Computational Problem Solving CSCI-603
Ciphers Lab 2

5/31/2023

1 Requirements

You will individually implement a program, `ciphers.py`, which encrypts/decrypts messages. The program will read in from the standard input and print the results in the standard output.

The program should execute as follows:

1. First prompt for the operation to perform. The options will be `E` for encryption (apply the transformation operations to the message), `D` for decryption (the given transformations have already been applied to generate the message), or `Q` for terminating the program.
2. If the user enters `Q`, the program finishes.
3. Otherwise, prompt for the message string.
4. Finally, prompt for the transformation operations string.
5. The program will send the output for the encryption/decryption process to the standard output.
6. Repeat step 1.

The format of the messages will be all upper-case letters (no spaces or punctuation). The format of the transformation strings will be as follows:

Table 1: Transformation operations

Operation	String form	Example	
S_i	`Si`	S_0	`S0`
S_i^k	`Si,k`	S_2^{-5}	`S2,-5`
R	`R`	R	`R`
R^i	`Ri`	R^{-3}	`R-3`
D_i	`Di`	D_2	`D2`
D_i^k	`Di,k`	D_2^3	`D2,3`
$T_{i,j}$	`Ti,j`	$T_{2,4}$	`T2,4`

If a series of transformations are to be supplied, they will be separated by semicolons. So, for example, if you were asked to encrypt the string HORSE given the transformation string `T2,4;S4;R` you would generate the string SHOES.

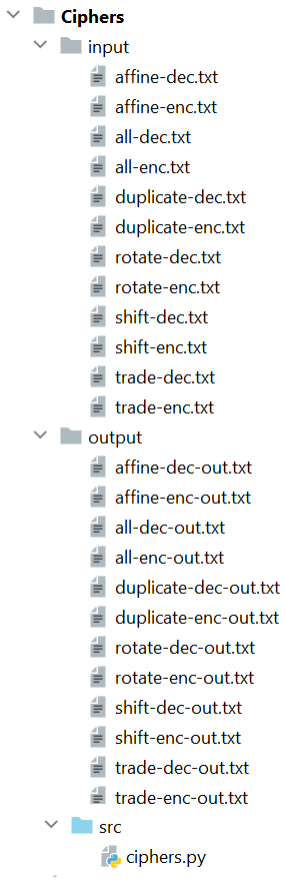
1.1 Starter Code

Get the starter code and example files by downloading them from:

https://www.cs.rit.edu/~csci603/Labs/02-Ciphers/code.zip

Extract the zip file, and then copy the `input`, `output`, and `src` directories into the root of your project folder in PyCharm. To make PyCharm aware the `src` directory has source code, you should right click on the `src` directory and select **Mark directory as... Sources root**. The `src` directory should be blue color.

Your project structure should look as follows:



Verify that you can see the starter code `ciphers.py` in the `src` sub-directory. Run the program by right clicking in the source code window. It should run but do nothing.

1.2 Affine transformation

Along with the transformations described in the problem-solving, your program must be able to encrypt/decrypt messages by applying a fifth transformation called **affine transformation**, $A_{a,b}$. The string representation of this transformation is `Aa,b`. For example, $A_{5,7}$ will be represented as `A5,7`.

The affine transformation is a substitution cipher where each character in the message is

mapped to an integer value between 0-25 (e.g. a=0, b=1, ..., z=25), encrypted with a mathematical function and then converted back to the letter relating to its new integer value.

1.2.1 Encryption

The encryption function is $E(x) = (ai + b)\ mod\ m$ where:

- a and b are keys provided by the user
- i is the letter's index from 0 to the alphabet's length - 1
- m is the length of the alphabet. For this lab, m is the fixed value 26

1.2.2 Decryption

The decryption function is $D(y) = a^{-1}(y - b)\ mod\ m$ where:

- y is the index of the encrypted letter ($y = E(x)$)
- a and b are keys provided by the user
- m is the length of the alphabet
- a^{-1} is the modular multiplicative inverse of a

The modular multiplicative inverse of a is an integer value a^{-1} such that the remainder of dividing a times a^{-1} by m is 1:

$a * a^{-1}\ mod\ m = 1$

A modular multiplicative inverse of a modulo m can be found by using the extended Euclidean algorithm. But since m has the fixed value 26 (the length of the alphabet), computing the modular multiplicative inverse of a can be simplified. We just need to find a positive integer x less than 26 such that $a * x\ mod\ 26 = 1$.

Notice that the modular multiplicative inverse of a only exists if a and m are coprime. Without that restriction on a, decryption might not be possible. For this lab, you may assume that both of the keys provided a and b are valid legal values. You do not need to check whether a is coprime of 26.

1.3 Sample Run

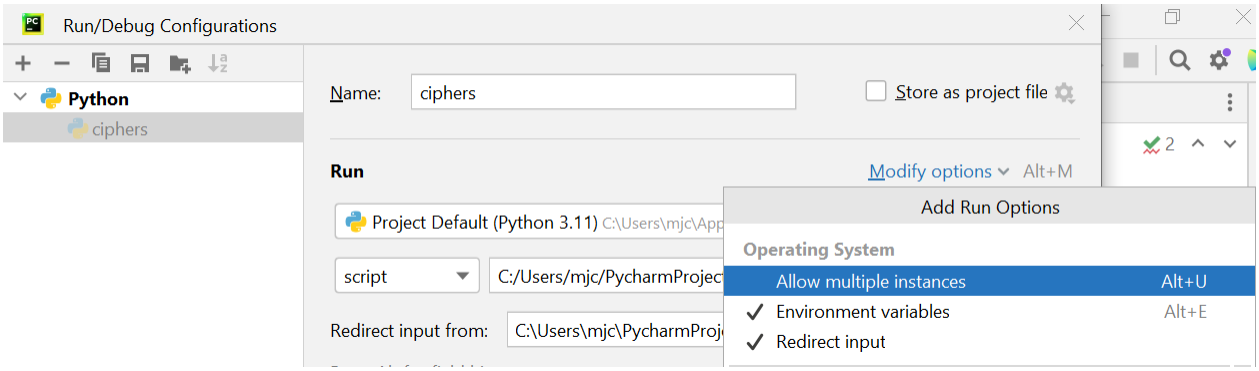
You have been provided with some sample files to verify the correctness of your solution. The files in the `input` folder contain the input required to run the program and the files in the `output` folder contain the output generated by your program when executed with its corresponding file from the `input` folder.

We have provided you with files to verify every operation individually and in combination with other operations. However, we encourage you to create your own test cases for a more thorough testing.

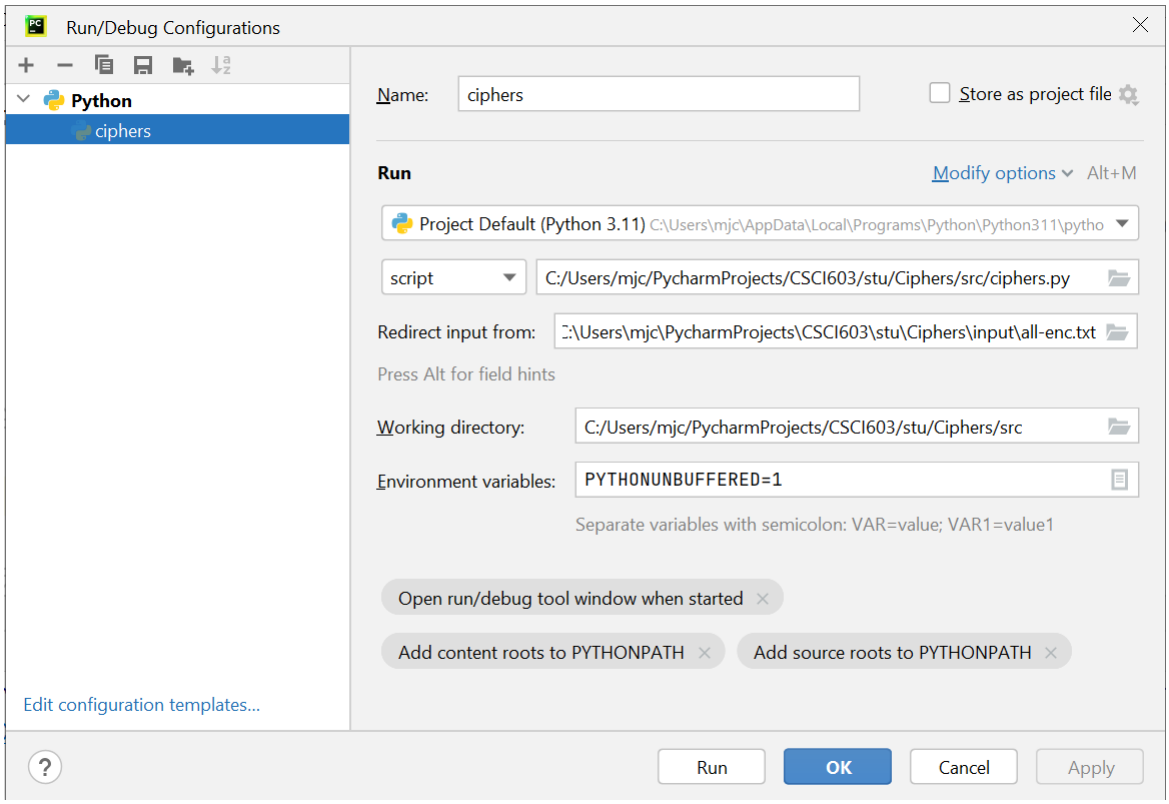
1.4 Simplifying Input

In order to save you the pain of having to enter into the console all the information the program requires to run, you can edit the run configuration to automatically redirect the input from a file. To do this, click on the run configuration pull down menu (left of the green run arrow) and select **Edit configurations**.

For the `ciphers` run configuration, click on the **Modify options** pull down menu and check the option **Redirect input**.



After that, you can specify the full path to any file with the required input. For example, you can run your program redirecting the input from any file from the `input` folder.

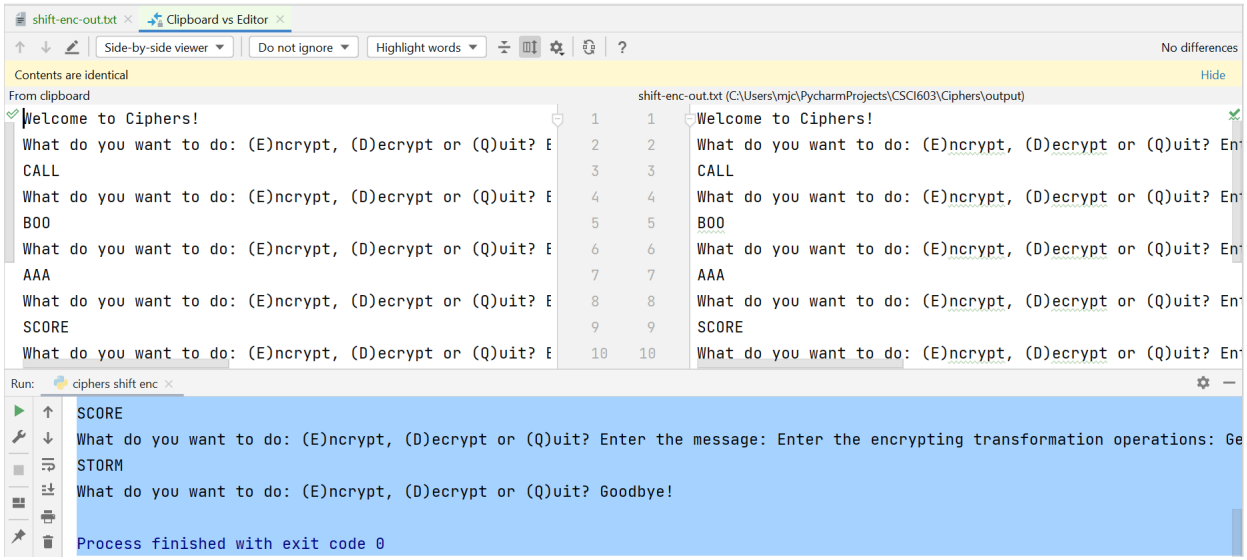


Now when your program executes an `input()` call it will read from the file versus asking you for input.

1.5 Comparing Output

The supplied outputs have a lot of text and can be very confusing to compare your output to. PyCharm provides a utility so you can compare a text file to the clipboard in a visual manner.

1. Open one of the output files in the Pycharm editor window.
2. Run the program with your desired input file.
3. Select all the text in the console and copy it to the clipboard.
4. In the solution output editor window right click and select **Compare with Clipboard**.
5. A new editor window will open highlighting the differences if there is any.



The ultimate goal here would be to make sure the output matches exactly.

2 Implementation Details

You are not allowed to use regular expressions for this lab. Everything should be done using `str` operations, e.g. slicing, concatenation, indexing, etc.

Additionally, you are not allowed to use the `global` keyword.

In order to receive full design points, you should be using functions to break down your program. For example, you should have one function that parses each transformation operations string into the sequence of transformations, and a function for every transformation. Look at your problem solving for more hints about how you can break this down to promote function reuse.

Your program must be properly documented to receive full style credit. The program should have a main docstring containing your name and a description of the assignment. Each function should have a properly formatted docstring with a description, arguments, return, etc.

You do not have to deal with erroneous input. It is assumed the user will provide valid input. The messages and operations will be legal, and are all formatted correctly.

3 Grading

The assignment grade is based on these factors:

- 20%: results of problem-solving
- 10%: Design - Your implementation uses functions to promote code reuse.
- 60%: Functionality
  - 5%: User input
  - 25%: Individual encryption operations
  - 15%: Overall encryption process
  - 15%: Decryption
- 10%: Code Style and Documentation

4 Submission

Go to your project's `src` folder and zip it up. Rename the zip file to `lab2.zip`. Upload this zip to the MyCourses Assignment dropbox by the due date.

- To zip on Windows, right click on the `src` folder and select `Send to -> Compressed (zipped) folder`.
- To zip on MacOS, right click on the `src` folder and select `Compress "src"`.