CSEN 301– Data Structures and Algorithms

Lecture 1: Introduction to Arrays

Prof. Dr. Slim Abdennadher
slim.abdennadher@guc.edu.eg

German University Cairo, Department of Media Engineering and Technology

Course structure

- Lectures
- Exercises and homework
  - Practical Assignments
  - Work in teams, use feedback from tutors
- Labs
  - Supervised lab Assignments
  - Work in teams

WWW-page: Useful info and important announcements

`met.guc.edu.eg`

Course Regulations

- Weekly graded lab assigments for random groups.
- For attendance, you should commit to your assigned class.
- You should start working on the lab assignment before the lab.

Tentative grading

Overall weighting of your grades:

- 10% for in-lab assignments.
- 20% for quizzes
- 25% for mid-term exam
- 45% for final exam

Survival guide

Tell me and I will forget;
show me and I may remember;
involve me and I will understand.

Keep up with the course material

- Attend lectures, tutorials, and labs
- Participate in the discussions (be active)
- Solve the assignments and understand the model answers provided

WWW-page

Visit course home page regularly for announcements and supplemental material

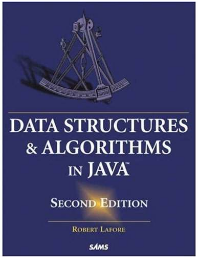
`met.guc.edu.eg`

Aims of this course

- To study the concept of algorithms and the concept of algorithm efficiency.
- To study the concept of abstract data types (ADTs) and the abstract data types most commonly used in software development (*stacks*, *queues*, *lists*, *sets*, ...).
- To study the basic data types most commonly used to represent these abstract data types (*arrays*, *linked lists*, *binary search trees*, ...), together with algorithms operating on these data structures.
- Java implementation of common algorithms, ADTs, and data structures.

Learning resources

- Textbook for this class:

  Robert Lafore. *Data Structures & Algorithms in Java*, Sams Publishing, 2003
- Resources at course website at **`met.guc.edu.eg`**

The need for efficient data structures and algorithms

- Representing information is fundamental to computer information processing
- Computer programs should organize their data in a way that supports efficient processing.
- For this reason the study of data structures and algorithms that manipulate them is essential to computer science and software engineering.
- Knowing appropriate ADTs and algorithms for particular problems would save your programming time as well as ensure the efficiency of your software.

Algorithms *vs.* programs

- Algorithm
  - Can be performed by humans or by machines
  - Can be expressed in any suitable language
  - Can be on any level of abstraction
- Program
  - Must be performed by a machine
  - Must be expressed in a programming language
  - Must be detailed and specific to avoid any ambiguities

- To employ an algorithm on a machine, it has to be transcribed into a programming language (*i. e.*, *coded*!).
- There may be many ways of coding the algorithm and there is a wide choice of programming languages. But all the resulting programs are implementations of the same underlying algorithm.
- Here we express our implementations in Java

Data structures

- A data structure is a systematic way of organizing a collection of data.
- A static data structure is one whose capacity is fixed at creation (*e. g.*, *array*).
- A dynamic data structure is one whose capacity is variable, so it can expand or contract at any time (*e. g.*, *linked list*, *binary tree*).
- For each data structure, we need algorithms for insertion, deletion, searching, *etc.*

Arrays – General properties

- An array is an indexed sequence of components

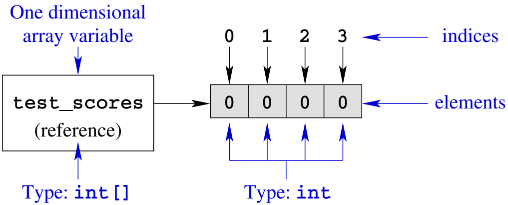
	data
0	23
1	38
2	14
3	–3
4	0
5	14
6	9
7	103
8	0
9	–56

- The length of an array is fixed when the array is constructed.
- Each array component has a fixed and unique index. The indices range from a lower bound to an upper bound.

Java primitive arrays

- Code to create a one-dimensional array that stores data items based on a primitive type:

```
int [] test_scores = new int [4];
```



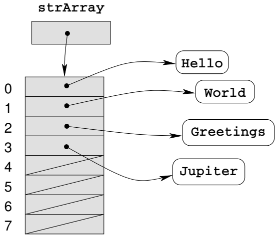
- Code to initialize an array of integers:

```
int [] test_scores = new int [] { 70, 80, 20, 30 };
```

Arrays of objects

- We have only considered arrays of elements of the various primitive types.
- But we can also have arrays of objects of any class, *e. g.*

```
String[] strArray = new String[8];
strArray[0] = "Hello" ;
strArray[1] = "World" ;
strArray[2] = "Greetings" ;
strArray[3] = "Jupiter" ;
```



- More generally we can have object arrays:

```
Object[] heap = new Object[20];
```

Example

Example: Writing a `String` to the monitor

```
class StringArray {
  public static void main ( String[] args )
  {
    string[] strArray = new String[8] ;
    strArray[0] = "Hello" ;
    strArray[1] = "World" ;
    strArray[2] = "Greetings" ;
    strArray[3] = "Jupiter" ;
    strArray[ strArray.length-1 ] = "the␣end" ;
    for (int j=0; j < strArray.length; j++ )
      if ( strArray[j] != null )
        System.out.println( "Slot␣" + j + ":␣" + strArray[j] );
      else
        System.out.println( "Slot␣" + j + ":␣" + "empty" );
  } }
```

Unordered array

- Insertion: Use the normal array syntax, *e. g.*

```
arr[0] = 5;
```

- Searching:
  - Step through the array, comparing the item with each element.
  - If the loop variable reaches the last occupied cell with no match being found, the item is not in the array.
- Deletion:
  - Search for the specified item
  - Move all the items with higher index values down one element to fill in the “hole” left by the deleted element.

Time complexity for unordered arrays

- Insertion:

$O(1)$

- Searching:

$O(n)$

- Deletion:

$O(n)$

Sorted arrays

- An array is sorted if its components are in ascending order (*i. e.*, each component is less than or equal to the component on its right).
- The meaning of the comparison "x is less than y" must be defined for each data type:
  - Meaning of less for numbers:
    x is numerically less than y (*i. e.*, $x < y$).
  - Conventional meaning of less for strings:
    x precedes y lexicographically (*e. g.*, "**`pool`**" is less than "**`poor`**", which is less than "**`pop`**").

Insertion and deletion

- Insertion:
  - Suppose we want to insert the value 8 into this sorted array (while keeping the array sorted).

1	3	4	7	9	12					

  - We can do this by shifting all the elements after the mark right by one location.

1	3	4	7	9	$\rightarrow$	12				

1	3	4	7	$\rightarrow$	9	12				

1	3	4	7	8	9	12				

- Deletion: Deleting an element is similar to the unordered arrays.

Binary search – The idea

How do we look up words in a list that is already sorted?

- Dictionary
- Phone book

Method

1. Open up the book roughly in the middle
2. Check in which half the word is.
3. Split that half again in two.
4. Continue until we find the word.

Binary search – An example

position:	0	1	2	3	4	5	6
content:	Amal	Amira	Engy	Mohammed	Noura	Rehab	Slim

We are searching Engy

1. The midpoint between 0 and 6 is 3
2. We compare Mohammed with Engy
3. Engy precedes Mohammed
4. We continue the search on the front half of the list

1. The midpoint between 0 and 2 is 1
2. We compare Amira with Engy
3. Engy follows Amira
4. We continue the search on the back half of the list

Binary search – An example

position:	0	1	2	3	4	5	6
content:	Amal	Amira	Engy	Mohammed	Noura	Rehab	Slim

1. The midpoint between 2 and 2 is 2
2. We compare Engy with Engy
3. Engy equals Engy
4. We have found the entry.

Example

```
public int find(long searchKey) {
  int lowerBound = 0;
  int upperBound = nElems - 1;
  int curIn;
  while(true)
    {
      curIn = (lowerBound + upperBound ) / 2;
      if(a[curIn] == searchKey)
        return curIn;                         // found it
      else if(lowerBound > upperBound)
        return nElems;                        // can't find it
      else                                    // divide range
        {
          if(a[curIn] < searchKey)
            lowerBound = curIn + 1;           // it's in upper half
          else
            upperBound = curIn - 1;           // it's in lower half
        }                                     // end else divide range
    }                                         // end while
}                                             // end find()
```

Time complexity for sorted arrays

- Insertion:

$O(n)$

- Searching:

$O(\log n)$

- Deletion:

$O(n)$

Conclusions

- Arrays have the following advantages:
  - Accessing an element by its index is very fast.
- Arrays have the following disadvantages:
  - All elements must be of the same type.
  - The array size is fixed and can never be changed.
  - Insertion into arrays and deletion from arrays is very slow.