polinaovchinnikova/BIS634_Assignment-2

Assignment 2

##Exercise 1.

```
with open('weights.txt') as f:
    weights = []
    for line in f:
        weights.append(float(line))
print("average =", sum(weights) / len(weights))
```

1. What went wrong? - MemmoryError When you call.append() on an existing list, the method adds a new item to the list's end, or right side. As a result, the array expands and expands. As a result, because Python requires additional memory to describe the data structure, float takes 24 bytes, and 500 million float takes 1.2 * 10^10 bytes in total. So, RAM is 8GB, which is 8.6 * 10^9 bytes (1GB = 10243 bytes), and total memory usage (1.2 * 10^10 bytes) is greater than RAM (8.6 * 10^9 bytes), resulting in a MemmoryError.
2. Suggest a way of sorting all the data in the memory One of the ways that the data could be sorted is by using Numpy to store all the data in memory which may save some extra memory. Also, instead of using a list to store the data, we could use an array that is built into Numpty `numpy.array`, that way the data is stored in a contiguous block of memory, which allows for a data buffer, a contiguous (and fixed) block of memory containing fixed-sized data items. Futhermore, a hash function and hash table could be used. Thus, the duplicate values are

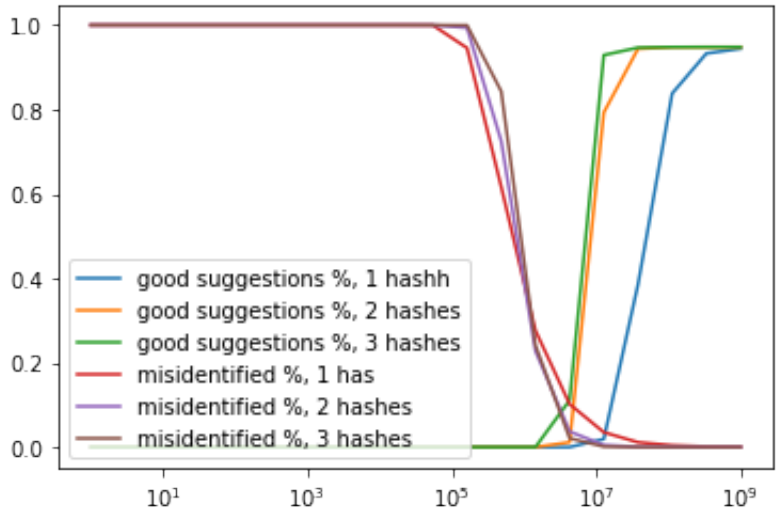
not going to take up additional space and would be stored in a standardized format.

3. Suggestion for calculating the average that would not require storing all the data in memory Instead of a list, variable sum could be used to store all of the data, and variable count could be used to count the number of data, where for each loop, each line of data is added to a variable sum, and the count is increased by one. Similarly, Welford's method, which is an online algorithm that computes both the mean and variance by looking at each data point only once and using O(1) memory, could be used.

##Exercise 2.

```
spelling_correction('floeer', data)
['floter', 'flower']
```

```
addwords("1")
spellcheck("bloeer", "1")
False
```



> Approximately how many bits is necessary for this approach to give good

> suggestions (as defined above) 90% of the time when using each of 1, 2, or 3 hash functions as above?

Approximately 7 bites are needed to reach the 90% using 3 hashes, as the size that is used is 1e7.

##Exercise 3. For each time, the `add` function is used to insert a single value into the tree: Add value to the root if root is None, then ff the root value is less than the value to be added, the value is added to the correct branch of the tree. Otherwise, value is added to the tree's left side.

Then a function was created to print the list in a form of a list that is based on the `list.append(tree.value)` and dependeing on if statement of the `tree.left` and `tree.right`

```
print(printTree(my_tree, list=[]))
[55, 37, 14, 17, 49, 62, 71]
```

Then using the `__contains__` method that allow you to use the in operator; e.g. after this change shows that 55 in my_tree should be True in the above example, whereas 42 in my_tree would be False.

```
my_tree.__contains__(55)
True
my_tree.__contains__(42)
False
```

Using various sizes n of trees (populated with random data) and sufficiently many calls to in (each individual call should be very fast, so you may have to run many repeated tests), demonstrate that in is executing in O(log n) times;

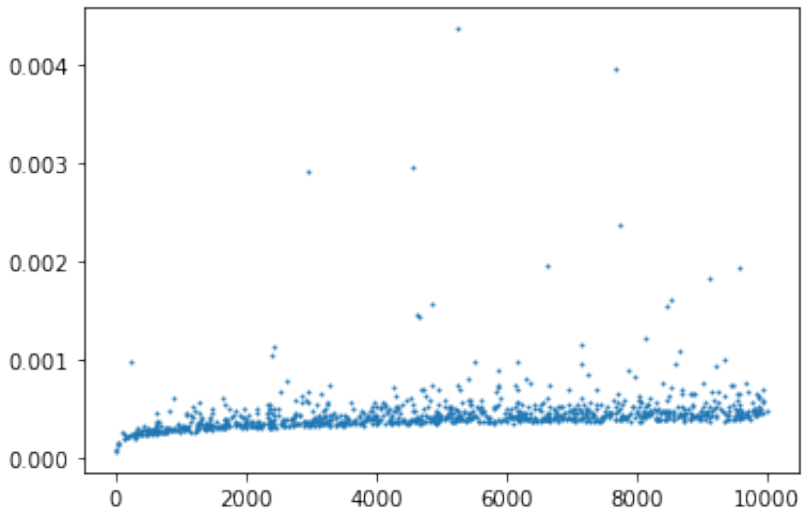
on a log-log plot, for sufficiently large n, the graph of time required for checking if a number is in the tree as a function of n should be almost horizontal

So, looking at the plot the in is executing in O(log n) times is shown by

```
test_time = []
n_sample = 1000
repeat = 100
```

and runing thorught a for loop that creayes the range depending on the repeat variable. Futhermore, by using the `random.randint()` which is a unbuild function of the random module. That allows us to generate random numbers.

> O(log n)

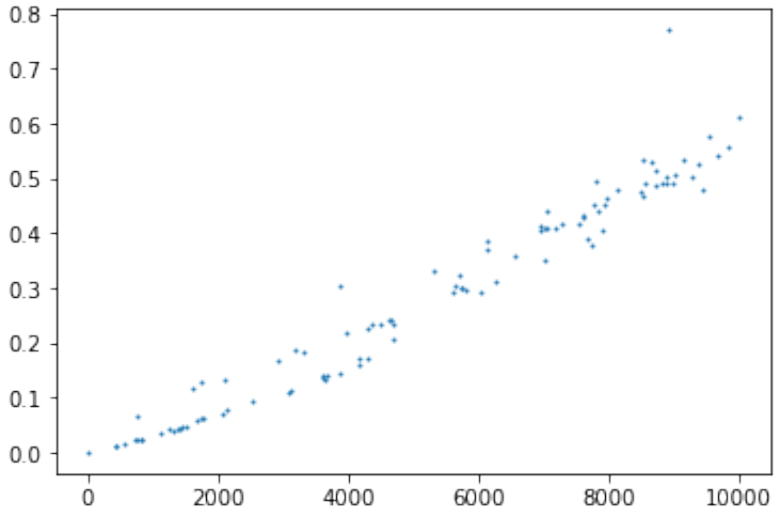


This speed is not free. Provide supporting evidence that the time to setup the tree is O(n log n) by timing it for various sized ns and showing that the runtime lies between a curve that is O(n) and one that is O(n**2)

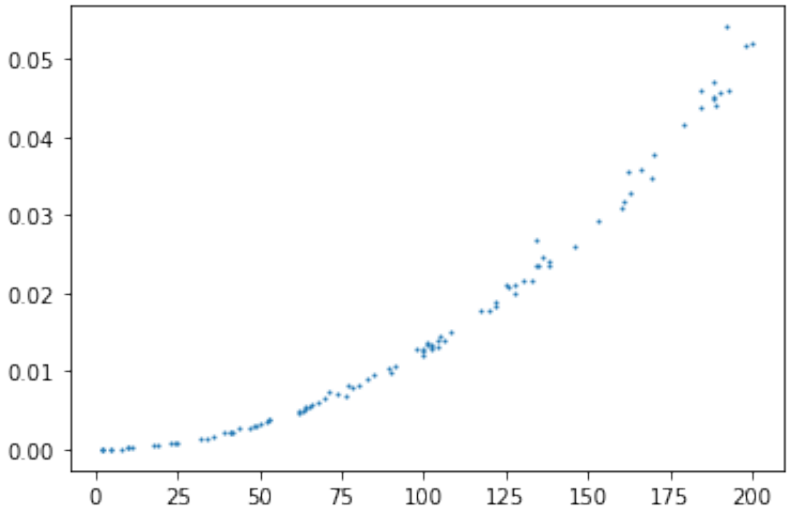
Then so to see the O(n) and one that is O(n**2) we could draw two graphs

that would show the runtime, which means that the time should lie between two given curves. So, then if the sequence is random (random enought), the tree should.

> O(n)

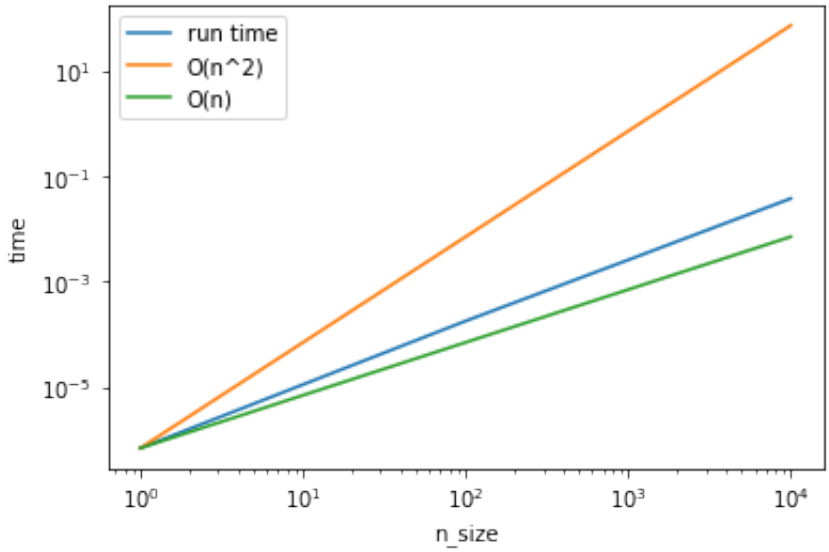


> O(n**2)



We can see that the time required to build up the tree for large tree sizes is between that of an algorithm with complexity O(n) and that of an algorithm with complexity O(n2), indicating that the complexity of the tree setup is O(nlogn)

> Tree Comparison



##Exercise 4. By looking at the algorithms and the test that are provided below. They both take lists of numbers and return a list of numbers. In particular, for the same input, they return the same output; that is, they solve the same data processing problem but they do it in very different ways. So the hypothesis for each of the algh are:

Algorithm 1: bubble sort, runs through the list entirely before making changes, which would only happen if the list would be sorted. Then, the algorithm compares each item in the list to one another item and if one item is smaller than another, the algorithm would change the order of the list.

Algorithm 2: restrictive algorithm, mergesort, split the list into units of one element, where it compares each element with the list to sort and merge.

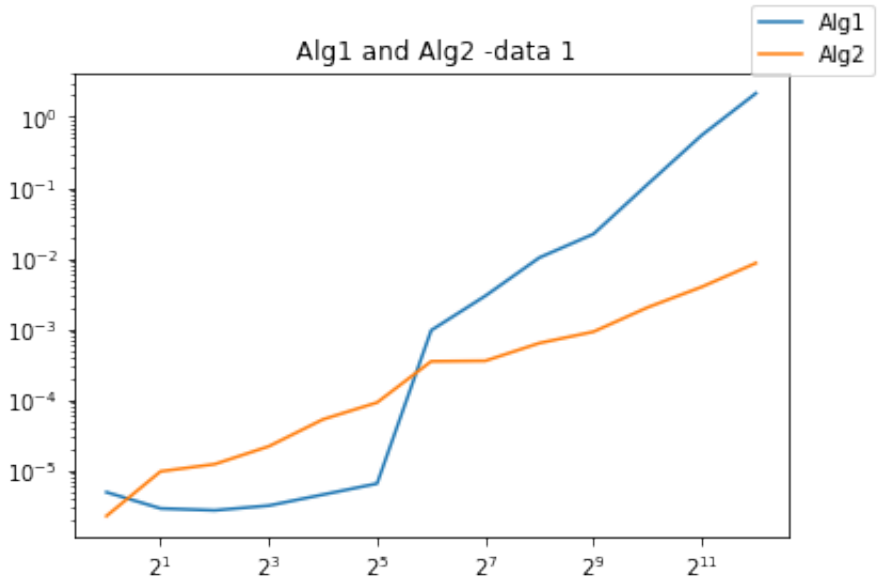
```
test_list = [55, 62, 37, 49, 71, 14, 17]
print(alg1(test_list))
print(alg2(test_list))
[14, 17, 37, 49, 55, 62, 71]
[14, 17, 37, 49, 55, 62, 71]
```

Tests:

1. Data 1

```
data1_data = pd.DataFrame(measure_dat1)
data1_data
```

> Data 1

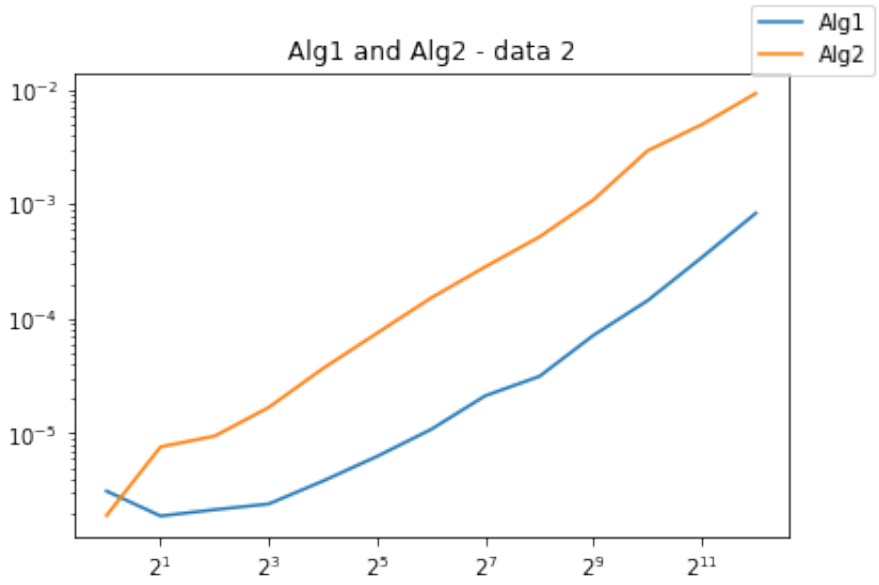


> The graph shows more of a flat line that indicates are stronger correlation/relationship between the two alg.

2. Data 2

```
data2_data = pd.DataFrame(measure_dat2)
data2_data
```

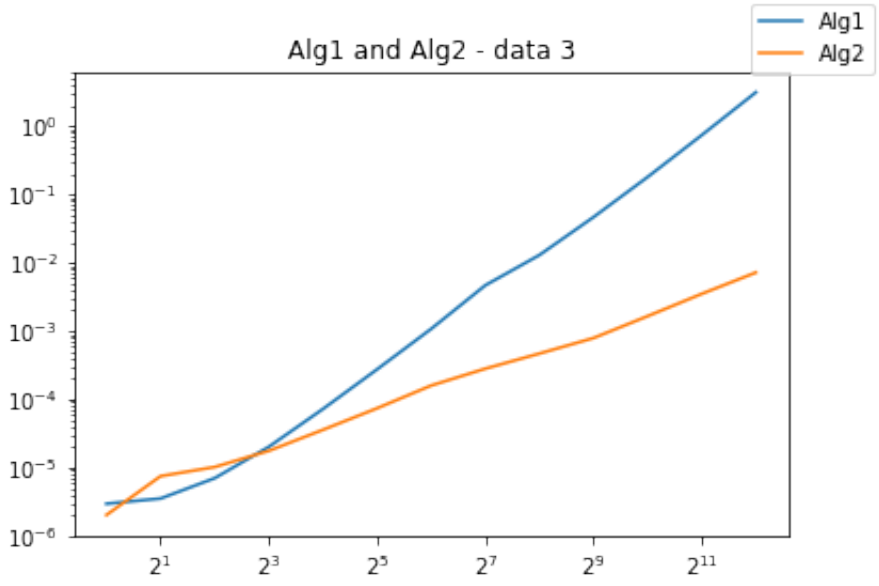
> Data 2



3. Data 3

```
data3_data = pd.DataFrame(measure_dat3)
data3_data
```

Data 3



By looking at the test data results it could be noted that for the test with data 1 and data 3, alg1 had a faster performance time in comparison to the alg2.

So I would recommend using the scaling performance in data 3, as visible on the graph lines the process runs in more of a straight line and it reaches the higher tree size faster.

Multiprocessing

Using `multiprocessing.Pool()` to parallelize the two independent tasks, as the built-in package that allows the system to run multiple processes simultaneously. It will enable the breaking of applications into smaller threads that can run independently. Furthermore, by parallelizing alg2 it allows us to perform parallel tasks that are split into subtasks that are assigned to multiple working directories and then completed simultaneously. So, the independent tasks whose results can be combined are based on the executable units which are left and right piles (that are combined later).

By looking at the graph it could be noted that the paralyzed model is slower at a small scale but gets faster as the scales growth. In other words, by parallelizing alg2, the algorithms have a higher initial overhead comparing to other algorithms.

Assignment 2

October 13, 2022

Exercise 2:

[ ]:
```
import bitarray
from hashlib import sha3_256, sha256, blake2b
import json
import bitarray
from tqdm import tqdm
import string
import matplotlib.pyplot as plt
```

[ ]:
```
size = int(1e7)
import bitarray
data = bitarray.bitarray(size)
bloomfilter = BloomFilter(size)
```

[ ]:
```
with open('/Users/polina/Desktop/words.txt') as f:
    for line in f:
        word = line.strip()
```

[ ]:
```
class BloomFilter(object):

    def __init__(self, size):


        self.bit_array = bitarray.bitarray(size)

        self.hashsize = size
        self.bit_array.setall(0)

    def add(self, words):


        hash1 = int(self.my_hash(words, self.hashsize))
        self.bit_array[hash1] = True


    def add_2(self, words):
```

```
        hash1 = int(self.my_hash(words, self.hashsize))
        hash2 = int(self.my_hash2(words, self.hashsize))
        self.bit_array[hash1] = True
        self.bit_array[hash2] = True


    def add_3(self, words):

        hash1 = int(self.my_hash(words, self.hashsize))
        hash2 = int(self.my_hash2(words, self.hashsize))
        hash3 = int(self.my_hash3(words, self.hashsize))
        self.bit_array[hash1] = True
        self.bit_array[hash2] = True
        self.bit_array[hash3] = True

    def check(self, test_words):
        hash1 = int(self.my_hash(test_words, self.hashsize))
        if self.bit_array[hash1] == False:
            return False
        else:
            return True

    def check_2(self, test_words):
        hash1 = int(self.my_hash(test_words, self.hashsize))
        hash2 = int(self.my_hash2(test_words, self.hashsize))
        if (self.bit_array[hash1] == False) or (self.bit_array[hash2] == False):
            return False
        else:
            return True

    def check_3(self, test_words):
        hash1 = int(self.my_hash(test_words, self.hashsize))
        hash2 = int(self.my_hash2(test_words, self.hashsize))
        hash3 = int(self.my_hash3(test_words, self.hashsize))
        if (self.bit_array[hash1] == False) or (self.bit_array[hash2] == False)␣
↪or (self.bit_array[hash3] == False):
            return False
        else:
            return True

    def my_hash(self, s, size):
        return int(sha256(s.lower().encode()).hexdigest(), 16) % size

    def my_hash2(self, s, size):
        return int(blake2b(s.lower().encode()).hexdigest(), 16) % size

    def my_hash3(self, s, size):
```

```
        return int(sha3_256(s.lower().encode()).hexdigest(), 16) % size

def replace(s, position, character):
    return s[:position] + character + s[position+1:]
```

[ ]:
```
def hashnumber():
    hashcount = input("hash number = ")
    return(hashcount)

# need to use Python 3.10 for match
#import sys;print(sys.version)
def add_word(hashcount):
    match hashcount:
        case "1":
            with open('/Users/polina/Desktop/words.txt') as f:
                for line in f:
                    word = line.strip()
                    bloomfilter.add(word)
            break
        case "2":
             with open('/Users/polina/Desktop/words.txt') as f:
                for line in f:
                    word = line.strip()
                    bloomfilter.add_2(word)
            break
        case "3":
            with open('/Users/polina/Desktop/words.txt') as f:
                for line in f:
                    word = line.strip()
                    bloomfilter.add_3(word)
```

[ ]:
```
import string
alphabet_list = string.ascii_lowercase
alphabet_list = list(alphabet_list)
print(alphabet_list)
```

[ ]:
```
def all_suggestions(test_words):
    suggest = []
    alphabet = alphabet_list
    result = spell_check(test_words, hashcount)
    if  result == False:
        for i in range(len(test_words)):
            for a in alphabet:
                suggest_word = replace(test_words, i, a)
                suggest.append(suggest_word)
    return(suggest)
```

```
# need to use Python 3.10 for match
def good_suggestion(all_suggestions, hashcount):
    correct_suggestion = []
    match hashcount:
        case "1":
            for n in all_suggestions:
                suggestresult = bloomfilter.check(n)
                if suggestresult == True:
                    correct_suggestion.append(n)
            break
        case "2":
            for n in all_suggestions:
                suggestresult = bloomfilter.check_2(n)
                if suggestresult == True:
                    correct_suggestion.append(n)
            break
        case "3":
            for n in all_suggestions:
                suggestresult = bloomfilter.check_3(n)
                if suggestresult == True:
                    correct_suggestion.append(n)
    return(correct_suggestion)

def spell_check(test_words, hashcount):
    match hashcount:
        case "1":
            result = bloomfilter.check(test_words)
            return result
        break
        case "2":
            result = bloomfilter.check_2(test_words)
            return result
        break
        case "3":
            result = bloomfilter.check_3(test_words)
            return result
```

[ ]:
```
hashcount = hashnumber()
```

[ ]:
```
add_word(hashcount)
```

[ ]:
```
test_words = input(" I asked my implementation to spell-check when using 1e7␣
 ↪bits: ")
```

[ ]:
```
spell_check(test_words, hashcount)
if spell_check(test_words, hashcount) != True:
```

```
    suggestionlist = all_suggestions(test_words)
    good_suggestionlist = good_suggestion(suggestionlist, hashcount)
    print(good_suggestionlist)
```

[ ]:
```
add_word("1")
spell_check("bloeer", "1")
```

[ ]:
```
with open('/Users/polina/Desktop/BIS_634/Assignmnet 2/typos.json', 'r') as f:
    file = f.read()
    text = json.loads(file)
    print(len(text))
```

[ ]:
```
from tqdm import tqdm
import numpy as np

def good_suggest(text, hashcount):
    correct = 0
    misidentified = 0
    good_suggestion = 0
    for i in range(len(text)):
        if text[i][0] == text[i][1]:
            correct += 1
        elif text[i][0] != text[i][1]:
            if spell_check(text[i][0], hashcount) == True:
                misidentified += 1
            else:
                suggestion = all_suggestions(text[i][0])
                good = good_suggestion(suggestion, hashcount)
                for n in good:
                    if (len(good) <= 3) and (n == text[i][1]):
                        good_suggestion += 1
    return correct, misidentified, good_suggestion
```

[ ]:
```
# hash 1
filter_size = np.logspace(0, 9, num=20, dtype=int)
misidentified1 = []
suggestion_list1 = []
correct1 = []
for n in range(len(filter_size)):
    bloomfilter = BloomFilter(int(filter_size[n]))
    add_word("1")
    answer1 = good_suggest(text, "1")
    misidentified1.append(answer1[1])
    suggestion_list1.append(answer1[2])
    correct1.append(answer1[0])

goodsuggestion1 = []
```

```
misidentified1 =[]

for i in range(len(misidentified1)):
    goodsuggestion = (suggestion_list1[i] / 25000)
    misidentified = (misidentified1[i] / 25000)
    goodsuggestion1.append(goodsuggestion)
    misidentified1.append(misidentified)
```

[ ]:
```
# hash 2
misidentified2 = []
suggestion_list2 = []
correct2 = []
for n in range(len(filter_size)):
    bloomfilter = BloomFilter(int(filter_size[n]))
    add_word("2")
    answer2 = good_suggest(text, "2")
    misidentified2.append(answer2[1])
    suggestion_list2.append(answer2[2])
    correct2.append(answer2[0])

goodsuggestion2 = []
misidentified2 =[]

for i in range(len(misidentified2)):
    goodsuggestion = (suggestion_list2[i] / 25000)
    misidentified = (misidentified2[i] / 25000)
    goodsuggestion2.append(goodsuggestion)
    misidentified2.append(misidentified)
```

[ ]:
```
# hash 3
misidentified3 = []
suggestion_list3 = []
correct3 = []
for n in range(len(filter_size)):
    bloomfilter = BloomFilter(int(filter_size[n]))
    add_word("3")
    answer3 = good_suggest(text, "3")
    misidentified3.append(answer3[1])
    suggestion_list3.append(answer3[2])
    correct3.append(answer3[0])

goodsuggestion3 = []
misidentified3 =[]

for i in range(len(misidentified3)):
    goodsuggestion = (suggestion_list3[i] / 25000)
    misidentified = (misidentified3[i] / 25000)
```

```
    goodsuggestion3.append(goodsuggestion)
    misidentified3.append(misidentified)
```

[ ]:
```
plt.xscale('log')
plt.plot(filter_size, goodsuggestion1, label="good suggestions %, 1 hashh")
plt.plot(filter_size, goodsuggestion2, label="good suggestions %, 2 hashes")
plt.plot(filter_size, goodsuggestion3, label="good suggestions %, 3 hashes")
plt.plot(filter_size, misidentified1, label="misidentified %, 1 has")
plt.plot(filter_size, misidentified2, label="misidentified %, 2 hashes")
plt.plot(filter_size, misidentified3, label="misidentified %, 3 hashes")
plt.legend(loc="lower left")
plt.show()
```

Exercise 3:

[ ]:
```
# import libraries
import pandas as pd
import numpy as np
import random
import time
```

[ ]:
```
class Tree:
    def __init__(self):
        self.value = None
        self.left = None
        self.right = None

    def add(self, item):
        if self.value is None:
            self.value = item
            return

        elif item < self.value:
            if self.left:
                self.left.add(item)
            else:
                self.left = Tree()
                self.left.add(item)
            return

        elif item > self.value:
            if self.right:
                self.right.add(item)
            else:
                self.right = Tree()
                self.right.add(item)
        return
```

```
    def __contains__(self, item):
        if self.value == item:
            return True
        elif self.left and item < self.value:
            return item in self.left
        elif self.right and item > self.value:
            return item in self.right
        else:
            return False
```

[ ]:
```
def printTree(tree, list=[]):
    if not tree: return []
    list.append(tree.value)
    if tree.left: printTree(tree.left, list)
    if tree.right: printTree(tree.right, list)
    return list
```

[ ]:
```
my_tree = Tree()
for item in [55, 62, 37, 49, 71, 14, 17]:
     my_tree.add(item)
print(printTree(my_tree, list=[]))
```

[ ]:
```
my_tree.__contains__(55)
```

[ ]:
```
my_tree.__contains__(42)
```

Using various sizes n of trees (populated with random data) and sufficiently many calls to in (each individual call should be very fast, so you may have to run many repeated tests), demonstrate that in is executing in O(log n) times; on a log-log plot, for sufficiently large n, the graph of time required for checking if a number is in the tree as a function of n should be almost horizontal.

[ ]:
```
import random
import time
import math
import statistics
import matplotlib.pyplot as plt
```

O(log n) times

[ ]:
```
test_time = []
n_sample = 1000
repeat = 100
for _ in range(n_sample):
    n = random.randint(0, 10000)
    my_tree = Tree()
    for _ in range(n):
        my_tree.add(random.random())
    start = time.time()
```

```
    for _ in range(repeat):
        my_tree.__contains__(random.random())
    end = time.time()
    test_time.append((end - start, n))
```

[ ]:
```
plt.scatter([x[1] for x in test_time], [x[0] for x in test_time], s=1)
plt.show()
```

This speed is not free. Provide supporting evidence that the time to setup the tree is O(n log n) by timing it for various sized ns and showing that the runtime lies between a curve that is O(n) and one that is O(n**2)

O(n)

[ ]:
```
test_time_2 = []
n_sample = 100
repeat = 10
for _ in range(n_sample):
    n = random.randint(0, 10000)
    secquence = [random.random() for _ in range(n)]
    start = time.time()
    for _ in range(repeat):
        my_tree = Tree()
        for i in secquence:
            my_tree.add(i)
    end = time.time()
    test_time_2.append((end - start, n))
```

[ ]:
```
plt.scatter([x[1] for x in test_time_2], [x[0] for x in test_time_2], s=1)
plt.show()
```

O(n**2)

[ ]:
```
test_time_3 = []
n_sample = 100
repeat = 10
for _ in range(n_sample):
    n = random.randint(0, 200)
    secquence = [random.random() for _ in range(n)]
    secquence = sorted(secquence)
    start = time.time()
    for _ in range(repeat):
        my_tree = Tree()
        for i in secquence:
            my_tree.add(i)
    end = time.time()
    test_time_3.append((end - start, n))
```

[ ]:
```
plt.scatter([x[1] for x in test_time_3], [x[0] for x in test_time_3], s=1)
plt.show()
```

n**2, and n

[ ]:
```
def time_function(n):
    timing = []
    n = [random.randint(1,n) for _ in range(n)]
    for attempt in [i for i in range(100)]:
        start = time.time()
        my_tree = Tree()
        for item in n:
            my_tree.add(item)
        end = time.time()
        timing.append(end - start)
    return min(timing)
```

[ ]:
```
n_size = [1,100,1000,10000]
true_size = [time_function(n) for n in n_size]
size = true_size [0]
quadratic = [size*n**2 for n in n_size]
linear = [size*n for n in n_size]
plt.plot(n_size,true_size)
plt.plot(n_size,quadratic)
plt.plot(n_size,linear)
plt.xscale('log')
plt.yscale('log')
plt.ylabel('time')
plt.xlabel('n_size')
plt.legend(['run time','O(n^2)','O(n)'],loc = 'upper left')
plt.show()
```

[ ]:
```

```

Exercise 4:

[ ]:
```
import matplotlib.pyplot as plt
import multiprocessing
from time import perf_counter
import numpy as np
import random
```

[ ]:
```
def alg1(data):
    data = list(data)
    changes = True
    while changes:
        changes = False
        for i in range(len(data) - 1):
```

```
            if data[i + 1] < data[i]:
                data[i], data[i + 1] = data[i + 1], data[i]
                changes = True
    return data
```

[ ]:
```
def alg2(data):
  if len(data) <= 1:
    return data
  else:
    split = len(data) // 2
    left = iter(alg2(data[:split]))
    right = iter(alg2(data[split:]))
    result = []
    # note: this takes the top items off the left and right piles
    left_top = next(left)
    right_top = next(right)
    while True:
      if left_top < right_top:
        result.append(left_top)
        try:
          left_top = next(left)
        except StopIteration:
          # nothing remains on the left; add the right + return
          return result + [right_top] + list(right)
      else:
        result.append(right_top)
        try:
          right_top = next(right)
        except StopIteration:
          # nothing remains on the right; add the left + return
          return result + [left_top] + list(left)
```

[ ]:
```
test_list = [55, 62, 37, 49, 71, 14, 17]
```

[ ]:
```
print(alg1(test_list))
print(alg2(test_list))
```

Data 1

[ ]:
```
def data1(n, sigma=10, rho=28, beta=8/3, dt=0.01, x=1, y=1, z=1):
    import numpy
    state = numpy.array([x, y, z], dtype=float)
    result = []
    for _ in range(n):
        x, y, z = state
        state += dt * numpy.array([
            sigma * (y - x),
            x * (rho - z) - y,
```

```
            x * y - beta * z
        ])
        result.append(float(state[0] + 30))
    return result
```

[ ]:
```
from time import perf_counter

def test_time_data(limit, source):
    measure = dict()
    measure['list_size'] = []
    measure['alg1_time'] = []
    measure['alg2_time'] = []

    for n in range(limit):
        measure['list_size'].append(2**n)

        test_list_0 = source(2**n)


        time_alg1_start = perf_counter()
        alg1(test_list_0)
        time_alg1_stop = perf_counter()
        measure['alg1_time'].append(time_alg1_stop-time_alg1_start)
        time_alg1_start = perf_counter()
        alg2(test_list_0)
        time_alg1_stop = perf_counter()
        measure['alg2_time'].append(time_alg1_stop-time_alg1_start)

    return measure
```

[ ]:
```
 measure_dat1 = test_time_data(13, data1)
```

[ ]:
```
data1_data = pd.DataFrame(measure_dat1)
data1_data
```

[ ]:
```
#create log-log plot
fig, ax = plt.subplots()
plt.plot(data1_data.list_size, data1_data.alg1_time, label='Alg1')
plt.plot(data1_data.list_size, data1_data.alg2_time, label='Alg2')
plt.xscale('log', base=2)
plt.yscale('log', base=10)
ax.set_title(' Alg1 and Alg2 -data 1')
fig.legend()
```

Data 2

[ ]:
```
def data2(n):
    return list(range(n))
```

[ ]:
```
measure_dat2 = test_time_data(13, data2)
```

[ ]:
```
data2_data = pd.DataFrame(measure_dat2)
data2_data
```

[ ]:
```
fig, ax = plt.subplots()
plt.plot(data2_data.list_size, data2_data.alg1_time, label='Alg1')
plt.plot(data2_data.list_size, data2_data.alg2_time, label='Alg2')
plt.xscale('log', base=2)
plt.yscale('log', base=10)
ax.set_title('Alg1 and Alg2 - data 2')
fig.legend()
```

Data 3

[ ]:
```
def data3(n):
    return list(range(n, 0, -1))
```

[ ]:
```
measure_dat3 = test_time_data(13, data3)
```

[ ]:
```
data3_data = pd.DataFrame(measure_dat3)
data3_data
```

[ ]:
```
fig, ax = plt.subplots()
plt.plot(data3_data.list_size, data3_data.alg1_time, label='Alg1')
plt.plot(data3_data.list_size, data3_data.alg2_time, label='Alg2')
plt.xscale('log', base=2)
plt.yscale('log', base=10)
ax.set_title('Alg1 and Alg2 - data 3')
fig.legend()
```

Multiprocessing

[ ]:
```
def parallelize_alg2(data):
    if len(data) <= 1:
        return data
    else:
        split = len(data) // 2
        with multiprocessing.Pool() as p:
            [left, right] = p.map(
                alg2, [data[:split], data[split:]])
        left = iter(left)
        right = iter(right)
        # combining the left and right data
        result = []
        left_top = next(left)
        right_top = next(right)
    while True:
```

```
        if left_top < right_top:
            result.append(left_top)
            try:
                left_top = next(left)
            except StopIteration:
            # nothing remains on the left; add the right + return
                return result + [right_top] + list(right)
        else:
            result.append(right_top)
            try:
                right_top = next(right)
            except StopIteration:
        # nothing remains on the right; add the left + return
                return result + [left_top] + list(left)
```

[ ]:
```
from tqdm import tqdm

if __name__ == '__main__':
    data_variant = np.logspace(0, 23, base=2, dtype=int)
    duration = []
    alg2data1time = []

    for n in tqdm(data_variant):
        data_set = data1(n, sigma=10, rho=28, beta=8/3, dt=0.01, x=1, y=1, z=1)
        alg2data1_start = perf_counter()
        alg2(data_set)     ## time taken by the unparallelized algo
        alg2data1_stop= perf_counter()
        alg2data1time.append(alg2data1_stop - alg2data1_start)
        start_time = perf_counter()
        parallelize_alg2(data_set)    #time taken by the parallelized algo
        stop_time = perf_counter()
        duration.append(stop_time - start_time)
        print(duration[-1],  alg2data1time[-1])
    plt.loglog(data_variant, alg2data1time, label = "mergesort alg2")
    plt.loglog(data_variant, duration, label = "prallelized alg2")
    plt.legend()
    plt.show()
```