Java Collections Framework (JCF): Lists, Stacks, Queues, Priority Queues, Sets, and Maps

Slides derived from the work of
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Data Structures vs Abstract Data Types

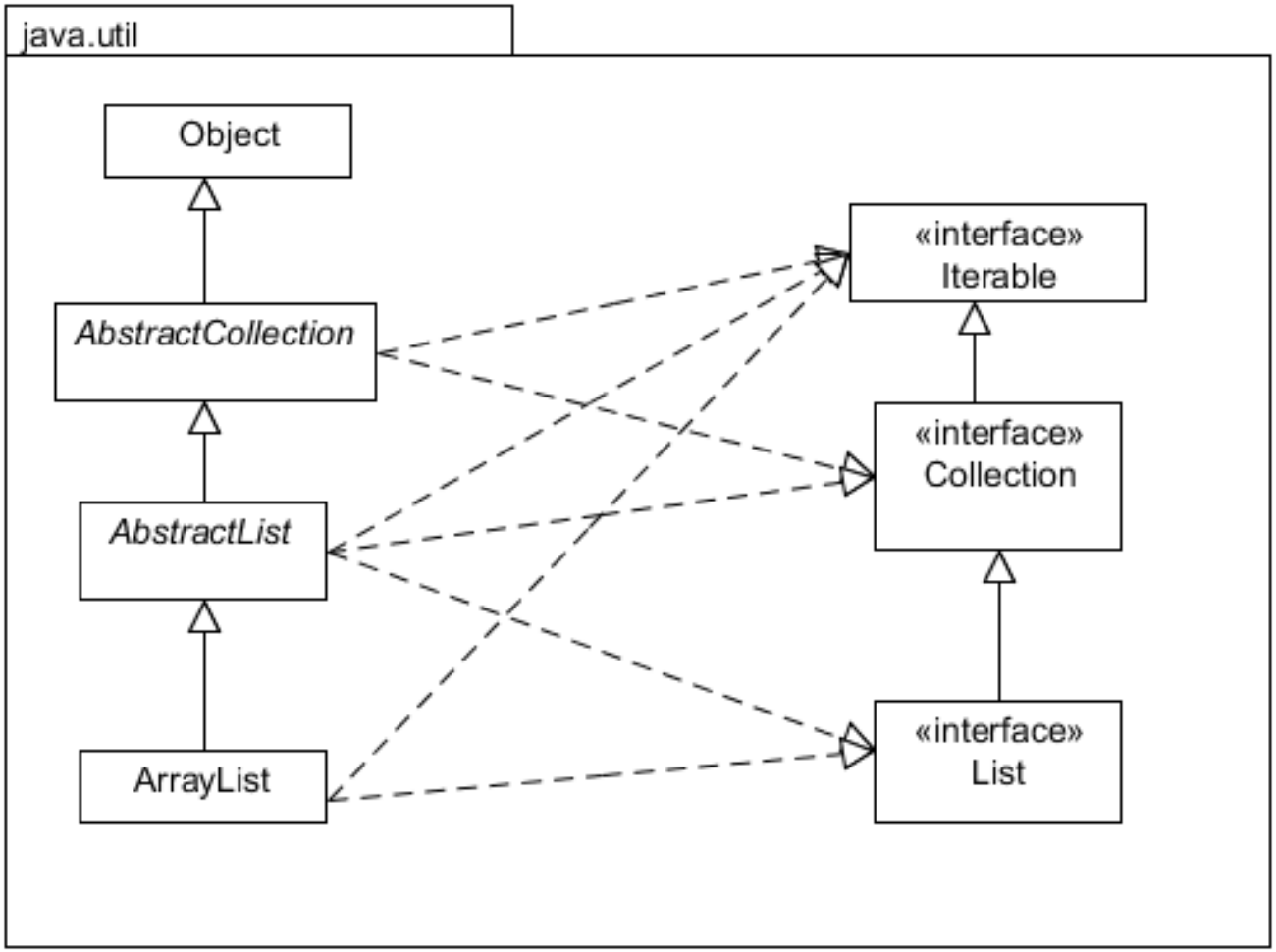
- Data Structure:
  - A specific way of organizing data and operations to access/use the data
  - Structure of the data tied directly to the implementation

- Abstract data type: An **implementation independent** group of data and a set of operations on this data

Data Structures We Know

- Both arrays and ArrayList are data structures
  - Implementation dependent
- What are the similarities between ArrayList and arrays?
  - Organization of data?
  - Operations?
- What are the differences between these?
  - Organization of data?
  - Operations?

Class Hierarchy for ArrayList



- Which are abstract data types?
- Which are data structures?

List Interface

- What is a list?
  - What is a grocery list?
  - How about a list of exam questions?

- Java API: examine List interface
  - Ordered Collection
  - Duplicates allowed
  - Provides Iterator
    - Examine Iterator API

Linked Lists

- Example of a linked list using people …
  - Singly linked list versus doubly linked list
  - How do we search for items?
  - How efficient is it to add items?

- Java API: examine LinkedList API

LinkedList

- Another class that implements the List interface: LinkedList (concrete class)
  - What methods are in LinkedList and not ArrayList?
- Critical data structure difference: LinkedList vs. ArrayList
  - Incremental allocation
  - Makes adding to the head and tail of the list cheaper

Choosing Lists

A LinkedList is used instead of an ArrayList when:

- Size of structure changes radically over time
  - Once ArrayLists get big, they stay big
- Random access not needed
  - What does this do to binary search?
- Insertion and deletion at head and tail and more common than search

LinkedList Example

- Series of events that must be completed in order
  - Floor
  - Horse
  - Rings
  - Vault
  - Parallel bars
  - High bar
- Teams can start anywhere in the sequence but must complete the sequence in order
- All competitors from each team compete in each event
- How do we represent this? **Code example

Collection Interface

- **Collection interface**: The root of the JCF hierarchy
  - Represent a group of objects
  - Operations include: add/remove/iterate

- **Collections class**: provides many static methods, including: shuffle, max, min, reverseOrder, sort, frequency, …

Examine API for Collections and Collection…

Event example II

- Sort the events for a competitor by the highest scores received
- Reverse sort the events (lowest scores first)
- Use an Iterator to loop through the scores
  - Explicit Iterator
  - Implicit Iterator (for each loop)

Queue

- Example of queue with people to buy tickets
- Key: First in, First out (FIFO)
- See: Java API: Queue Interface

Example

Store people about to compete in an event in Queue

Priority Queue

- Standard Queue: order by insertion order
- Priority Queue: order by some ordering
  - Natural order or defined by a Comparator

- Java API: Examine PriorityQueue API
- Example: office hours
  - What happens if President Boren shows up?

Stack

- Last in First out (LIFO)
- Add (push) and remove (pop) items to/from the top of the stack

- Data structure for Stack is extensible array

Stack

- Example: grading exams
- Example: System stack
  - main() method is at the bottom
  - Most recent method call is at top
  - Call a new method: pushes the method onto the stack
  - Return from a method: pops the top method off of the stack

Uses for Collections

- Shuffle exam questions on multiple choice tests
- Frequency to figure out how many coins of each type you have
- ReplaceAll to fix all of an item in an inventory (recalls etc)
- ReplaceAll to give everyone the same grade
- IndexOfSublist to return a sublist all students born in Boston assuming they are sorted by birth location
- nCopies to make lots of clones
- Empty to get rid of all your homework

Backward Compatibility

- Vector and Stack
  - Part of Java from the start
  - Were retrofitted into JCF
  - Synchronized– expensive, but needed for threading
- Vector
  - Data structure: extensible array
  - Added methods from List interface that weren't in class
  - Added generic
- Uses Enumeration interface (old form of Iterator)

Sets and Maps

Set Interface

- Set is another abstract data type
  - Elements in a set are not ordered
  - No duplicate elements
- How could Set be implemented with an array data structure?
  - Why isn’t this good enough?

Set Interface

- Examine class hierarchy in API
  - Note similarities and differences to design for ArrayList hierarchy
- What operations are typical of sets in mathematics?
- What operations does Java Set support?
  - Which Java Set operations are similar to those in discrete math?

Choosing Sets

- Sets are used when order isn't important
  - We're so used to using arrays, that we tend to think of order being important when it isn't
- Example: Bug tracking software
  - Store bug reports
  - Find bug reports
- Example: grocery list
- Remember sets are the theoretical basis of most of computer science—they are everywhere

HashSet

HashSet is a data structure (also called a hash table) that implements the Set interface

HashSet: Data Structure

Approach:

- Create a hash code from the object
  - May not be unique
  - Should be based on a characteristic of the object
  - Eclipse can generate automatically (** demo)
- We've seen this method in the Object class
- Use the hash code as an address in a huge array (called a *hash table*)

Example

- Create a set of students
  - What should our hash code be?
- Use set operations from Set Interface API
  - http://docs.oracle.com/javase/tutorial/collections/interfaces/set.html

Example HashSet

- Suppose we're storing numerical data
- Hash code is number % tableSize
  - This isn't a very good hash code!!!
- Let the table size be 100
  - Insert 23983, 10484, 3817692, 1968372, 938983
- Collision: move to the next free spot in the table
- Classic time/space tradeoff

Critical Hash Table Measurements

- Load factor: # of used elements/table size
- Load factor needs to stay small for a table to work well
- When the load factor gets close to 1, clustering is a problem
- Java fixes this by reallocating the table when it gets too dense (expensive!)

Critical Hash Table Measurements

Choosing the table size, the load factor, and the hash functions are critical parts to the success of hashing

- If these are done well, hashing is fabulous
- Lots of people don't use hashing because of fear of these factors
  - **If managed correctly, hashing can be incredibly good**

Example for Home

- Create a HashSet that stores 1000 randomly generated integers
- Search for each integer
- Measure time
  - System.nanotime()
- Compare to ArrayList
  - How many lines of code have to be changed?
  - Compare what happens when table size properly created initially

Questions?

- HashSets
  - What are the pros and cons?
- HashMap
  - How are these used?

TreeSet

- The problem with HashSet is that elements aren't ordered in any useful way
  - How would you sort data in a hash table?
  - LinkedHashSet orders elements by time of entry, but this often isn't a useful order
- TreeSet uses a natural ordering (Comparable)
  - Can use alternate ordering (Comparator)

Note: we are breaking from the mathematical notion of set

How Does TreeSet Work?

- Example brief introduction of Binary Search Tree
  - Tree balancing
- Will see full implementations in CS 2413 Data Structures

Map

- Another incredibly useful ADT!
- Stores <key, value> pairs
  - Key used to organize data (no duplicates)
  - Value is the data itself (duplicates allowed)

Map

Example: In computer gaming, all objects are stored in a Map <objectID, object>

- Objects are players, furniture, non-playable characters, etc.

Map Interface

- Examine methods in API carefully
  - How would you get iteration?
- Examine class hierarchy in API
  - Lots of implementation options

Example

- Implement a map that stores and retrieves names by an identification number
  - Use HashMap
- Examine differences in data ordering with HashMap, TreeMap, LinkedHashMap
  - HashMap used a lot in Java!

Collections Review

- JCF stores its static methods in one shared class
- Examine which methods apply to which type
  - Why doesn't Set have sort/reverse?