Islamic University of Technology (IUT)
Organization of Islamic Cooperation (OIC)
Department of Electrical and Electronic Engineering (EEE)

EEE 4416 **Lab – 08**

Introduction to Algorithms

So far, you have learned the syntax of the MATLAB programming language, many of the built-in functions that MATLAB offers, and applied your knowledge to solve different problems. Understanding the syntax is the first step towards learning a programming language. The syntax varies from language to language, but the approach may remain the same. You will find a large amount of similarity between MATLAB and python's 'numpy' library as they are designed in a similar fashion.

However, just knowing the syntax is not always enough. In real-world applications, many such problems appear where a straight-forward approach may not always work. Furthermore, it could take a long time to execute (high time complexity). For instance, look at the following example –

You are given a gird. Each cell of the grid has a value associated with it. The start cell and the end cell have values of zero. You start from the upper left corner and need to get to the bottom right. You can move only to adjacent cells either by sliding right, up or down. Your goal is to find the path that makes the sum of the values you've passed the lowest.

Give it a try.

1	**12**	**4**	**6**	**8**	**10**	**100**
1	**5**	**7**	**87**	**98**	**2**	**200**
20	**56**	**74**	**1**	**34**	**56**	**21**

In this small grid, you can see - there are many possible paths available. To find the optimal path, you need to check each and every one of them, which is quite a time consuming task. If the size

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of the grid is larger, say, 1000*1000, imagine – how many hundreds and thousands of paths are possible and checking each path one by one does not seem like a proper approach. This type of approach is called 'brute-forcing' and it is usually impossible to obtain the desired result this way, even with a powerful processor.

To deal with such problems, there are other intelligent approaches that can solve the problem in real time. To solve different problems, many different algorithms have been developed. Such algorithms can solve even a seemingly impossible task in linear time. Some of the most popular algorithms are mentioned below –

- Divide and Conquer
- Searching algorithms – linear, binary, jump, interpolation, etc.
- Sorting algorithms – quick sort, merge sort, bubble sort, heap sort, insertion sort, etc.
- Greedy algorithm
- Dynamic programming
- Backtracking
- Graph algorithms – Breadth first search (BFS), Depth-first search (DFS), Minimum spanning tree (MST), Dijkstra's shortest path, etc.
- Randomized algorithms
- Branch and bound – for combinatorial optimization problem.
- Bit algorithms

The above problem in the example can be solved very easily using graph algorithms, in particular Dijkstra's shortest path approach. The solution to the problem is –

1->12->4->6->8->10->2->56->21

Search Algorithms

In the earlier labs, you have frequently used the 'find' function to extract the index of a particular element in an array. While built-in functions in MATLAB make our tasks easier but it is also necessary to understand how those built-in functions actually work. These functions employ different algorithms and techniques to get the job done.

The purpose of search algorithms is to locate or retrieve an element from data. The data can be stored in any kind of data structure, like a list or a dictionary. These searching algorithms can be divided into two categories –

1. Sequential Search
2. Interval Search

The sequential search algorithms traverse the list sequentially to find the desired value. The interval search algorithms work for sorted data. Instead of checking every element in the list like sequential search, interval search algorithms look for the desired element heuristically. It is based on the 'divide and conquer' algorithm.

Different searching algorithms –

- Linear Search
- Binary Search
- Jump Search
- Interpolation Search
- Exponential Search
- Breadth First Search (BFS) etc.

Linear Search

In this algorithm, you search each element in the list sequentially to find the desired value. You start with the first element and continue until a match is found.

The time complexity of the algorithm is: O(n).
Best-case scenario: O(1) → 1st element is the desired one
Worst-case scenario: O(n) → value not in the array

It is not the most efficient approach when the sample size is very large.

Programming Exercise

- Write a code to check whether an element exist in an array or not using the linear search algorithm. Find the index values as well.

```
% Linear search

tic

a= randi(100000,1,1000000);  % creating a random 1D array with 1 million parameters
val= 1200000;

for i= 1:length(a)
    if a(i)==val
        out='value found';
        break
    else
        out='value not found';
    end
end
out

toc
```

Built-in functions

MATLAB has built-in functions to allow you to search for an item in an array. However, here we are more interested in finding out the actual approach behind MATLAB's built-in functions.

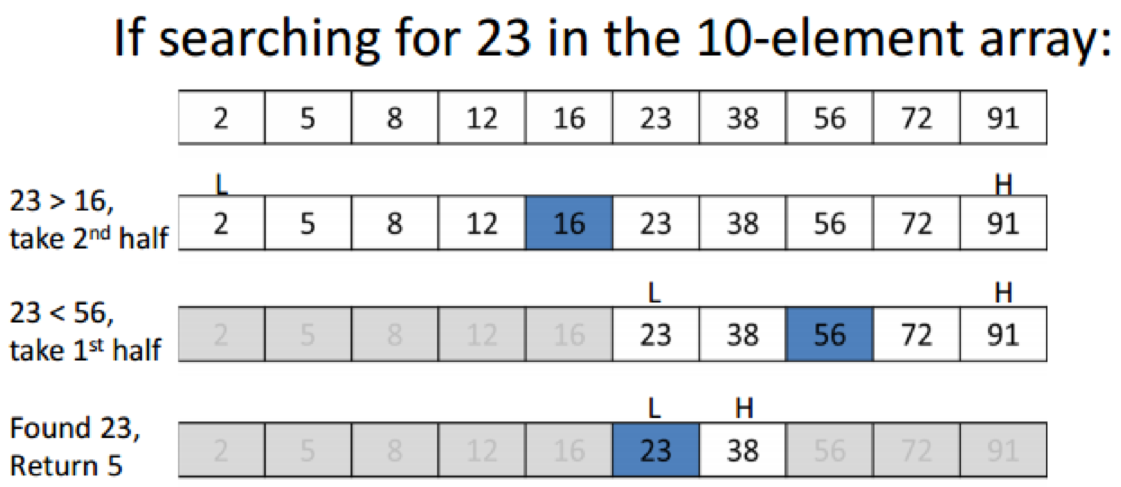
- *find (a==val)* will return the indices where the element is located.
- ismember (val,a) will return logical true/false whether the value exist in the array or not.

Binary Search

This is an interval search technique. It only works in a sorted array. So, the original list needs to be arranged in an ascending order (numeric) or dictionary order (string) if not originally sorted. This method works based on decrease and conquer technique to find the desired value with less time complexity. In case of large data, the number of iterations required to find the value is significantly reduced in binary search compared to sequential search algorithm.

In binary search, we start with the middle element in the sorted array. If that is the desired element, then search is complete with minimum steps (best-case). If not, then we find whether the desired value is smaller or larger than the middle element. Based on that, we narrow the search to only half of the original array. Then the middle element of the new array (size = n/2) is found, and the process is repeated. This way, with each step, the size of the array is halved, and the total number of iterations required to find the value is reduced.

The time complexity of the algorithm is: O(log(n)), which makes it much more efficient than linear search.



Algorithm

i. Start by assigning index value → low = 1, high = number of elements in the array.
ii. Find the mid element index of the array using mid = (low+high)/2. Take the floor value in case of fraction.
iii. Check whether array(mid) is lower or higher than the item we are searching for.
iv. If array(mid) < search_item, then the item exists in the upper half. So, we can narrow the search in the upper half portion only by moving low to mid+1.
v. If array(mid) > search_item, then the item exists in the lower half. So, we can narrow the search in the lower half portion of the array only by moving high to mid-1.
vi. Repeat the steps 2 to 5 until the element is found. Otherwise, the item is not on the list.

Programming Exercise

- Write a code to check whether an element exist in an array or not using binary search algorithm.

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```
% binary search

rng(1,'twister');   % generating same numbers on each run
s=rng;              % for more info -
https://www.mathworks.com/help/matlab/math/controlling-random-number-generation.html

a= randi(100000,1,1000000);  % creating a random 1D array with 1 million parameters
a= sort(a,'a');              % binary search only works on sorted array
%a=[1,2,3,3,4,4,5,5,10,20];
val= 1031;

low=1;
high= length(a);
mid= floor((low+high)/2);

while low<=high
    if a(mid)<val
        low= mid+1;
    elseif a(mid)>val
        high= mid-1;
    else
        out= 'value is found';
        val_index= mid;
        break;
    end

    mid= floor((low+high)/2);
end

if low>high
    out= 'value not found';
    val_index=nan;
end

out
val_index
```

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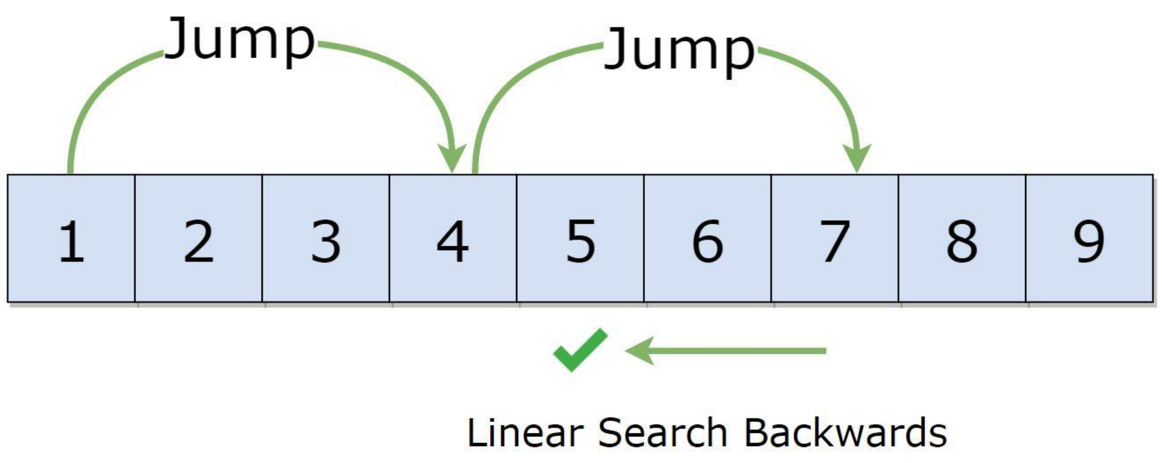
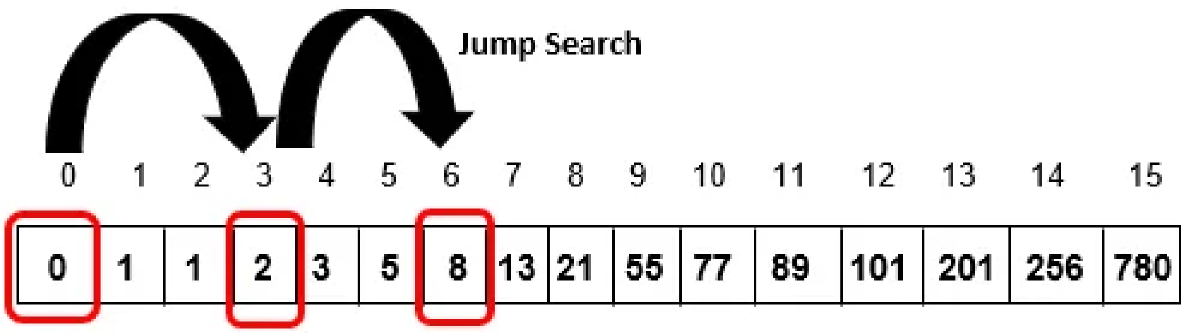
Jump Search

Jump search is an improvement over linear search, but less efficient than binary search. Unlike linear search, it works only on sorted array. Instead of searching through all elements sequentially, it jumps a few step/skips a few elements to reduce the number of iterations required.



In the figure, a jump step of 3 is utilized. So, the method checks the index – 1, 4, 7, and so on. The step size is taken depending on the size of the original array.



Say, the element we are looking for is 77. Using jump search, we will take four jumps first and reach index 12 and find the value larger than the search key. Then we will go backwards and perform a linear search operation (two steps required) to find the desired value.
As can be seen, the number of iterations required to find the value is lower than linear search.

The time complexity of the algorithm is: O(√n)
The time complexity is in between linear search and binary search.

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Interpolation Search

This is an improvement over binary search. While binary search always goes for the middle element, interpolation search can go in different locations according to the search item. If the search item is closer to the last element in the list, interpolation search will start searching towards the end side.

The time complexity of the algorithm is: O(log(log(n))) - (best case).

Assignment

1. Implement MATLAB's find function's operation using 'linear search' and 'binary search' algorithms. The 'find' function returns all the matches in the array along with the indices.
2. Write a code to check whether an element exist in an array or not using 'jump search' algorithm.

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