New Features in Java 5.0

Angelika Langer
Trainer / Consultant
http://www.AngelikaLanger.com

---

new features in J2SE 5.0

- J2SE 5.0 released in September 2004
- new features in language & core libraries
  - generics
  - enums
  - annotations
  - autoboxing, for-each, loop, static import, varargs
  - concurrency utilities

agenda

- generics
- enums
- annotations
- autoboxing, for-each loop, static import, varargs
- concurrency utilities

purpose of generics

- generic types needed for collections
  - implementation is independent of the contained elements
  - use a *generic* `List` instead of `IntList` and `StringList`
- traditional technique for generic types in Java:
  - implementation in terms of `Object` references
- side effects:
  - no collection of primitive types
    - use wrapper types and autoboxing
  - no homogeneous collections
    - lots of casts required

use of non-generic collections

- no homogeneous collections
  - lots of casts required
- no compile-time checks
  - late error detection at runtime

```
LinkedList list = new LinkedList();
list.add(new Integer(0));
Integer i = (Integer) list.get(0);
String  s = (String)  list.get(0);
```

fine at compile-time, but fails at runtime

casts required

use of generic collections

- collections are homogeneous
  - no casts necessary
- early compile-time checks
  - based on static type information

```
LinkedList<Integer> list = new LinkedList<Integer>();
list.add(new Integer(0));
Integer i = list.get(0);
String  s = list.get(0);
```

compile-time error

benefits of generic types

- increased expressive power
- improved type safety
- explicit type parameters and implicit type casts

definition of generic types

```
interface Collection<A>  {
  public void add (A x);
  public Iterator<A> iterator ();
}
```

```
class LinkedList<A> implements Collection<A> {
  protected class Node {
    A elt;
    Node next = null;
    Node (A elt) { this.elt = elt;  }
  }
  ...
}
```

- *type variable* = "placeholder" for an unknown type
- usage
  - in signatures of methods
  - for declaration of fields and variables
  - as type argument to other generic types

requirements to a type parameter (i)

- `LinkedList` does not require anything of its element type
  - passes around references
  - no object access

```
class LinkedList<A> implements Collection<A> {
  protected Node head = null, tail = null;
  ...
  public void add (A elt) {
    if (head == null) {
      head = new Node(elt);
      tail = head;
    } else {
      tail.next = new Node(elt);
      tail = tail.next;
    }
  }
}
```

requirements to a type parameter (ii)

- `Hashtable` needs methods from `Object`
  - present in all types
  - not a special requirement

```
public class Hashtable<K,V> {
  private static class Entry<K,V> { … }
  private Entry<K,V>[] table;
  …
  public Data get(K key) {
    int hash = key.hashCode();
    for (Entry<Key,Data> e = table[hash & hashMask];
         e != null; e = e.next) {
      if ((e.hash == hash) && e.key.equals(key)) {
        return e.value;
      }
    }
    return null;
  }
}
```

requirements to a type parameter (iii)

- `TreeMap` need more than `Object` methods

```
public interface Comparable<T> {
  public int compareTo(T arg) ;
}
```

```
public class TreeMap<K extends Comparable<K>,V> {
    private static class Entry<K,V> { ... }
    …
    private Entry<K,V> getEntry(K key) {
        Entry<K,V> p = root;
        K k = key;
        while (p != null) {
            int cmp = k.compareTo(p.key);
            if (cmp == 0)       return p;
            else if (cmp < 0)   p = p.left;
            else                p = p.right;
        }
        return null;
    }
    …
}
```

bounded type parameters

- *bounds* = classes or interfaces that a type variable extends and implements
- purpose:
  - make available no-static methods of a type variable
  - gives no access to constructors or static methods
- syntax:

`TypeVariable extends Superclass &`
Interface$_1$ & Interface$_2$ & ... & Interface$_n$

```
class Pair<A extends Comparable<A> & Cloneable,
           B extends Comparable<B> & Cloneable>
  implements Comparable<Pair<A,B>>, Cloneable { … }
```

using generic types

- can use generic types with or without type argument specification
  - with concrete type arguments
    - *concrete instantiation*
  - without type arguments
    - *raw type*
  - with wildcard arguments
    - *wildcard instantiation*

---

concrete instantiation

- type argument is a concrete type

```
void printDirectoryNames(Collection<File> files) {
  for (File f : files)
    if (f.isDirectory())
      System.out.println(f);
}
```

- more expressive type information
  - enables compile-time type checks

```
List<File> targetDir = new LinkedList<File>();
... fill list with File objects ...
printDirectoryNames(targetDir);
```

raw type

- no type argument specified

```
void printDirectoryNames(Collection files) {
  for (Iterator it = files.iterator(); it.hasNext(); ) {
    File f = (File) it.next();
    if (f.isDirectory())
      System.out.println(f);
  }
}
```

- permitted for compatibility reasons
  - permits mix of non-generic (legacy) code with generic code

```
List<File> targetDir = new LinkedList<File>();
... fill list with File objects ...
printDirectoryNames(targetDir);
```

---

wildcard instantiation

- type argument is a wildcard

```
void printElements(Collection<?> c) {
  for (Object e : c)
    System.out.println(e);
}
```

- a wildcard stands for a family of types
  - bounded and unbounded wildcards supported

```
Collection<File> targetDir = new LinkedList<File>();
... fill list with File objects ...
printElements(targetDir);
```

wildcards

- 3 families of types:
  - – unbounded wildcard `?`
    - all types
  - – upper-bound wildcard `? extends Supertype`
    - all types that are subtypes of `Supertype`
  - – lower-bound wildcard `? super Subtype`
    - all types that are supertypes of `Subtype`

---

definition of generic methods

```
class Collections {

  public static
  <A extends Comparable<A>> A max (Collection<A> xs) {
    Iterator<A> xi = xs.iterator();
    A w = xi.next();
    while (xi.hasNext()) {
      A x = xi.next();
      if (w.compareTo(x) < 0) w = x;
    }
    return w;
  }

}
```

- constructors may be generic, too

use of generic methods

- no special invocation syntax
  - type arguments are inferred from actual arguments

```
final class Test {
  public static void main (String[ ] args) {
    LinkedList<Byte> byteList = new LinkedList<Byte>();
    byteList.add(new Byte((byte)0));
    byteList.add(new Byte((byte)1));

    Byte y = Collections.max(byteList);
  }
}
```

wrap-up

- generics increase type safety and expressiveness
- generic types & generic methods
- type variables = placeholder for unknown type
- bounds = give access to non-static methods
- instantiation with concrete type and wildcard
- raw type permitted for compatibility
- implicit type inference for generic methods

agenda

- generics
- enums
- annotations
- autoboxing, for-each loop, static import, varargs
- concurrency utilities

---

enum type

- enum types in Java 5.0:

```
public enum Season { winter, spring, summer, fall }
```

- type-safe alternative to old-style static finals

```
public class Season {
  static final int WINTER;  static final int SPRING; ... }
```

- design goals:
  - compile-time type safety
  - performance comparable to `int` constants
  - typesafe constants aren't compiled into clients
    - you can add, reorder or remove constants without recompiling clients
  - printed values are informative
  - enum constants can be used in collections, e.g. as HashMap keys

enums with fields - use in switch

```
public enum Coin {
  penny(1), nickel(5), dime(10), quarter(25);

  private final int value;
  private Coin(int value) { this.value = value; }
  public int value() { return value; }
}
```

```
private enum CoinColor { copper, nickel, silver }
```

```
CoinColor color(Coin c) {
  if (c == null) throw new NullPointerException();
  switch(c) {
    case Coin.penny:   return CoinColor.copper;
    case Coin.nickel:  return CoinColor.nickel;
    case Coin.dime:    return CoinColor.silver;
    case Coin.quarter: return CoinColor.silver;
  }
  throw new AssertionError("Unknown coin: " + c);
}
```

methods per enum value

```
public abstract enum Operation {
  plus  {double eval(double x, double y) { return x + y; }},
  minus {double eval(double x, double y) { return x - y; }},
  times {double eval(double x, double y) { return x * y; }},
  div   {double eval(double x, double y) { return x / y; }};

  // perform arithmetic operation represented by this constant
  abstract double eval(double x, double y);
}
```

```
void f(double x, double y) {
  for (Operation op : Operation.values()) {
    System.out.println(x+" "+op+" "+y+" = "+op.eval(x, y));
  }
}
```

agenda

- generics
- enums
- annotations
- autoboxing, for-each loop, static import, varargs
- concurrency utilities

---

program annotation facility

- allows developers
  - to define custom *annotation types*
  - to *annotate* fields, methods, classes, etc. with *annotations* corresponding to these types

- allow tools to read and process the annotations
  - no direct effect on semantics of a program
  - e.g. tool can produce additional Java source files or XML documents related to the annotated program

sample usage

- annotated class

```
@Copyright("2002 Yoyodyne Propulsion Systems, Inc.")
public class OscillationOverthruster { ... }
```

- corresponding definition of annotation type

```
public @interface Copyright { String value(); }
```

- reading an annotation via reflection

```
String copyrightHolder
= OscillationOverthruster.class.
  getAnnotation(Copyright.class).value();
```

retention

- it makes little sense to retain all annotations at run time
  - would increase run-time memory-footprint

- annotations can have different lifetime:

SOURCE:
  - discarded after compilation

CLASS:
  - recorded in the class file as signature attributes
  - not retained until run time

RUNTIME:
  - recorded in the class file *and* retained by the VM at run time
  - may be read reflectively

agenda

- generics
- enums
- annotations
- autoboxing, for-each loop, static import, varargs
- concurrency utilities

---

autoboxing

- automatic conversion of data of primitive type to corresponding wrapper type and vice versa

```
int[] values = { 5, 13, 12, 40, 30 };
Collection<Integer> collection = new ArrayList<Integer>();
for (int val : values)
{ collection.add(val); }
```

autoboxing

```
Collection<Integer> collection;
int summe = 0;
for (Integer val : collection)
{ summe += val; }
```

auto-unboxing

enhanced for-loop

- standard idiom to iterate over a collection is somewhat verbose:

```
for (Iterator i = c.iterator(); i.hasNext(); ) {
  String s = (String) i.next();
  ...
}
```

- new form of for loop specifically designed for iteration over collections and arrays:

```
for (String s : c) {
  ...
}
```

implement interface Iterable or is an array

static import

- allow importation of static methods and fields
  - in the manner that classes and interfaces can now be imported
- example:
  - methods from `java.lang.Math` are static methods
  - must be named `Math.abs(x)`, `Math.sqrt(x)`, `Math.max(a,b)`

```
import static java.lang.Math.*;

...

x = sqrt(5);
y = abs(y);
z = max(x,y);
```

varargs

- varargs allow specification of a sequence of arguments
- have convenient invocation syntax

```
public class Formatter {
  public void format(String format, Object... args) { ... }
}
formatter.format("%d bytes in %d seconds (%.2f KB/s)\n",
      512,
      60,
      ((double)(512 / 1024) / (double)60)
);
```

agenda

- generics
- enums
- annotations
- autoboxing, for-each loop, static import, varargs
- concurrency utilities

situation before JDK 5.0

- concurrency API more or less stable since JDK 1.0
  - but big changes with JDK 5.0 – why ? what was missing ?

- high-level concurrency support
  - very few *active objects* in the JDK
    - most desired: thread pool
      - you find countless examples in Java books, magazines on the web, etc.

  - no high-level synchronization / communication abstractions between threads
    - e.g. a blocking queue
    - you always had to start with **`wait()`** / **`notify()`**

Callable vs. Runnable

- similar to **`Runnable`**, but
  - returns a result
  - throws an exception if it fails
  - still no parameter
- defined as:

```
public interface Callable<V> {
   V call() throws Exception;
}
```

future pattern

- `Future` = abstraction that let’s you obtain the result of an asynchronous activity
  - called *future* or *IOU* (for “I owe you a result”)

- `FutureTask` = façade that combines
  - an asynchronous task (`Runnable/Callable`)
  - waiting and retrieval of results from the task
  - interruption of task and check for cancellation/success

---

example for a `FutureTask<V>`

```
class MyCallableRunner {
  public MyCallableRunner(final int cnt) {
    Callable<Long> c = new Callable<Long>() {
       public Long call() {
          long start = new Date().getTime();
          for (int i=0; i<cnt; i++) {
             System.out.println("-");
          }
          return new Long (new Date().getTime() – start);
       };

    FutureTask<Long> f = new FutureTask<Long>(c);
    Thread t = new Thread(f);
    t.setDaemon(false);
    t.start();
    System.out.println (“It took “ + f.get() +
                    “ msec to print “ + cnt +
                    “ times the character: \”-\” .”);
  }
}
```

queue - description

- data structure based on first-in-first-out (fifo) policy
  - oppose to a stack: fist-in-last-out (filo)
- blocking queue
  - most commonly used exchange medium between cooperating threads working according to the producer-consumer-pattern

```
class Producer implements Runnable {
  private final BlockingQueue queue;
  Producer(BlockingQueue q) { queue = q; }
  public void run() {
    try { while(true) { queue.put(produce()); } }
    catch (InterruptedException ex) { ... handle ...}
  }
  Object produce() { ... }
}
class Consumer implements Runnable {
} …
```

blocking queue - example

```
class Consumer implements Runnable {
  private final BlockingQueue queue;
  Concumer(BlockingQueue q) { queue = q; }
  public void run() {
    try { while(true) { consume(queue.take()); } }
    catch (InterruptedException ex) { ... handle ...}
  }
  void consume(Object x) { ... }
}
```

```
class Setup {
  void main() {
    BlockingQueue q = new LinkedBlockingQueue();
    Producer p = new Producer(q);
    Consumer c1 = new Consumer(q);
    Consumer c2 = new Consumer(q);
    new Thread(p).start();
    new Thread(c1).start();
    new Thread(c2).start();
  }
}
```

synchronizers

- exchanger
  - synchronization point at which two threads can exchange objects
- barrier
  - allows a set of threads to all wait for each other to reach a common barrier point
- semaphore
  - restricts the number of threads than can access some (physical or logical) resource
- latch
  - allows one or more threads to wait until a set of operations being performed in other threads completes

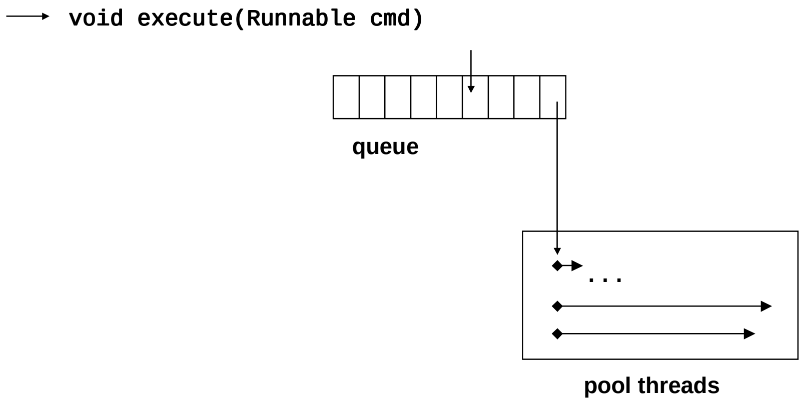
count down latch - example

- a pair of classes in which a group of worker threads use two countdown latches:
  - 1st latch: start signal that prevents any worker from proceeding until the driver is ready for them to proceed
  - 2nd latch: completion signal that allows the driver to wait until all workers have completed

thread pool

- threads often maintained in a pool
  - for performance improvement and/or better control the behavior of the overall system
- class `ThreadPoolExecutor` implements a thread pool
  - execute a `Runnable` or submit a `Callable` task
  - `task` put into an internal queue
    - queue can be configured: any queue class that implements `BlockingQueue`
    - special case: size == 0
  - when `task` is at the beginning of the queue and
    a pool thread becomes idle
    task is taken from the queue and applied to this pool thread

supplying a task to a pool thread



`void execute(Runnable cmd)`

queue

. . .

pool threads

configuration of `ThreadPoolExecutor`

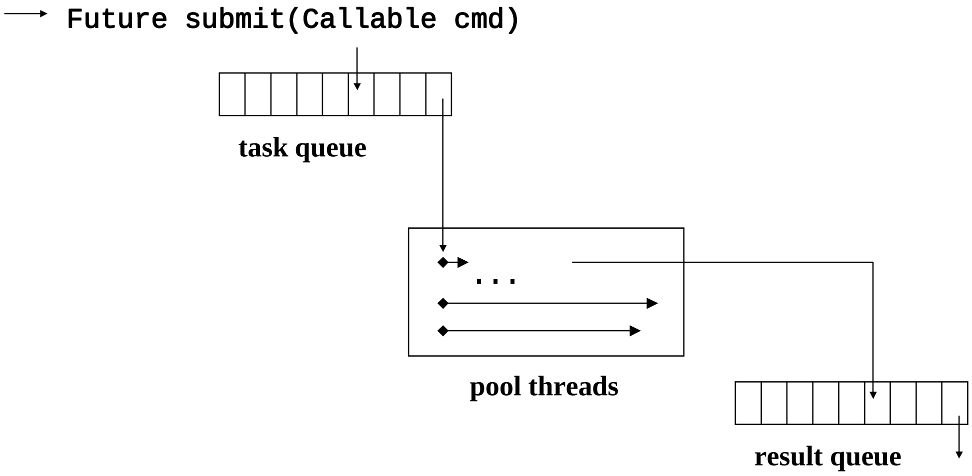
- important issue: configuration / tuning
  - core pool size
  - maximum pool size
  - internal queue
  - timeout value for pool threads
  - thread factory
  - rejected execution handler
- predefined factory methods
- subclasses can override `protected` methods

---

scatter-gather processing

- thread pool
  - supports *scatter* phase in a scatter-gather architecture
  - takes `Runnable`s that do not produce a result
- completion service
  - supports *gather* phase in a scatter-gather architecture
  - takes `Callable`s that do produce a result
  - converts them to `FutureTask`s
  - places the `Future`s into a queue
  - from which they can be retrieved for further processing

architecture of a completion service



---

usage - example

- run a set of solvers for a certain problem concurrently
  - each solver returns a result
- process the results in a method `use()`
  - if solver returned a non-null value

```
void solve(Executor e, Collection<Callable<Result>> solvers)
    throws InterruptedException, ExecutionException {
  CompletionService<Result> ecs
    = new ExecutorCompletionService<Result>(e);
  for (Callable<Result> s : solvers) ecs.submit(s);
  int n = solvers.size();
  for (int i = 0; i < n; ++i) {
    Result r = ecs.take().get();
    if (r != null) use(r);
  }
}
```

not mentioned yet ...

- explicit locks
- explicit conditions
- scheduled tasks
- lock-free programming
- memory model issues

---

wrap-up

- key change in the language: generics
- minor language additions: enums, autoboxing, etc.
- annotations for tool builders
- improved support for concurrent programming

author

Angelika Langer

Training & Mentoring

Object-Oriented Software Development in C++ & Java

Email: al@AngelikaLanger.com

http: www.AngelikaLanger.com