Sorting

BBM 101 - Introduction to Programming I

Hacettepe University
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Fuat Akal, Aykut Erdem, Erkut Erdem

Slides based on material prepared by Ruth Anderson, Michael Ernst and Bill Howe in the course CSE 140 University of Washington

Sorting

```
hamlet = "to be or not to be that is the
question whether tis nobler in the mind to
suffer".split()

print("hamlet:", hamlet)

print("sorted(hamlet):", sorted(hamlet))
print("hamlet:", hamlet)

print("hamlet.sort():", hamlet.sort())
print("hamlet:", hamlet)
```

- Lists are mutable – they can be changed
  - including by functions

Sorting

```
hamlet: ['to', 'be', 'or', 'not', 'to', 'be', 'that',
'is', 'the', 'question', 'whether', 'tis', 'nobler',
'in', 'the', 'mind', 'to', 'suffer']

sorted(hamlet): ['be', 'be', 'in', 'is', 'mind',
'nobler', 'not', 'or', 'question', 'suffer', 'that',
'the', 'the', 'tis', 'to', 'to', 'to', 'whether']

hamlet: ['to', 'be', 'or', 'not', 'to', 'be', 'that',
'is', 'the', 'question', 'whether', 'tis', 'nobler',
'in', 'the', 'mind', 'to', 'suffer']

hamlet.sort(): None

hamlet: ['be', 'be', 'in', 'is', 'mind', 'nobler',
'not', 'or', 'question', 'suffer', 'that', 'the',
'the', 'tis', 'to', 'to', 'to', 'whether']
```

Customizing the Sort Order

Goal: sort a list of names *by last name*

```
names = ["Isaac Newton", "Albert Einstein", "Niels
Bohr", "Marie Curie", "Charles Darwin", "Louis
Pasteur", "Galileo Galilei", "Margaret Mead"]
```

```
print("names:", names)
```

```
sorted(names): ['Albert Einstein', 'Charles
Darwin', 'Galileo Galilei', 'Isaac Newton',
'Louis Pasteur', 'Margaret Mead', 'Marie
Curie', 'Niels Bohr']
```

This does NOT work:

```
print("sorted(names):", sorted(names))
```

When sorting, how should we compare these names?

```
"Niels Bohr"
"Charles Darwin"
```

Sort Key

A sort key is a different value that you use to sort a list, instead of the actual values in the list

```
def last_name(str):
    return str.split(" ")[1]

print('last_name("Isaac Newton"):',
last_name("Isaac Newton"))
```

Two ways to use a sort key:

1. Create a new list containing the sort key, and then sort it
2. Pass a key function to the sorted function

1. Use a Sort Key to Create a New List

Create a different list that contains the sort key, sort it, then extract the relevant part:

```
names = ["Isaac Newton", "Fred Newton", "Niels Bohr"]
# keyed_names is a list of [lastname, fullname] lists
keyed_names = []
for name in names:
  keyed_names.append([last_name(name), name])
```

1) Create the new list.

Take a look at the list you created, it can now be sorted:

```
print("keyed_names:", keyed_names)
print("sorted(keyed_names):", sorted(keyed_names))
print("sorted(keyed_names, reverse = True):")
print(sorted(keyed_names, reverse
```

sorted_names: ['Isaac Newton', 'Fred Newton', 'Niels Bohr']

(This works because Python compares two elements that are lists *elementwise*.)

```
sorted_keyed_names = sorted(keyed_names, reverse = True)
sorted_names = []
for keyed_name in sorted_keyed_names:
  sorted_names.append(keyed_name[1])
print("sorted_names:", sorted_names)
```

2) Sort the list new list.

3) Extract the relevant part.

1. Use a Sort Key to Create a New List

Create a different list that contains the sort key, sort it, then extract the relevant part:

```
names = ["Isaac Newton", "Fre
# keyed_names is a list of [l
keyed_names = []
for name in names:
  keyed_names.append([last_na
```

keyed_names: [['Newton', 'Isaac Newton'], ['Newton', 'Fred Newton'], ['Bohr', 'Niels Bohr']]
sorted(keyed_names): [['Bohr', 'Niels Bohr'], ['Newton', 'Fred Newton'], ['Newton', 'Isaac Newton']]
sorted(keyed_names, reverse = True): [['Newton', 'Isaac Newton'], ['Newton', 'Fred Newton'], ['Bohr', 'Niels Bohr']]

Take a look at the list you created, it can now be sorted:

```
print("keyed_names:", keyed_names)
print("sorted(keyed_names):", sorted(keyed_names))
print("sorted(keyed_names, reverse = True):")
print(sorted(keyed_names, reverse
```

sorted_names: ['Isaac Newton', 'Fred Newton', 'Niels Bohr']

(This works because Python compares two elements that are lists *elementwise*.)

```
sorted_keyed_names = sorted(keyed_names, reverse = True)
sorted_names = []
for keyed_name in sorted_keyed_names:
  sorted_names.append(keyed_name[1])
print("sorted_names:", sorted_names)
```

2) Sort the list new list.

3) Extract the relevant part.

2. Use a Sort Key as the Key Argument

Supply the **key** argument to the **sorted** function or the **sort** function

```
def last_name(str):
    return str.split(" ")[1]
names = ["Isaac Newton", "Fred Newton", "Niels Bohr"]
print("sorted(names, key = last_name):")
print(sorted(names, key = last_name))

print("sorted(names, key = last_name, reverse = True):")
print(sorted(names, key = last_name, reverse = True))

print(sorted(names, key = len))

def last_name_len(name):
    return len(last_name(name))

print(sorted(names, key = last_name_len))
```

2. Use a Sort Key as the Key Argument

Supply the **key** argument to the **sorted** function or the **sort** function

```
def last_name(str):
    return str.split(" ")[1]
names = ["Isaac Newton", "Fred Newton", "Niels Bohr"]
print("sorted(names, key = last_name):")
print(sorted(names, key = la

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def last_name_len(name):
    return len(last_name(name))

print(sorted(names, key = last_name_len))
```

```
sorted(names, key = last_name): ['Niels Bohr', 'Isaac Newton', 'Fred Newton']
sorted(names, key = last_name, reverse = True): ['Isaac Newton', 'Fred Newton', 'Niels Bohr']

['Niels Bohr', 'Fred Newton', 'Isaac Newton']
['Niels Bohr', 'Isaac Newton', 'Fred Newton']
```

itemgetter is a Function that Returns a Function

```
import operator                          All: ('m','i','k','e')

print(operator.itemgetter(2, 7, 9, 10)("dumbstricken"))
operator.itemgetter(2, 5, 7, 9)("homesickness")
operator.itemgetter(2, 7, 9, 10)("pumpernickel")
operator.itemgetter(2, 3, 6, 7)("seminaked")
operator.itemgetter(1, 2, 4, 5)("smirker")

operator.itemgetter(9, 7, 6, 1)("beatnikism")
operator.itemgetter(14, 13, 5, 1)("Gedankenexperiment")
operator.itemgetter(12, 10, 9, 5)("mountebankism")
```

Using itemgetter

```
from operator import itemgetter

student_score = ('Robert', 8)
itemgetter(0)(student_score)
itemgetter(1)(student_score)

student_scores = [('Robert', 8), ('Alice', 9),
('Tina', 7)]
```

↝ "Robert"

↝ 8

- Sort the list by name:

```
sorted(student_scores, key=itemgetter(0) )
```

- Sort the list by score

```
sorted(student_scores, key=itemgetter(1) )
```

Two Ways to Import `itemgetter`

```
from operator import itemgetter
student_score = ('Robert', 8)
itemgetter(0)(student_score)
itemgetter(1)(student_score)
```

↝ "Robert"

↝ 8

Or

```
import operator
student_score = ('Robert', 8)
operator.itemgetter(0)(student_score)
operator.itemgetter(1)(student_score)
```

↝ "Robert"

↝ 8

Sorting Based on Two Criteria

Two approaches:

Approach #1: Use an itemgetter with two arguments

Approach #2: Sort twice (most important sort ***last***)

```
student_scores = [('Robert', 8), ('Alice', 9),
                  ('Tina', 10), ('James', 8)]
```

Goal: sort based on score;
if there is a tie within score, sort by name

Approach #1:

```
sorted(student_scores, key=itemgetter(1,0))
```

Approach #2:

```
sorted_by_name = sorted(student_scores, key=itemgetter(0))
sorted_by_score = sorted(sorted_by_name, key=itemgetter(1))
```

Sort on Most Important Criteria LAST

- Sorted by score (ascending), when there is a tie on score, sort using name

```
from operator import itemgetter
student_scores = [('Robert', 8), ('Alice', 9), ('Tina', 10),
('James', 8)]

sorted_by_name = sorted(student_scores, key=itemgetter(0))
>>> sorted_by_name
[('Alice', 9), ('James', 8), ('Robert', 8), ('Tina', 10)]

sorted_by_score = sorted(sorted_by_name, key=itemgetter(1))
>>> sorted_by_score
[('James', 8), ('Robert', 8), ('Alice', 9), ('Tina', 10)]
```

More Sorting Based on Two Criteria

If you want to sort different criteria in different directions, you must use multiple calls to **`sort`** or **`sorted`**

```
student_scores = [('Robert', 8), ('Alice', 9), ('Tina', 10),
('James', 8)]
```

Goal: sort score from highest to lowest; if there is a tie within score, sort by name alphabetically (= lowest to highest)

```
sorted_by_name = sorted(student_scores, key=itemgetter(0) )
sorted_by_hi_score = sorted(sorted_by_name,
                            key=itemgetter(1), reverse=True)
```

Sorting: strings vs. numbers

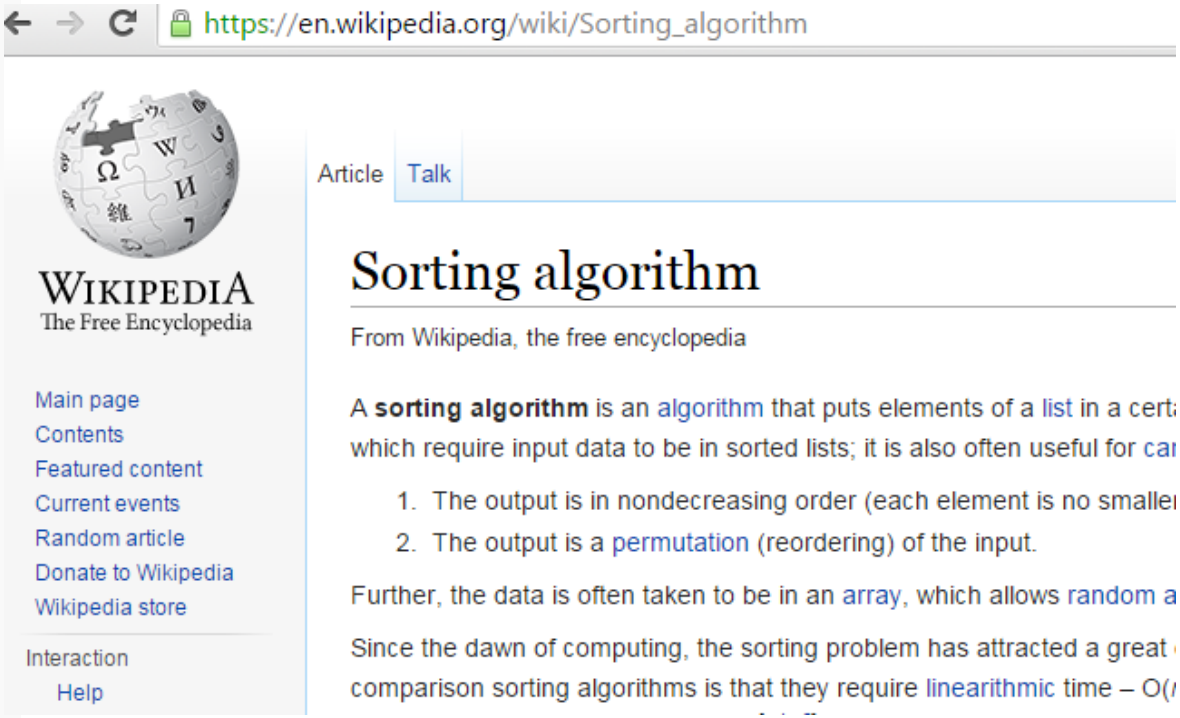
- Sorting the powers of 5:

```
>>> sorted([125, 5, 3125, 625, 25])
[5, 25, 125, 625, 3125]
>>> sorted(["125", "5", "3125", "625", "25"])
['125', '25', '3125', '5', '625']
```

Sorting

from *BBC Documentary: The Secret Rules of Modern Living Algorithms*

Different sorting algorithms



Bubble Sort

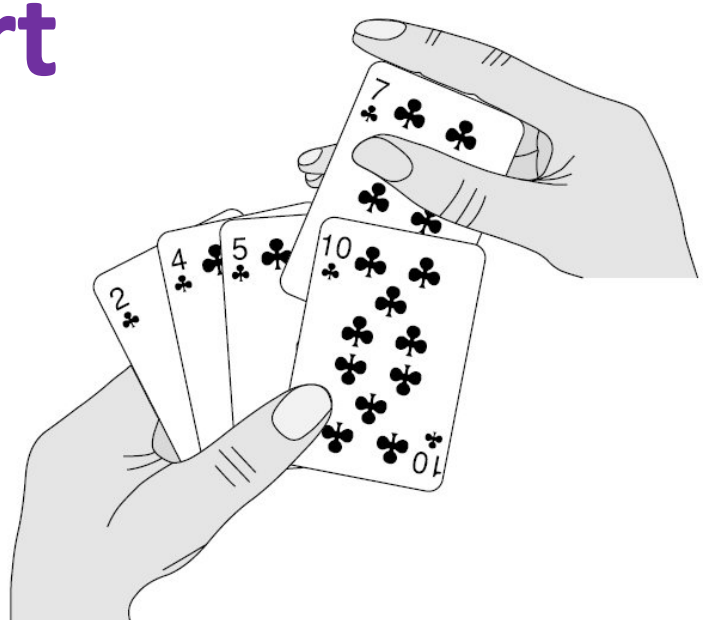
- It repeatedly steps through the list to be sorted,
- compares each pair of adjacent items and swaps them if they are in the wrong order.
- The pass through the list is repeated until no swaps are needed, which indicates that the list is sorted.
- The algorithm, which is a comparison sort, is named for the way smaller elements "bubble" to the top of the list.

Bubble Sort

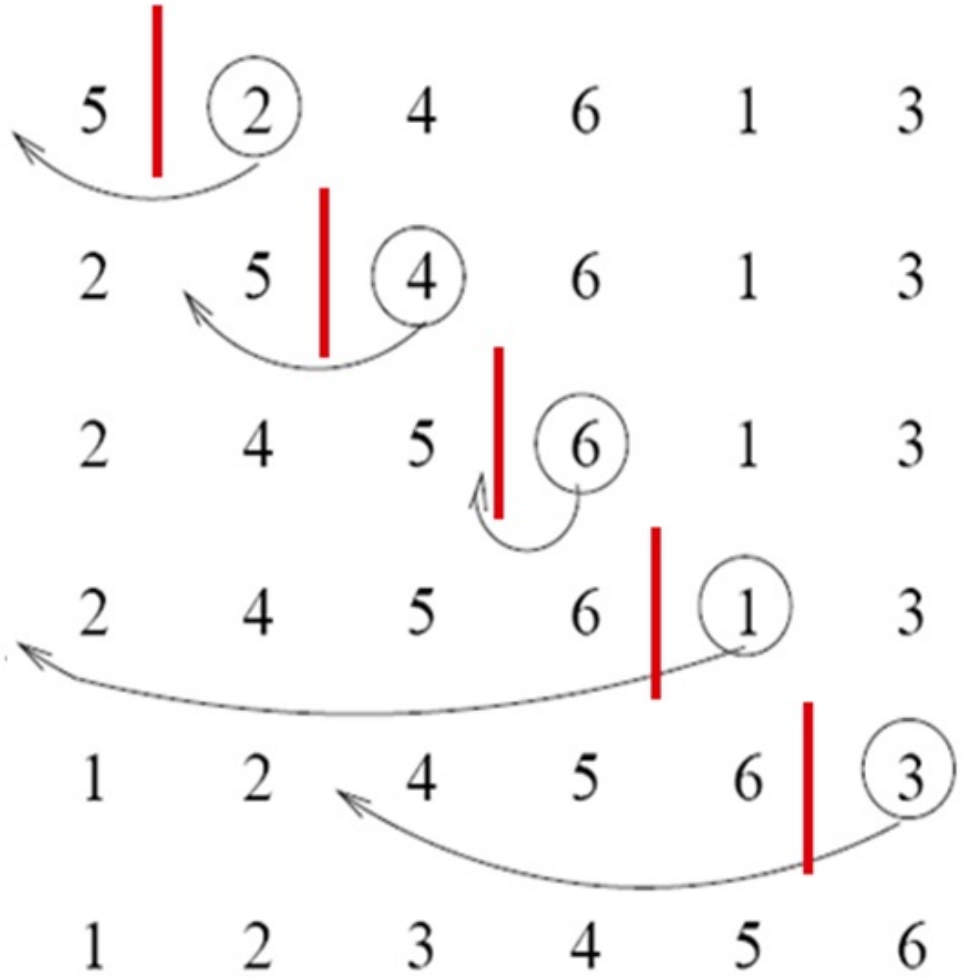
```
def bubbleSort(alist):
    for passnum in range(len(alist)-1,0,-1):
        for i in range(passnum):
            if alist[i]>alist[i+1]:
                temp = alist[i]
                alist[i] = alist[i+1]
                alist[i+1] = temp

alist = [54,26,93,17,77,31,44,55,20]
bubbleSort(alist)
print(alist)
```

Insertion sort



- Idea:



- maintain a sorted sublist in the lower positions of the list.
- Each new item is then "inserted" back into the previous sublist such that the sorted sublist is one item larger.

Done !

Insertion sort

```
def insertionSort(alist):
    for index in range(1,len(alist)):
        currentvalue = alist[index]
        position = index

        while position>0 and alist[position-1]>currentvalue:
              alist[position]=alist[position-1]
              position = position-1

        alist[position]=currentvalue

alist = [54,26,93,17,77,31,44,55,20]
insertionSort(alist)
print(alist)
```

Insertion sort

https://www.youtube.com/watch?v=ROalU379l3U

www.sorting-algorithms.com

Sorting Algorithm Animations

Problem Size: 20 · 30 · 40 · 50 Magnification: 1x · 2x · 3x

Algorithm: Insertion · Selection · Bubble · Shell · Merge · Heap · Quick · Quick3

Initial Condition: Random · Nearly Sorted · Reversed · Few Unique

	Insertion	Selection	Bubble	Shell	Merge	Heap	Quick	Quick3
Random								
Nearly Sorted								
Reversed								
Few Unique