COMP 204

Algorithm design: Selection and Insertion Sort

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based on material from Yue Li, Christopher J.F. Cameron and Carlos G. Oliver

Sorting algorithms

A **sorting algorithm** is an algorithm that takes

- a list/array as input
- performs specified operations on the list/array
- outputs a sorted list/array

For example:

- $[a, c, d, b]$ could be sorted alphabetically to $[a, b, c, d]$
- $[1, 3, 2, 0]$ could be sorted:
  - increasing order: $[0, 1, 2, 3]$
  - or decreasing order: $[3, 2, 1, 0]$

Why is it useful to sort data?

Sorted data searching can be optimized to a very high level

- also used to represent data in more readable formats

Contacts

- your mobile phone stores the telephone numbers of contacts by names
- names can easily be searched to find a desired number

Dictionary

- dictionaries store words in alphabetical order to allow for easy searching of any word

Remember **binary search**?

Adding more algorithms to your toolbox

In the last lecture, we covered searching algorithms, specifically:

- linear search
- binary search

Today, we will cover the following sorting algorithms:

- selection sort
- insertion sort

Images for selection sort are taken from an online tutorial: `https://www.tutorialspoint.com/data_structures_algorithms/`

Selection sort

Conceptually the most simple of all the sorting algorithms

Start be selecting the smallest item in a list

- then place this item at the start of the list
- repeat for the remaining items in the list
  - move next smallest/largest item to the second position
  - then the next
  - and so on and so on...
  - until the list is sorted

Let's consider the following unsorted list:

Selection sort - Iteration #1

Scan the whole list to find the smallest number (10)

Swap 14 (first element) and 10 (smallest element).

Selection sort - Iteration #2

Search for smallest element starting from second element: Find 14.

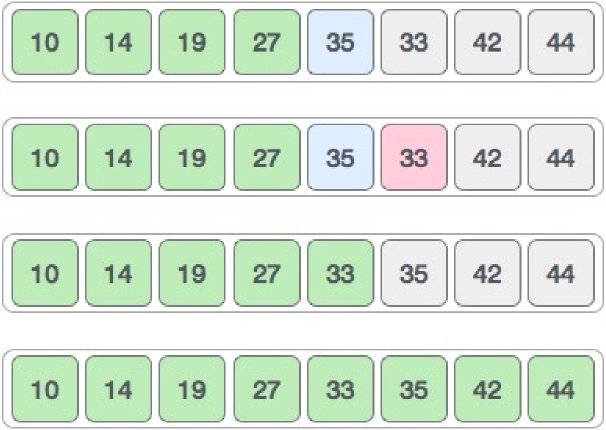
Swap 33 (second element) with 14 (smallest).

Selection sort - Iterations #3, 4, 5...

The same process is applied to the rest of the items in the list

Selection sort #6

Until the list is sorted



Selection sort algorithm

Selection sort (*sequence*)

Step 1 - find the item with the smallest value in *sequence*

Step 2 - swap it with the first item in *sequence*

Step 3 - find the item with the second smallest value in *sequence*

Step 4 - swap it with the second item in *sequence*

Step 5 - find the item with the third smallest value in *sequence*

Step 6 - swap it with the third item in *sequence*

Step 7 - repeat finding the item with the next smallest value

Step 8 - then swap it with the correct item until *sequence* is sorted

Selection sort: pseudocode

Algorithm 1 Selection sort

```
procedure SELECTION_SORT(sequence)
    N ← length of sequence
    for i ← 0 to N − 1 do
        min_index ← i
        for j ← i + 1 to N − 1 do
            if sequence[j] ≤ sequence[min_index] then
                min_index ← j
            end if
        end for
        SWAP(sequence[i],sequence[min_index])
    end for
end procedure
```

Selection sort: Python implementation

```
def selection_sort(sequence):
    N = len(sequence)
    for i in range(0,N):
        min_index = i
        for j in range(i+1,N):
            if sequence[j] <= sequence[min_index]:
                min_index = j
        sequence[i],sequence[min_index] = \
            sequence[min_index],sequence[i]
    return sequence
```

Insertion sort

Insertion sort works by repeatedly

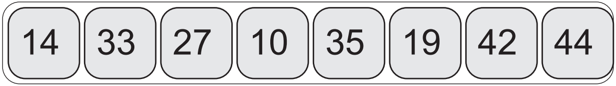
- inserting the next element of the unsorted portion of the list into the sorted portion of the list
- resulting in progressively larger sequences of a sorted list

Start with a sorted list of 1 element on the left and N-1 unsorted items on the right

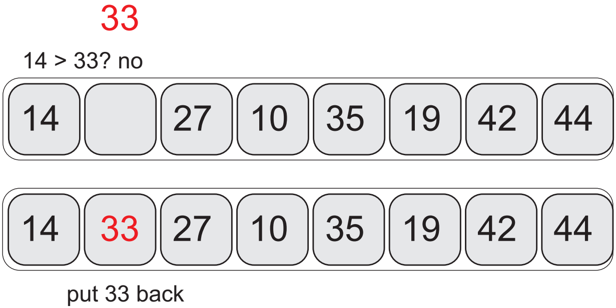
- take the first unsorted item
- insert it into the sorted list, moving elements as necessary
- now have a sorted list of size 2, and N -2 unsorted elements
- repeat for all items

Insertion sort - Iteration 1

Let's reuse our unsorted list from before and sort it in ascending order:



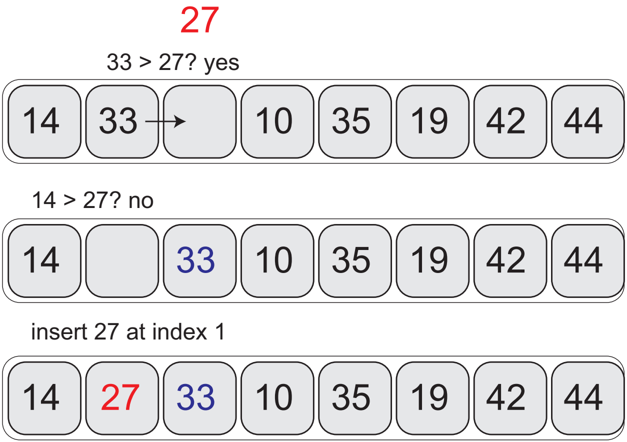
Iteration 1:
Start by finding out where to insert element at index 1 (**33**) into sorted portion of list (index 0 to 0):



List[0...1] is now sorted!

Insertion sort - Iteration 2

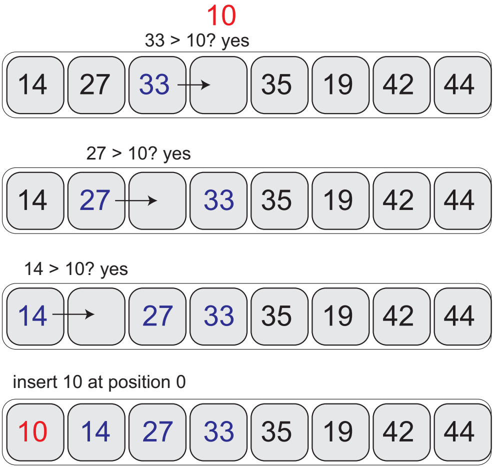
Insert element at index 2 (**27**) into sorted portion of list (index 0 to 1):



List[0...2] is now sorted!

Insertion sort - Iteration 3

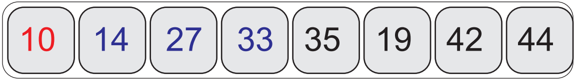
Insert element at index 3 (**10**) into sorted portion of list (index 0 to 2):



List[0...3] is now sorted!

Insertion sort - Iteration 4

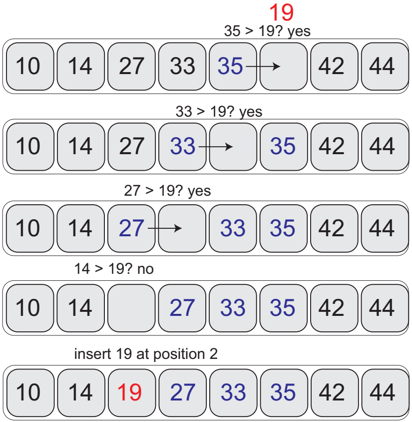
Insert element at index 4 (**35**) into sorted portion of list (index 0 to 3):



Nothing to do! List[0...4] is now sorted!

Insertion sort - Iteration 5

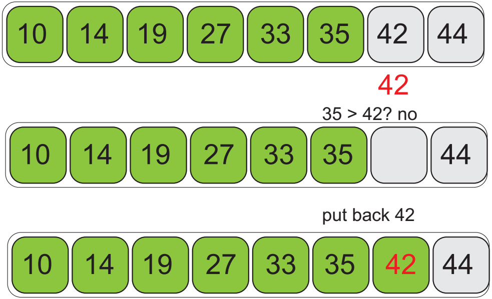
Insert element at index 5 (**19**) into sorted portion of list (index 0 to 4):



List[0...5] is now sorted!

Insertion sort - Iteration 6

Insert element at index 6 (**42**) into sorted portion of list (index 0 to 5):

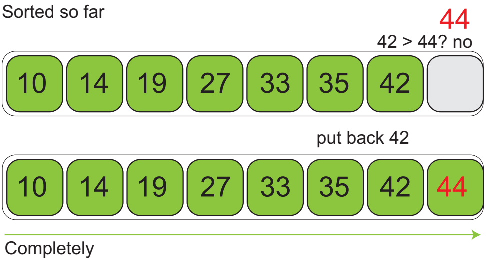


Nothing to do!

List[0...6] is now sorted!

Insertion sort - Iteration 7 (last one!)

Insert element at index 7 (**44**) into sorted portion of list (index 0 to 6):



Nothing to do!

List[0...7] is now sorted!
We're done!

Insertion sort: pseudocode

Algorithm 2 Insertion sort

```
procedure INSERTION_SORT(sequence)
    for i ← 1 to N do
        key ← sequence[i]
        // inset key into the sorted sub-list
        j ← i
        while j > 0 and sequence[j − 1] > key do
            sequence[j] ← sequence[j − 1]
            j ← j − 1
        end while
        sequence[j] ← key
    end for
end procedure
```

Insertion sort: Python implementation

```
def insertion_sort(sequence):
    N = len(sequence)
    for i in range(1,N):
        key = sequence[i]
        j = i
        while(j > 0 and sequence[j-1] > key):
            sequence[j] = sequence[j-1]
            j -= 1
        sequence[j] = key
    return sequence
```

Notes

- SelectionSort and InsertionSort can sort lists of any types of objects (numbers, strings, lists, images...), provided that we can define the comparison operator "$>$".
- SelectionSort and InsertionSort work well on relatively small lists, but...
- The amount of work done by these algorithms is proportional to the *square* of the length of the list.
  - Sorting very large lists can take a very long time.
- Many other sorting algorithms exist: MergeSort, QuickSort, etc.
  - They are a bit more complicated, but
  - Work much faster on large lists