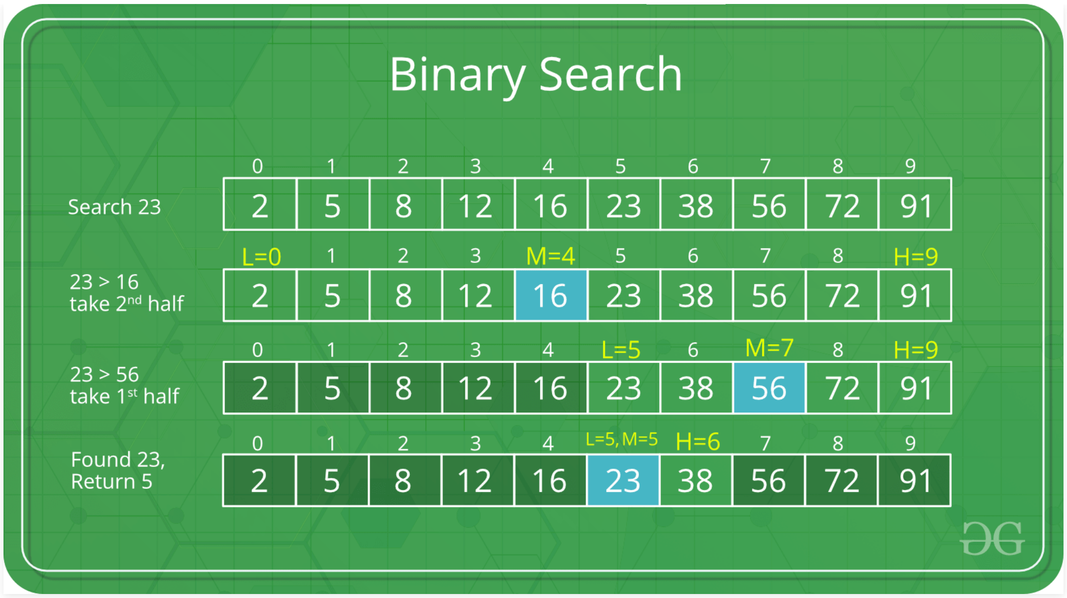
Binary Search

Difficulty Level : Easy • Last Updated : 19 Oct, 2021

Given a sorted array arr[] of n elements, write a function to search a given element x in arr[].
A simple approach is to do a **linear search.** The time complexity of the above algorithm is O(n). Another approach to perform the same task is using Binary Search.
Binary Search: Search a sorted array by repeatedly dividing the search interval in half. Begin with an interval covering the whole array. If the value of the search key is less than the item in the middle of the interval, narrow the interval to the lower half. Otherwise, narrow it to the upper half. Repeatedly check until the value is found or the interval is empty.

Example :



The idea of binary search is to use the information that the array is sorted and reduce the time complexity to O(Log n).

Recommended: Please solve it on "***PRACTICE***" first, before moving on to the solution.

We basically ignore half of the elements just after one comparison.

1. Compare x with the middle element.
2. If x matches with the middle element, we return the mid index.
3. Else If x is greater than the mid element, then x can only lie in the right half subarray after the mid element. So we recur for the right half.
4. Else (x is smaller) recur for the left half.

Recursive implementation of Binary Search

C++

```
// C++ program to implement recursive Binary Search
#include <bits/stdc++.h>
using namespace std;

// A recursive binary search function. It returns
// location of x in given array arr[l..r] is present,
// otherwise -1
```

```
int binarySearch(int arr[], int l, int r, int x)
{
    if (r >= l) {
        int mid = l + (r - l) / 2;

        // If the element is present at the middle
        // itself
        if (arr[mid] == x)
            return mid;

        // If element is smaller than mid, then
        // it can only be present in left subarray
        if (arr[mid] > x)
            return binarySearch(arr, l, mid - 1, x);

        // Else the element can only be present
        // in right subarray
        return binarySearch(arr, mid + 1, r, x);
    }

    // We reach here when element is not
    // present in array
    return -1;
}

int main(void)
{
    int arr[] = { 2, 3, 4, 10, 40 };
    int x = 10;
    int n = sizeof(arr) / sizeof(arr[0]);
    int result = binarySearch(arr, 0, n - 1, x);
    (result == -1) ? cout << "Element is not present in array"
                   : cout << "Element is present at index " << result;
    return 0;
}
```

C

```
// C program to implement recursive Binary Search
#include <stdio.h>

// A recursive binary search function. It returns
// location of x in given array arr[l..r] is present,
// otherwise -1
int binarySearch(int arr[], int l, int r, int x)

    if (r >= l) {
        int mid = l + (r - l) / 2;

        // If the element is present at middle
```

```
        // itself
        if (arr[mid] == x)
            return mid;

        // If element is smaller than mid, then
        // it can only be present in left subarray
        if (arr[mid] > x)
            return binarySearch(arr, l, mid - 1, x);

        // Else the element can only be present
        // in right subarray
        return binarySearch(arr, mid + 1, r, x);
    }

    // We reach here when element is not
    // present in array
    return -1;
}

int main(void)
{
    int arr[] = { 2, 3, 4, 10, 40 };
    int n = sizeof(arr) / sizeof(arr[0]);
    int x = 10;
    int result = binarySearch(arr, 0, n - 1, x);
    (result == -1) ? printf("Element is not present in array")
                   : printf("Element is present at index %d",
                            result);
    return 0;
}
```

Java

```
// Java implementation of recursive Binary Search
class BinarySearch {
    // Returns index of x if it is present in arr[l..
    // r], else return -1
    int binarySearch(int arr[], int l, int r, int x)
    {
        if (r >= l) {
            int mid = l + (r - l) / 2;

            // If the element is present at the
            // middle itself
            if (arr[mid] == x)
                return mid;

            // If element is smaller than mid, then
            // it can only be present in left subarray
            if (arr[mid] > x)
```

```
                return binarySearch(arr, l, mid - 1, x);

            // Else the element can only be present
            // in right subarray
            return binarySearch(arr, mid + 1, r, x);
        }

        // We reach here when element is not present
        // in array
        return -1;
    }

    // Driver method to test above
    public static void main(String args[])
    {
        BinarySearch ob = new BinarySearch();
        int arr[] = { 2, 3, 4, 10, 40 };
        int n = arr.length;
        int x = 10;
        int result = ob.binarySearch(arr, 0, n - 1, x);
        if (result == -1)
            System.out.println("Element not present");
        else
            System.out.println("Element found at index " + result);
    }
}
/* This code is contributed by Rajat Mishra */
```

Python3

```
# Python3 Program for recursive binary search.

# Returns index of x in arr if present, else -1
def binarySearch (arr, l, r, x):

    # Check base case
    if r >= l:

        mid = l + (r - l) // 2

        # If element is present at the middle itself
        if arr[mid] == x:
            return mid

        # If element is smaller than mid, then it
        # can only be present in left subarray
        elif arr[mid] > x:
            return binarySearch(arr, l, mid-1, x)

        # Else the element can only be present
```

```
        # in right subarray
        else:
            return binarySearch(arr, mid + 1, r, x)

    else:
        # Element is not present in the array
        return -1

# Driver Code
arr = [ 2, 3, 4, 10, 40 ]
x = 10

# Function call
result = binarySearch(arr, 0, len(arr)-1, x)

if result != -1:
    print ("Element is present at index % d" % result)
else:
    print ("Element is not present in array")
```

C#

```
// C# implementation of recursive Binary Search
using System;

class GFG {
    // Returns index of x if it is present in
    // arr[l..r], else return -1
    static int binarySearch(int[] arr, int l,
                            int r, int x)
    {
        if (r >= l) {
            int mid = l + (r - l) / 2;

            // If the element is present at the
            // middle itself
            if (arr[mid] == x)
                return mid;

            // If element is smaller than mid, then
            // it can only be present in left subarray
            if (arr[mid] > x)
                return binarySearch(arr, l, mid - 1, x);

            // Else the element can only be present
            // in right subarray
            return binarySearch(arr, mid + 1, r, x);
        }

        // We reach here when element is present
```

```
            // in array
            return -1;
        }

        // Driver method to test above
        public static void Main()
        {

            int[] arr = { 2, 3, 4, 10, 40 };
            int n = arr.Length;
            int x = 10;
```



```
                Console.WriteLine("Element found at index "
                                  + result);
        }
    }

// This code is contributed by Sam007.
```

PHP

```
<?php
// PHP program to implement
// recursive Binary Search

// A recursive binary search
// function. It returns location
// of x in given array arr[l..r]
// is present, otherwise -1
function binarySearch($arr, $l, $r, $x)
{
if ($r >= $l)
{
        $mid = ceil($l + ($r - $l) / 2);

        // If the element is present
        // at the middle itself
        if ($arr[$mid] == $x)
            return floor($mid);

        // If element is smaller than
        // mid, then it can only be
        // present in left subarray
        if ($arr[$mid] > $x)
            return binarySearch($arr, $l
```

```
                                        $mid - 1, $x);

        // Else the element can only
        // be present in right subarray
        return binarySearch($arr, $mid + 1,
                                    $r, $x);
}

// We reach here when element
// is not present in array
return -1;
}

// Driver Code
$arr = array(2, 3, 4, 10, 40);
$n = count($arr);
$x = 10;
$result = binarySearch($arr, 0, $n - 1, $x);
if(($result == -1))
echo "Element is not present in array";
else
echo "Element is present at index ",
                            $result;

// This code is contributed by anuj_67.
?>
```

Javascript

```
<script>
// JavaScript program to implement recursive Binary Search

// A recursive binary search function. It returns
// location of x in given array arr[l..r] is present,
// otherwise -1
function binarySearch(arr, l, r, x){
    if (r >= l) {
        let mid = l + Math.floor((r - l) / 2);

        // If the element is present at the middle
        // itself
        if (arr[mid] == x)
            return mid;

        // If element is smaller than mid, then
        // it can only be present in left subarray
        if (arr[mid] > x)
            return binarySearch(arr, l, mid - 1, x);

        // Else the element can only be      ent
```

```
        // in right subarray
        return binarySearch(arr, mid + 1, r, x);
    }

    // We reach here when element is not
    // present in array
    return -1;
}

let arr = [ 2, 3, 4, 10, 40 ];
let x = 10;
let n = arr.length
let result = binarySearch(arr, 0, n - 1, x);
(result == -1) ? document.write( "Element is not present in array")
                   : document.write("Element is present at index " +result);
</script>
```

Output :

```
Element is present at index 3
```

Here you can create a check function for easier implementation.

Here is recursive implementation with check function which I feel is a much easier implementation:

C++

```
#include <bits/stdc++.h>
using namespace std;

//define array globally
const int N = 1e6 +4;

int a[N];
int n;//array size

//element to be searched in array
   int k;

bool check(int dig)
{
    //element at dig position in array
    int ele=a[dig];

    //if k is less than
    //element at dig position
```

```
        //then we need to bring our higher ending to dig
        //and then continue further
        if(k<=ele)
        {
            return 1;
        }
        else
        {
        return 0;
        }
    }
    void binsrch(int lo,int hi)
    {
        while(lo<hi)
        {
            int mid=(lo+hi)/2;
            if(check(mid))
            {
                hi=mid;
            }
            else
            {
                lo=mid+1;
            }
        }
        //if a[lo] is k
        if(a[lo]==k)
            cout<<"Element found at index "<<lo;// 0 based indexing
        else
            cout<<"Element doesnt exist in array";//element was not in our array

    }


    int main()
    {
        cin>>n;
       for(int i=0; i<n; i++)
       {
        cin>>a[i];
       }
       cin>>k;

       //it is being given array is sorted
       //if not then we have to sort it

       //minimum possible point where our k can be is starting index
       //so lo=0
       //also k cannot be outside of array so end point
       //hi=n

       binsrch(0,n);
```

```
    return 0;
}
```

Iterative implementation of Binary Search

C++

```
// C++ program to implement recursive Binary Search
#include <bits/stdc++.h>
using namespace std;

// A iterative binary search function. It returns
// location of x in given array arr[l..r] if present,
// otherwise -1
int binarySearch(int arr[], int l, int r, int x)
{
    while (l <= r) {
        int m = l + (r - l) / 2;

        // Check if x is present at mid
        if (arr[m] == x)
            return m;

        // If x greater, ignore left half
        if (arr[m] < x)
            l = m + 1;

        // If x is smaller, ignore right half
        else
            r = m - 1;
    }

    // if we reach here, then element was
    // not present
    return -1;
}

int main(void)

    int arr[] = { 2, 3, 4, 10, 40 };
    int x = 10;
    int n = sizeof(arr) / sizeof(arr[0]
    int result = binarySearch(arr, 0, n x);
```

```
    (result == -1) ? cout << "Element is not present in array"
                   : cout << "Element is present at index " << result;
    return 0;
}
```

C

```
// C program to implement iterative Binary Search
#include <stdio.h>

// A iterative binary search function. It returns
// location of x in given array arr[l..r] if present,
// otherwise -1
int binarySearch(int arr[], int l, int r, int x)
{
    while (l <= r) {
        int m = l + (r - l) / 2;

        // Check if x is present at mid
        if (arr[m] == x)
            return m;

        // If x greater, ignore left half
        if (arr[m] < x)
            l = m + 1;

        // If x is smaller, ignore right half
        else
            r = m - 1;
    }

    // if we reach here, then element was
    // not present
    return -1;
}

int main(void)
{
    int arr[] = { 2, 3, 4, 10, 40 };
    int n = sizeof(arr) / sizeof(arr[0]);
    int x = 10;
    int result = binarySearch(arr, 0, n - 1, x);
    (result == -1) ? printf("Element is not present"
                            " in array")
                   : printf("Element is present at "
                            "index %d",
                            result);
    return 0;
}
```

Java

```
// Java implementation of iterative Binary Search
class BinarySearch {
    // Returns index of x if it is present in arr[],
    // else return -1
    int binarySearch(int arr[], int x)
    {
        int l = 0, r = arr.length - 1;
        while (l <= r) {
            int m = l + (r - l) / 2;

            // Check if x is present at mid
            if (arr[m] == x)
                return m;

            // If x greater, ignore left half
            if (arr[m] < x)
                l = m + 1;

            // If x is smaller, ignore right half
            else
                r = m - 1;
        }

        // if we reach here, then element was
        // not present
        return -1;
    }

    // Driver method to test above
    public static void main(String args[])
    {
        BinarySearch ob = new BinarySearch();
        int arr[] = { 2, 3, 4, 10, 40 };
        int n = arr.length;
        int x = 10;
        int result = ob.binarySearch(arr, x);
        if (result == -1)
            System.out.println("Element not present");
        else
            System.out.println("Element found at "
                               + "index " + result);
    }
}
```

Python3

```python
# Python3 code to implement iterative Binary
# Search.

# It returns location of x in given array arr
# if present, else returns -1
def binarySearch(arr, l, r, x):

    while l <= r:

        mid = l + (r - l) // 2;

        # Check if x is present at mid
        if arr[mid] == x:
            return mid

        # If x is greater, ignore left half
        elif arr[mid] < x:
            l = mid + 1

        # If x is smaller, ignore right half
        else:
            r = mid - 1

    # If we reach here, then the element
    # was not present
    return -1

# Driver Code
arr = [ 2, 3, 4, 10, 40 ]
x = 10

# Function call
result = binarySearch(arr, 0, len(arr)-1, x)

if result != -1:
    print ("Element is present at index % d" % result)
else:
    print ("Element is not present in array")
```

C#

```csharp
// C# implementation of iterative Binary Search
using System;

class GFG {
    // Returns index of x if it is present in arr[],
    // else return -1
    static int binarySearch(int[] arr, int x)
    {
        int l = 0, r = arr.Length - 1;
```

```
        while (l <= r) {
            int m = l + (r - l) / 2;

            // Check if x is present at mid
            if (arr[m] == x)
                return m;

            // If x greater, ignore left half
            if (arr[m] < x)
                l = m + 1;

            // If x is smaller, ignore right half
            else
                r = m - 1;
        }

        // if we reach here, then element was
        // not present
        return -1;
    }

    // Driver method to test above
    public static void Main()
    {
        int[] arr = { 2, 3, 4, 10, 40 };
        int n = arr.Length;
        int x = 10;
        int result = binarySearch(arr, x);
        if (result == -1)
            Console.WriteLine("Element not present");
        else
            Console.WriteLine("Element found at "
                              + "index " + result);
    }
}
// This code is contributed by Sam007
```

PHP

```
<?php
// PHP program to implement
// iterative Binary Search

// A iterative binary search
// function. It returns location
// of x in given array arr[l..r]
// if present, otherwise -1
function binarySearch($arr, $l,
                      $r, $x)
{
```

```
    while ($l <= $r)
    {
        $m = $l + ($r - $l) / 2;

        // Check if x is present at mid
        if ($arr[$m] == $x)
            return floor($m);

        // If x greater, ignore
        // left half
        if ($arr[$m] < $x)
            $l = $m + 1;

        // If x is smaller,
        // ignore right half
        else
            $r = $m - 1;
    }

    // if we reach here, then
    // element was not present
    return -1;
}

// Driver Code
$arr = array(2, 3, 4, 10, 40);
$n = count($arr);
$x = 10;
$result = binarySearch($arr, 0,
                       $n - 1, $x);
if(($result == -1))
echo "Element is not present in array";
else
echo "Element is present at index ",
                            $result;

// This code is contributed by anuj_67.
?>
```

Javascript

```
<script>
// Program to implement iterative Binary Search


// A iterative binary search function. It returns
// location of x in given array arr[l..r] is present,
// otherwise -1

 function binarySearch(arr, x)
```

```
{
    let l = 0;
    let r = arr.length - 1;
    let mid;
    while (r >= l) {
         mid = l + Math.floor((r - l) / 2);

        // If the element is present at the middle
        // itself
        if (arr[mid] == x)
            return mid;

        // If element is smaller than mid, then
        // it can only be present in left subarray
        if (arr[mid] > x)
            r = mid - 1;

        // Else the element can only be present
        // in right subarray
        else
            l = mid + 1;
    }

    // We reach here when element is not
    // present in array
    return -1;
}

    arr =new Array(2, 3, 4, 10, 40);
    x = 10;
    n = arr.length;
    result = binarySearch(arr, x);

(result == -1) ? document.write("Element is not present in array")
               : document.write ("Element is present at index " + result);

// This code is contributed by simranarora5sos and rshuklabbb
</script>
```

Output :

```
Element is present at index 3
```

Time Complexity:

The time complexity of Binary Search can be written as

```
T(n) = T(n/2) + c
```

The above recurrence can be solved either using the Recurrence Tree method or the Master method. It falls in case II of the Master Method and the solution of the recurrence is $Theta(Logn)$.

Auxiliary Space: O(1) in case of iterative implementation. In the case of recursive implementation, O(Logn) recursion call stack space.

Algorithmic Paradigm: Decrease and Conquer.

Note:

Here we are using

> *int mid = low + (high – low)/2;*

Maybe, you wonder why we are calculating the ***middle index*** this way, we can simply add the *lower and higher index and divide it by 2.*

> *int mid = (low + high)/2;*

But if we calculate the ***middle index*** like this means our code is not 100% correct, it contains bugs.

That is, it fails for larger values of int variables low and high. Specifically, it fails if the sum of low and high is greater than the maximum positive int value(2^{31} – 1).

The sum overflows to a negative value and the value stays negative when divided by 2. In java, it throws *ArrayIndexOutOfBoundException.*

> *int mid = low + (high – low)/2;*

So it's better to use it like this. This bug applies equally to merge sort and other divide and conquer algorithms.

Geeksforgeeks Courses: