Searching

Tiziana Ligorio
Hunter College of The City University of New York

Today's Plan

Midterm discussion

Searching algorithms and their analysis

Searching

Looking for something!

In this discussion we will assume searching for an element in a vector/array

Linear search

Most intuitive

Start at first position and keep looking until you find it

```
template <class Comparable>
int linearSearch(const std::vector<Comparable>& a, const Comparable& value)
{

    for (int i = 0; i < a.size(); i++)
    {
        if (a[i] == value) {
            return i;
        }
    }
    return-1;
}
```

How long does linear search take?

If you assume value is in the array and probability of finding it at any location is uniform, on **average n/2**

If value is not in the array (worst case) **n**

Either way it's $O(n)$

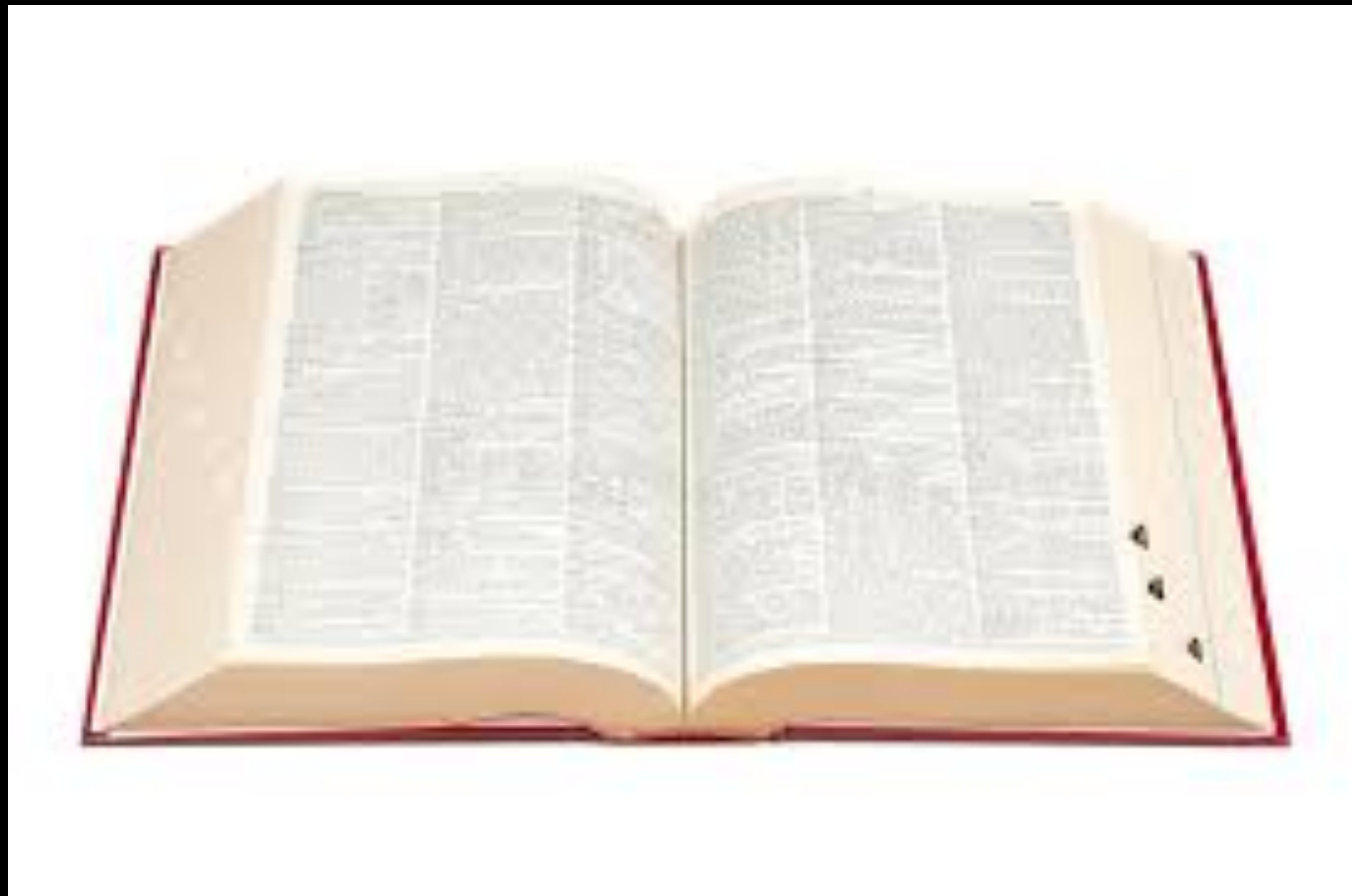
What if you know **array is sorted**?
Can you do better than linear search?

Lecture Activity

You are given a sorted array of integers.

How would you search for 115? (try to do it in fewer than n steps: don't search sequentially)

You can write pseudocode or succinctly explain your algorithm

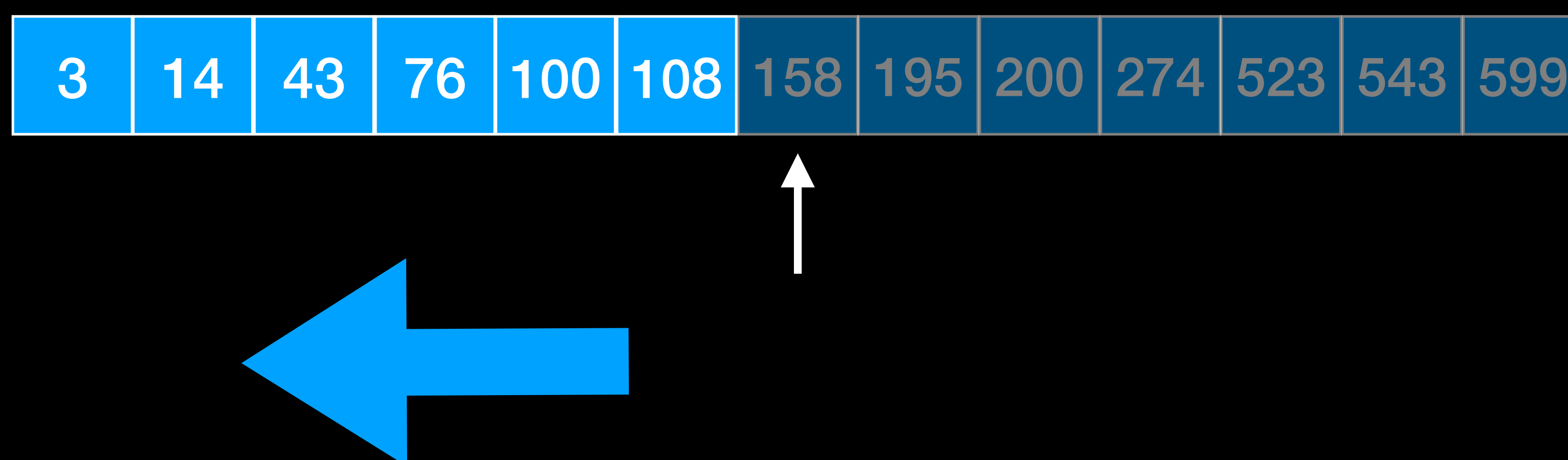


Look in ?

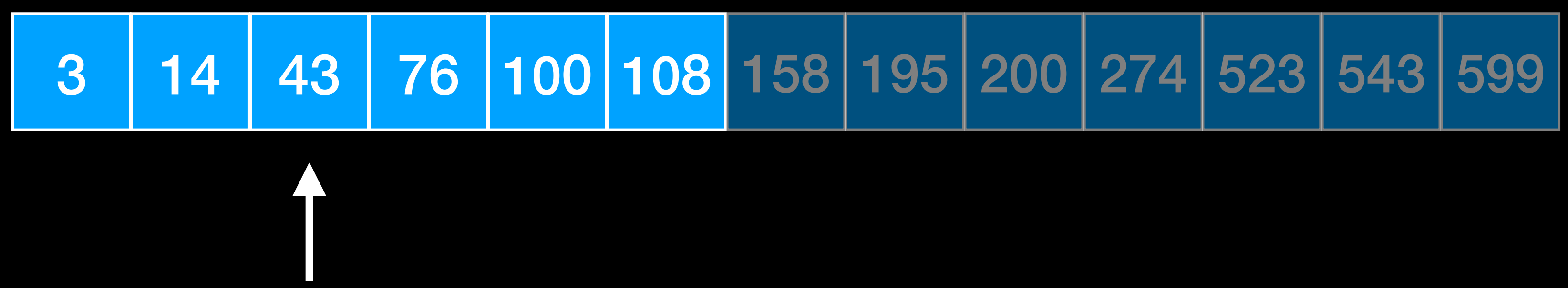
Binary Search

3	14	43	76	100	108	158	195	200	274	523	543	599

Binary Search



Binary Search



Binary Search

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Binary Search

3	14	43	76	100	108	158	195	200	274	523	543	599

```cpp
template <class Comparable>
int binarySearch(const std::vector<Comparable>& v, const Comparable& x)
{
    int low = 0, high = v.size() - 1;

    while(low <= high)
    {
      int mid = (low + high) / 2;
      if(v[mid] < x)
        low = mid + 1; //search upper half
      else if (v[mid] > x)
        high = mid - 1; // search lower half
      else
        return mid;  //found

    }
    return -1; //not found
}
```

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low high

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low						mid						high

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O(?)

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low high mid

Binary Search

What is happening here?

Binary Search

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Size of search is **cut in half** at each step

Binary Search

What is happening here?

Size of search is **cut in half** at each step

The running time

Let $T(n)$ be the running time and **assume $n = 2^k$**

Simplification: assume n is a power of 2 so it can be evenly divided in two parts

$T(n) = T(n/2) + 1$

One comparison

Search lower OR upper half

Binary Search

What is happening here?

Size of search is **cut in half** at each step

Let $T(n)$ be the running time and **assume $n = 2^k$**

$T(n) = T(n/2) + 1$

$T(n/2) = T(n/4) + 1$

One comparison

Search lower OR upper half of n/2

Binary Search

What is happening here?

Size of search is **cut in half** at each step

Let $T(n)$ be the running time and **assume $n = 2^k$**

$T(n) = \boxed{T(n/2)} + 1$

$T(n/2) = T(n/4) + 1$

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Binary Search

What is happening here?

Size of search is **cut in half** at each step

Let $T(n)$ be the running time and **assume $n = 2^k$**

$T(n) = T(n/2) + 1$

2^1 1

$T(n) = T(n/4) + 2$

. . .

2^2 2

Binary Search

What is happening here?

Size of search is **cut in half** at each step

Let $T(n)$ be the running time and **assume $n = 2^k$**

$T(n) = T(n/2) + 1$

$T(n) = T(n/4) + 2$

. . .

$T(n) = T(n/2^k) + k$

Binary Search

What is happening here?

Size of search is **cut in half** at each step

Let $T(n)$ be the running time and **assume** $\mathbf{n = 2^k}$

$T(n) = T(n/2) + 1$

$T(n) = T(n/4) + 2$

. . .

$T(n) = T(n/2^k) + k$

$T(n) = T(1) + \log_2(n)$

The number to which I need to raise 2 to get n
And we said $n = 2^k$

$n/n = 1$

Binary Search

What is happening here?

Size of search is **cut in half** at each step

Let $T(n)$ be the running time and **assume $n = 2^k$**

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. . .

$T(n) = T(n/2^k) + k$

$T(n) = T(1) + \log_2(n)$

Binary search is $O(\log(n))$

Sorting

Rearranging a sequence into increasing (decreasing) order!

Several approaches

Can do it in many ways

What is the best way?

Let's find out using Big-O

Lecture Activity

Write **pseudocode** to sort an array.

543	3	523	76	200	158	195	108	43	274	100	14	599

There are many approaches to sorting
We will look at some comparison-based approaches here

Next time: Sorting