Basics of programming 3

Java collections

Java Generics

Generics

- Objective: code reuse with generic types
- `C` solution
  - `void* malloc(size_t s)`
    - casting is dangerous
    - error may remain hidden
  - `#define max(a,b) ((a)>(b)?(a):(b))`
    - side-effects cause problems

Generics

- Objective: code reuse with generic types
- **C++** solution
  - `template <class T> T max(T a, T b) { return (a>b)?a:b; }`
    - semantic and syntactic requirements for **T**
      - documentation is important
    - errors might be uncovered at compile time

Generics

- Objective: code reuse with generic types
- **`Java`** original solution (pre 5.0)
  - all classes are subclasses of *Object*
    - **`C`**'s **`void*`** philosophy in new disgease
    - code is full of casting
    - errors uncovered during runtime

Generics example: Object cast

```
public class Store {
  Object[] os; int size;
  public Store(int i) {
    os = new Object[i];
    size = 0;
  }
  public void put(Object o) {
    os[size] = o; size++;
  }
  public Object get(int i) {
    return os[i];
  }
  public int size() {
    return size;
  }
}
```

```
Store s = new Store(10);

s.put("hello ");
s.put("world");
s.put("!");

for (int i = 0;
     i < s.size();
     i++) {

  String l = (String)s.get(i);
  System.out.print(l);

}
```

Java generic classes

- Since Java 5
- Similar to C++ templates
  - But: no class generated for each parametrization
- Parameter interface is definite
  - programmer knows it
- Errors uncovered during compile time
- Cast-free source code

Generics example: Template

```
public class Store<T> {
  T[] os; int size;
  public Store(int i) {
    os = (T[])(new Object[i]);
    size = 0;
  }
  public void put(T o) {
    os[size] = o; size++;
  }
  public T get(int i) {
    return os[i];
  }
  public int size() {
    return size;
  }
}
```

```
Store<String> s =
       new Store<String>(10);

s.put("hello ");
s.put("world");
s.put("!");

for (int i = 0;
     i < s.size();
     i++) {

  String l = s.get(i);
  System.out.print(l);

}
```

Generics and inheritance (array)

```
Object[] oa = new String[10];
oa[0] = ”Hello”;
oa[1] = new Integer(2);
        //ArrayStoreException
```

- **`Object[]`** can be replaced by **`String[]`**
- Only types compatible with dynamic-type can be stored

Generics and inheritance

```
void printStore(Store<Object> of) {
  for (int i = 0; i < of.size(); i++) {
    System.out.println(of.get(i));
  }
}
```

```
Store<String> sf = new Store<String>(10);
Store<Object> of = sf;
of.put(new Integer(13));
```

- **`Store<Object>`** is **not** a superclass of **`Store<String>`!**
- Their types are incompatible

Wildcard: ?

```
void printStore(Store<?> of) {
 for (int i = 0; i < of.size(); i++) {
    System.out.println(of.get(i));
  }
}
```

```
Store<String> sf = new Store<String>();
Store<?> of = sf;
of.put(new Integer(13));  // CT error
of.put("Hello");          // CT error
```

- **<?>** can be converted to anything, like **<Object>**
- other direction is prohibited

Bound wildcard: *extends*

```
void putAll(Store<E> s) {
  for(int i = 0; i < s.size(); i++) {
      put(s.get(i));
}
```

- What if type of **`s`** is **`Store<F>`**, where **`F`** is subclass of **`E`**?

```
void putAll(Store<? extends E> s) {
  for(int i = 0; i < s.size(); i++) {
      put(s.get(i));
}
```

Bound wildcard: *super*

```
void put2All(Store<E> s) {
  for(int i = 0; i < size(); i++) {
      s.put(get(i));
}
```

- What if type of **`s`** is **`Store<F>`**, where **`E`** is subclass of **`F`**?

```
void put2All(Store<? super E> s) {
  for(int i = 0; i < size(); i++) {
      s.put(get(i));
}
```

Multiple generic parameters

- What if generic type must be **`X`** and **`Y`** at the same time?

```
<T extends X & Y>
```

```
public static
<T extends Object & Comparable<? Super T>>
T max(Collection<? extends T> coll)
```

Java Collection Framework

Collections: array

- built-in type
- immutable size
  - C/C++ doesn't check, has **`realloc`**
  - Java checks, no **`realloc`**
    - cannot avoid reference copy
- inheritance and type compatibility is problematic

```
Object[] oa = new String[10];
oa[3] = new Double(3.14);
```

- convenient use

Collections: dynamic datastr.

- Linked list
  - single or double-linked, ring, sentinel/guard, comb
- Binary (n-ary) tree
  - balance, red-black, AVL
- Word-tree
- Hash-table
  - hash function is important

Collections: general features

- Common basic functionality
  - insert, search, delete
    - CRUD: create, read, update, delete
  - iteration
- Different implementations
  - ordered
  - set/bag
  - deep/shallow copy
  - optimization: e.g. insert vs. search

Collection usage

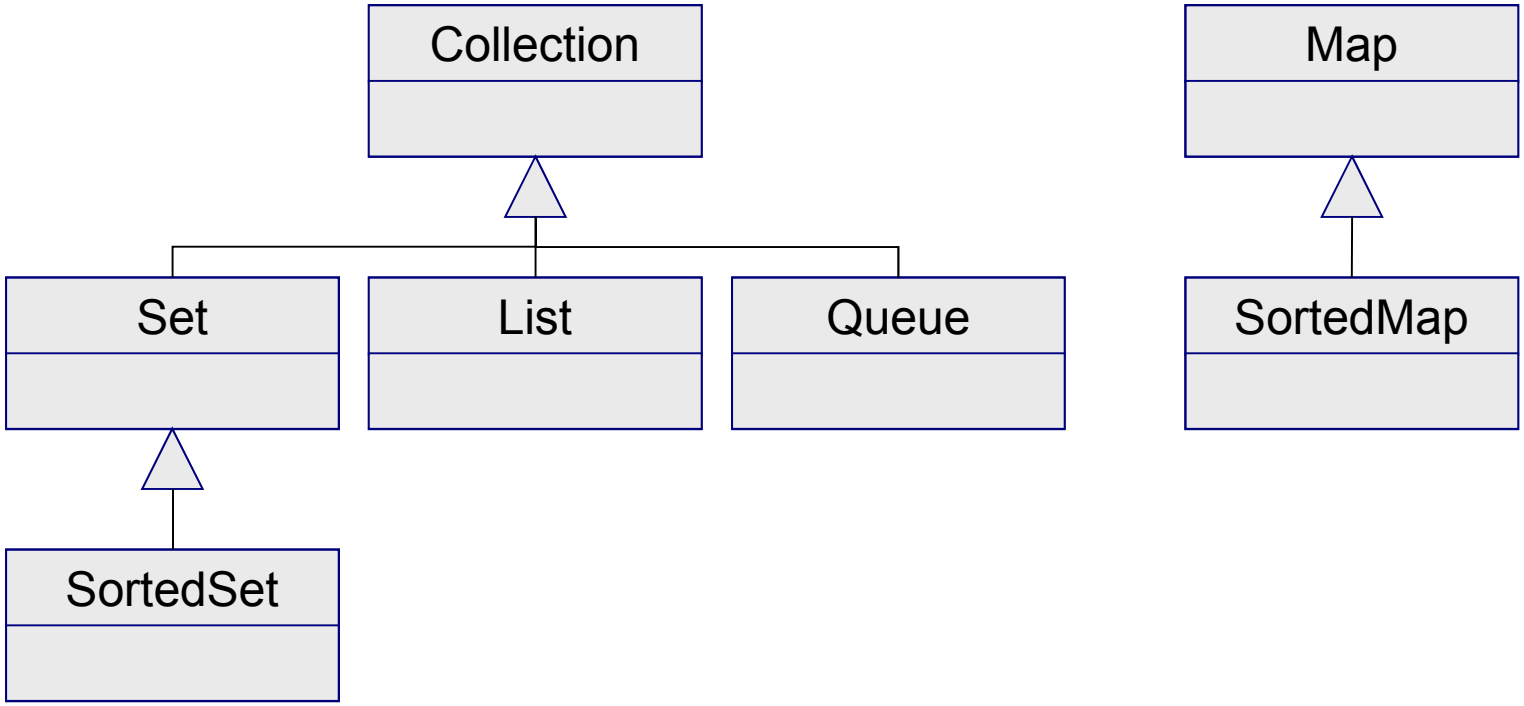
```
List<Integer> l = new ArrayList<Integer>();
// since J2SE 7
// List<Integer> l = new ArrayList<>();

for (int i = 0; i < args.length; i++) {
      l.add(Integer.parseInt(args[i]));
}

for (int i = 0; i < l.size(); i++) {
      System.out.println(l.get(i)+10);
}
```

Collection framework

- Interfaces



Interface `Collection`

- General collection functionality
- May be
  - ordered or not
  - set or bag
- Generic definition:

```
Collection<E>
```

Interface `Collection` 2

- `void add(E e)` *optional*
  - adding new object
- `void addAll(Collection<? extends E> c)` *optional*
  - `c` collection's all objects added
  - only references are copied: shallow copy
- `boolean remove(E e)` *optional*
  - removes object if contained
- `boolean removeAll(Col<? ext E> c)` *optional*
  - all object in `c` are deleted from this collection
  - only references are deleted, no direct destruction takes place!

Interface `Collection` 3

- `boolean contains(E e)` *optional*
  - true if e is stored
- `boolean containsAll(`*`Col`*`<? `*`ext`*` E> c)` *optional*
  - true, if all objects in c are stored
- `int size()`
  - number of stored objects
- `boolean isEmpty()`
  - true if empty
- `void clear()`
  - all references stored are deleted

Interface `Collection` 4

- `boolean retainAll(`*`Col`*`<? `*`ext`*` E> c)` *optional*
  - retaining only those objects stored in c
- `boolean equals(E e)`
  - equality
  - must be symmetric
- `Object[] toArray()`
  - collection converted to array
- `<T> T[] toArray(T[] ta)`
  - collection converted to array of type similat to that of `ta`
- `Iterator<E> iterator()`
  - returns an iterator for this collection

Interface `Iterator`

- Iteration over elements
  - different semantics from C++ STL iterators!
- Definition: `Iterator<E>`
- `boolean hasNext()`
  - true, if there are uniterated elements
- `E next()`
  - returns next element, if any
- `void remove()`
  - removes element last returned by `next()`

Interface `Iterator` 2

- Typical usage:

```
Collection<Integer> c = ...;
...
Iterator<Integer> i = c.iterator();

while (i.hasNext()) {
	int a = i.next(); // outboxing
	if (a < 0) {
		i.remove();
	}
}
```

Interface `Iterator` 3

- Handling multiple access
  - modifying collection during iterations causes errors
  - `ConcurrentModificationException` is thrown

```
Collection c = ...;
...
Iterator i1 = c.iterator();
Iterator i2 = c.iterator();
i1.next();
i2.next();
i2.remove();
i1.next();   // here exception is thrown
```

Interface `Set`

- Set: every object stored only once
- Ordering is unknown
- Iterator may iterate in any order
- No extra methods
  - all Collection methods are implemented
- Typical implementation: `HashSet`
  - good hash function needed for efficiency

Interface `SortedSet`

- Set with content ordered
- Content decides ordering
  - natural or `Comparator`
    - Natural: `Comparable.compareTo(Object o)`
    - Comparator: `int compare(Object o1, Object o2)`

      Compares its two arguments for order

      boolean **equals**(Object obj)

      obj is equal to this Comparator
- `Iterator` iterates in order
- Typical implementation: `TreeSet`

Interface `List`

- Sequence of elements
- A single object can appear multiple times
- The index of each element is known
  - access by index is provided
- Searchable
- Provides `ListIterator` for easier access
  - subclass of Iterator, extended functionality
- Typical implementation: `ArrayList`

Interface `List` 2

- Extra methods of `List<E>`
  - `add(int index, E e)`
  - `E get(int index)`
  - `int indexOf(Object)`
  - `int lastIndexOf(Object)`
  - `E remove(int index)`
  - `boolean remove(Object o)`
  - `E set(int index, E e)`
  - `List<E> subList(int from, int to)`
  - `...`

Interface `Map`

- Stored keys and values
- For a key the value can be set and get
- Using mutable keys are not advised
- Three view
  - set of keys
  - set of values
  - set of key-value pairs
- Typical implementation: `HashMap`

Interface `Map` 2

- Definition: `Map<K,V>`
  - `K` key types
  - `V` value type
- Methods similar to Collection methods:
  - `void clear()`
  - `boolean equals()`
  - `boolean isEmpty()`
  - `int size()`

Interface `Map` 3

- `V put(K key, V value)`
  - adding the key-value pair to the map
- `void putAll(Map<? ext K, ? ext V> m)`
  - adding all pairs in m to this map
- `V get(K key)`
  - returns value for this key, does not remove it
- `V remove(K key)`
  - return value for this key, key-value removed

Interface `Map` 4

- `boolean containsKey(Object key)`
- `boolean containsValue(Object value)`
  - true if contained
- `Set<K> keySet()`
  - returns set of keys
- `Collection<V> values()`
  - return collection of values
- `Set<Map.Entry<K,V>> entrySet()`
  - return set of key-value pairs

Interface `SortedMap`

- Extending Map with sorted keys
  - natural or `Comparator`
  - similar to SortedSet
- Views accordingly
  - `keys(), values(), entrySet()`
  - iterators iterate according to key order
- Typical implementation: `TreeMap`

For-each loop

- Pre Java 5 with *iterator*
  - `hasNext()` and `next()`
- Since Java 5 simplified *for* loop (also for arrays)

```
Collection<Integer> c = ...;
...
for (Integer i : c) {
       System.out.println(i);
}
```

```
static public void main(String[] args) {
  for (String s : args) { System.out.println(s); }
}
```

For-each-loop vs Iterator

- For-each-loop
  - + more readable code
  - - no collection modification
- Iterator
  - + element removal supported
  - - code overhead, readability (?)

`Collections`: a helper class

- Sorting, min-max search, etc.
  - `sort(List<T> l)`
  - `sort(List<T> l, Comparator<T> c)`
- Reversing
  - `reverse(List<T> l)`
- Rotation
  - `rotate(List<T> l, int distance)`
- Shuffling
  - `shuffle(List<T> l)`
  - `shuffle(List<T> l, Random r)`

Collection wrappers: const

- Collections as parameters
  - Java: shallow copy → mutable by default
  - C++: *const* keyword → immutability
- How to pass immutable collections in Java?
- `java.util.Collections`
  - `Collection unmodifiableCollection(Collection c)`
  - `List unmodifiableList(List c)`
  - `Map unmodifiableMap(Map c)`
  - `Set unmodifiableSet(Set c)`