Introduction to:
Computers & Programming:
Strings and Other Sequences
in Python
Part I

Adam Meyers
New York University
Outline

• What is a Data Structure?
• What is a Sequence?
• Sequences in Python
• All About Strings
What is a Data Structure?

• A Structure for Storing Data
• Formally defined parts
• Formally defined relations between parts
• Particular algorithms are designed to run with particular data structures
• We will focus on some data structures that are implemented in Python
  – Note that other programming languages may use the same names for different structures
What is a Sequence in Python?

- Sequences are ordered set of elements
  - Function `len` used to determine length
  - Elements selected with indices, subsequences selected with slices

- Different Python Sequences:
  - String = a sequence of characters
    - String methods including: `len`, `strip`, `lower`, `upper`, ...
  - Range = sequence of numbers defined by starting point and length
  - List = sequence of elements of any type, including mixed types
    - It is possible to alter a list, once created
    - In many programming languages, these are called arrays
  - Tuples – similar to List
    - Main difference = Cannot be changed once created
Strings in Python

• A String is a sequence consisting of characters
  – Characters also have special properties
• Special syntax allows the identification of subsequences or “slices”
• Special Python functions operate on the data structure “string”
  – testing, searching, changing case, formatting, stripping, splitting, etc.
New Data Type: Character

- **Character**
  - The smallest part of a string
  - Represented by 1 byte (ASCII) or 1 to 4 bytes (UTF-8)

- **Character ↔ Unicode (UTF-8) Number:**
  - Unicode Chart (base 10):
    - `chr(number)` ## Number to unicode character
    - `ord(character)` ## Unicode character to number
  - Unicode Chart (base 16):
    - [http://www.utf8-chartable.de/unicode-utf8-table.pl?number=1024&utf8=string-literal](http://www.utf8-chartable.de/unicode-utf8-table.pl?number=1024&utf8=string-literal)
Printing, Characters and Strings

- Special Characters can be part of strings
  - \n = newline character
  - \t = tab character

- Printing special characters in strings
  - print('Hello\nWorld')
  - print('Hello\tWorld')

- Escape Codes for Unicode in Base 16
  - \uxxxx = 4 digit (base 16) unicode character
  - print('\u0770') ## Arabic letter (sh sound)

- Print output of chr (base 10)
  - print(chr(1904)) ## Same Arabic character

- For loop for printing first 128 characters (ASCII)
  - for number in range(128):
    print(number,chr(number))
Using Characters

• Convert Upper Case to Lower Case
  – Let's try to figure this out logically by trying out the type conversions on the previous slide
    • ord('a')
    • ord('A')
    • Use chr to convert numbers to characters
    • Use for loop to convert words
  – Do the reverse: convert Lower Case to Upper Case

• Convert Number Characters 1-9 to corresponding letters using a similar strategy

• Convert whole strings using a for loop
Common Escape Characters

- `\` backslash
- `'` single quote
- `"` double quote
- `\n` newline
- `\r` (carriage) return
- `\t` tab
Let's number the positions around the characters, beginning with 0 and ending with the length of the string.

- Given a string: 'chicken'
- Lets number the positions around each character starting with zero:
  - \(0 \ 1 \ 2 \ 3 \ 4 \ 5 \ 6 \ 7\)
- This now allows us to refer to:
  - the characters beginning at 0 or 1 or 2 ….
  - the characters preceding or following 3
  - the characters between 2 and 5
  - etc
Indices from Either Direction

- An Index allows access to items in a sequence beginning at any position from 0 to length – 1 (no character begins at length – that would be the end of the string)
  - 'Hello'[0] == 'H'
  - 'Hello'[1] == 'e'
  - ...
  - 'Hello'[4] == 'o'

- A Negative index allows access to items in a sequence counting in reverse – negative indices refer to distances from the end.
  - 'Hello'[-1] == 'o'
  - 'Hello'[-2] == 'l'
  - ...
  - 'Hello'[-5] == 'H'
Slices: Parts of Strings (and other sequences)

- 'dishes'[0:2] == 'di'
- 'dishes'[4:6] == 'es'
- 'dishes'[:2] == 'di'
- 'dishes'[-2:] == 'es'
- 'dishes'[:] == 'dishes'
- SEQUENCE[start:end]
  - *start* and *end* can be positive integers from 0 to the length of the sequence or negative integers up to -1 X the string length
  - If start is left out, the string starts from the beginning
  - If end is left out, the string goes all the way to the end
Example: Regular Plurals in English

- This is for “normal” words, not exceptions
  - Not *sheep, oxen, octopi, aircraft, men, women,* …
  - These could be handled by a separate dictionary
- If final letter is a vowel, add 's'
- Else if final letter is “y”
  - If second-to-last letter is vowel, add 's'
  - Else remove “y” and add “ies”
- Else if final letters are a member of (x, s, z, ch, sh)
  - Add “es”
- Else add 's'
Morphological Rules in Linguistics

• Morphological rules include
  – Rules that add suffixes and/or prefixes
    • **noun + -s**
  – Other regular sound changes that result in different forms of the same word
    • **'sit' + past → 'sat'**

• Irregular morphology
  – Depends on the grammar, one assumes
    • **'sit' → 'sat'** is either irregular or a regular instance of an irregular paradigm (spit/spat, babysit/babysat, shit/shat)
  – Some cases would be irregular for all grammars
    • **'go' + past → 'went'**
Implementing the Plural Rule in Python

• morphology.py

• Uses the member operator **in**
  – A boolean operator which tests whether an item is a member of a sequence

• Uses another kind of sequence: the list
  – Delimiters = square brackets
  – Members = python objects
  – Separators = commas

• Structure of program: Decision tree using logical operators
Several Slides Listing String Functions

• Go to example-string-functions.py
• A few listed on the next few slides
  – A small subset used on midterm2 and final
• These all take the form:
  string.functionname(arguments)
• Examples,
  – 'abc'.islower()
    • Evaluates as True
  – 'Hello World'.center(20,'*')
    • Evaluates as '****Hello World*****'
string.functions(): Case/Format

- Case-Changing Functions
  - Example: `s = "the tourist saw Mary"
  - `s.lower()`, `s.upper()`, `s.swapcase()`
  - `s.captitalize()`  --- `s[0]` only
  - `s.title()` – similar except capital after space

- Format Functions
  - `s.center(LENGTH, ch)` – e.g., *** string ***
  - `s.ljust(length, ch), s.rjust(length, ch)` – similar
  - `s.format(vars)`
    - '{whose} {thing} is nice'.format(whose = 'John\'s', thing = 'code')
    - Additional details for fine-tuning print out
      - https://docs.python.org/3.1/library/string.html#formatspec
  - Example 2 with fancier formatting (:.4 and :.2 indicate number of decimal places):
    - 'First Number: {num1:.4} Second number: {num2:.2}'.format(num1=5.344,num2=6.923455)
string.function(): Tests and Search

• Testing (Boolean)
  – endswith(suffix)
  – startswith(prefix)
  – isalnum(), isalpha(), isdigit(), isnumeric(),
    isidentifier(), islower(), isupper, istitle(),
    isprintable(), isspace()

• Search functions
  – find(substring), rfind(substring)
    • return index or -1
  – index(substring), rindex(substring)
    • return index or error
string.functions(): Stripping off Characters

• Stripping Functions
  – Remove unwanted characters from edges of string
• s.strip(optional_arg)
  – If left out all white space characters are stripped
    • (tab,space,newline, …)
  – Otherwise all characters in optional_arg string
• s.lstrip and s.rstrip (left or right only)
Split and Partition functions

• Partition
  – s.partition(arg), s.split(arg)
  – create a list of substrings, partitioned by arg

• Split **** Useful for Homework ****
  – Example: “five hundred thirty”.split(' ') → ['five','hundred','thirty']
  – Split does not include the separators, but partition does
    • Try “five hundred thirty”.partition(' ')

• Rightward Versions
  – rpartition and rsplit variants: search for separators from right
    • only relevant if an optional max argument is used
Lists in Python

• left square bracket, elements separated by commas, right square bracket
  – Example: [1,2,3,4]

• Same system for slices and identifying elements as used for strings
  – list_of_4 = [1,2,3,4]
  – list_of_4[0] → 1
  – list_of_4[1:3] → [2,3]

• Additional feature, you can change a list using indices
  – list_of_4 = [1,2,3,4]
  – list_of_4 → [1,2,3,'jello']

• Convert strings to list of strings
  – 'This is a list'.split(' ') → ['This','is','a','list']
Lists with *in*, *len* and *loops*

- The *in* operator and function *len* behave as expected
  - 4 in [1,2,3,4] → True
  - 99 in [1,2,3,4] → False
  - len([1,2,3,4]) → 4

- *for* loops behave as expected
  - for item in [1,2,3,4]:
    print(item)

- *while* loops with accumulators
  ```python
  big_string = "
  index = 0
  words = ['the', 'big','green','monster']
  while index < len(words):
    big_string = big_string+words[index]+' '+
    index = index + 1
  big_string → 'the big green monster ' ## note extra space at the end
  ```
List Methods that Change Lists

- list.append(X) – adds an item to the end of a list, by changing the list
  - Abc = ['a','b','c']
  - Abc.append('d')
  - Abc → ['a','b','c','d']

- list.pop() – removes the last item in the list and returns it
  - Abc.pop()
    • returns 'd'
    • Abc → ['a','b','c']

- list.pop(indexX) – removes the item beginning at indexX (similar to keyword del, used in the modules)
  - Abc.pop(0)  ## like del Abc[0] (except del does not return anything)
    • Returns 'a'
    • Abc → ['b','c']
List Methods that Change Lists 2

- List.extend(list2) – adds items in list2 to list
  - Abc.extend(['d','e'])
  - Abc → ['a','b','c','d','e']

- List.reverse() – changes the order of a list, turning it backwards
  - Abc.reverse()
  - Abc → ['d','e','c','b','a']
Lists are Mutable

• Lists can be changed in a different way than other data types we have discussed up until now.

• Functions/Methods on strings create new strings
  – Abc = 'abcd'
  – Abc.upper() ## produces a new string
  – Abc = ['a','b','c']

• Functions/Methods on lists change existing list
  – Abc.reverse()
  – The variable Abc points to a list
    • The list exists independently of the variable
    • Using list methods on the variable will change the list it points to
    • Even if Abc is global, a function can change the list it points to
Other Operator/Functions for lists/strings

- **+** – like `List.extend`, but does not change the list (used in the modules)
  - `Abc = ['a','b','c']`
  - `Efg = ['e','f','g']`
  - `Abc + Efg → ['a','b','c','d','e','f','g']` ## returns combo
  - `Abc → ['a','b','c']` ## does not change input list

- **>, <** – sort order of strings (by unicode number)
  - 'abc' < 'efg'
  - 'EFG' < 'abc'

- **max, min** – finds first/last item in list (per unicode order)
  - `max(['abc','efg','EFG']) → 'efg'
  - `min(['abc','efg','EFG']) → 'EFG'

- **List.sort()** – sorts the items in a list, comparing elements with `max`
  - `my_list = ['abc','efg','EFG']`
  - `my_lists.sort()`
  - `my_list → ['EFG', 'abc', 'efg']`
Converting Spelled Out Numbers (HW)

- What integer corresponds to “two hundred sixty two”?
- 'two hundred sixty two'.split() → ['two', 'hundred', 'sixty', 'two']
- Convert string to numbers: ['two', 'hundred', 'sixty', 'two'] → [2, 100, 60, 2]
- Initialize total 2 (1st number), combine remaining numbers 1 at a time:
  - If total is lower than next number, multiply. If higher, add.
  - 1st Iteration: total is lower than next number. Therefore multiply
    - Total = 2, Next = 100, set Total to 200
  - 2nd and 3rd iterations: Total is higher than next number. Therefore add
    - Total = 200, next number = 60, set Total to 260
    - Total = 260, next number = 2, set Total to 262
  - Note that 2 equal numbers will not part of normal number sequence
- This method would not work for numbers over 1000
Extending to Cover Numbers 1000 and higher

- Applying method on previous slide to larger numbers requires refinement:
  - Ex: One hundred twenty seven thousand three hundred one
    - $(((1 \times 100) + 20 + 7) \times 1000)) + ((3 \times 100) + 1) \rightarrow 127,301$

- English numbers separate into units of 0 → 999
  - Go through the number list more than once, creating smaller lists on each pass
    - First only combine numbers less than 1000 (as per previous slide)
      - handle cases like “one hundred fifty three” wherever they occur in the string (even if they modify thousand, million, etc.)
    - Next multiply instances of numbers more than 1000, with preceding numbers less than 1000
    - On a final pass, add the remaining numbers together

- For example, 'five hundred thirty five thousand seven hundred one'
  - ['five','hundred','thirty','five','thousand','seven','hundred','one'] # split
  - [5,100,30,5,1000,7,100,1] ## convert to numbers
  - [535,1000,701] # on 1st pass, covert sequences of less than 1000
  - [535000,701] # on second pass, multiply 1000 and up, with preceding numbers less than 1000
  - 535701 ## finally add all numbers together
Walk Through for number over 1000

• Your loop must keep track of more than one item by looking ahead or behind or storing intermediate solutions to problems:
  – 2 variables: output (accumulates output); hold stores number you are “working on”
  – Part 1: ['four', 'thousand' 'two', 'hundred', 'sixty', 'two'] → [4, 1000, 2,100,60,2]
  – for number in [4, 1000, 2, 100, 60, 2]
    • Iteration 1: store 4 in hold
    • Iteration 2: 1000 is over 999, store both 4 and 1000 in output (empty hold)
    • Iteration 3: store 2 in hold
    • Iteration 4: multiply 2 X 100 and store 200 in hold (replacing 2)
    • Iteration 5: add 200 and 60 – store 260 in hold (replacing 200)
    • Iteration 6: add 260 and 2 – store 262 in hold
  – Put the remaining item in hold into output.
  – Output now equals: [4, 1000, 262]
  – Program stores partial results in hold and puts those results into output when ready
• The remaining steps:
  – Multiply: [4, 1000, 262] → [4000, 262]
  – Add: [4000, 262] → 4262
Larger Example:
One million five hundred three thousand four hundred seventy three

- Make number list: One million five hundred three thousand four hundred seventy three $\rightarrow [1, 1000000, 5, 100, 3, 1000, 4, 100, 70, 3]$

- Run on parts of sequence less than 1000:
  - $[1, 1000000, 5, 100, 3, 1000, 4, 100, 70, 3] \rightarrow [1, 1000000, 503, 1000, 473]$
  - (requires repeatedly storing temporary results less than 1000)
  - It can also be done in 2 passes, multiply [low, high] on first pass and add [higher, lower] on second pass, i.e.,
    - $[1, 1000000, 5, 100, 3, 1000, 4, 100, 70, 3] \rightarrow [1, 1000000, 500, 3, 1000, 400, 70, 3]$
    - $[1, 1000000, 500, 3, 1000, 400, 70, 3] \rightarrow [1, 1000000, 503, 1000, 473]$
    - Separating it this way makes it easier to adapt the program for the extra credit problem

- Do Multiplication
  - $[1, 1000000, 543, 1000, 473] \rightarrow [1000000, 543000, 473]$

- Do Addition
  - $[1000000, 543000, 473] \rightarrow 1,543,473$
Summary I

• Sequences are Data Structures in which items are combined together in a predescribed order
• Sequences share certain properties in Python, but many also have special functions and operators specific to them.
• Strings are sequences of Characters
• Strings are important for the print function, as well as other processing involving text
Summary II

• String manipulation involves
  – slicing and concatenating strings
  – converting characters to other characters
  – looping through sequences and making regular changes

• String manipulation is important for several applications
  – Applications involving linguistics: morphology, spell-checking, information extraction, machine translation, search, etc.
Summary III

• Lists are sequences of any type of element
• Lists are mutable
  – Rather than creating new lists, some functions actually change the lists that they operate on
  – If a local variable points to a list, functions operating on that variable can change the list
• Strings can be split apart to create lists
• Lists are useful for applying functions to particular items in a sequence.
Homework (Due 17th Class)

- http://cs.nyu.edu/courses/fall17/CSCI-UA.0002-007/hw6.html