Searching in an array

CS10003 PROGRAMMING AND DATA STRUCTURES

Searching

Check if a given element (called key) occurs in the array.

- Example: array of student records; rollno can be the key.

Two methods to be discussed:

a) If the array elements are unsorted.
   - Linear search
b) If the array elements are sorted.
   - Binary search

Basic Concept of Linear Search

Basic idea

- Start at the beginning of the array.
- Inspect elements one by one to see if it matches the key.
- If a match is found, return the array index where the match was found.
- If no match is found, a special value is returned (like –1).

Linear Search (contd.)

Function `linear_search` returns the array index where a match is found.

It returns –1 if there is no match.

```
int linear_search (int a[], int size, int key)
{
    int pos = 0;
    while ((pos < size) && (key != a[pos]))
       pos++;
    if (pos < size)
       return pos;           /* Return the position of match */
    return -1;               /* No match found */
}
```

Time Complexity of Linear Search

A measure of how many basic operations an algorithm needs to perform before terminating.

Example of basic operation: match / compare two elements.

- If there are *n* elements in the array:
  - Best case:

    match found in first element (1 search operation)
  - Worst case:

    no match found, or match found in the last element (n search operations)
  - Average case: (n + 1) / 2 search operations

Binary Search

Basic Concept

Binary search is applicable if the array is *sorted*.

Basic Idea

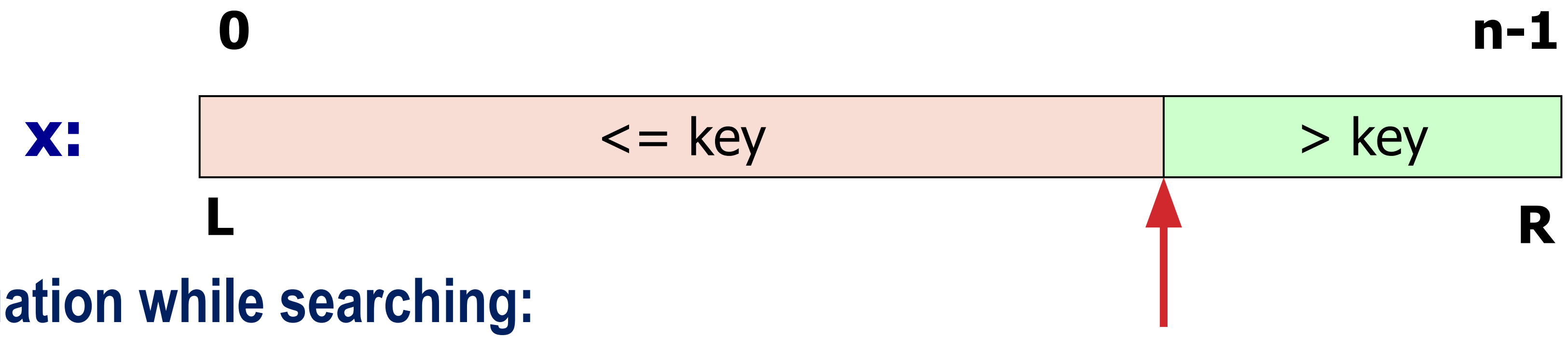
- **Look for the target in the middle.**
- **If you don't find the key, you can ignore half of the array, and repeat the process with the other half.**

In every step, we reduce, by a factor of two, the number of elements to search from.

The Basic Strategy

What do we want?

- Plan to find the array index between values larger and smaller than key:



- Situation while searching:
  - Initially, the search window is the entire array, that is, L and R are initialized to the indices of the first and the last elements.

- Look at the element at index [(L+R)/2].
  - Discard one half of the search window depending on the outcome of test.

Initialization and Return Value

```
int bin_search (int x[], int size, int key)
{
   int L, R, mid;
   L = 0;  R = size - 1;
   while (L != R)
   {
       mid = (L + R) / 2;
       if (key <= x[mid])  R = mid;
       else L = mid + 1;
   }
   if (key == x[L])
          return L;
       else
          return -1;
}
```

If key appears in x[0…size–1], return its location, pos such that x[pos]==key.

If not found, return –1

Binary Search Examples

Sorted array

-17	-5	3	6	12	21	45	63	50
0	1	2	3	4	5	6	7	8

Trace

```
bin_search (x, 9, 3);
```

```
L   R   M   key <= x[M]?
0   8   4   3 <= 12?    [True]
0   4   2   3 <= 3?     [True]
0   2   1   3 <= -5?   [False]
2   2        [Loop terminates]
key == x[L]?            [True]
```

```
binsearch(x, 9, 2);
```

```
L   R   M   key <= x[M]?
0   8   4   2 <= 12?    [True]
0   4   2   2 <= 3?     [True]
0   2   1   2 <= -5?   [False]
2   2        [Loop terminates]
key == x[L]?           [False]
```

We can modify the algorithm by checking equality with `x[mid]`.

Another Version of Iterative Binary Search

```
int bin_search_1 (int x[], int size, int key)
{
    int L, R, mid;
    L = 0; R = size-1;
    while (L <= R)
      {
          mid = (L + R) / 2;
          if (key == x[mid]) return mid;
          if (key < x[mid]) R = mid - 1;
          else L = mid + 1;
      }
    return -1;
}
```

Unsorted vs Sorted Array Search: Where's the difference?

Suppose that the array x has 1000 elements.

Linear search

If *key* is a member of x, it would require about 500 comparisons on the average.

Binary search

- After 1st compare, left with 500 elements.
- After 2nd compare, left with 250 elements.
- After at most 10 steps, you are done.

Time Complexity

If there are *n* elements in the array.

- Number of iterations required:

  $log_2 n$

For n = 64 (say).

- Initially, list size = 64.
- After first compare, list size = 32.
- After second compare, list size = 16.
- After third compare, list size = 8.
- …
- After sixth compare, list size = 1.

$2^k = n$, where k is the number of steps.

$\log_2 64 = 6$

$\log_2 1024 = 10$

Recursive Version of Binary Search

The algorithm for binary search directly leads to a recursive formulation.

- **The algorithm is called recursively by adjusting the left or right pointers, as applicable.**
- **The base condition is: the element is found, or the left and right pointers cross.**

```c
int binarySearch (int x[], int L, int R, int key)
{
     int mid;
     if (L <= R)   {
         mid = (L + R) / 2;
         if (key == x[mid])    // If the element is present at the middle
              return mid;
         if (key < x[mid])     // Look into the left subarray
              return binarySearch (x, L, mid-1, key);
         else                  // Look into the right subarray
              return binarySearch (x, mid+1, R, key);
     }
     // Element is not present in array
     return -1;
}
```

Returns location of key in given array arr[L … R] if present, otherwise –1

```c
int result = binarySearch (arr, 0, n-1, key);
if (result == -1)
   printf ("Key is not present in array\n");
else
   printf("Key is present at index %d\n", result);
```