Java Enterprise Application Development

Lecture 7
Generics

Dr. Fan Hongfei
15 October 2025

Review

- Generic programming in C++
  - Function template
  - Class template
  - Standard Template Library (STL)
    - Containers: vector, list, map, set, ...
    - Algorithms: sort, find, binary_search, ...
    - Iterators: begin(), end()
    - Function objects

Introduction to Generics

- Example without generics

```
class ArrayList {
    private Object[] elementData;
    public Object get(int i) {...}
    public Object add(Object o) {...}
}
```

- Supporting any type of object, but always leading to bugs
- **Type casting** is **necessary**

```
ArrayList myList = new ArrayList();
String str = (String) myList.get(0);
//...
myList.add(Integer.valueOf(233));
```

Introduction to Generics (cont.)

- **Generics**: enabling **types** (classes, interfaces) to be **parameters**
  - Stronger type checks at compile time
  - Elimination of casting
  - Enabling the implementation of generic algorithms


```
List<String> strList = new ArrayList<>();
strList.add("Hello");
// no cast
System.out.println(strList.get(0));
// compile-time error
// strList.add(Integer.valueOf(233));
```

Generic Types

- A generic class or interface that is parameterized over types
- Defined with the following format

```
class ClassName<T1, T2, …, Tn> {…}
```

- A type variable can be any **non-primitive** type
- Invoking and instantiating easily

```
ClassName<Type> instance = new ClassName<Type>();
```

- Diamond: compiler **infers** type arguments from context

```
List<String> myList = new ArrayList<>();
```

Generic Types (cont.)

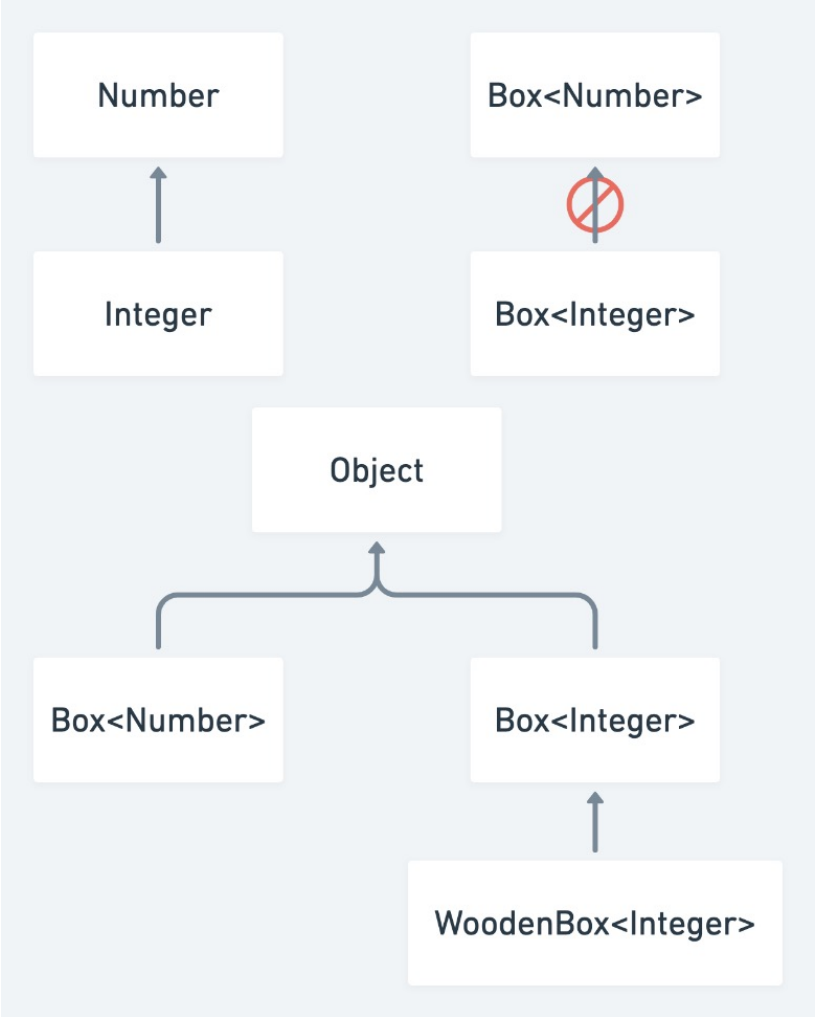
- Type parameter naming **conventions**
  - T -> Type
  - S, U, V etc. -> 2nd, 3rd, 4th types
  - E -> Element
  - N -> Number
  - K -> Key
  - V -> Value

Generic Methods

- Methods that introduce their **own** type parameters
- Both static and non-static methods are allowed
- Syntax: a list of type parameters, **inside angle brackets**, appearing before the return type
- For static generic methods, the type parameter section must appear before the method's return type

Generics and Inheritance

- Arrays are **covariant**
  - T[] may contain elements of T or any subtype of T
  - S[] is a subtype of T[] if S is a subtype of T
- Java generics are **invariant**
  - MyClass<S> has no relationship to MyClass<T>
  - Subtype a generic class or interface by extending or implementing it



Bounded Type Parameters and Wildcards

- Bounded type parameters
  - **Restrict** the types that can be used as type arguments
  - List the type parameter's name, followed by ***extends***
  - Multiple bounds are supported, **using "&"**
- Wildcard: "?" representing an unknown type
  - Used as the type of a parameter, field, local variable or return type
  - *List<?>, Box<?>, Map<?, ?>…*
  - **Upper bounded, lower bounded, and unbounded**

Bounded Type Parameters and Wildcards (cont.)

- **Unbounded** wildcards
  - Examples: *List<?>, Box<?>*
  - Scenarios
    - Using functionality provided in the *Object* class
    - Using methods in the generic class that do not depend on the type parameter
- **Upper bounded** wildcards
  - Restriction on the variable: **? *extends***
  - Restricting the unknown type to be a specific type or a subtype of that type: *List<? extends Number>, Box<? extends Integer>…*
- **Lower bounded** wildcards
  - Restriction on the variable: **? *super***
  - Restricting the unknown type to be a specific type or a super type of that type: *List<? super Integer>…*

Type Erasure

- The compiler erases all type parameters, ensuring that no new classes are created for parameterized types
  - Replace all type parameters in generic types with their bounds, or *Object* if the type parameters are unbounded
  - Insert type casts if necessary to preserve type safety
- Incurring no runtime overhead
  - Only raw types during runtime

Best Practice

- Do not use raw types
  - Except for class literals: *List.class, String[].class* (*List<String>.class* is illegal in java)
- Prefer lists to arrays
- Use bounded wildcards to increase API flexibility
  - public void pushAll(Iterable<E> src) (x)
  - public void pushAll(Iterable<? extends E> src) (√)

Further Reading

- Chapter 8 Generic Programming in *Core Java (10th Edition)*
- Item 26-33 in *Effective Java (3rd Edition)*
- Lesson: Generics
  https://docs.oracle.com/javase/tutorial/java/generics/index.html