16. Processing Arrays

Java

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Searching Arrays

Searching Arrays

- Searching is the process of looking for a specific element in an array
- There are many algorithms and data structures devoted to searching.
- In this section, two commonly used approaches are discussed:
  - ***Linear search***
  - ***Binary search***

Linear Search

- The linear search approach compares the key element, **key** sequentially with each element in the array.
- The method continues to do so until the key matches an element in the array or the array is exhausted without a match being found.
- If a match is made, the linear search returns the index of the element in the array that matches the key.
- If no match is found, the search returns -1.

Linear Search Animation

Linear Search

```
1  public class LinearSearch {
2    /** The method for finding a key in the list */
3    public static int linearSearch(int[] list, int key) {
4      for (int i = 0; i < list.length; i++)
5        if (key == list[i])
6          return i;
7      return -1;
8    }
9  }
```

- Trace the method using the following statements:

```
int[] list = {1, 4, 4, 2, 5, -3, 6, 2};
int i = linearSearch(list, 4);
int j = linearSearch(list, -4);
int k = linearSearch(list, -3);
```

Linear Search

- The result:

```
int[] list = {1, 4, 4, 2, 5, -3, 6, 2};
int i = linearSearch(list, 4); // returns 1
int j = linearSearch(list, -4); // returns -1
int k = linearSearch(list, -3); // returns 5
```

- On average, the algorithm will have to compare half of the elements in an array before finding the key if it exists.
- Since the execution time of a linear search increases linearly as the number of array elements increases, linear search is inefficient for a large array.

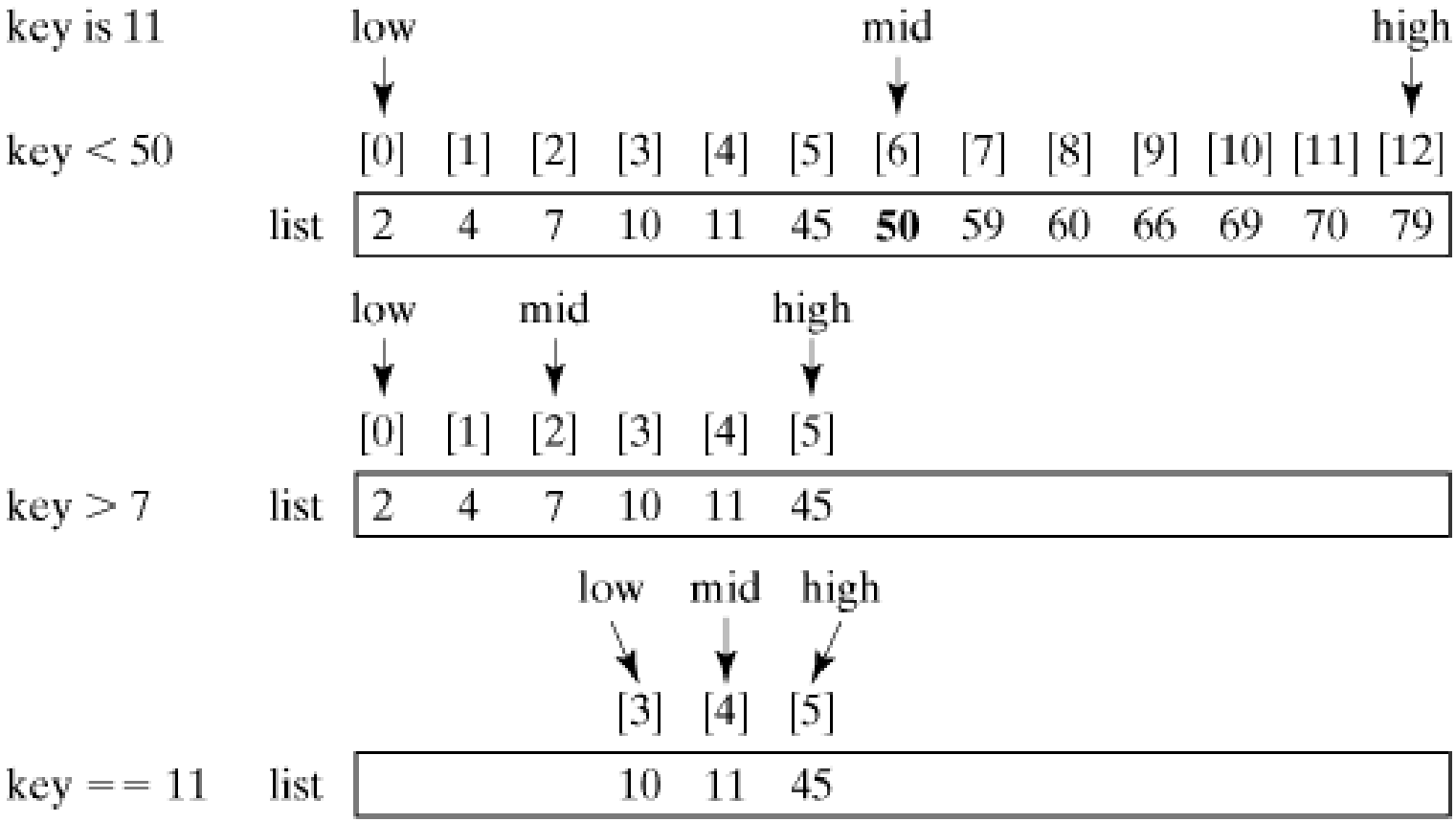
Binary Search

- For binary search to work, the elements in the array must already be ordered.
- Without loss of generality, assume that the array is in ascending order.

  e.g., 2 4 7 10 11 45 50 59 60 66 69 70 79

- The binary search first compares the key with the element in the middle of the array.

Binary Search Approach



Binary Search Approach

- The binary search returns the index of the search key if it is contained in the list.
- Otherwise, it returns -(insertion point + 1).
- The insertion point is the point at which the key would be inserted into the list.
- For example,
  - the insertion point for key 5 is 2, so the binary search returns -3;
  - the insertion point for key 51 is 7, so the binary search returns -8.

Binary Search Approach

```
1  public class BinarySearch {
2    /** Use binary search to find the key in the list */
3    public static int binarySearch(int[] list, int key) {
4      int low = 0;
5      int high = list.length - 1;
6
7      while (high >= low) {
8        int mid = (low + high) / 2;
9        if (key < list[mid])
10         high = mid - 1;
11       else if (key == list[mid])
12         return mid;
13       else
14         low = mid + 1;
15     }
16
17     return -low - 1;
18   }
19 }
```

Binary Search Approach

- Trace the program using the following statements:

```
int[] list = {2, 4, 7, 10, 11, 45, 50, 59, 60, 66,
   69, 70, 79};
int i = binarySearch(list, 2); // returns 0
int j = binarySearch(list, 11); // returns 4
int k = binarySearch(list, 12); // returns -6
```

Binary Search Approach

- Linear search is useful for finding an element in a small array or an unsorted array, but it is inefficient for large arrays.
- Binary search is more efficient, but requires that the array be pre-sorted.

Sorting Arrays

Sorting Arrays

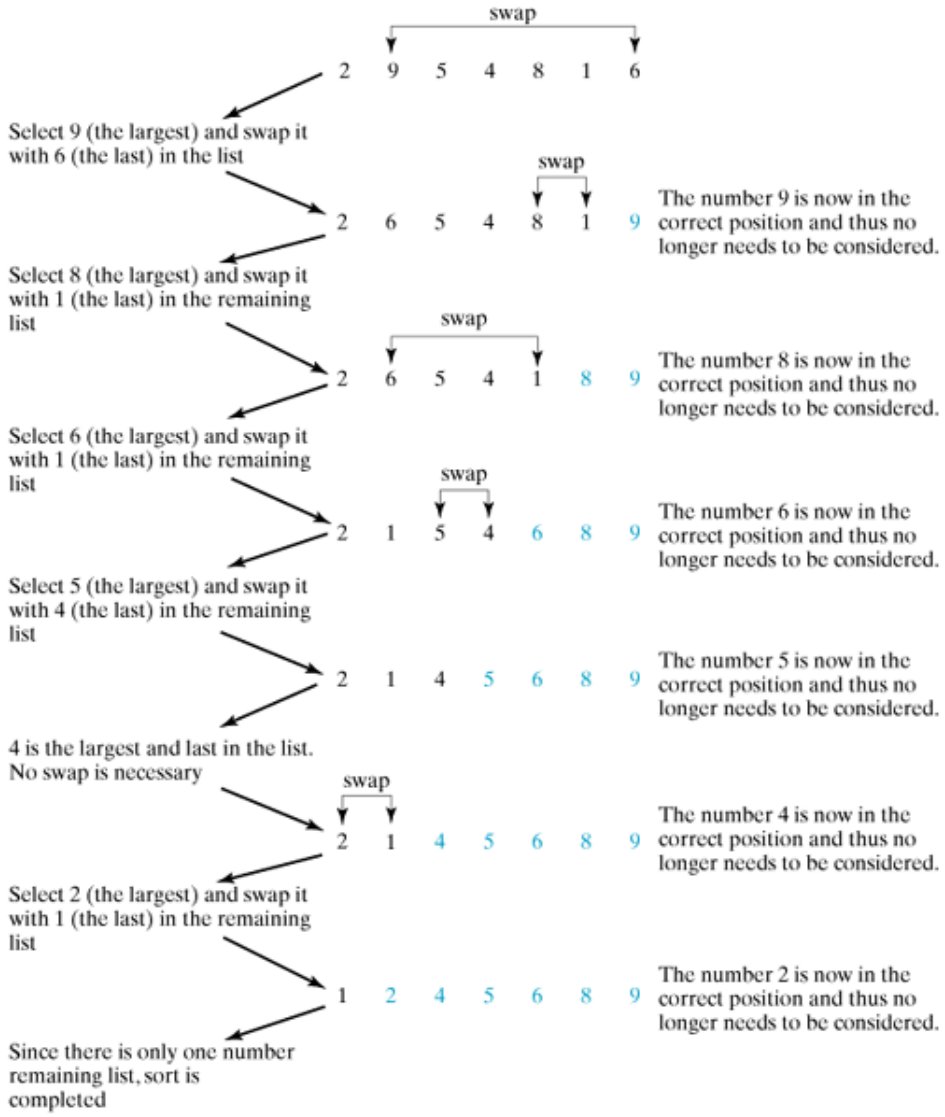
- Many different algorithms have been developed for sorting.
- This section introduces two simple sorting algorithms:
  - ***Selection sort***
  - ***Insertion sort***.

Selection Sort

- Selection sort finds the largest number in the list and places it last.
- It then finds the largest number remaining and places it next to last, and so on until the list contains only a single number.

Selection Sort

- The figure shows how to sort a list {2, 9, 5, 4, 8, 1, 6} using selection sort.



Selection Sort

```
1  public class SelectionSort {
2    /** Main method */
3    public static void main(String[] args) {
4      // Initialize the list
5      double[] myList = {5.0, 4.4, 1.9, 2.9, 3.4, 3.5};
6
7      // Print the original list
8      System.out.println("My list before sort is: ");
9      printList(myList);
10
11     // Sort the list
12     selectionSort(myList);
13
14     // Print the sorted list
15     System.out.println();
16     System.out.println("My list after sort is: ");
17     printList(myList);
18   }
19
20   /** The method for printing numbers */
21   static void printList(double[] list) {
22     for (int i = 0; i < list.length; i++)
23       System.out.print(list[i] + "  ");
24     System.out.println();
25   }
26
```

Selection Sort

```
27    /** The method for sorting the numbers */
28    static void selectionSort(double[] list) {
29      for (int i = list.length - 1; i >= 1; i--) {
30        // Find the maximum in the list[0..i]
31        double currentMax = list[0];
32        int currentMaxIndex = 0;
33
34        for (int j = 1; j <= i; j++) {
35          if (currentMax < list[j]) {
36            currentMax = list[j];
37            currentMaxIndex = j;
38          }
39        }
40
41        // Swap list[i] with list[currentMaxIndex] if necessary;
42        if (currentMaxIndex != i) {
43          list[currentMaxIndex] = list[i];
44          list[i] = currentMax;
45        }
46      }
47    }
48  }
```

Insertion Sort

- The insertion-sort algorithm sorts a list of values by repeatedly inserting a new element into a sorted sublist until the whole list is sorted.
- The Figure shows how to sort a list {2, 9, 5, 4, 8, 1, 6} using insertion sort.

Insertion Sort

Step 1: Initially, the sorted sublist contains the first element in the list. Insert 9 to the sublist.

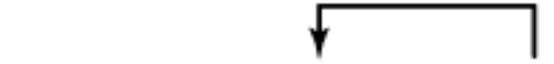
Step 2: The sorted sublist is {2, 9}. Insert 5 to the sublist.

Step 3: The sorted sublist is {2, 5, 9}. Insert 4 to the sublist.

Step 4: The sorted sublist is {2, 4, 5, 9}. Insert 8 to the sublist.

Step 5: The sorted sublist is {2, 4, 5, 8, 9}. Insert 1 to the sublist.

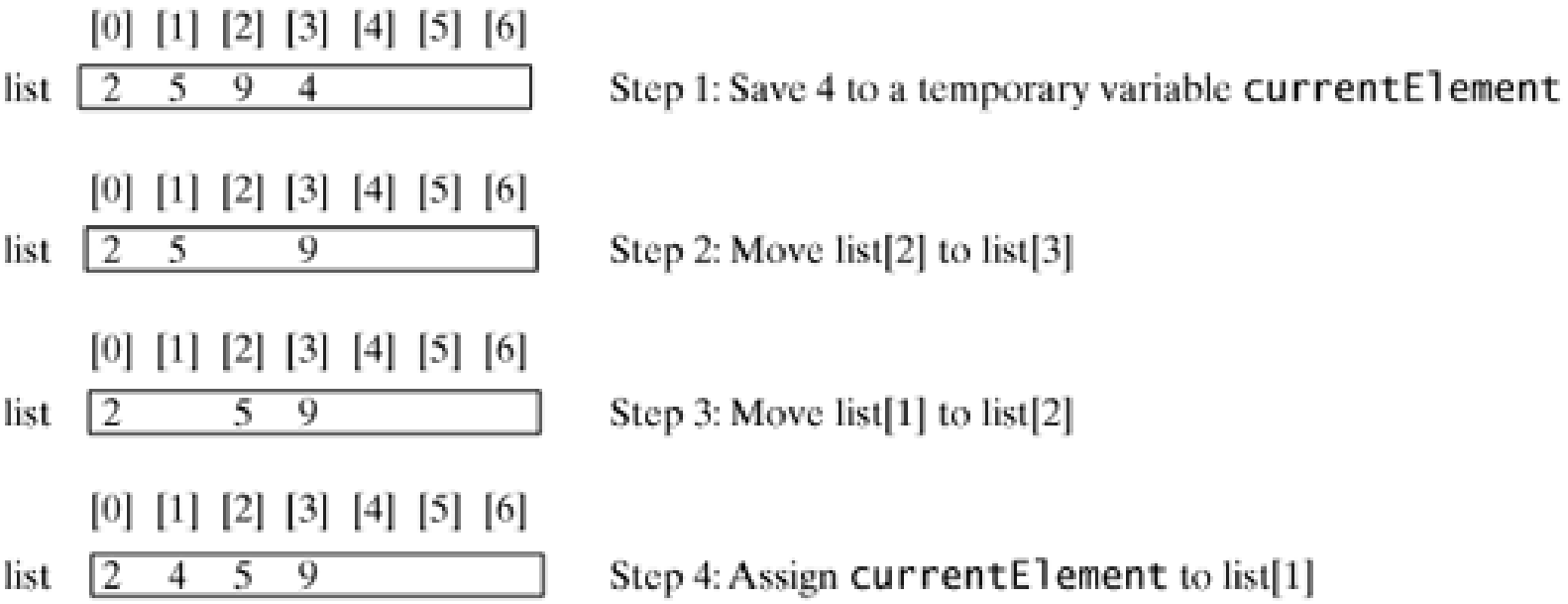
Step 6: The sorted sublist is {1, 2, 4, 5, 8, 9}. Insert 6 to the sublist.



Step 7: The entire list is now sorted

Insertion Sort

- How to Insert?



Insertion Sort

```
1  public class InsertionSort {
2    /** Main method */
3    public static void main(String[] args) {
4      // Initialize the list
5      double[] myList = {5.0, 4.4, 1.9, 2.9, 3.4, 3.5};
6
7      // Print the original list
8      System.out.println("My list before sort is: ");
9      printList(myList);
10
11     // Sort the list
12     insertionSort(myList);
13
14     // Print the sorted list
15     System.out.println();
16     System.out.println("My list after sort is: ");
17     printList(myList);
18   }
19
20   /** The method for printing numbers */
21   static void printList(double[] list) {
22     for (int i = 0; i < list.length; i++) {
23       System.out.print(list[i] + "  ");
24     }
25     System.out.println();
26   }
27
```

Insertion Sort

```
28    /** The method for sorting the numbers */
29    public static void insertionSort(double[] list) {
30      for (int i = 1; i < list.length; i++) {
31        /** insert list[i] into a sorted sublist list[0..i-1] so that
32         list[0..i] is sorted. */
33        double currentElement = list[i];
34        int k;
35        for (k = i - 1; k >= 0 && list[k] > currentElement; k--) {
36          list[k + 1] = list[k];
37        }
38
39        // Insert the current element into list[k+1]
40        list[k + 1] = currentElement;
41      }
42    }
43  }
```

Arrays Class

Arrays Class

- The java.util.Arrays class contains various static methods for sorting and searching arrays, comparing arrays, and filling array elements.
- These methods are overloaded for all primitive types.

The sort Method

- You can use the sort method to sort a whole array or a partial array.

```
double[] numbers = {6.0, 4.4, 1.9, 2.9, 3.4, 3.5};
java.util.Arrays.sort(numbers);
// Sort the whole array

char[] chars = {'a', 'A', '4', 'F', 'D', 'P'};
java.util.Arrays.sort(chars, 1, 3);
// Sort part of the array
```

The binarySearch Method

- You can use the binarySearch method to search for a key in an array.
- The array must be pre-sorted in increasing order. If the key is not in the array, the method returns -(insertion point +1).
-

The binarySearch Method

```
int[] list = {2, 4, 7, 10, 11, 45, 50, 59, 60, 66,
  69, 70, 79};
System.out.println("(1) Index is " +
  java.util.Arrays.binarySearch(list, 11));
System.out.println("(2) Index is " +
  java.util.Arrays.binarySearch(list, 12));

char[] chars = {'a', 'c', 'g', 'x', 'y', 'z'};
System.out.println("(3) Index is " +
  java.util.Arrays.binarySearch(chars, 'a'));
System.out.println("(4) Index is " +
  java.util.Arrays.binarySearch(chars, 't'));
```

- Output?

The binarySearch Method

- The output of the code is

```
(1) Index is 4
(2) Index is -6
(3) Index is 0
(4) Index is -4
```

The equals method

- You can use the equals method to check whether two arrays are equal. Two arrays are equal if they have the same contents.

```
int[] list1 = {2, 4, 7, 10};
int[] list2 = {2, 4, 7, 10};
int[] list3 = {4, 2, 7, 10};
System.out.println(java.util.Arrays.equals
  (list1, list2)); // true
System.out.println(java.util.Arrays.equals
  (list2, list3)); // false
```

The fill method

- You can use the fill method to fill in the whole array or part of the array.

```
int[] list1 = {2, 4, 7, 10};
int[] list2 = {2, 4, 7, 10};

// fill 5 to the whole array
java.util.Arrays.fill(list1, 5);

// fill 8 to a partial array
java.util.Arrays.fill(list2, 1, 3, 8);
```

Array Class

- You can find all methods from the following URL:

http://java.sun.com/javase/6/docs/api/

References

References

- Y. Daniel Liang, **Introduction to Java Programming**, Sixth Edition, Pearson Education, 2007. (Chapter 6)
- S. Zakhour and et. al., **The Java Tutorial: A Short Course on the Basics**, 4th Edition, Prentice Hall, 2006. (Chapter 3)

The End