

## CSC 212: Data Structures and Abstractions

### Basic Sorting Algorithms

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## Announcements

- Programming #1
  - ✓ 24 / 57 / 78
- Programming #2
  - ✓ will be posted today (maze generation)
  - ✓ focus on classes and dynamic arrays (`std::vector`)
- If C++ is still a significant issue ...
  - ✓ consider taking this class next semester

2

## Looking for internships/jobs?

<https://careers.google.com/how-we-hire/interview/>

[https://www.amazon.jobs/en/landing\\_pages/software-development-topics](https://www.amazon.jobs/en/landing_pages/software-development-topics)

<https://www.facebook.com/careers/life/preparing-for-your-software-engineering-interview-at-facebook/>

3

Worst-case, Average-case,  
Best-case

## Warming up: Analyze this code

```
unsigned int argmin(const std::vector<int> &values) {  
    unsigned int length = values.size();  
    assert(length > 0);  
    unsigned int idx = 0;  
    int current = values[0];  
    for (unsigned int i = 1; i < length; i++) {  
        if (values[i] < current) {  
            current = values[i];  
            idx = i;  
        }  
    }  
    return idx;  
}
```

$T(n) = ?$   
based on number of comparisons

5


## Warming up: Analyze this code


```
bool argk(const std::vector<int> &values, int k, unsigned int &idx) {  
    unsigned int length = values.size();  
    for (unsigned int i = 0; i < length; i++) {  
        if (values[i] == k) {  
            idx = i;  
            return true;  
        }  
    }  
    return false;  
}
```


$T(n) = ?$   
based on number of comparisons

6

## Different types of analysis

 **Worst-case:** maximum time of algorithm  
on any input

 **Average-case:** expected time of algorithm  
over all inputs

 **Best-case:** minimum time of algorithm on  
some (optimal) input

7

## Different types of analysis

- While **asymptotic analysis** describes  $T(n)$  as  $n$  approaches infinity ...
  - asymptotic notation: big O, big Omega, big Theta
- Case analysis** looks into the different input types
  - best-case, worst-case, average-case

These analysis types are orthogonal  
to each other

8

## Worst-case, Average-case, Best-case

- Ex: factorial of a number (iterative algorithm)
- Ex: sequential search (return first occurrence)
- Ex: sequential search (return last occurrence)

9

## Basic Sorting Algorithms

## Sorting

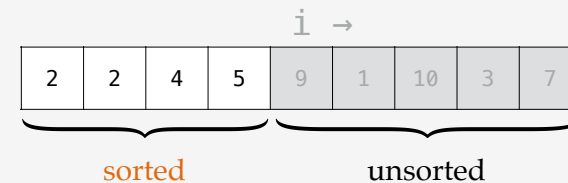
- Given **n** elements that can be compared according to a **total order** relation
  - ✓ we want to rearrange them in non-increasing / non-decreasing order
  - ✓ for example (non-decreasing):
    - **input**: sequence of items  $A = [k_0, k_1, \dots, k_{n-1}]$
    - **output**: permutation of A  $B \mid B[0] \leq B[1] \leq \dots B[n-1]$

Central problem in computer science

11

## Insertion Sort

- Array is divided into **sorted** and **unsorted** parts
  - ✓ algorithm scans array from **left to right**
- Invariants
  - ✓ elements in **sorted** are in ascending order
  - ✓ elements in **unsorted** have not been seen



12

## Insertion Sort Demo

```
void insertionSort(int *A, unsigned int n) {
    int temp;
    unsigned int i, j;
    // grows the left part (sorted)
    for (i = 0 ; i < n ; i++) {
        // inserts A[j] in sorted part
        for (j = i ; j > 0 ; j--) {
            if (A[j] < A[j-1]) {
                temp = A[j];
                A[j] = A[j-1];
                A[j-1] = temp;
            }
            else
                break;
        }
    }
}
```

Number of comparisons?    Number of exchanges?

14

## Analysis — Insertion Sort (comparisons)

- Running time depends on the input
- Worst-case?
  - ✓ input reverse sorted
- Best-case?
  - ✓ input already sorted
- Average-case?
  - ✓ expect every element to move  $O(n/2)$  times

15

## Partially sorted arrays

- An **inversion** is a pair of keys that are out of order

1	3	4	5	2	6	10	15	7
---	---	---	---	---	---	----	----	---

“array is **partially sorted** if the number of pairs that are out-of-order is  $O(n)$ ”

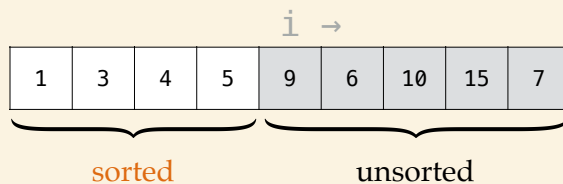
For partially-sorted arrays, insertion sort runs in **linear time**.

$$\Theta(n)$$

16

## Selection Sort

- Array is divided into **sorted** and **unsorted** parts
  - ✓ algorithm scans array from **left to right**
- Invariants
  - ✓ elements in **sorted** are **fixed** and in ascending order
  - ✓ no element in **unsorted** is smaller than any element in **sorted**



17

## Selection Sort Demo

```
void selectionsort(int *A, unsigned int n) {  
    int temp;  
    unsigned int i, j, min;  
    // grows the left part (sorted)  
    for (i = 0 ; i < n ; i ++ ) {  
        min = i;  
        // find min in unsorted part  
        for (j = i+1 ; j < n ; j ++ ) {  
            if (A[j] < A[min]) {  
                min = j;  
            }  
        }  
        // swap A[i] and A[min]  
        temp = A[i];  
        A[i] = A[min];  
        A[min] = temp;  
    }  
}
```

Number of comparisons?    Number of exchanges?

19

## Analysis — Selection Sort (comparisons)

- Worst-case?
- Best-case?
- Average-case?
- Running time is quadratic
  - ✓ insensitive to the input (quadratic in all cases)
  - ✓ linear number of exchanges (minimal data movement)

20

## Summary

	Best-Case	Average-Case	Worst-Case
Selection Sort	$\theta(n^2)$	$\theta(n^2)$	$\theta(n^2)$
Insertion Sort	$\theta(n)$	$\theta(n^2)$	$\theta(n^2)$