2 = list1;    // Legal
Wildcards

The complement...

```
ArrayList<Number>
```

```
ArrayList<Object>
```

```
ArrayList<? super Number>
```

```
ArrayList<Number>
```

```
ArrayList<Object>
```
Wildcards

`ArrayList<Object> list1 = new ArrayList<Object>();
ArrayList<? super Number> list2 = list1;    // Legal`
Wildcard Example I

Return to Arrays in Java API

\[\text{binarySearch(T[] a, T key, Comparator<? super T> c)}\]

• The class that is passed as the third parameter must implement the Comparator interface or have a superclass that implements the Comparator interface
Wildcard Example II

Examine Collections in Java API: copy list

```java
public static<T> void
copy (List<? super T> dest, List<? extends T> src)
```

- The `<T>` before the method name determines the base type
- The source must be a class that is or extends `T`
- The destination must be a class that is or is a superclass of `T`
Wildcards and Generic Types

• Give us a tremendous amount of flexibility
• Wildcard types are defined and checked at compile time
  • Reduce runtime errors!
• Project 2: `<? extends StatisticsAbstract>`
• Lab 7: we will define:
  • Generic notion of a Card<T>
  • Generic notion of a Deck<E extends Card<T>, T>