CMSC201
Computer Science I for Majors

Lecture 23 – Algorithms and Analysis

Prof. Jeremy Dixon

Last Class We Covered

- Tuples
- Dictionaries
  - Creating
  - Accessing
  - Manipulating
- Dictionaries vs Lists

Any Questions from Last Time?

Review: Tuples

- Create five tuples about you
  - (e.g., your major is CMSC, your age is 19)
- Create a tuple with all of the courses you're taking this semester
- Create a tuple with a single element
- Create an empty tuple
- Create a tuple by casting a list

Review: Dictionaries

- Create a dictionary that contains four different (key, value) pairs, similar to “a is for apple”
  – Add one additional (key, value) pair
  – Update one of your (key, value) pairs
  – Remove one of your (key, value) pairs

- Why must dictionary keys be unique?
- Do values need to be unique?

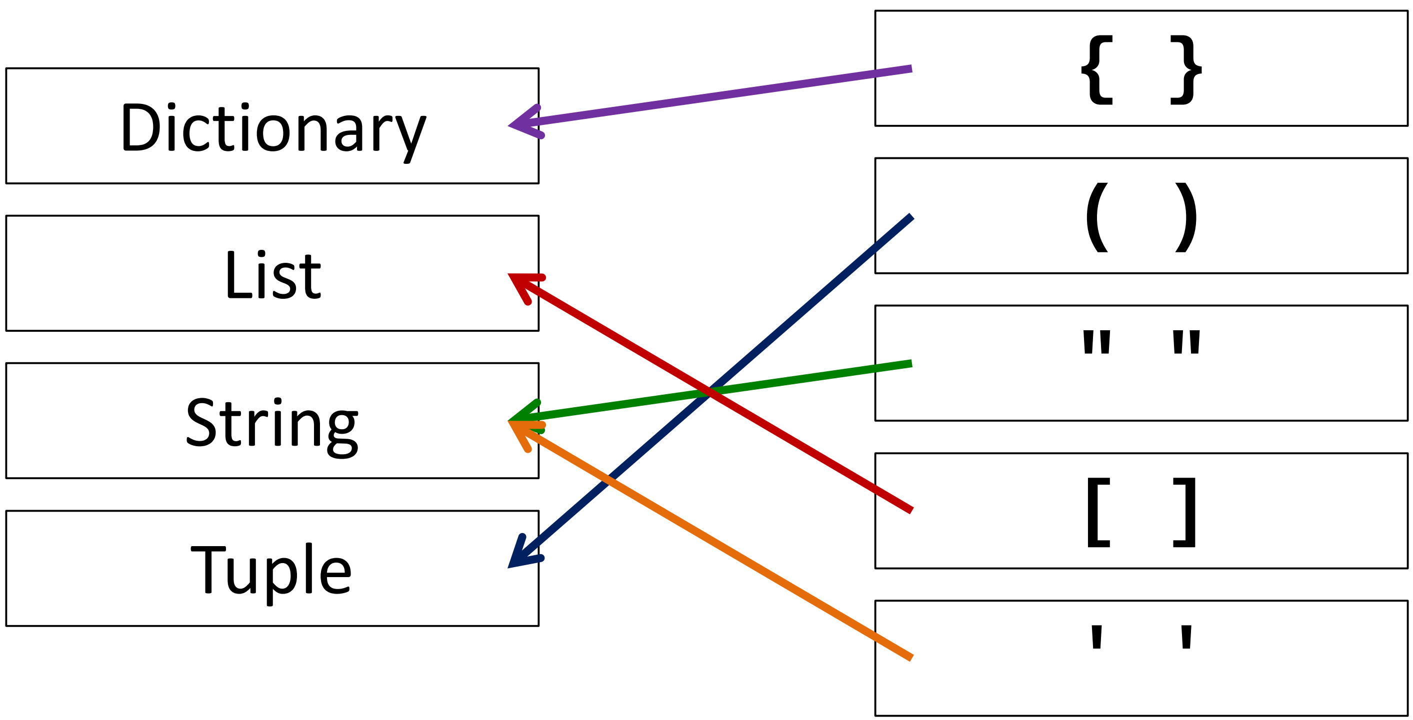
Review: Matching Symbols

- Match the following data types to the symbols needed to create them (may be more than one)

Dictionary	{ }
List	( )
String	" "
Tuple	[ ]
	' '

Review: Matching Symbols

- Match the following data types to the symbols needed to create them (may be more than one)



Review: Mutability

- Which of the following are mutable data types?

Boolean	???
Dictionary	???
Float	???
Integer	???
List	???
String	???
Tuple	???

Review: Mutability

- Which of the following are mutable data types?

Boolean	Immutable
Dictionary	**Mutable**
Float	Immutable
Integer	Immutable
List	**Mutable**
String	Immutable
Tuple	Immutable

Review: Implementation

- You are given a dictionary of the NATO phonetic alphabet, in the form:

  `alpha = {"A" : "Alpha", "B" : "Bravo", "C" : "Charlie", ...` *etc.***`}`**

- Write a function to convert a string from the user into its phonetic code words
  - You need only handle letters (upper and lowercase)

Review: Implementation Example

- Here is an example of how it should work:

```
Please enter a word: EXAMPLE
The word "EXAMPLE" becomes
"Echo X-ray Alpha Mike Papa Lima Echo"

Please enter a word: dogmeat
The word "dogmeat" becomes
"Delta Oscar Golf Mike Echo Alpha Tango"
```

Any Questions about the Material we Just Reviewed?

Today’s Objectives

- To learn more about searching algorithms
  - Linear search
  - Binary search
- To understand why certain algorithms are “better” than others
- To learn about asymptotic performance
  - To examine how fast an algorithm “runs”

Search

Searching

- Sometimes, we use the location of a piece of information in a list to store information
- If I have the list `[4, 5, 2, 3]`, there may be some significance to this order
  - That means sometimes we want to find where in the list something is!

Exercise: Search

- Write a function that takes a list and a variable and returns the first location of the variable in the list
  - If it's not found, return -1

```
def find(myList, myVar):
```

Exercise Solution

```
def find(myList, myVar):
    for i in range(0, len(myList)):
        if myList[i] == myVar:
            return i
    # we didn't find the variable
    return -1
```

Linear Search

- This is called linear search!
- It’s a pretty common, simple operation

- It’s especially useful when our information isn’t in a sorted order

Searching Sorted Information

- Now, imagine we're looking for information in something sorted, like a phone book
- We know someone's name, and want to find their entry in the book (just like we knew the variable we were trying to locate earlier)

- What is a good algorithm for locating their phone number? Think about how you would do this.

Algorithm in English

- Open the book midway through.
  - If the person’s name is **on** the page you opened to
    - You’re done!
  - If the person’s name is **after** the page you opened to
    - Tear the book in half, throw the first half away and repeat this process on the second half
  - If the person’s name is **before** the page you opened to
    - Tear the book in half, throw the second half away and repeat this process on the first half
- This is very hard on phone books, but you’ll find the name!

Binary Search

Binary Search

- We can use this to search sorted lists!
- To make our problem slightly easier, let's make it the problem of "checking to see if something is in a sorted list"
  - For purposes of our example, if there's no "middle" of the list, we'll just look at the lower of the two possible indices
  - So if the list has 11 elements, the fifth one would be our middle

Binary Search

- Binary search is a problem that can be broken down into
  - Something simple (breaking a list in half)
  - A smaller version of the original problem (searching that half of the list)
- That means we can use ... recursion!

Exercise: Recursive Binary Search

- Write a recursive binary search!
- Remember to ask yourself:
  - What is our base case(s)?
  - What is the recursive step?

Exercise: Recursive Binary Search

- Write a recursive binary search!
- Remember to ask yourself:
  - What is our base case(s)?
  - What is the recursive step?

```
def binarySearch(myList, item):
```

- A hint: in order to get the number at the middle of the list, use this line:

```
myList[len(myList) // 2]
```

Exercise Solution

```
def binarySearch(myList, item):
   if(len(myList) == 0):
      return False
   middle = len(myList) // 2

   if(myList[middle] == item):
      return True
   elif(myList[middle] < item):
      return binarySearch(myList[middle+1:], item)
   else:
      return binarySearch(myList[:middle], item)
```

Algorithm Run Time

Run Time for Search

- Say we have a list that <u>does not</u> contain what we're looking for.
- How many things in the list does linear search have to look at for it to figure out the item's not there for a list of 8 things?
- 16 things?
- 32 things?

Run Time for Search

- Say we have a list that <u>does not</u> contain what we're looking for.
- What about for binary search?
  - How many things does it have to look at to figure out the item's not there for a list of 8 things?
  - 16 things?
  - 32 things?
- Notice anything different?

Different Run Times

- These algorithms scale differently!
  - Linear search does work equal to the number of items in the list
  - Binary search does work equal to the $\log_2$ of the numbers in the list!
- A $\log_2(x)$ is basically asking "2 to what power equals x?"
  - This is the same as saying, "how many times must we divide x in half before we hit 1?"

Different Run Times

- As our list gets bigger and bigger, which of the search algorithms is faster?
  - Linear or binary search?

- How much faster is binary search?

Another Example

Sum of All Products

- Say we have a list, and we want find the sum of everything in that list multiplied by everything else in that list
  - So if the list is [1, 2, 3], we want to find the value of:
  - **`1*1 + 1*2 + 1*3 + 2*1 + 2*2 + 2*3 + 3*1 + 3*2 + 3*3`**
- As an exercise, try writing this function!

```
def sumOfAllProducts(myList):
```

Exercise Solution

```
def sumOfAllProducts(myList):
  result = 0
  for item in myList:
    for item2 in myList:
      result += item * item2
  return result
```

Run Time for Sum of All Products

- How many multiplications does this have to do for a list of 8 things?
    - For 8 things, it does 64 multiplications
  - 16 things?
    - For 16 things, it does 256 multiplications
  - 32 things?
    - For 32 things, you do 1024 multiplications
- In general, if you give it a list of size **N**, you'll have to do $\mathbf{N}^2$ multiplications!

Asymptotic Analysis

Asymptotic Analysis

- For a list of size **N**, linear search does **N** operations. So we say it is **O(N)** (pronounced "big Oh of n")
- For a list of size **N**, binary search does **lg(N)** operations, so we say it is **O(lg(N))**
- For a list of size **N**, our sum of products function does $\mathbf{N^2}$ operations, which means it is $\mathbf{O(N^2)}$

- The function in the parentheses indicates how fast the algorithm scales

Example

- What is the big O of the following, given a list of size **N**:

```
for i in myList:
    for j in myList:
        for k in myList:
            print(i*j*k)
```

- This will be **O(N³)**

Any Other Questions?

General Announcements

- Lab 12 this week – last lab of the semester!

- Project 2 is out
  - Due by Tuesday, December 8th at 8:59:59 PM
  - Do NOT procrastinate!

- Next Class: Sorting

Announcements: Final Exam

- Final Exam will held be on Friday, **December 11th from 3:30 to 5:30 PM**
- Being held in three separate rooms
  - Section 1 (Gibson, MW @ 1) – CHEM 030
  - Section 7 (Dixon, TR @ 5:30) – CHEM 030
  - Section 13 (Dixon, TR @ 10) – CHEM 030
  - Section 19 (Morawski, MW @ 4) – PAHB 132
  - Section 25 (Gibson, TR @ 4) – PHYS 101
- Make sure you go to the correct room!

Announcements: Surveys

- Next class, we will be doing the in-class SCEQ (Student Course Evaluation Questionnaire)
  - This is an important metric for assessment

- The second survey is available and was announced on Blackboard
  - This is 1% of your grade, and is your chance to give feedback on your experience with the course