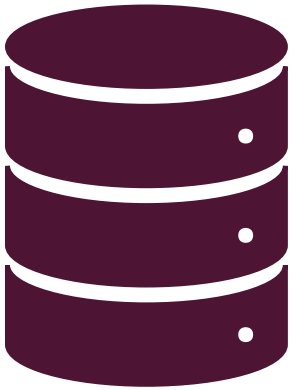


DATA STRUCTURES

WENYE LI
CUHK-SZ

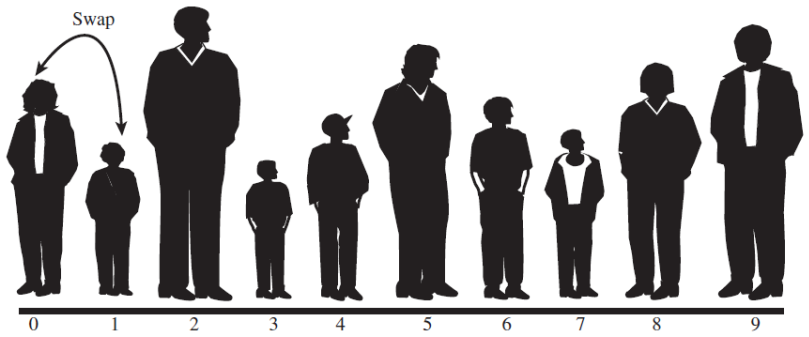
SORTING

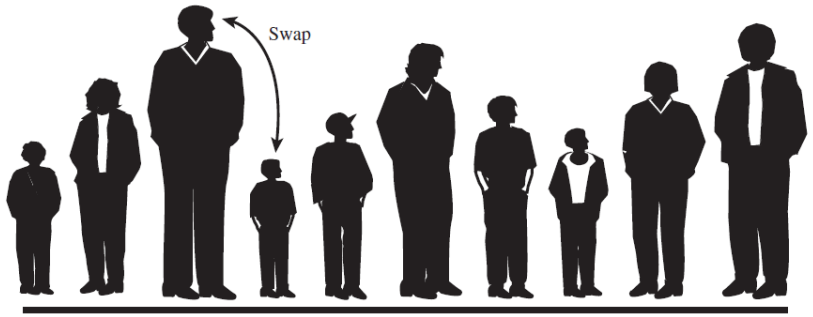
- Sorting is the process of arranging the elements of an array so that they can be placed either in ascending or descending order.
- Consider an array $A = \{A_1, A_2, \cdots, A_n\}$,
  - The array is called to be in ascending order if $A_1 \leq A_2 \leq \cdots \leq A_n$,
  - Descending, if $A_1 \geq A_2 \geq \cdots \geq A_n$

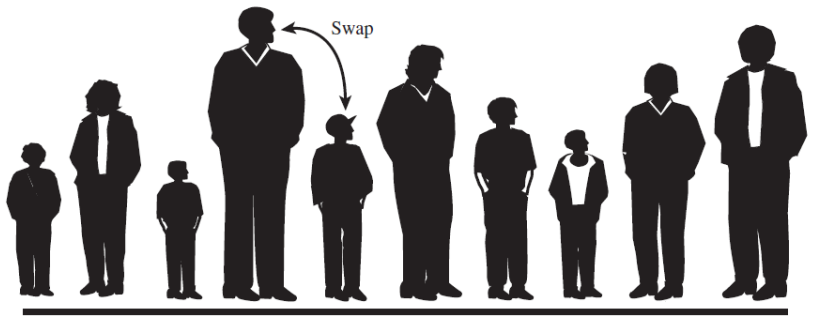
SN	Sorting Algorithms	Description
1	Bubble Sort	It is the simplest sort method which performs sorting by repeatedly moving the largest element to the highest index of the array. It comprises of comparing each element to its adjacent element and replace them accordingly.
2	Bucket Sort	Bucket sort is also known as bin sort. It works by distributing the element into the array also called buckets. In this sorting algorithms, Buckets are sorted individually by using different sorting algorithm.
3	Comb Sort	Comb Sort is the advanced form of Bubble Sort. Bubble Sort compares all the adjacent values while comb sort removes all the turtle values or small values near the end of the list.
4	Counting Sort	It is a sorting technique based on the keys i.e. objects are collected according to keys which are small integers. Counting sort calculates the number of occurrence of objects and stores its key values. New array is formed by adding previous key elements and assigning to objects.
5	Heap Sort	In the heap sort, Min heap or max heap is maintained from the array elements deending upon the choice and the elements are sorted by deleting the root element of the heap.
6	Insertion Sort	As the name suggests, insertion sort inserts each element of the array to its proper place. It is a very simple sort method which is used to arrange the deck of cards while playing bridge.
7	Merge Sort	Merge sort follows divide and conquer approach in which, the list is first divided into the sets of equal elements and then each half of the list is sorted by using merge sort. The sorted list is combined again to form an elementary sorted array.
8	Quick Sort	Quick sort is the most optimized sort algorithms which performs sorting in O(n log n) comparisons. Like Merge sort, quick sort also work by using divide and conquer approach.
9	Radix Sort	In Radix sort, the sorting is done as we do sort the names according to their alphabetical order. It is the lenear sorting algorithm used for Inegers.
10	Selection Sort	Selection sort finds the smallest element in the array and place it on the first place on the list, then it finds the second smallest element in the array and place it on the second place. This process continues until all the elements are moved to their correct ordering. It carries running time O(n2) which is worst than insertion sort.
11	Shell Sort	Shell sort is the generalization of insertion sort which overcomes the drawbacks of insertion sort by comparing elements separated by a gap of several positions.

SIMPLE SORTING

- Key idea:
  - Compare two items
  - Swap two items, or copy one item
  - Bubble Sort, Selection Sort, Insertion Sort







Bubble sort: the beginning of the first pass.

Bubble sort: the end of the first pass.

Bubble Sort:

Compare two players.

If the one on the left is taller, swap them.

Move one position right.

When you reach the first sorted player, start over at the left end of the line.

Continue this process until all players are in order.

```
class ArrayBub {
    private long[] a; // ref to array a
    private int nElems; // number of data items
    public ArrayBub(int max) // constructor
    {
        a = new long[max]; // create the array
        nElems = 0; // no items yet
    }
    public void insert(long value) // put element into array
    {
        a[nElems] = value; // insert it
        nElems++; // increment size
    }
    public void display() // displays array contents
    {
        for(int j = 0; j < nElems; j++) // for each element,
            System.out.print(a[j] + " "); // display it
        System.out.println("");
    }
    public void bubbleSort()
    {
        int out, in;
        for(out = nElems - 1; out > 1; out--) // outer loop (backward)
            for(in = 0; in < out; in++) // inner loop (forward)
                if( a[in] > a[in + 1] ) // out of order?
                    swap(in, in + 1); // swap them
    } // end bubbleSort()
    private void swap(int one, int two)
    {
        long temp = a[one];
        a[one] = a[two];
        a[two] = temp;
    }
} // end class ArrayBub
class BubbleSortApp {
    public static void main(String[] args) {
        int maxSize = 100; // array size
        ArrayBub arr; // reference to array
        arr = new ArrayBub(maxSize); // create the array
        arr.insert(77); // insert 10 items
        arr.insert(99);
        arr.insert(44);
        arr.insert(55);
        arr.insert(22);
        arr.insert(88);
        arr.insert(11);
        arr.insert(00);
        arr.insert(66);
        arr.insert(33);
        arr.display(); // display items
        arr.bubbleSort(); // bubble sort them
        arr.display(); // display them again
    } // end main()
} // end class BubbleSortApp
```

```
public void bubbleSort()
   {
   int out, in;

   for(out=nElems-1; out>1; out--)   // outer loop (backward)
      for(in=0; in<out; in++)        // inner loop (forward)
         if( a[in] > a[in+1] )       // out of order?
            swap(in, in+1);          // swap them
   }  // end bubbleSort()
```

```
77 99 44 55 22 88 11 0 66 33
0 11 22 33 44 55 66 77 88 99
```

In general, where N is the number of items in the array, there are N-1 comparisons on the first pass, N-2 on the second, and so on. The formula for the sum of such a series is

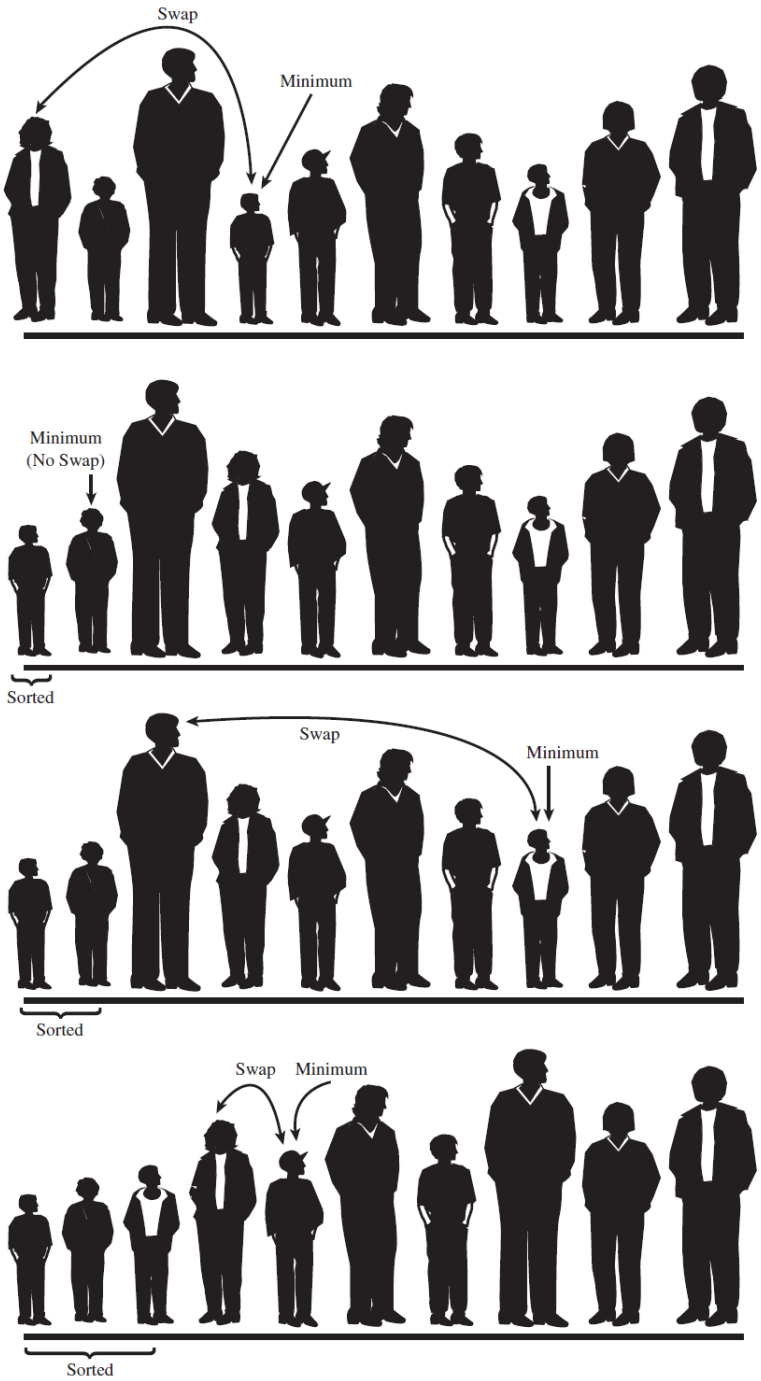
$(N-1) + (N-2) + (N-3) + \ldots + 1 = N*(N-1)/2$

$N*(N-1)/2$ is 45 (10*9/2) when N is 10.

Thus, the algorithm makes about $N^2/2$ comparisons (ignoring the –1, which doesn't make much difference, especially if N is large).

There are fewer swaps than there are comparisons because two bars are swapped only if they need to be. If the data is random, a swap is necessary about half the time, so there will be about $N^2/4$ swaps. (Although in the worst case, with the initial data inversely sorted, a swap is necessary with every comparison.)

Both swaps and comparisons are proportional to N^2. Because constants don't count in Big O notation, we can ignore the 2 and the 4 and say that the bubble sort runs in $O(N^2)$ time.



Selection sort on baseball players.

```
public void selectionSort()
   {
   int out, in, min;

   for(out=0; out<nElems-1; out++)   // outer loop
      {
      min = out;                     // minimum
      for(in=out+1; in<nElems; in++) // inner loop
         if(a[in] < a[min] )         // if min greater,
             min = in;               // we have a new min
      swap(out, min);                // swap them
      }  // end for(out)
   }  // end selectionSort()
```

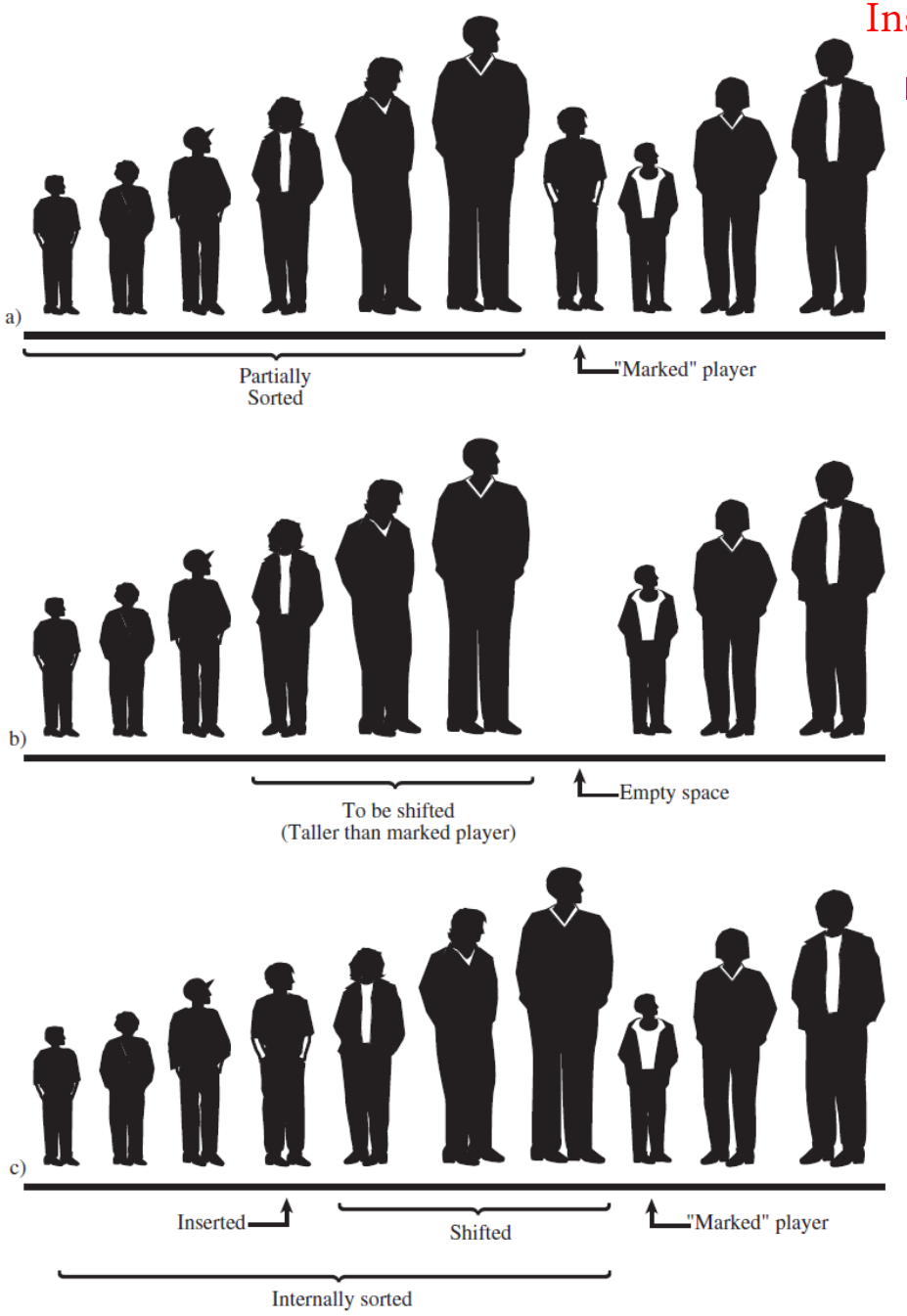
Selection Sort:

Making a pass through all players and picking the shortest one. This shortest player is then swapped with the player on the left end of the line, at position 0. Now the leftmost player is sorted and won't need to be moved again.

The next time you pass down the players, you start at position 1, and, finding the minimum, swap with position 1. This process continues until all players are sorted.

The selection sort performs the same number of comparisons as the bubble sort: N*(N-1)/2. For 10 data items, this is 45 comparisons. However, 10 items require fewer than 10 swaps. With 100 items, 4,950 comparisons are required, but fewer than 100 swaps. For large values of N, the comparison times will dominate, so we would have to say that the selection sort runs in $O(N^2)$ time, just as the bubble sort did. However, it is unquestionably faster because there are so few swaps. For smaller values of N, the selection sort may in fact be considerably faster, especially if the swap times are much larger than the comparison times.

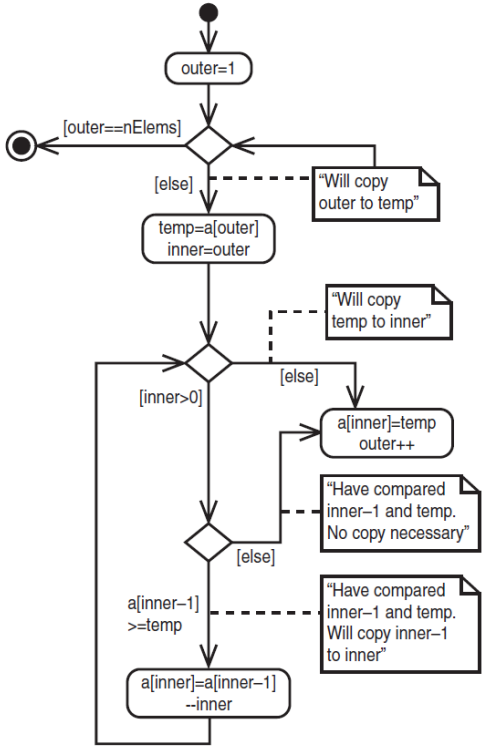
Insertion Sort



The insertion sort on baseball players.

```
public void insertionSort()
   {
   int in, out;

   for(out=1; out<nElems; out++)     // out is dividing line
      {
      long temp = a[out];            // remove marked item
      in = out;                      // start shifts at out
      while(in>0 && a[in-1] >= temp) // until one is smaller,
         {
         a[in] = a[in-1];            // shift item to right
         --in;                       // go left one position
         }
      a[in] = temp;                  // insert marked item
      }  // end for
```



Activity diagram for `insertSort()`.

In most cases the insertion sort is the best of the elementary sorts described in this chapter. It still executes in $O(N^2)$ time, but it's about twice as fast as the bubble sort and somewhat faster than the selection sort in normal situations.

SUMMARY OF SIMPLE SORTING

- The sorting algorithms all assume an array as a data storage structure.
- Sorting involves comparing data items in the array and moving them until sorted.
- All execute in $O(N^2)$ time. Nevertheless, some can be substantially faster than others.
- An invariant is a condition that remains unchanged while an algorithm runs.
- The bubble sort is the least efficient, but the simplest, sort.
- The insertion sort is the most commonly used of the $O(N^2)$ sorts.
- A sort is stable if the order of elements with the same key is retained.
- None of the sorts require more than a single temporary variable, in addition to the original array.

ADVANCED SORTING

- Shell Sort, and Quick Sort
  - Operate much faster than simple sorting
  - To be presented in next course

THANKS