COMP 364: Computer Tools for Life Sciences

Algorithm design: Selection and Insertion Sort

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Key course information

Quiz #4 is available today!

- available on MyCourses (multiple choice questions)
- Quiz #4 closes at 11:59:59 pm on Monday, October 16th
- questions cover topics from the last two weeks

Midterm review sessions

- 1:00-2:00 pm on Thursday, October 19th
  - hosted by Roman (TR 3104)
- 5:00-7:00 pm on Friday, October 20th
  - hosted by Pouriya (TR 3104)
- TAs will not prepare material, be sure to arrive with questions

Sorting algrotihms

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 are taken from the following online tutorial: `https://www.tutorialspoint.com/data_structures_algorithms/`

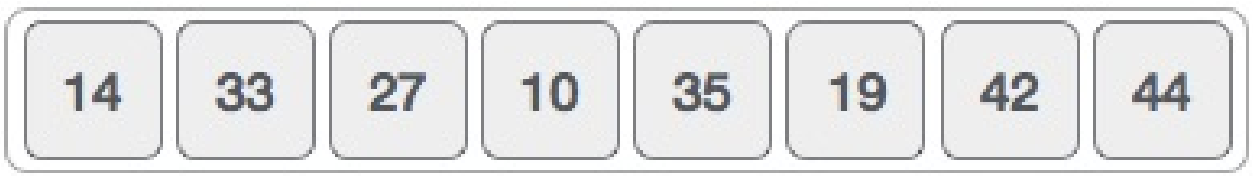
Selection sort

Conceptually the most simple of all the sorting algorithms

Start be selecting the smallest (or largest) 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 #2

For the first position in the resulting sorted list

- the whole list is scanned sequentially
- the first position is where 14 is currently stored

We search the whole list

- to find that 10 is the lowest value in the list

Selection sort #3

We then replace 14 with 10

After one iteration

- 10, which happens to be the minimum value in the list
- appears in the first position of the sorted list

For the second position

- where 33 is residing
- we start scanning the rest of the list in a linear manner

Selection sort #4

14 is found to be the second lowest value in the list

- and should appear at the second place
- we swap these values.

After two iterations

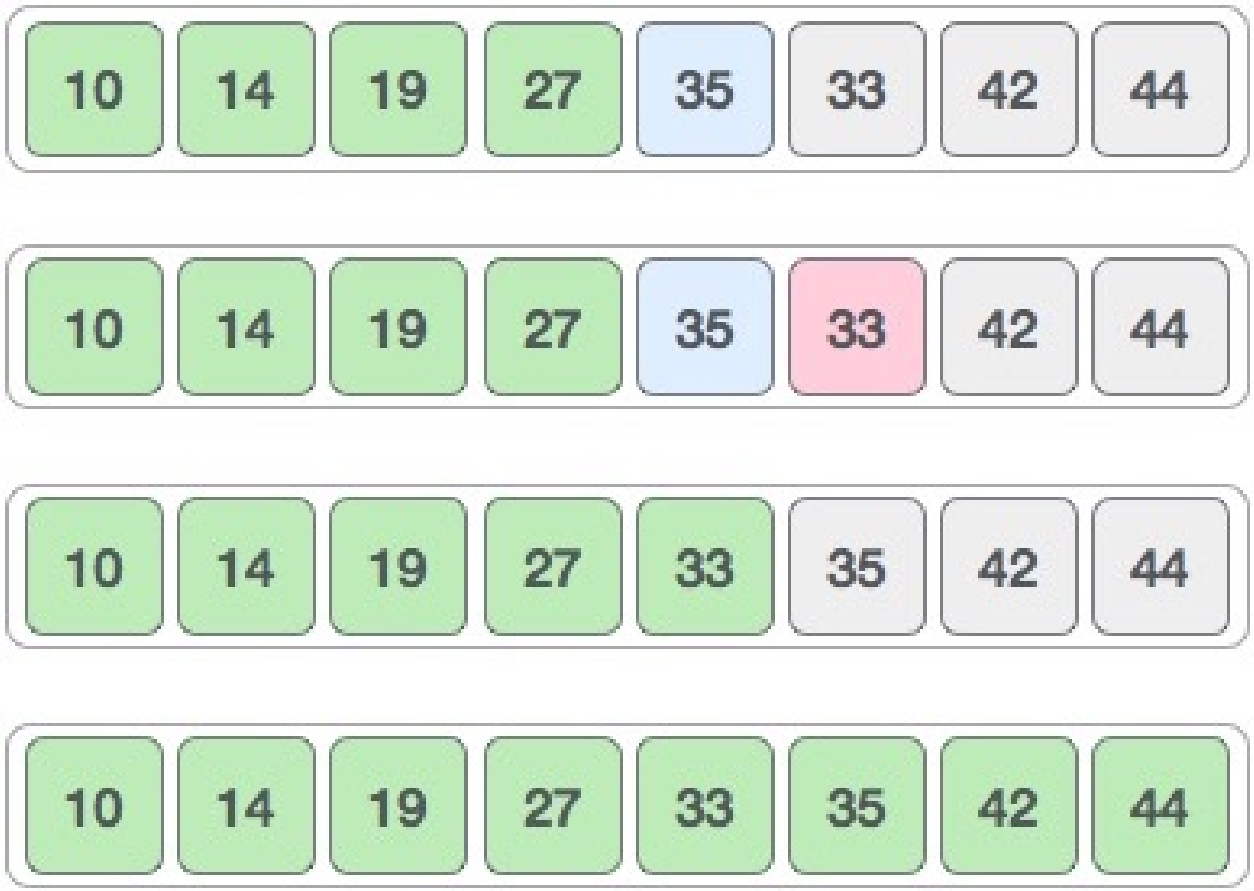
- the two items with the least values
- are positioned at the beginning in a sorted manner

Selection sort #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

```
1:  procedure SELECTION_SORT(sequence)
2:      N ← length of sequence
3:      for i ← 0 to N − 1 do
4:          min ← i
5:          for j ← i + 1 to N − 1 do
6:              if sequence[j] ≤ sequence[min] then
7:                  min ← j
8:              end if
9:          end for
10:         SWAP(sequence[i],sequence[min])
11:     end for
12: end procedure
```

Selection sort: Python implementation

```
1  import random
2
3  sequence = list(range(0,10))
4  random.shuffle(sequence)# shuffles items
5  N = len(sequence)
6  for i in range(0,N,1):  # why not N-1?
7      min = i
8      for j in range(i+1,N,1):
9          if sequence[j] <= sequence[min]:
10             min = j
11     sequence[i],sequence[min] = sequence[min],sequence[i]
12 print(sequence)          # prints ???
```

Insertion sort

Insertion sort does what you might expect

- inserts each item of the list into its proper position
- 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 #2

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

Start by comparing the first two items

Insertion sort #3

We find that both 14 and 33 are already in ascending order.

- for now, 14 is in sorted sub-list

Insertion sort then moves ahead and compares 33 with 27

Insertion sort #4

33 is not in the correct position

Swap 33 with 27

- also check that all the elements of sorted sub-list
- we see that the sorted sub-list has only one element 14
- 27 is greater than 14
- therefore, the sorted sub-list remains sorted after swapping

Insertion sort #5

Now that we have 14 and 27 in the sorted sub-list

- compare 33 with 10

Values are not in a sorted order

So we swap them

Insertion sort #6

However, swapping makes 27 and 10 unsorted

We swap them too

We find 14 and 10 in an unsorted order

Insertion sort #7

We swap them again

- by the end of third iteration, we have a sorted sub-list of 4 items

This process goes on until all the unsorted values are covered in a sorted sub-list

Insertion sort algorithm

Insertion sort (*sequence*)

Step 1 - If it is the first element, item is already sorted

Step 2 - select next item

Step 3 - compare against all other items in the sorted sub-list

Step 4 - shift all the elements in the sorted sub-list that are greater than the value to be sorted

Step 5 - Insert the value in the sorted sub-list

Step 6 - repeat until list is sorted

Insertion sort: pseudocode

Algorithm 2 Insertion sort

```
1:  procedure INSERTION_SORT(sequence)
2:      for i ← 1 to N − 1 do
3:          key ← sequence[i]
4:          // inset key into the sorted sub-list
5:          j ← i − 1
6:          while j >= 0 and sequence[j] > key do
7:              sequence[j + 1] ← sequence[j]
8:              j ← j − 1
9:          end while
10:         sequence[j + 1] ← key
11:     end for
12: end procedure
```

Insertion sort: Python implementation

```
1  import random
2
3  sequence = list(range(0,10))
4  random.shuffle(sequence)
5  N = len(sequence)
6  for i in range(1,N,1):
7      j = i-1
8      key = sequence[i]
9      while(j >= 0 and sequence[j] > key):
10         sequence[j+1] = sequence[j]
11         j -= 1
12     sequence[j+1] = key
13 print(sequence)          # prints ???
```

Summary

Why learn both selection and insertion sort?

- insertion sort is expected to be faster
- selection sort makes more comparisons than movements
  - insertion sort is the opposite
- if less movement is needed
  - e.g., list is almost sorted
  - then selection sort is the better choice

Question: based on the algorithms you have already learned, how could you further improve insertion sort?