Heaps and Heap Sorting

- Heaps implemented in an Array
  - Heap Sorting
- Reading: L&C 12.5

Implementing Heaps in an Array

- Two of the programming steps for a heap using links were complicated
  - Finding the next parent for an add
  - Finding the new value for next after a remove
- Those steps are trivial for a heap in an array
- If the index 0 is the root and "next" is the index for a reference to the next open space:
  - After adding an element, just increment next
  - To remove an element, just decrement next

Implementing Heaps in an Array

- The class header, attributes, and constructor:

```
public class ArrayHeap<T extends Comparable> ...
{        // not shown as a subclass like in textbook
  private static final int DEFAULT_CAPACITY = 50;
  protected int count;
  protected T[] tree;

  public ArrayHeap()
  {
    count = 0;
    tree = (T[]) new Object[DEFAULT_CAPACITY];
  }
```

Implementing Heaps in an Array

- The add method:

```
public void addElement(T obj)
{
  if (count == tree.length)
    expandCapacity();   // same as for any array

  tree[count++] = obj;

  if (count > 1)
    heapifyAdd();
}
```

Implementing Heaps in an Array

- The heapifyAdd helper method

```
private void heapifyAdd()
{
  int next = count - 1;
  T temp = tree[next];    // pick up new value

  while ((next != 0) &&   // move up the tree as needed
    temp.compareTo(tree[(next-1)/2]) < 0) {
      tree[next] = tree[(next-1)/2]; //move parent down
      next = (next - 1)/2;
  }
  tree[next] = temp;      // (re)insert new value
}
```

Implementing Heaps in Arrays

- The removeMin method:

```
public T removeMin() ...
{
  // check for empty heap not shown
  T minElement = tree[0];  // start at the root
  tree[0] = tree[count-1];
  heapifyRemove();
  tree[--count] == null;   // kill stale reference

  return minElement;
}
```

Implementing Heaps in Arrays

- The heapifyRemove method (My version):

```
private void heapifyRemove()
{
  int node = 0;
  T temp = tree[node];
  int next = 0;
  do {
    if (next != 0) { // skip until second+ pass
      tree[node] = tree[next];
      node = next;
    }
```

Implementing Heaps in an Array

- The heapifyRemove method (continued):

```
     int left = 2 * node + 1;
     int right = 2 * (node + 1);
     if(tree[left] == null && tree[right] == null)
       next = count;     // force end of loop
     else if (tree[right] == null  ||
              tree[left].compareTo(tree[right]) < 0)
       next = left;
     else
       next = right;
   } while (next < count &&
            tree[next].compareTo(temp) < 0 );
   tree[node] = temp;
```

Implementing Heaps in Arrays

- I didn’t like the repetition of 8 lines of code in the initialization before the while loop and as 80% of the code in the body of the loop
- Whenever you see that situation in code, it is a clue that a do-while loop might be better
- I rewrote the heapifyRemove method as a do-while loop instead of the textbook code that uses a while loop - both code versions perform the same steps in the same order

Heap Sorting

- If we have a method with a parameter that is an array of type T to be sorted, it can be written to use a heap instead of one of the in-place array sorts we studied in lecture 19
- We can take each element from the array and put it in a heap
- Then loop removing the min from the heap and putting each element back into the array in order

Heap Sorting

```
// only this method needs to be shown for the example
public void heapsort(T[] data)
{
  HeapADT<T> temp = new ArrayHeap<T>();
  // copy the array into the heap
  for (T datum : data)      // use a for-each loop
    temp.addElement(datum);
  // place the sorted elements back into the array
  int count = 0;
  while(!temp.isEmpty())
    data[count++] = temp.removeMin();
} // temp goes out of scope
```

Heap Sorting Performance

- The performance is 2*N*log N or O(N logN)
- That is the same as quicksort or merge sort
- It uses the same amount of extra memory as the merge sort algorithm