CMSC201
Computer Science I for Majors

Lecture 23 – Algorithms and Analysis

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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?

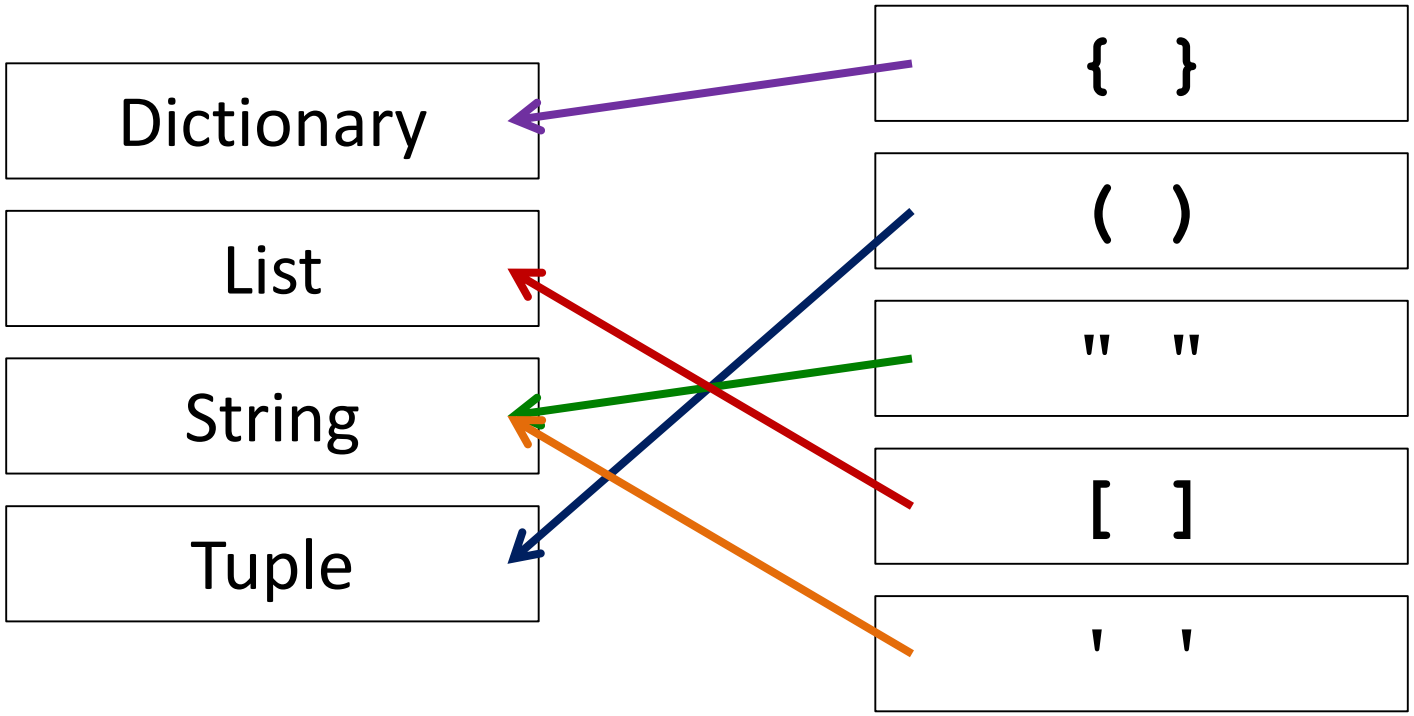
Review: Matching Symbols

- 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 only need to handle letters (case insensitive)

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 `[41, 50, 22, 9, 17]`, 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?

```
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 does not 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 does not 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 to 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 N^2 operations, which means it is $O(N^2)$

- 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 (N^3)**

Any Other Questions?

General Announcements

- Lab 12 this week – last lab of the semester!
- Project 2 is out
  - Due by Monday, May 9th at 8:59:59 PM
  - Extension!
- Next Class: Sorting

Announcements: Surveys

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

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

SCEQ Details

- Use only a #2 pencil
- Catalog number should be in top left corner
- Fill in the number of credits earned towards your degree at the beginning of the semester
  - If less than 100, fill the two right-most columns
  - If less than 10, fill the right-most column
- Fill in your cumulative GPA
  - Fill unknown digits with “0”

SCEQ Details

- Fill in your officially declared major

Computer Sci	63	Applied Physics	62
Computer Eng	07	Atmo Physics	41
Information Sys	83	Eng (General)	76
Math	61	Chemical Eng	37
Bioinformatics	98	Biology	55

  - If you haven't declared a major, enter "00"
  - If yours isn't listed, raise your hand and I'll tell you

SCEQ Details

- For this course, fill out the Scantron, sections:
  - A (General)
  - B (Lecture) – "Instructor A" column only
  - D (Laboratory)
- Fill out the Blue sheet
  - Additional comments can be written on the back
- Bring completed sheets to the front