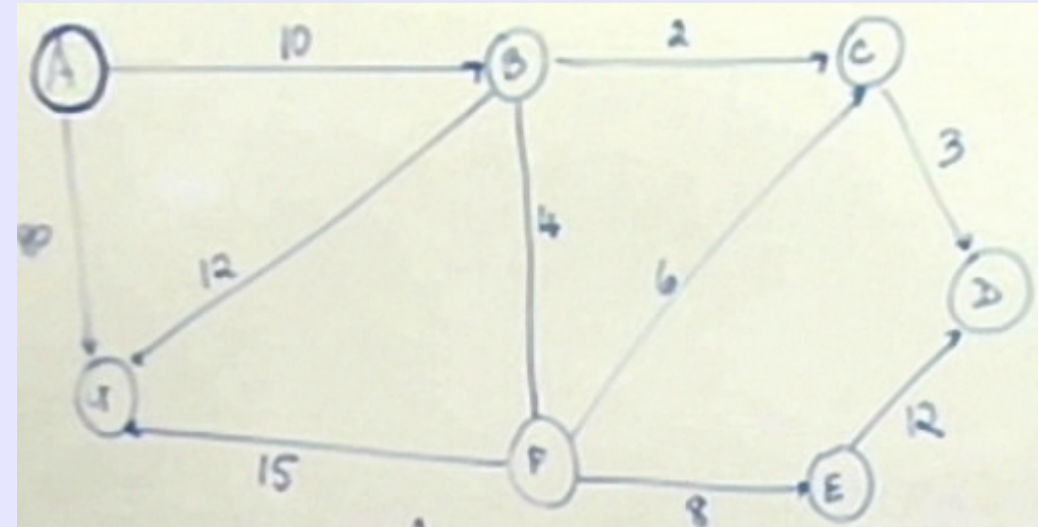
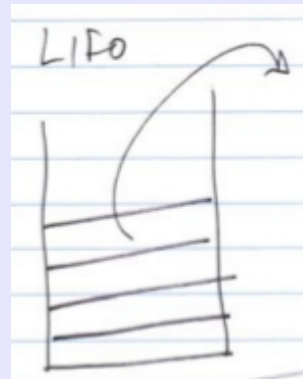
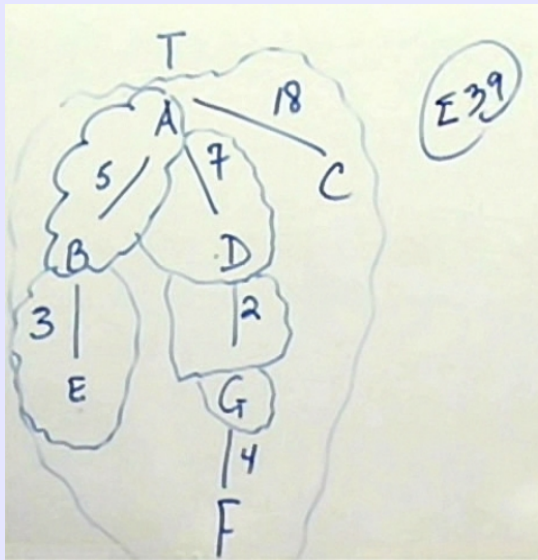


avg	worst case
$O(\log n)$	$O(n)$
$O(\log n)$	$O(n)$

80	72	72	70	59	60	50	49	
0	1	2	3	4	5	6	7	8



CS 401: Introduction to Advanced Studies (Data Structures)
Vijay K. Gurbani, Ph.D., Illinois Institute of Technology

Lecture 11: **Sorting**

Sorting

- 20-25% of computing time devoted to sorting in commercial applications.
- Sorting is dominated by:
 - Programmer's time
 - Machine time (runtime complexity)
 - Space
- It is not possible to minimize all three!

Sorting

- Formally:

Sorting: a method that takes an input sequence, $S = \langle a_1, a_2, \dots, a_{n-1}, a_n \rangle$ and produces a permuted sequence, $S' = \langle a'_1, a'_2, \dots, a'_{n-1}, a'_n \rangle$ such that $a'_1 \leq a'_2$ and $a'_2 \leq a'_3 \dots a'_n \leq a'_{n+1}$.

Evaluation metrics for sorts

- Runtime (of course)
- Space (also apparent)
- Stability (what is this?)

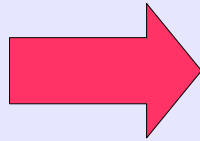
Evaluation metrics for sorts

- Runtime (of course)
- Space (also apparent)
- Stability (what is this?)
 - Informally, stability means that if an element a comes before b in the unsorted input, then their relative ordering is preserved in the sorted output (i.e., a comes before b in the sorted output as well).
 - So, why is stability important? (Let's revisit this after an example).

Evaluation metric for sorts

Sort following using airport
as the key:

8:00a	JFK
8:10a	ORD
9:23a	EWR
4:34p	BRU
8:12a	ORD
9:55a	EWR



4:34p	BRU
9:23a	EWR
9:55a	EWR
8:00a	JFK
8:10a	ORD
8:12a	ORD

4:34p	BRU
9:55a	EWR
9:23a	EWR
8:00a	JFK
8:10a	ORD
8:12a	ORD

Which of the 4 output sorts
is

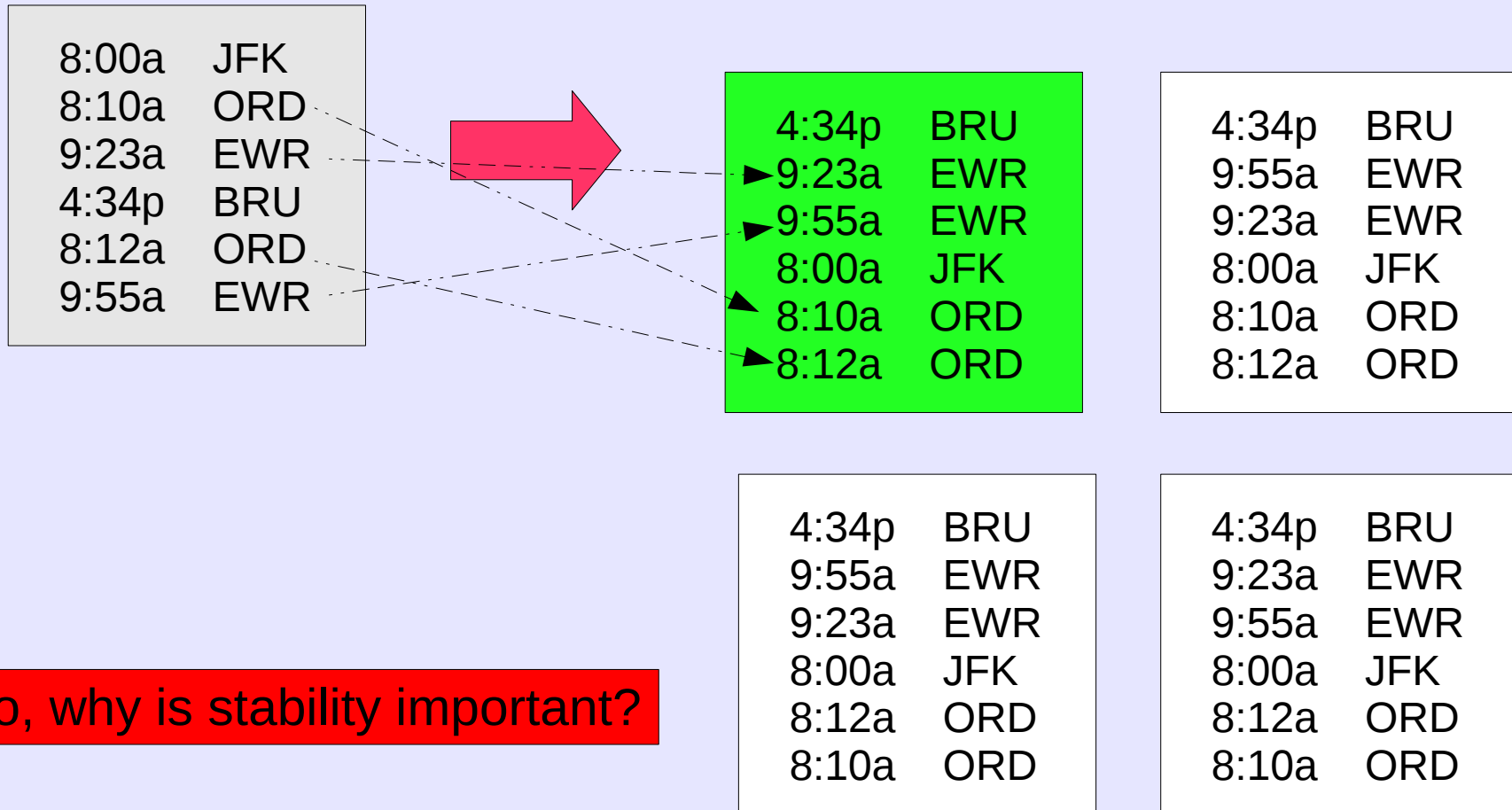
- Correct?
- Stable?

4:34p	BRU
9:55a	EWR
9:23a	EWR
8:00a	JFK
8:12a	ORD
8:10a	ORD

4:34p	BRU
9:23a	EWR
9:55a	EWR
8:00a	JFK
8:12a	ORD
8:10a	ORD

Evaluation metric for sorts

Sort following using airport
as the key:



So, why is stability important?

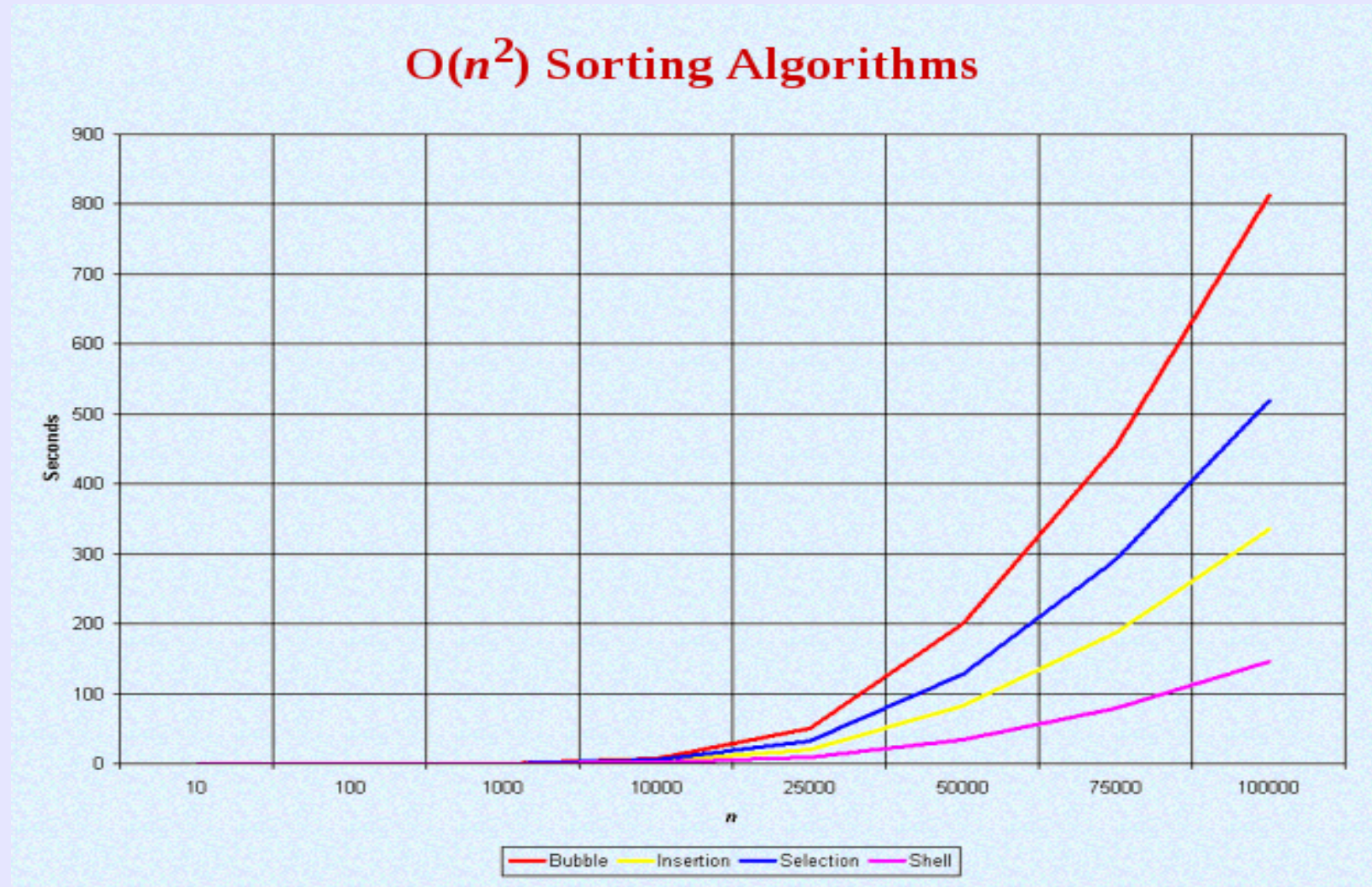
Sorting

- Two types of sort algorithms:
 - Quadratic Sorts
 - Easy to understand.
 - Simple to implement.
 - Not very efficient on large data.
 - Divide and Conquer
 - More complex.
 - Efficient on large data.

Sorting: Quadratic Sorts

- Bubble sort
- Insertion sort
- Selection sort

Quadratic Sort Performance



Slide source: <http://www.personal.kent.edu/~rmuhamma/Algorithms/MyAlgorithms/Sorting/sortingIntro.htm>

Bubble Sort

- Simple.
- Not efficient.
- Make multiple passes ($n - 1$) through the unsorted array, swapping adjacent elements until the array is sorted.
- Can use some simple optimizations to speed up bubble sort.

Bubble Sort

Initial (unsorted)
Array

25
57
48
37
12
92
86
33

Bubble Sort

Initial (unsorted)
Array

25
57
48
37
12
92
86
33

Pass 1

25
57
48
37
12
92
86
33



Bubble Sort

Initial (unsorted)
Array

25
57
48
37
12
92
86
33

Pass 1

25
57
48
37
12
92
86
33

Swap




Bubble Sort

Initial (unsorted)
Array

25
57
48
37
12
92
86
33

Pass 1

25
48
57
37
12
92
86
33



Bubble Sort

Initial (unsorted)
Array

25
57
48
37
12
92
86
33

Pass 1

25
48
57
37
12
92
86
33

 Swap


Bubble Sort

Initial (unsorted)
Array

25
57
48
37
12
92
86
33

Pass 1

25
48
37
57
12
92
86
33



Bubble Sort

Initial (unsorted)
Array

25
57
48
37
12
92
86
33

Pass 1

25
48
37
57
12
92
86
33

Swap



Bubble Sort

Initial (unsorted)
Array

25
57
48
37
12
92
86
33

Pass 1

25
48
37
12
57
92
86
33



Bubble Sort

Initial (unsorted)
Array

25
57
48
37
12
92
86
33

Pass 1

25
48
37
12
57
92
86
33



Bubble Sort

Initial (unsorted)
Array

25
57
48
37
12
92
86
33

Pass 1

25
48
37
12
57
92
86
33



Swap

Bubble Sort

Initial (unsorted)
Array

25
57
48
37
12
92
86
33

Pass 1

25
48
37
12
57
86
92
33



Bubble Sort

Initial (unsorted)
Array

25
57
48
37
12
92
86
33

Pass 1

25
48
37
12
57
86
92
33



Swap

Bubble Sort

Initial (unsorted)
Array

25
57
48
37
12
92
86
33

Pass 1

25
48
37
12
57
86
33
92



Bubble Sort

Initial (unsorted)
Array


25
57
48
37
12
92
86
33

Pass 1

25
48
37
12
57
86
33
92

Bubble Sort


Initial (unsorted) Array	Pass 1	Pass 2
25	25	25
57	48	48
48	37	37
37	12	12
12	57	57
92	86	86
86	33	33
33	92	92



Bubble Sort


Initial (unsorted) Array	Pass 1	Pass 2
25	25	25
57	48	48
48	37	37
37	12	12
12	57	57
92	86	86
86	33	33
33	92	92

Swap



Bubble Sort


Initial (unsorted) Array	Pass 1	Pass 2
25	25	25
57	48	37
48	37	48
37	12	12
12	57	57
92	86	86
86	33	33
33	92	92



Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2
25	25	25
57	48	37
48	37	48
37	12	12
12	57	57
92	86	86
86	33	33
33	92	92


Swap



Bubble Sort

Initial (unsorted)
Array Pass 1 Pass 2


25	25	25
57	48	37
48	37	12
37	12	48
12	57	57
92	86	86
86	33	33
33	92	92



Bubble Sort

Initial (unsorted)
Array Pass 1 Pass 2

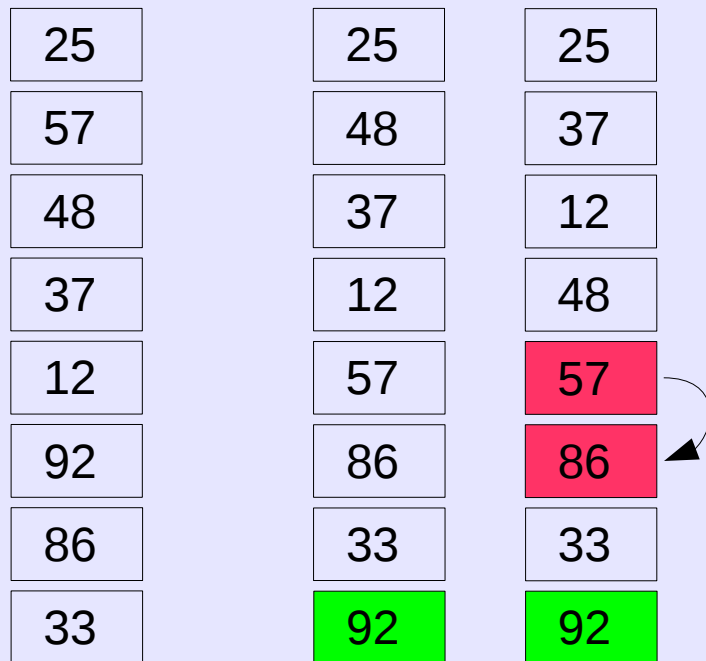
25	25	25
57	48	37
48	37	12
37	12	48
12	57	57
92	86	86
86	33	33
33	92	92



Bubble Sort

Initial (unsorted)
Array Pass 1 Pass 2


25	25	25
57	48	37
48	37	12
37	12	48
12	57	57
92	86	86
86	33	33
33	92	92



Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2
25	25	25
57	48	37
48	37	12
37	12	48
12	57	57
92	86	86
86	33	33
33	92	92


Swap



Bubble Sort

Initial (unsorted)
Array Pass 1 Pass 2


25	25	25
57	48	37
48	37	12
37	12	48
12	57	57
92	86	33
86	33	86
33	92	92



Bubble Sort

Initial (unsorted)
Array Pass 1 Pass 2

25	25	25
57	48	37
48	37	12
37	12	48
12	57	57
92	86	33
86	33	86
33	92	92




Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2
25	25	25
57	48	37
48	37	12
37	12	48
12	57	57
92	86	33
86	33	86
33	92	92

Bubble Sort

Initial (unsorted)
Array Pass 1 Pass 2 Pass 3

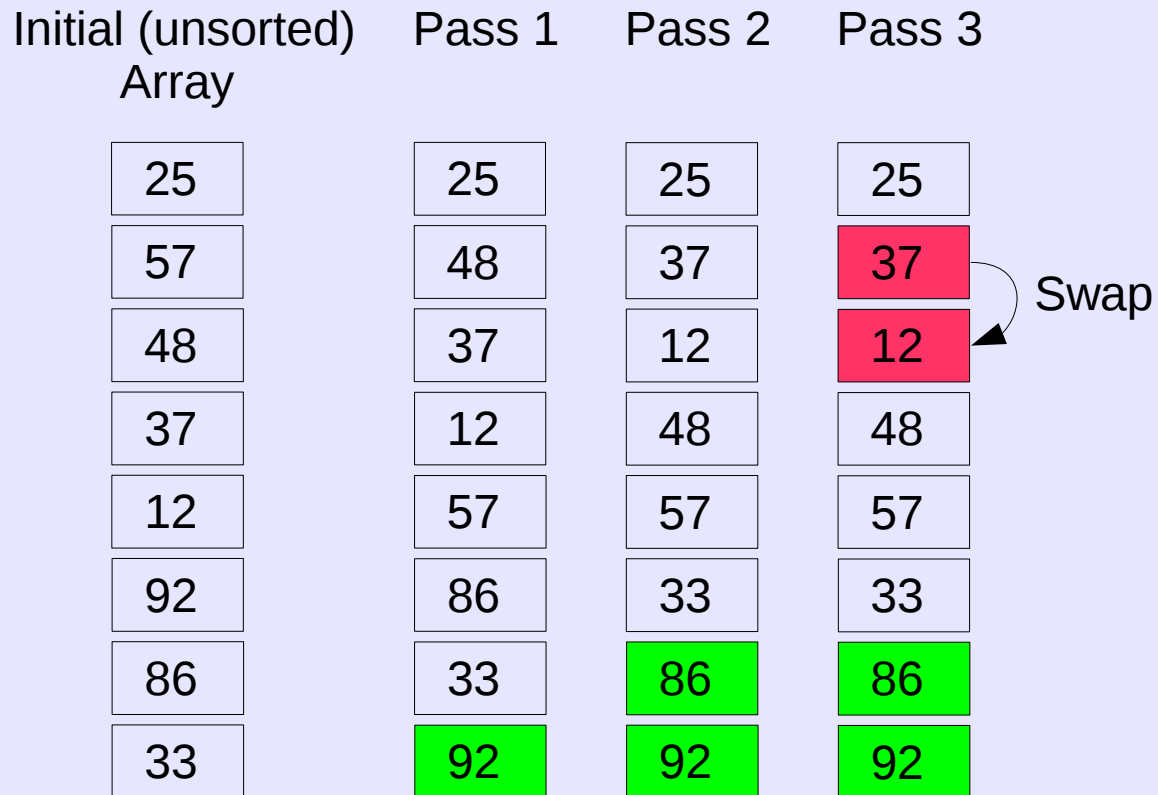
25	25	25	25
57	48	37	37
48	37	12	12
37	12	48	48
12	57	57	57
92	86	33	33
86	33	86	86
33	92	92	92



Bubble Sort


Initial (unsorted) Array	Pass 1	Pass 2	Pass 3
25	25	25	25
57	48	37	37
48	37	12	12
37	12	48	48
12	57	57	57
92	86	33	33
86	33	86	86
33	92	92	92

Swap



Bubble Sort


Initial (unsorted) Array	Pass 1	Pass 2	Pass 3
25	25	25	25
57	48	37	12
48	37	12	37
37	12	48	48
12	57	57	57
92	86	33	33
86	33	86	86
33	92	92	92



Bubble Sort

Initial (unsorted)
Array Pass 1 Pass 2 Pass 3

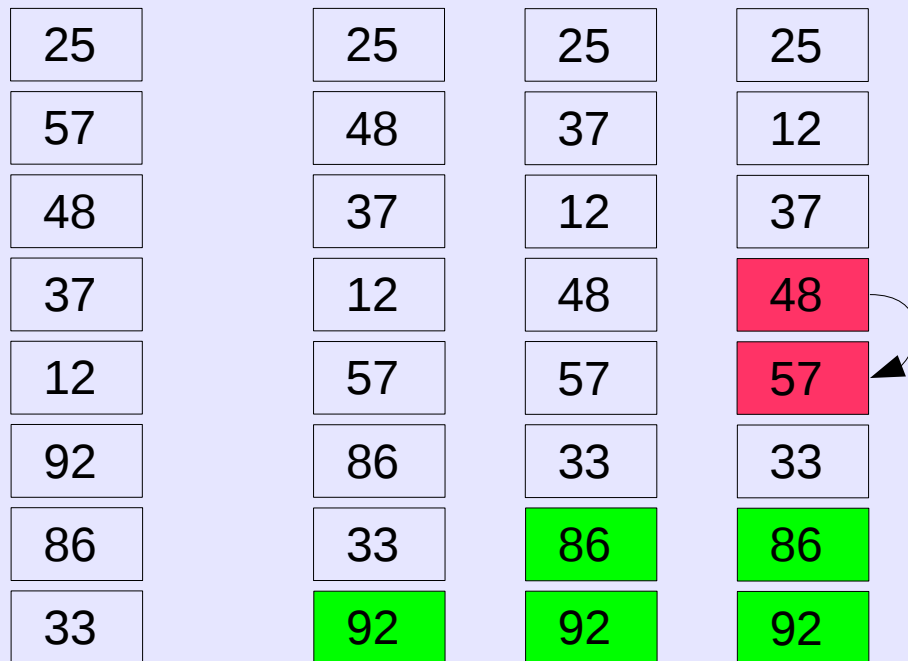
25	25	25	25
57	48	37	12
48	37	12	37
37	12	48	48
12	57	57	57
92	86	33	33
86	33	86	86
33	92	92	92



Bubble Sort

Initial (unsorted)
Array Pass 1 Pass 2 Pass 3

25	25	25	25
57	48	37	12
48	37	12	37
37	12	48	48
12	57	57	57
92	86	33	33
86	33	86	86
33	92	92	92



Bubble Sort

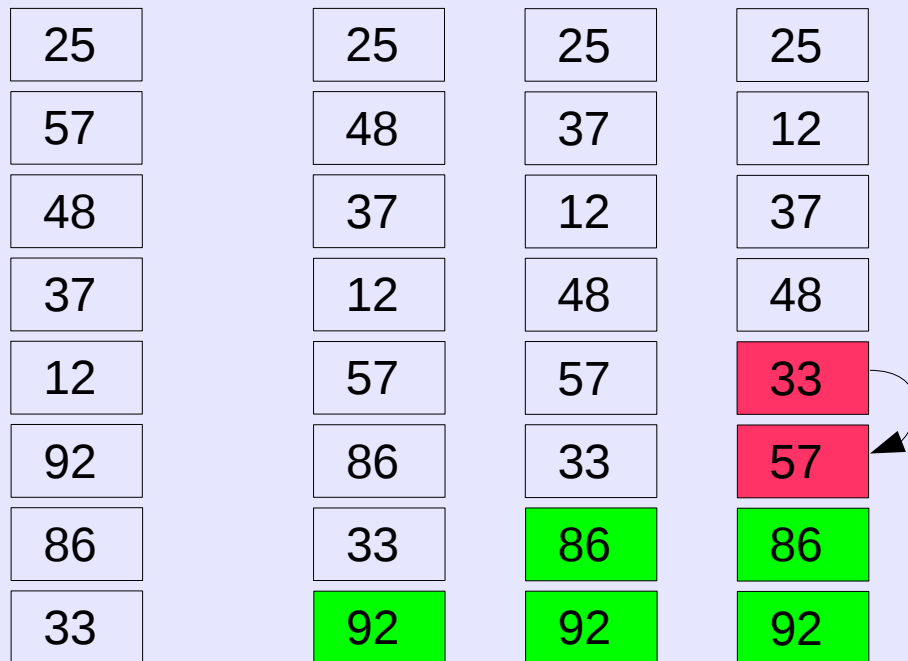
Initial (unsorted) Array	Pass 1	Pass 2	Pass 3
25	25	25	25
57	48	37	12
48	37	12	37
37	12	48	48
12	57	57	57
92	86	33	33
86	33	86	86
33	92	92	92

Swap

Bubble Sort

Initial (unsorted)
Array Pass 1 Pass 2 Pass 3

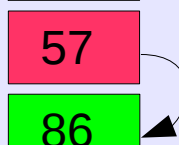
25	25	25	25
57	48	37	12
48	37	12	37
37	12	48	48
12	57	57	33
92	86	33	57
86	33	86	86
33	92	92	92



Bubble Sort

Initial (unsorted)
Array Pass 1 Pass 2 Pass 3


25	25	25	25
57	48	37	12
48	37	12	37
37	12	48	48
12	57	57	33
92	86	33	57
86	33	86	86
33	92	92	92



Bubble Sort

Initial (unsorted)
Array Pass 1 Pass 2 Pass 3

25	25	25	25
57	48	37	12
48	37	12	37
37	12	48	48
12	57	57	33
92	86	33	57
86	33	86	86
33	92	92	92



Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3
25	25	25	25
57	48	37	12
48	37	12	37
37	12	48	48
12	57	57	33
92	86	33	57
86	33	86	86
33	92	92	92

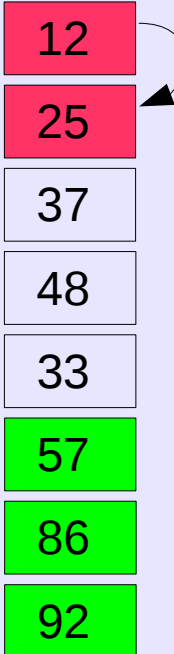
Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4
25	25	25	25	25
57	48	37	12	12
48	37	12	37	37
37	12	48	48	48
12	57	57	33	33
92	86	33	57	57
86	33	86	86	86
33	92	92	92	92

Swap


Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4
25	25	25	25	12
57	48	37	12	25
48	37	12	37	37
37	12	48	48	48
12	57	57	33	33
92	86	33	57	57
86	33	86	86	86
33	92	92	92	92




Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4
25	25	25	25	12
57	48	37	12	25
48	37	12	37	37
37	12	48	48	48
12	57	57	33	33
92	86	33	57	57
86	33	86	86	86
33	92	92	92	92



Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4
25	25	25	25	12
57	48	37	12	25
48	37	12	37	37
37	12	48	48	48
12	57	57	33	33
92	86	33	57	57
86	33	86	86	86
33	92	92	92	92




Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4
25	25	25	25	12
57	48	37	12	25
48	37	12	37	37
37	12	48	48	48
12	57	57	33	33
92	86	33	57	57
86	33	86	86	86
33	92	92	92	92

Swap

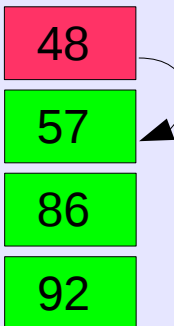
Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4
25	25	25	25	12
57	48	37	12	25
48	37	12	37	37
37	12	48	48	33
12	57	57	33	48
92	86	33	57	57
86	33	86	86	86
33	92	92	92	92




Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4
25	25	25	25	12
57	48	37	12	25
48	37	12	37	37
37	12	48	48	33
12	57	57	33	48
92	86	33	57	57
86	33	86	86	86
33	92	92	92	92



Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4
25	25	25	25	12
57	48	37	12	25
48	37	12	37	37
37	12	48	48	33
12	57	57	33	48
92	86	33	57	57
86	33	86	86	86
33	92	92	92	92



Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4
25	25	25	25	12
57	48	37	12	25
48	37	12	37	37
37	12	48	48	33
12	57	57	33	48
92	86	33	57	57
86	33	86	86	86
33	92	92	92	92

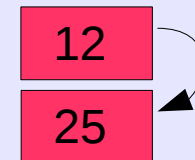


Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4
25	25	25	25	12
57	48	37	12	25
48	37	12	37	37
37	12	48	48	33
12	57	57	33	48
92	86	33	57	57
86	33	86	86	86
33	92	92	92	92


Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5
25	25	25	25	12	12
57	48	37	12	25	25
48	37	12	37	37	37
37	12	48	48	33	33
12	57	57	33	48	48
92	86	33	57	57	57
86	33	86	86	86	86
33	92	92	92	92	92



Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5
25	25	25	25	12	12
57	48	37	12	25	25
48	37	12	37	37	37
37	12	48	48	33	33
12	57	57	33	48	48
92	86	33	57	57	57
86	33	86	86	86	86
33	92	92	92	92	92



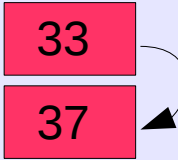
Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5
25	25	25	25	12	12
57	48	37	12	25	25
48	37	12	37	37	37
37	12	48	48	33	33
12	57	57	33	48	48
92	86	33	57	57	57
86	33	86	86	86	86
33	92	92	92	92	92

Swap


Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5
25	25	25	25	12	12
57	48	37	12	25	25
48	37	12	37	37	33
37	12	48	48	33	37
12	57	57	33	48	48
92	86	33	57	57	57
86	33	86	86	86	86
33	92	92	92	92	92




Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5
25	25	25	25	12	12
57	48	37	12	25	25
48	37	12	37	37	33
37	12	48	48	33	37
12	57	57	33	48	48
92	86	33	57	57	57
86	33	86	86	86	86
33	92	92	92	92	92




Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5
25	25	25	25	12	12
57	48	37	12	25	25
48	37	12	37	37	33
37	12	48	48	33	37
12	57	57	33	48	48
92	86	33	57	57	57
86	33	86	86	86	86
33	92	92	92	92	92




Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5
25	25	25	25	12	12
57	48	37	12	25	25
48	37	12	37	37	33
37	12	48	48	33	37
12	57	57	33	48	48
92	86	33	57	57	57
86	33	86	86	86	86
33	92	92	92	92	92



Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5
25	25	25	25	12	12
57	48	37	12	25	25
48	37	12	37	37	33
37	12	48	48	33	37
12	57	57	33	48	48
92	86	33	57	57	57
86	33	86	86	86	86
33	92	92	92	92	92

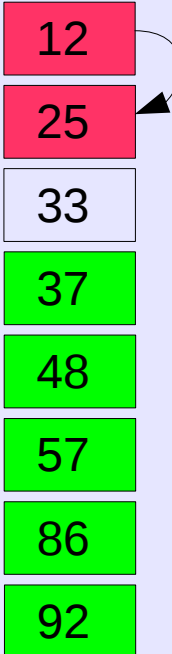


Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5
25	25	25	25	12	12
57	48	37	12	25	25
48	37	12	37	37	33
37	12	48	48	33	37
12	57	57	33	48	48
92	86	33	57	57	57
86	33	86	86	86	86
33	92	92	92	92	92

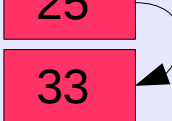
Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Pass 6
25	25	25	25	12	12	12
57	48	37	12	25	25	25
48	37	12	37	37	33	33
37	12	48	48	33	37	37
12	57	57	33	48	48	48
92	86	33	57	57	57	57
86	33	86	86	86	86	86
33	92	92	92	92	92	92



Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Pass 6
25	25	25	25	12	12	12
57	48	37	12	25	25	25
48	37	12	37	37	33	33
37	12	48	48	33	37	37
12	57	57	33	48	48	48
92	86	33	57	57	57	57
86	33	86	86	86	86	86
33	92	92	92	92	92	92




Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Pass 6
25	25	25	25	12	12	12
57	48	37	12	25	25	25
48	37	12	37	37	33	33
37	12	48	48	33	37	37
12	57	57	33	48	48	48
92	86	33	57	57	57	57
86	33	86	86	86	86	86
33	92	92	92	92	92	92




Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Pass 6
25	25	25	25	12	12	12
57	48	37	12	25	25	25
48	37	12	37	37	33	33
37	12	48	48	33	37	37
12	57	57	33	48	48	48
92	86	33	57	57	57	57
86	33	86	86	86	86	86
33	92	92	92	92	92	92




Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Pass 6
25	25	25	25	12	12	12
57	48	37	12	25	25	25
48	37	12	37	37	33	33
37	12	48	48	33	37	37
12	57	57	33	48	48	48
92	86	33	57	57	57	57
86	33	86	86	86	86	86
33	92	92	92	92	92	92




Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Pass 6
25	25	25	25	12	12	12
57	48	37	12	25	25	25
48	37	12	37	37	33	33
37	12	48	48	33	37	37
12	57	57	33	48	48	48
92	86	33	57	57	57	57
86	33	86	86	86	86	86
33	92	92	92	92	92	92



Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Pass 6
25	25	25	25	12	12	12
57	48	37	12	25	25	25
48	37	12	37	37	33	33
37	12	48	48	33	37	37
12	57	57	33	48	48	48
92	86	33	57	57	57	57
86	33	86	86	86	86	86
33	92	92	92	92	92	92

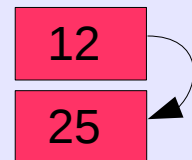


Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Pass 6
25	25	25	25	12	12	12
57	48	37	12	25	25	25
48	37	12	37	37	33	33
37	12	48	48	33	37	37
12	57	57	33	48	48	48
92	86	33	57	57	57	57
86	33	86	86	86	86	86
33	92	92	92	92	92	92

Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Pass 6	Pass 7
25	25	25	25	12	12	12	12
57	48	37	12	25	25	25	25
48	37	12	37	37	33	33	33
37	12	48	48	33	37	37	37
12	57	57	33	48	48	48	48
92	86	33	57	57	57	57	57
86	33	86	86	86	86	86	86
33	92	92	92	92	92	92	92




Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Pass 6	Pass 7
25	25	25	25	12	12	12	12
57	48	37	12	25	25	25	25
48	37	12	37	37	33	33	33
37	12	48	48	33	37	37	37
12	57	57	33	48	48	48	48
92	86	33	57	57	57	57	57
86	33	86	86	86	86	86	86
33	92	92	92	92	92	92	92




Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Pass 6	Pass 7
25	25	25	25	12	12	12	12
57	48	37	12	25	25	25	25
48	37	12	37	37	33	33	33
37	12	48	48	33	37	37	37
12	57	57	33	48	48	48	48
92	86	33	57	57	57	57	57
86	33	86	86	86	86	86	86
33	92	92	92	92	92	92	92




Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Pass 6	Pass 7
25	25	25	25	12	12	12	12
57	48	37	12	25	25	25	25
48	37	12	37	37	33	33	33
37	12	48	48	33	37	37	37
12	57	57	33	48	48	48	48
92	86	33	57	57	57	57	57
86	33	86	86	86	86	86	86
33	92	92	92	92	92	92	92




Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Pass 6	Pass 7
25	25	25	25	12	12	12	12
57	48	37	12	25	25	25	25
48	37	12	37	37	33	33	33
37	12	48	48	33	37	37	37
12	57	57	33	48	48	48	48
92	86	33	57	57	57	57	57
86	33	86	86	86	86	86	86
33	92	92	92	92	92	92	92



Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Pass 6	Pass 7
25	25	25	25	12	12	12	12
57	48	37	12	25	25	25	25
48	37	12	37	37	33	33	33
37	12	48	48	33	37	37	37
12	57	57	33	48	48	48	48
92	86	33	57	57	57	57	57
86	33	86	86	86	86	86	86
33	92	92	92	92	92	92	92



Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Pass 6	Pass 7
25	25	25	25	12	12	12	12
57	48	37	12	25	25	25	25
48	37	12	37	37	33	33	33
37	12	48	48	33	37	37	37
12	57	57	33	48	48	48	48
92	86	33	57	57	57	57	57
86	33	86	86	86	86	86	86
33	92	92	92	92	92	92	92



Bubble Sort

Initial (unsorted) Array	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Pass 6	Pass 7
25	25	25	25	12	12	12	12
57	48	37	12	25	25	25	25
48	37	12	37	37	33	33	33
37	12	48	48	33	37	37	37
12	57	57	33	48	48	48	48
92	86	33	57	57	57	57	57
86	33	86	86	86	86	86	86
33	92	92	92	92	92	92	92

Bubble Sort Optimizations

- 2 optimizations
 - Note that at the end of each pass k , k elements are in place (sorted), $(n - k)$ remain unsorted.
 - If in a pass you do no swaps, array is sorted.
- Runtime complexity analysis...

Bubble Sort Complexity

- Complexity:
 - Runtime complexity of Bubble Sort: $O(n^2)$
 - Space complexity of Bubble Sort: $O(1)$
 - Stable: yes.

Insertion Sort

- Simple.
- Not efficient.
- Make multiple passes (n) through the unsorted array, considering a new element in each pass and inserting the new element in its proper place.
- Faster than Bubble Sort.

Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Insertion Sort

Initial (unsorted)
Array

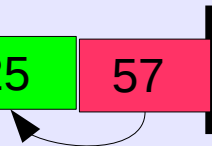
25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----



Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Swap

Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

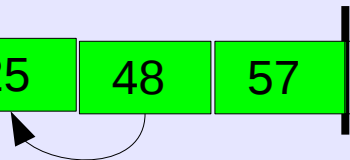
25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----



Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Swap

Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

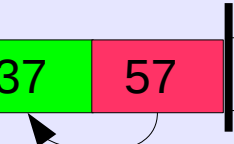
25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	48	37	57	12	92	86	33
----	----	----	----	----	----	----	----



Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	48	37	57	12	92	86	33
----	----	----	----	----	----	----	----

Swap

Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

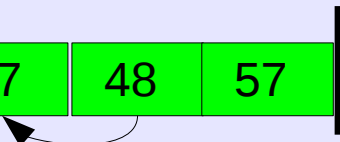
25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----



Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

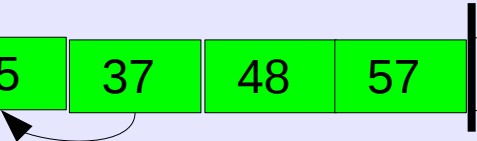
25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57		12	92	86	33
----	----	----	----	--	----	----	----	----



Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

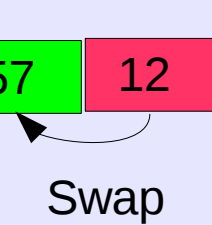
25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----



Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

25	37	48	12	57	92	86	33
----	----	----	----	----	----	----	----

Swap

Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

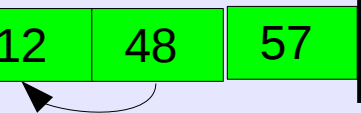
25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

25	37	12	48	57	92	86	33
----	----	----	----	----	----	----	----



Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

25	37	12	48	57	92	86	33
----	----	----	----	----	----	----	----

Swap

Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

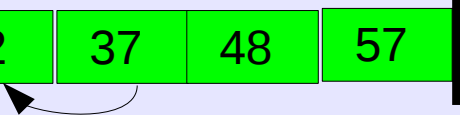
25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

25	12	37	48	57	92	86	33
----	----	----	----	----	----	----	----



Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

25	12	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Swap

Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----



Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

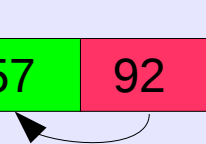
25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 6

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----



Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 6

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 7

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Swap

Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

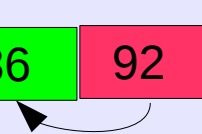
12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 6

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 7

12	25	37	48	57	86	92	33
----	----	----	----	----	----	----	----



Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 6

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 7

12	25	37	48	57	86	92	33
----	----	----	----	----	----	----	----



Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 6

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 7

12	25	37	48	57	86	92	33
----	----	----	----	----	----	----	----

Pass 8

12	25	37	48	57	86	92	33
----	----	----	----	----	----	----	----

Swap

Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 6

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 7

12	25	37	48	57	86	92	33
----	----	----	----	----	----	----	----

Pass 8

12	25	37	48	57	86	33	92
----	----	----	----	----	----	----	----



Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 6

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 7

12	25	37	48	57	86	92	33
----	----	----	----	----	----	----	----

Pass 8

12	25	37	48	57	86	33	92
----	----	----	----	----	----	----	----

Swap

Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 6

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 7

12	25	37	48	57	86	92	33
----	----	----	----	----	----	----	----

Pass 8

12	25	37	48	57	33	86	92
----	----	----	----	----	----	----	----



Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 6

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 7

12	25	37	48	57	86	92	33
----	----	----	----	----	----	----	----

Pass 8

12	25	37	48	57	33	86	92
----	----	----	----	----	----	----	----



Swap

Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 6

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 7

12	25	37	48	57	86	92	33
----	----	----	----	----	----	----	----

Pass 8

12	25	37	48	33	57	86	92
----	----	----	----	----	----	----	----

Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 6

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 7

12	25	37	48	57	86	92	33
----	----	----	----	----	----	----	----

Pass 8

12	25	37	48	33	57	86	92
----	----	----	----	----	----	----	----

Swap

CS 401
vgurbani@iit.edu

Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 6

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 7

12	25	37	48	57	86	92	33
----	----	----	----	----	----	----	----

Pass 8

12	25	37	33	48	57	86	92
----	----	----	----	----	----	----	----

Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 6

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 7

12	25	37	48	57	86	92	33
----	----	----	----	----	----	----	----

Pass 8

12	25	37	33	48	57	86	92
----	----	----	----	----	----	----	----

Swap

CS 401
vgurbani@iit.edu

Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 6

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 7

12	25	37	48	57	86	92	33
----	----	----	----	----	----	----	----

Pass 8

12	25	33	37	48	57	86	92
----	----	----	----	----	----	----	----



Insertion Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 2

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 3

25	48	57	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 4

25	37	48	57	12	92	86	33
----	----	----	----	----	----	----	----

Pass 5

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 6

12	25	37	48	57	92	86	33
----	----	----	----	----	----	----	----

Pass 7

12	25	37	48	57	86	92	33
----	----	----	----	----	----	----	----

Pass 8

12	25	33	37	48	57	86	92
----	----	----	----	----	----	----	----



Insertion Sort Complexity

- Complexity:
 - Runtime complexity of Insertion Sort: $O(n^2)$
 - Space complexity of Insertion Sort: $O(1)$
 - Stable: yes.

Selection Sort

- Simple.
- Not efficient.
- Make multiple passes ($n - 1$) through the unsorted array; in each pass, select smallest unsorted item and swap it with the item in the next position to be filled.
- Not as good as Insertion Sort.

Selection Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----



Swap

Selection Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

12	57	48	37	25	92	86	33
----	----	----	----	----	----	----	----



Selection Sort

Initial (unsorted)
Array

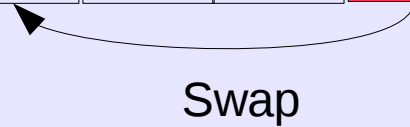
25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

12	57	48	37	25	92	86	33
----	----	----	----	----	----	----	----

Pass 2

12	57	48	37	25	92	86	33
----	----	----	----	----	----	----	----



Selection Sort

Initial (unsorted)
Array

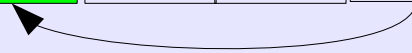
25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

12	57	48	37	25	92	86	33
----	----	----	----	----	----	----	----

Pass 2

12	25	48	37	57	92	86	33
----	----	----	----	----	----	----	----



Selection Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

12	57	48	37	25	92	86	33
----	----	----	----	----	----	----	----

Pass 2

12	25	48	37	57	92	86	33
----	----	----	----	----	----	----	----

Pass 3

12	25	48	37	57	92	86	33
----	----	----	----	----	----	----	----



Selection Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

12	57	48	37	25	92	86	33
----	----	----	----	----	----	----	----

Pass 2

12	25	48	37	57	92	86	33
----	----	----	----	----	----	----	----

Pass 3

12	25	33	37	57	92	86	48
----	----	----	----	----	----	----	----



Selection Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

12	57	48	37	25	92	86	33
----	----	----	----	----	----	----	----

Pass 2

12	25	48	37	57	92	86	33
----	----	----	----	----	----	----	----

Pass 3

12	25	33	37	57	92	86	48
----	----	----	----	----	----	----	----

Pass 4

12	25	33	37	57	92	86	48
----	----	----	----	----	----	----	----

In place

Selection Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

12	57	48	37	25	92	86	33
----	----	----	----	----	----	----	----

Pass 2

12	25	48	37	57	92	86	33
----	----	----	----	----	----	----	----

Pass 3

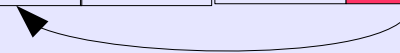
12	25	33	37	57	92	86	48
----	----	----	----	----	----	----	----

Pass 4

12	25	33	37	57	92	86	48
----	----	----	----	----	----	----	----

Pass 5

12	25	33	37	57	92	86	48
----	----	----	----	----	----	----	----



Swap

Selection Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

12	57	48	37	25	92	86	33
----	----	----	----	----	----	----	----

Pass 2

12	25	48	37	57	92	86	33
----	----	----	----	----	----	----	----

Pass 3

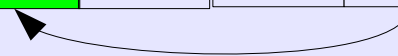
12	25	33	37	57	92	86	48
----	----	----	----	----	----	----	----

Pass 4

12	25	33	37	57	92	86	48
----	----	----	----	----	----	----	----

Pass 5

12	25	33	37	48	92	86	57
----	----	----	----	----	----	----	----



Selection Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

12	57	48	37	25	92	86	33
----	----	----	----	----	----	----	----

Pass 2

12	25	48	37	57	92	86	33
----	----	----	----	----	----	----	----

Pass 3

12	25	33	37	57	92	86	48
----	----	----	----	----	----	----	----

Pass 4

12	25	33	37	57	92	86	48
----	----	----	----	----	----	----	----

Pass 5

12	25	33	37	48	92	86	57
----	----	----	----	----	----	----	----

Pass 6

12	25	33	37	48	92	86	57
----	----	----	----	----	----	----	----

Swap

Selection Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

12	57	48	37	25	92	86	33
----	----	----	----	----	----	----	----

Pass 2

12	25	48	37	57	92	86	33
----	----	----	----	----	----	----	----

Pass 3

12	25	33	37	57	92	86	48
----	----	----	----	----	----	----	----

Pass 4

12	25	33	37	57	92	86	48
----	----	----	----	----	----	----	----

Pass 5

12	25	33	37	48	92	86	57
----	----	----	----	----	----	----	----

Pass 6

12	25	33	37	48	57	86	92
----	----	----	----	----	----	----	----



Selection Sort

Initial (unsorted)
Array

25	57	48	37	12	92	86	33
----	----	----	----	----	----	----	----

Pass 1

12	57	48	37	25	92	86	33
----	----	----	----	----	----	----	----

Pass 2

12	25	48	37	57	92	86	33
----	----	----	----	----	----	----	----

Pass 3

12	25	33	37	57	92	86	48
----	----	----	----	----	----	----	----

Pass 4

12	25	33	37	57	92	86	48
----	----	----	----	----	----	----	----

Pass 5

12	25	33	37	48	92	86	57
----	----	----	----	----	----	----	----

Pass 6

12	25	33	37	48	57	86	92
----	----	----	----	----	----	----	----

Pass 7

12	25	33	37	48	57	86	92
----	----	----	----	----	----	----	----

In place

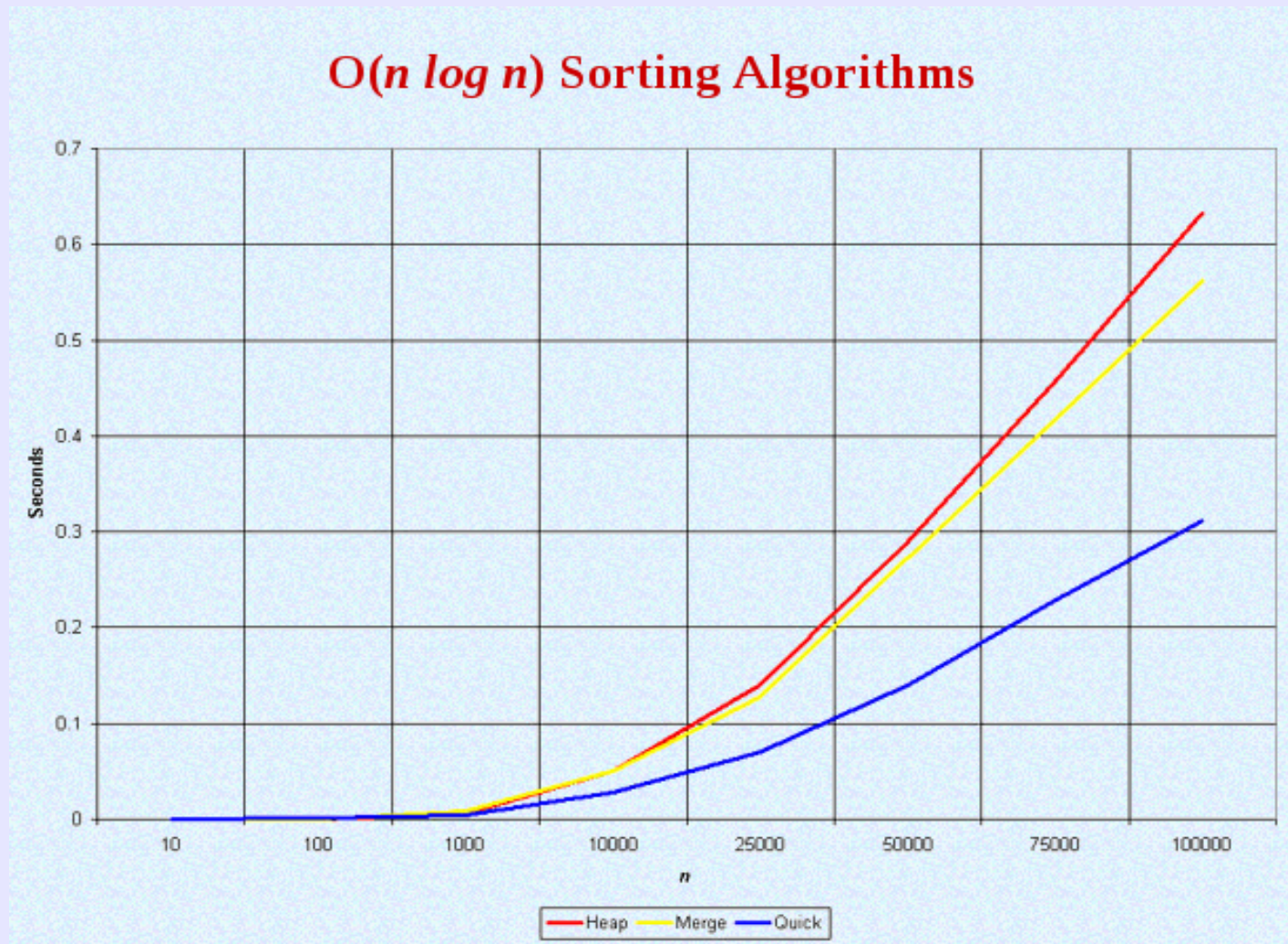
Selection Sort Complexity

- Complexity:
 - Runtime complexity of Selection Sort: $O(n^2)$
 - Space complexity of Selection Sort: $O(1)$
 - Stable: no.

Sorting: Divide and Conquer Sorts

- Heap sort
- Merge sort
- Quick sort

Divide and Conquer Sort Performance



Slide source: <http://www.personal.kent.edu/~rmuhamma/Algorithms/MyAlgorithms/Sorting/sortingIntro.htm>

Heap sort