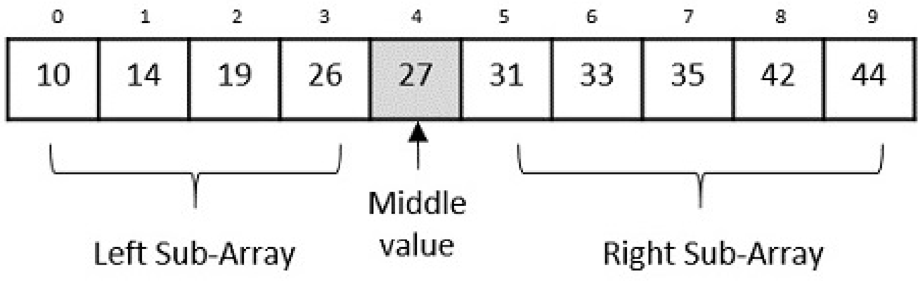
Binary Search Algorithm

Binary search is a fast search algorithm with run-time complexity of Ο(log n). This search algorithm works on the principle of divide and conquer, since it divides the array into half before searching. For this algorithm to work properly, the data collection should be in the sorted form.

Binary search looks for a particular key value by comparing the middle most item of the collection. If a match occurs, then the index of item is returned. But if the middle item has a value greater than the key value, the right sub-array of the middle item is searched. Otherwise, the left sub-array is searched. This process continues recursively until the size of a subarray reduces to zero.



Binary Search Algorithm

Binary Search algorithm is an interval searching method that performs the searching in intervals only. The input taken by the binary search algorithm must always be in a sorted array since it divides the array into subarrays based on the greater or lower values. The algorithm follows the procedure below −

Step 1 − Select the middle item in the array and compare it with the key value to be searched. If it is matched, return the position of the median.

Step 2 − If it does not match the key value, check if the key value is either greater than or less than the median value.

Step 3 − If the key is greater, perform the search in the right sub-array; but if the key is lower than the median value, perform the search in the left sub-array.

Step 4 − Repeat Steps 1, 2 and 3 iteratively, until the size of sub-array becomes 1.

Step 5 − If the key value does not exist in the array, then the algorithm returns an unsuccessful search.

Pseudocode

The pseudocode of binary search algorithms should look like this −

```
Procedure binary_search
   A ← sorted array
   n ← size of array
   x ← value to be searched

   Set lowerBound = 1
   Set upperBound = n

   while x not found
      if upperBound < lowerBound
         EXIT: x does not exists.

      set midPoint = lowerBound + ( upperBound - lowerBound ) / 2

      if A[midPoint] < x
         set lowerBound = midPoint + 1

      if A[midPoint] > x
         set upperBound = midPoint - 1

      if A[midPoint] = x
         EXIT: x found at location midPoint
   end while
end procedure
```

Analysis

Since the binary search algorithm performs searching iteratively, calculating the time complexity is not as easy as the linear search algorithm.

The input array is searched iteratively by dividing into multiple sub-arrays after every unsuccessful iteration. Therefore, the recurrence relation formed would be of a dividing function.

To explain it in simpler terms,

- During the first iteration, the element is searched in the entire array. Therefore, length of the array = n.
- In the second iteration, only half of the original array is searched. Hence, length of the array = n/2.
- In the third iteration, half of the previous sub-array is searched. Here, length of the array will be = n/4.
- Similarly, in the ith iteration, the length of the array will become $n/2^i$

To achieve a successful search, after the last iteration the length of array must be 1. Hence,

```
n/2i = 1
```

That gives us −

```
n = 2i
```

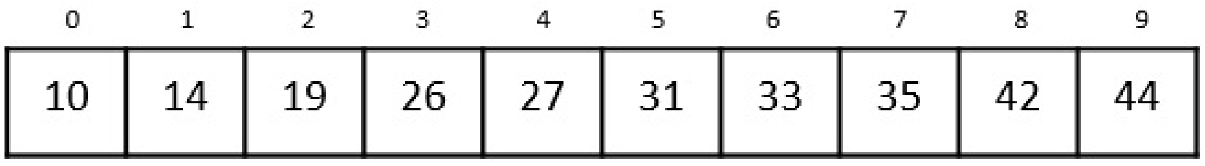
Applying log on both sides,

```
log n = log 2i
log n = i. log 2
i = log n
```

The time complexity of the binary search algorithm is **O(log n)**

Example

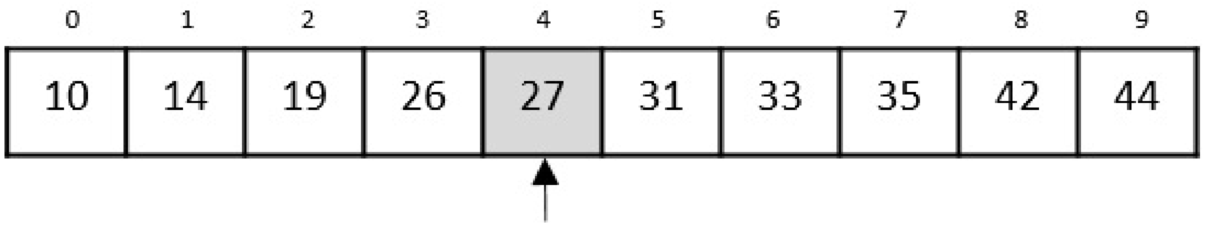
For a binary search to work, it is mandatory for the target array to be sorted. We shall learn the process of binary search with a pictorial example. The following is our sorted array and let us assume that we need to search the location of value 31 using binary search.



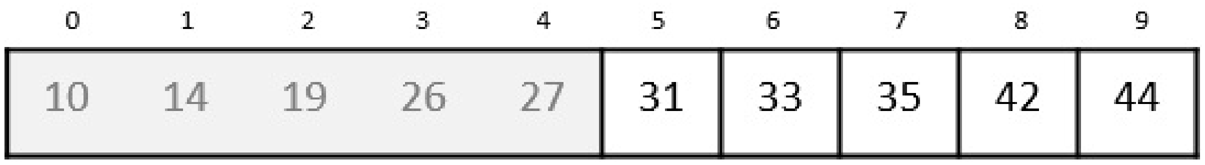
First, we shall determine half of the array by using this formula −

```
mid = low + (high - low) / 2
```

Here it is, 0 + (9 - 0) / 2 = 4 (integer value of 4.5). So, 4 is the mid of the array.



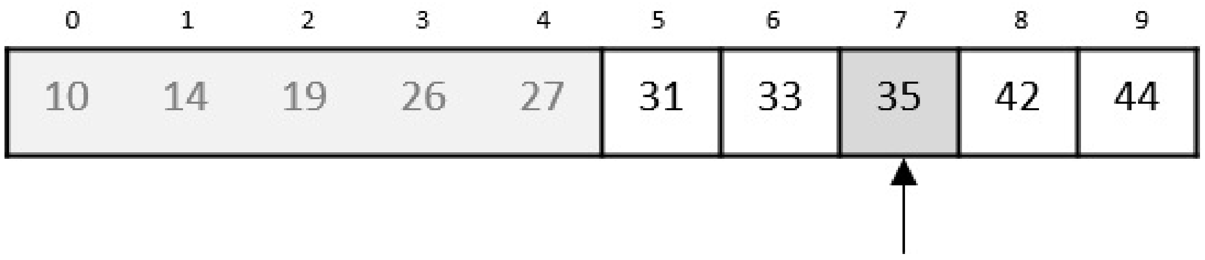
Now we compare the value stored at location 4, with the value being searched, i.e. 31. We find that the value at location 4 is 27, which is not a match. As the value is greater than 27 and we have a sorted array, so we also know that the target value must be in the upper portion of the array.



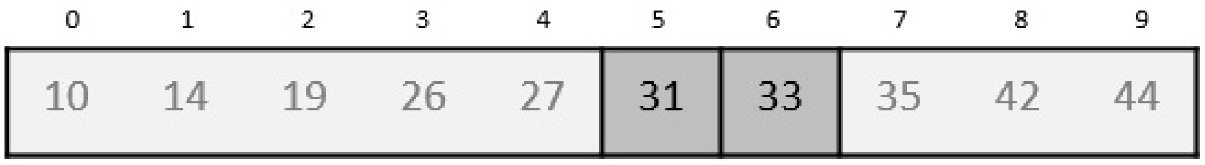
We change our low to mid + 1 and find the new mid value again.

```
low = mid + 1
mid = low + (high - low) / 2
```

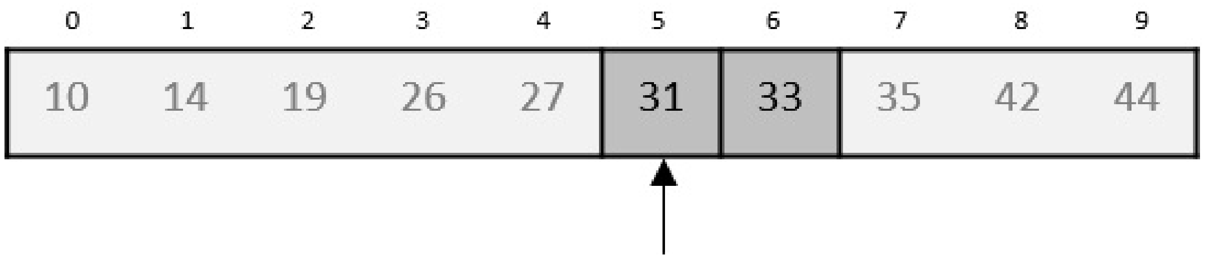
Our new mid is 7 now. We compare the value stored at location 7 with our target value 31.



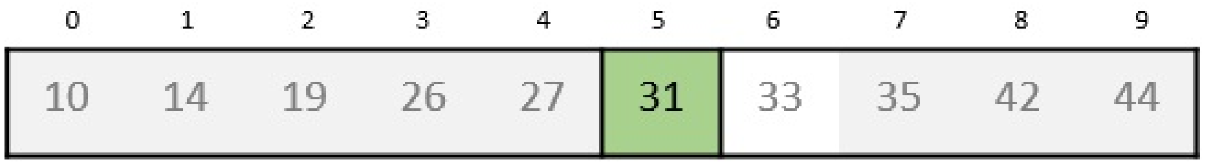
The value stored at location 7 is not a match, rather it is less than what we are looking for. So, the value must be in the lower part from this location.



Hence, we calculate the mid again. This time it is 5.



We compare the value stored at location 5 with our target value. We find that it is a match.



We conclude that the target value 31 is stored at location 5.

Binary search halves the searchable items and thus reduces the count of comparisons to be made to very less numbers.

Implementation

Binary search is a fast search algorithm with run-time complexity of O(log n). This search algorithm works on the principle of divide and conquer. For this algorithm to work properly, the data collection should be in a sorted form.

C C++ Java Python

```
#include<stdio.h>
void binary_search(int a[], int low, int high, int key){
   int mid;
   mid = (low + high) / 2;
   if (low <= high) {
      if (a[mid] == key)
         printf("Element found at index: %d\n", mid);
      else if(key < a[mid])
         binary_search(a, low, mid-1, key);
      else if (a[mid] < key)
         binary_search(a, mid+1, high, key);
   } else if (low > high)
      printf("Unsuccessful Search\n");
}
int main(){
   int i, n, low, high, key;
   n = 5;
   low = 0;
   high = n-1;
   int a[10] = {12, 14, 18, 22, 39};
   key = 22;
   binary_search(a, low, high, key);
   key = 23;
   binary_search(a, low, high, key);
   return 0;
}
```

Output

```
Element found at index: 3
Unsuccessful Search
```