

CSE 142 Programming I

Sorting

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Problem:

- ↗ Put an array of items in order
 - † Either ascending or descending

- ↗ Given an array $a[0] \dots a[n-1]$, reorder the elements so that $a[0] \leq a[1] \leq a[2]$ etc.

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Applications

- ↗ Why would we want to do this?

- ↗ This is used all over the place to organize data
 - † Can easily merge data
 - † Order logs
 - † Prepare output
 - † etc.

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Algorithms

- ↗ What is an **algorithm**?

- ↗ When we design an algorithm, what things should we think about?

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Back to Our Problem

- ↗ How might we approach sorting?
- ↗ What basic operation(s) do we need?
- ↗ How do we put the basic pieces together?

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Simple Idea

- ↗ We can put things “more” in order by swapping two elements that are out of order
 - ↗ Go through the array, and swap neighboring elements if they’re out of order
 - † Repeat until done

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Bubble Sort

```
void bubblesort(int nums[], int first, int last){  
    int i, changed;  
    do {  
        changed = FALSE;  
        for (i=first; i<last; i++){  
            if (nums[i] > nums[i+1]) {  
                swap(&nums[i], &nums[i+1]);  
                changed = TRUE;  
            }  
        }  
    } while (changed);  
}
```

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Example

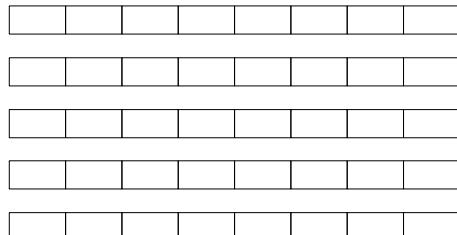
5	0	4	2	100	6	5	-8

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Example Continued (Ugh!)



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That Hurt

✗ Why did this take so long?

✗ How many times do we have to loop?

✗ How much work each time?

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How Can We Improve This?

✗ Big problem: each out of order bar can only move 1 step towards its destination each time

✗ Can we improve this?
† (Of course, silly!)

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Idea!

✗ Instead of just comparing neighboring bars, compare things farther away

✗ We have a lot of options...

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New Algorithm

- ✓ Find the smallest element, and swap it with the first element
- ✓ Find the next smallest element, and swap it with the second element
- ✓ Proceed until done

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Selection Sort

```
void selectionsort (int nums[], int first, int last){  
    int i, j, smallest, smallindex;  
    for (i=first; i<last; i++){  
        smallest = nums[i];  
        smallindex = i;  
        for (j=i+1; j<=last;j++){  
            if (nums[j] < smallest){  
                smallest = nums[j];  
                smallindex = j; }  
        }  
        swap(&nums[i], &nums[smallindex]);  
    }  
}
```

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Example

5	0	4	2	100	6	5	-8

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Example Continued (Ugh!)

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Is this any better?

- ✓ How many times do we have to loop over the array?
- ✓ How much work every time?

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Sorts Compared?

- ✓ In practice, selection sort is much faster than bubble sort
- ✓ In fact, bubble sort is particularly bad

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Can We Do Better?

↳ Maybe if we...

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Some Further Insights

↳ Selection sort improved on bubble sort but, with selection sort, we have to scan through the remainder of the array once for each element we pick out

↳ Why can't we do more work on each scan?

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Quicksort

- ↳ Idea: pick an element—any element—and call it the **pivot**
- ↳ Go through the array and put everything smaller than the pivot at the front, and everything larger than the pivot at the end
- ↳ Put the pivot in the middle
- ↳ Recursively Quicksort each half

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Example

5	0	4	2	100	6	5	-8

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Quicksort Code

```
void quicksort(int nums[],  
    int first, int last){  
    int i, j;  
    int pivot;  
  
    if (first >= last) return;  
  
    pivot = nums[first];  
    i = first;  
    j = last+1;  
    while (i < j){  
        do {  
            i++;  
        } while (pivot > nums[i]);  
        do {  
            j--;  
        } while (nums[j] > pivot);  
        if (i < j)  
            swap(&nums[i], &nums[j]);  
    }  
    swap(&nums[first], &nums[j]);  
    quicksort(nums, first, j-1);  
    quicksort(nums, j+1, last);  
    return;  
}
```

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How Long Does This Take?

↳ This is harder to analyze than the other two.

↳ In the worst case, it's not too hard to see it takes n^2 time

↳ What about the average time?

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Quicksort Best Case

- Each time, if we're lucky, we split the list in two. Each "level" takes a total of n time to do
- There are $\log(n)$ "levels", so the total time is $n \log(n)$
 - We say " $n \log n$ "

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Quicksort Average Case

- It turns out that the average case is $n \log(n)$ as well.
 - (This is not easy to see.)

- Can we do better?

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Optimal Sorting

- It turns out that the best one can do with a general sorting algorithm is $n \log(n)$.
 - For special cases we can do better

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Algorithms We've Seen:

- Searching:

Name	Speed
Linear Search	n
Binary Search	$\log(n)$

- Sorting:

Name	Speed
Bubble Sort	n^2
Selection Sort	n^2
Quicksort	$n \log(n)$

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The Message:

- Algorithm design is very important!
- We've examined algorithm speed, but there are other considerations:
 - Space
 - Correctness
 - Even ease of programming may be important

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