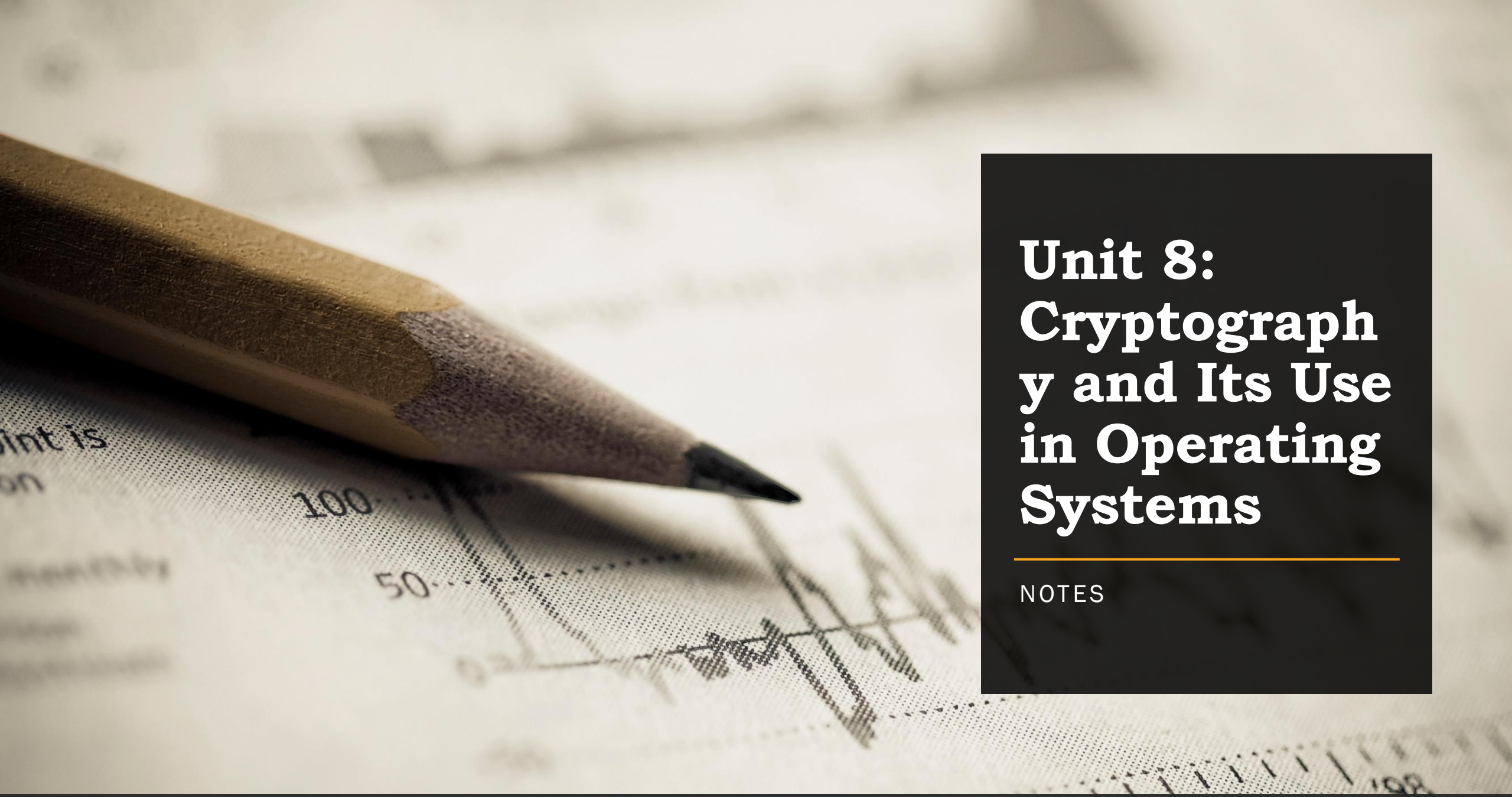

Unit 8: Cryptography and Its Use in Operating Systems

NOTES

TutorialPoint (2020) Cryptography with Python Tutorial

Available from:
https://www.tutorialspoint.com/cryptography_with_python/index.htm

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Cryptography is the **art of communication** between **two users** via **coded messages**. The science of cryptography emerged with the basic motive of providing **security to the confidential messages** transferred from one party to another.

Cryptography is defined as the art and science of concealing the message to introduce privacy and secrecy as recognized in information security.

Terminologies of Cryptography

The frequently used terms in cryptography are explained here −

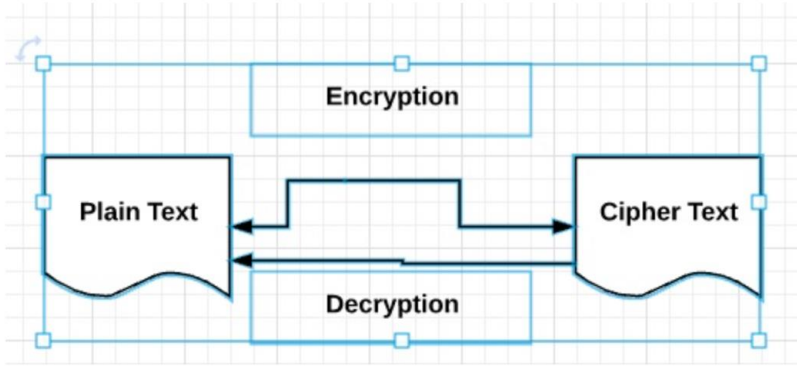
Plain Text: The plain text message is the text which is readable and can be understood by all users. The plain text is the message which undergoes cryptography.

Cipher Text: Cipher text is the message obtained after applying cryptography on plain text.

Encryption: The process of converting plain text to cipher text is called encryption. It is also called as encoding.

Decryption: The process of converting cipher text to plain text is called decryption. It is also termed as decoding.

The diagram given below shows an illustration of the complete process of cryptography −



Characteristics of Modern Cryptography

The basic characteristics of modern cryptography are as follows −

- It operates on bit sequences.
- It uses mathematical algorithms for securing the information.
- It requires parties interested in secure communication channel to achieve privacy.

Double strength encryption, also called as multiple encryption, is the process of encrypting an already encrypted text one or more times, either with the same or different algorithm/pattern.

The other names for double strength encryption include cascade encryption or cascade ciphering.

Levels of Double Strength Encryption

Double strength encryption includes various levels of encryption that are explained here under −

First layer of encryption

The cipher text is generated from the original readable message using hash algorithms and symmetric keys. Later symmetric keys are encrypted with the help of asymmetric keys. The best illustration for this pattern is combining the hash digest of the cipher text into a capsule. The receiver will compute the digest first and later decrypt the text in order to verify that text is not tampered in between.

Second layer of encryption

Second layer of encryption is the process of adding one more layer to cipher text with same or different algorithm. Usually, a 32-bit character long symmetric password is used for the same.

Third layer of encryption

In this process, the encrypted capsule is transmitted via SSL/TLS connection to the communication partner.

The following diagram shows double encryption process pictorially −

Third layer of encryption

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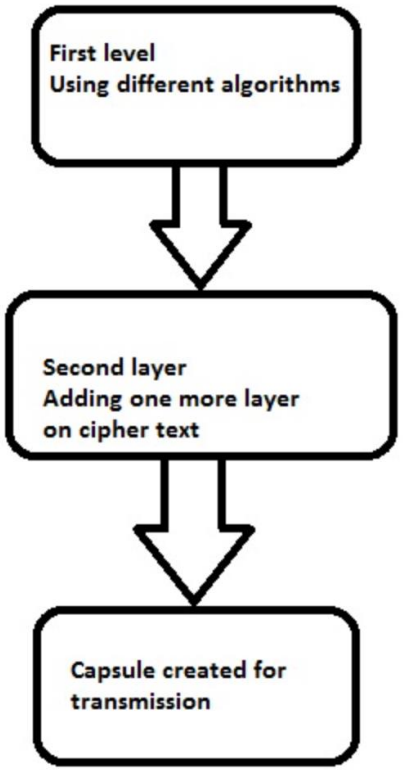
The following diagram shows double encryption process pictorially −



Hybrid Cryptography

Hybrid cryptography is the process of using multiple ciphers of different types together by including benefits of each of the cipher. There is one common approach which is usually followed to generate a random secret key for a symmetric cipher and then encrypt this key via asymmetric key cryptography.

Due to this pattern, the original message itself is encrypted using the symmetric cipher and then using secret key. The receiver after receiving the message decrypts the message using secret key first, using his/her own private key and then uses the specified key to decrypt the message.

Cryptography Packages

Python includes a package called cryptography which provides cryptographic recipes and primitives. It supports Python 2.7, Python 3.4+, and PyPy 5.3+. The basic installation of cryptography package is achieved through following command −

```
pip install cryptography
```

Open cmd/command line of Windows, type this line

There are various packages with both high level recipes and low level interfaces to common cryptographic algorithms such as **symmetric ciphers**, **message digests** and **key derivation functions.**

Throughout this tutorial, we will be using various packages of Python for implementation of cryptographic algorithms.

Cryptography installed

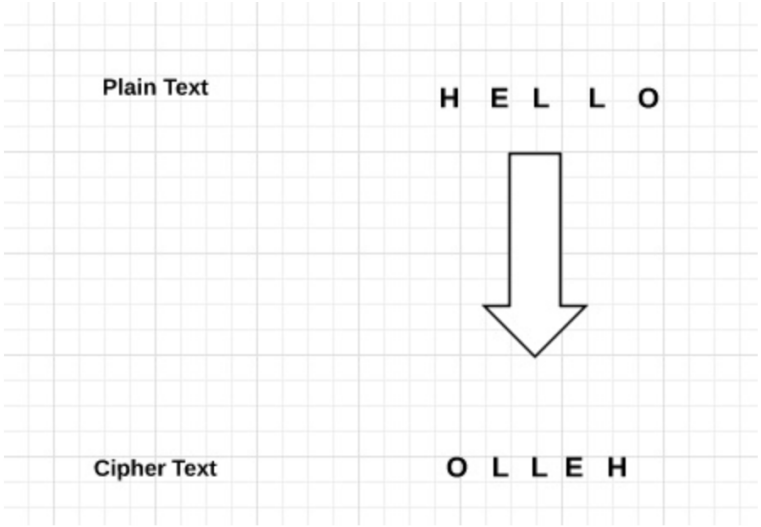
Algorithm of Reverse Cipher

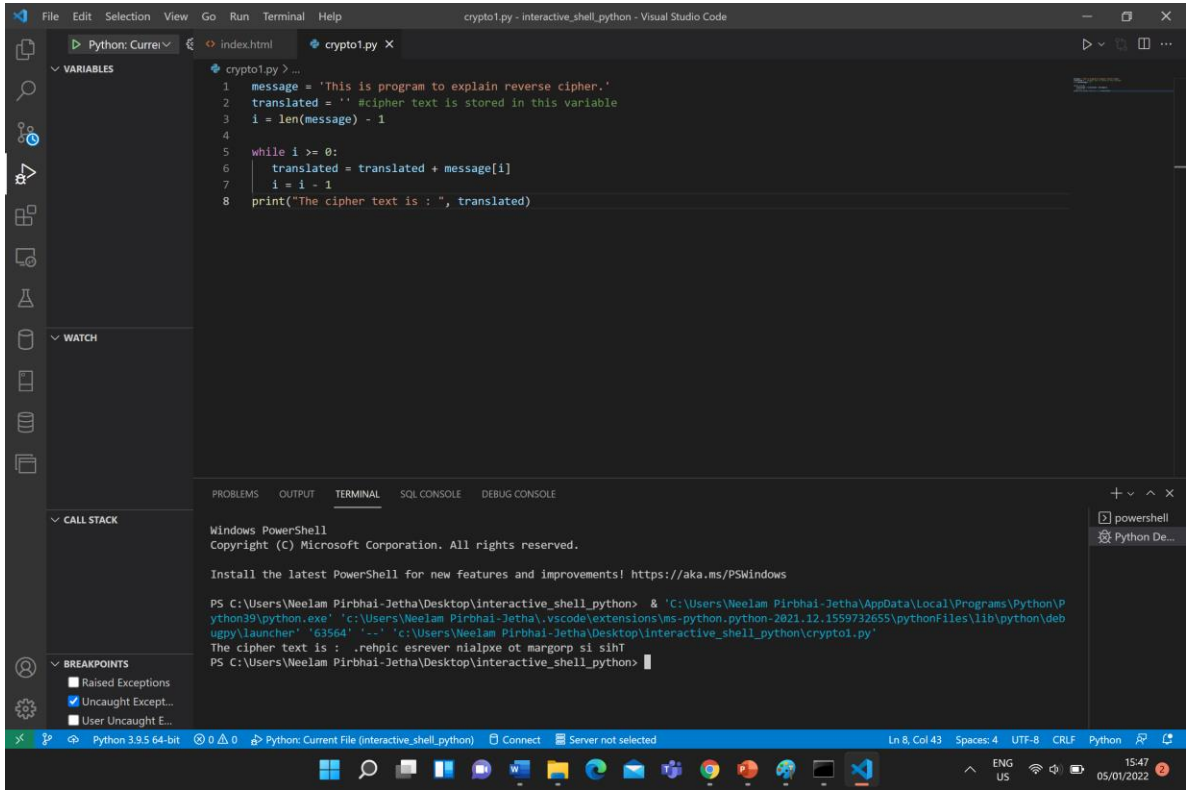
The algorithm of reverse cipher holds the following features −

- Reverse Cipher uses a pattern of reversing the string of plain text to convert as cipher text.
- The process of encryption and decryption is same.
- To decrypt cipher text, the user simply needs to reverse the cipher text to get the plain text.

Drawback

The major drawback of reverse cipher is that it is very weak. A hacker can easily break the cipher text to get the original message. Hence, reverse cipher is not considered as good option to maintain secure communication channel,.





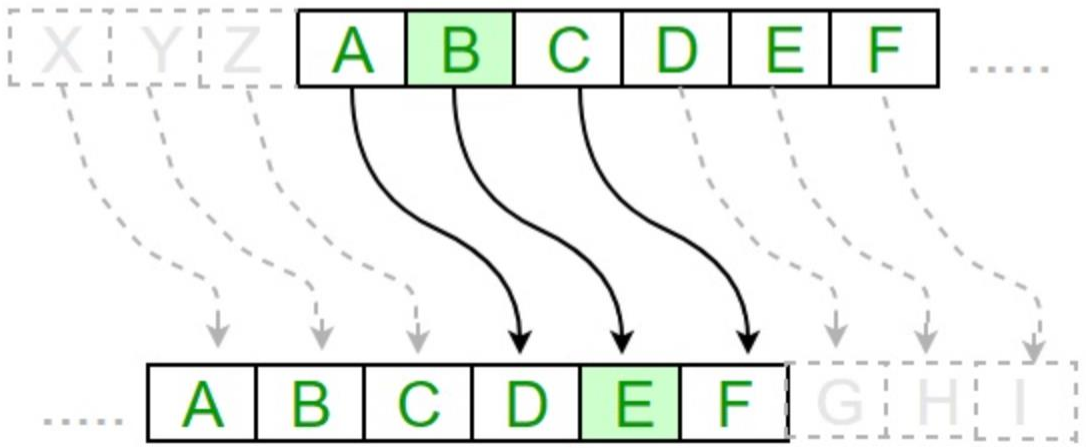

```
message = input ("Add your text here:")
print(message)
translated = " " #cipher text is stored in this variable
i = len(message) - 1

while i >= 0:
   translated = translated + message[i]
   i = i - 1
print("The cipher text is : ", translated)
```

Algorithm of Caesar Cipher

The algorithm of Caesar cipher holds the following features −

- Caesar Cipher Technique is the simple and easy method of encryption technique.
- It is simple type of substitution cipher.
- Each letter of plain text is replaced by a letter with some fixed number of positions down with alphabet.

The following diagram depicts the working of Caesar cipher algorithm implementation −

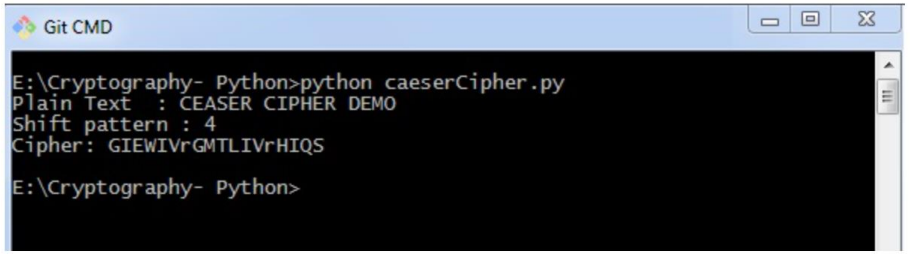


The program implementation of Caesar cipher algorithm is as follows −

```
def encrypt(text,s):
result = ""
   # transverse the plain text
   for i in range(len(text)):
      char = text[i]
      # Encrypt uppercase characters in plain text

      if (char.isupper()):
         result += chr((ord(char) + s-65) % 26 + 65)
      # Encrypt lowercase characters in plain text
      else:
         result += chr((ord(char) + s - 97) % 26 + 97)
      return result
#check the above function
text = "CEASER CIPHER DEMO"
s = 4

print "Plain Text : " + text
print "Shift pattern : " + str(s)
print "Cipher: " + encrypt(text,s)
```

Output

You can see the Caesar cipher, that is the output as shown in the following image −



Hacking of Caesar Cipher Algorithm

The cipher text can be hacked with various possibilities. One of such possibility is **Brute Force Technique,** which involves trying every possible decryption key. This technique does not demand much effort and is relatively simple for a hacker.

The program implementation for hacking Caesar cipher algorithm is as follows −

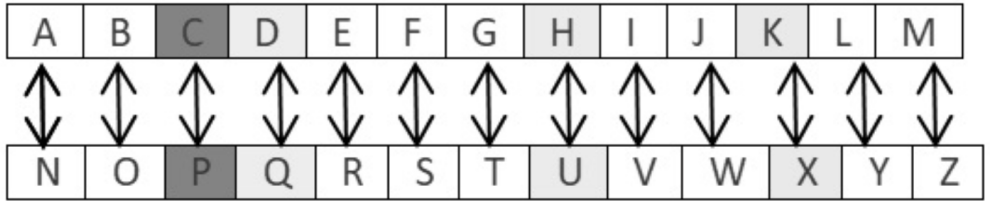
```
message = 'GIEWIVrGMTLIVrHIQS' #encrypted message
LETTERS = 'ABCDEFGHIJKLMNOPQRSTUVWXYZ'

for key in range(len(LETTERS)):
   translated = ''
   for symbol in message:
      if symbol in LETTERS:
         num = LETTERS.find(symbol)
         num = num - key
         if num < 0:
            num = num + len(LETTERS)
         translated = translated + LETTERS[num]
      else:
         translated = translated + symbol
print('Hacking key #%s: %s' % (key, translated))
```

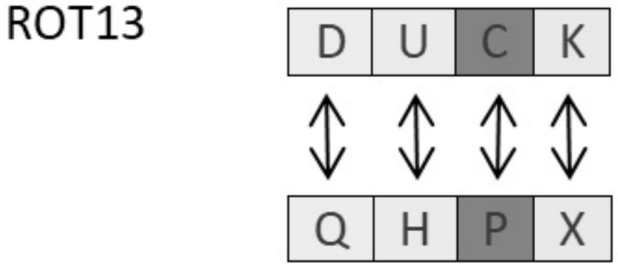
Explanation of ROT13 Algorithm

ROT13 cipher refers to the abbreviated form **Rotate by 13 places**. It is a special case of Caesar Cipher in which shift is always 13. Every letter is shifted by 13 places to encrypt or decrypt the message.

Example

The following diagram explains the ROT13 algorithm process pictorially −





Program Code

The program implementation of ROT13 algorithm is as follows −

```
from string import maketrans

rot13trans = maketrans('ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz',
   'NOPQRSTUVWXYZABCDEFGHIJKLMnopqrstuvwxyzabcdefghijklm')

# Function to translate plain text
def rot13(text):
   return text.translate(rot13trans)
def main():
   txt = "ROT13 Algorithm"
   print rot13(txt)

if __name__ == "__main__":
   main()
```

Drawback

The ROT13 algorithm uses 13 shifts. Therefore, it is very easy to shift the characters in the reverse manner to decrypt the cipher text.

Analysis of ROT13 Algorithm

ROT13 cipher algorithm is considered as special case of Caesar Cipher. It is not a very secure algorithm and can be broken easily with frequency analysis or by just trying possible 25 keys whereas ROT13 can be broken by shifting 13 places. Therefore, it does not include any practical use.

Transposition Cipher is a cryptographic algorithm where the order of alphabets in the plaintext is rearranged to form a cipher text. In this process, the actual plain text alphabets are not included.

Example

A simple example for a transposition cipher is **columnar transposition cipher** where each character in the plain text is written horizontally with specified alphabet width. The cipher is written vertically, which creates an entirely different cipher text.

Consider the plain text **hello world**, and let us apply the simple columnar transposition technique as shown below

h	e	l	l
o	w	o	r
l	d		

The plain text characters are placed horizontally and the cipher text is created with vertical format as **: holewdlo lr.** Now, the receiver has to use the same table to decrypt the cipher text to plain text.

Code

The following program code demonstrates the basic implementation of columnar transposition technique −

```
def split_len(seq, length):
   return [seq[i:i + length] for i in range(0, len(seq), length)]
def encode(key, plaintext):
   order = {
      int(val): num for num, val in enumerate(key)
   }
ciphertext = ''

for index in sorted(order.keys()):
   for part in split_len(plaintext, len(key)):
      try:ciphertext += part[order[index]]
         except IndexError:
            continue
   return ciphertext
print(encode('3214', 'HELLO'))
```

Explanation

- Using the function **split_len(),** we can split the plain text characters, which can be placed in columnar or row format.
- **encode** method helps to create cipher text with key specifying the number of columns and prints the cipher text by reading characters through each column.

> **Note** − Cryptanalysts observed a significant improvement in crypto security when transposition technique is performed. They also noted that re-encrypting the cipher text using same transposition cipher creates better security.

Transposition Cipher (Encryption…)

Pyperclip

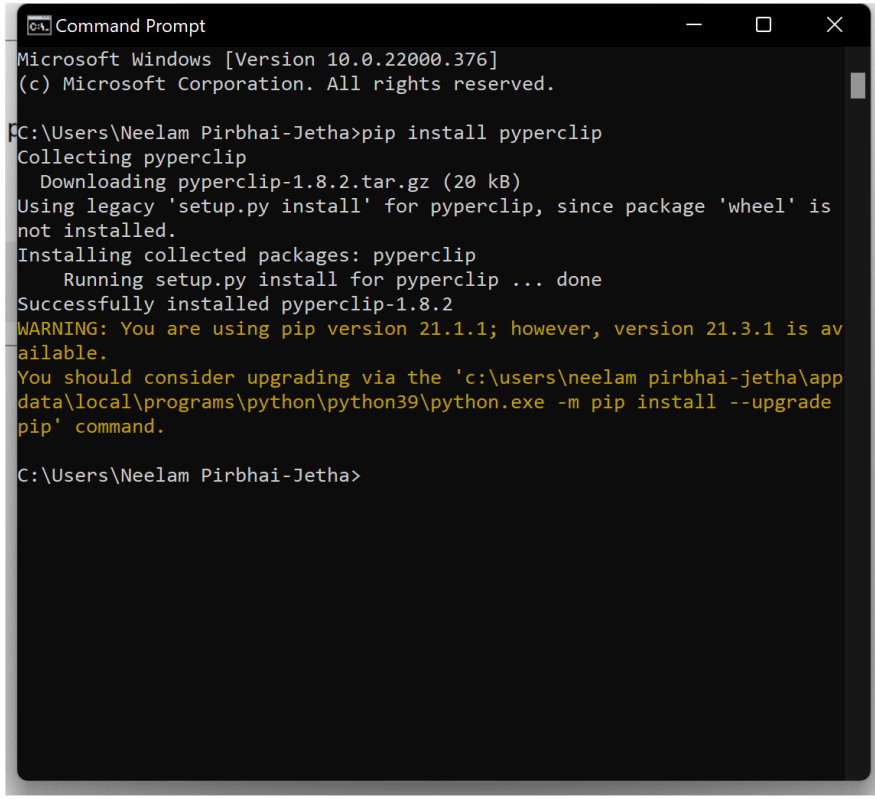
The main usage of **pyperclip** plugin in Python programming language is to perform cross platform module for copying and pasting text to the clipboard. You can install python **pyperclip** module using the command as shown

```
pip install pyperclip
```

Code

The python code for encrypting transposition cipher in which pyperclip is the main module is as shown below –

```
import pyperclip
def main():
   myMessage = 'Transposition Cipher'
   myKey = 10
   ciphertext = encryptMessage(myKey, myMessage)

   print("Cipher Text is")
   print(ciphertext + '|')
   pyperclip.copy(ciphertext)

def encryptMessage(key, message):
   ciphertext = [''] * key

   for col in range(key):
      position = col
      while position < len(message):
         ciphertext[col] += message[position]
                        position += key
      return ''.join(ciphertext) #Cipher text
if __name__ == '__main__':
   main()
```



Transposition Cipher (Decryption…)

Code

Observe the following code for a better understanding of decrypting a transposition cipher. The cipher text for message **Transposition Cipher** with key as **6** is fetched as **Toners raiCntisippoh.**

```
import math, pyperclip
def main():
   myMessage= 'Toners raiCntisippoh'
   myKey = 6
   plaintext = decryptMessage(myKey, myMessage)

   print("The plain text is")
   print('Transposition Cipher')

def decryptMessage(key, message):
   numOfColumns = math.ceil(len(message) / key)
   numOfRows = key
   numOfShadedBoxes = (numOfColumns * numOfRows) - len(message)
   plaintext = float('') * numOfColumns
   col = 0
   row = 0

   for symbol in message:
      plaintext[col] += symbol
      col += 1
      if (col == numOfColumns) or (col == numOfColumns - 1 and row >= numOfRows
         col = 0 row += 1 return ''.join(plaintext)
if __name__ == '__main__':
   main()
```

Explanation

The cipher text and the mentioned key are the two values taken as input parameters for decoding or decrypting the cipher text in reverse technique by placing characters in a column format and reading them in a horizontal manner.

You can place letters in a column format and later combined or concatenate them together using the following piece of code −

```
for symbol in message:
   plaintext[col] += symbol
   col += 1

   if (col == numOfColumns) or (col == numOfColumns - 1 and row >= numOfRows - n
   col = 0
   row += 1
return ''.join(plaintext)
```

In Python, it is possible to encrypt and decrypt files before transmitting to a communication channel. For this, you will have to use the plugin **PyCrypto**. You can installation this plugin using the command given below.

```
pip install pycrypto
```

Code

The program code for encrypting the file with password protector is mentioned below −

```
# ================Other Configuration===============
# Usages :
usage = "usage: %prog [options] "
# Version
Version="%prog 0.0.1"
# ===================================================
# Import Modules
import optparse, sys,os
from toolkit import processor as ps
def main():
   parser = optparse.OptionParser(usage = usage,version = Version)
   parser.add_option(
      '-i','--input',type = 'string',dest = 'inputfile',
      help = "File Input Path For Encryption", default = None)

   parser.add_option(
      '-o','--output',type = "string",dest = 'outputfile',
      help = "File Output Path For Saving Encrypter Cipher",default = ".")

   parser.add_option(
      '-p','--password',type = "string",dest = 'password',
      help = "Provide Password For Encrypting File",default = None)

   parser.add_option(
      '-p','--password',type = "string",dest = 'password',
      help = "Provide Password For Encrypting File",default = None)

   (options, args)= parser.parse_args()

   # Input Conditions Checkings
   if not options.inputfile or not os.path.isfile(options.inputfile):
      print " [Error] Please Specify Input File Path"
      exit(0)
```

https://www.tutorialspoint.com/cryptography_with_python/cryptography_with_python_encryption_of_files.htm

In this chapter, let us discuss decryption of files in cryptography using Python. Note that for decryption process, we will follow the same procedure, but instead of specifying the output path, we will focus on input path or the necessary file which is encrypted.

Code

The following is a sample code for decrypting files in cryptography using Python −

```
#!/usr/bin/python
# ---------------- READ ME --------------------------------------------
# This Script is Created Only For Practise And Educational Purpose Only
# This Script Is Created For http://bitforestinfo.blogspot.in
# This Script is Written By
#
#
##################################################
######## Please Don't Remove Author Name #########
############### Thanks ###########################
##################################################
#
#
# =================Other Configuration================
```

Base64 encoding converts the binary data into text format, which is passed through communication channel where a user can handle text safely. Base64 is also called as **Privacy enhanced Electronic mail (PEM)** and is primarily used in email encryption process.

Python includes a module called **BASE64** which includes two primary functions as given below −

- **base64.decode(input, output)** − It decodes the input value parameter specified and stores the decoded output as an object.
- **Base64.encode(input, output)** − It encodes the input value parameter specified and stores the decoded output as an object.

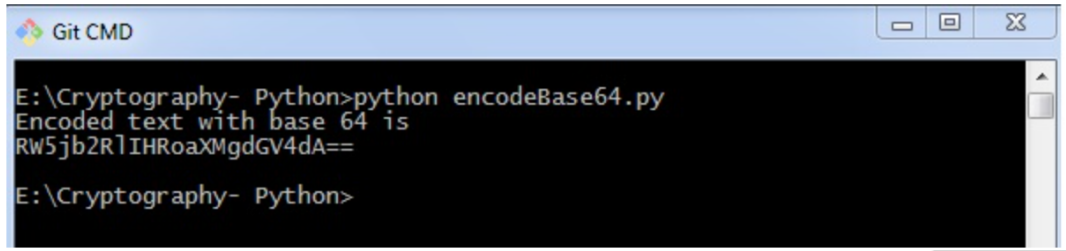
Program for Encoding

You can use the following piece of code to perform base64 encoding −

```
import base64
encoded_data = base64.b64encode("Encode this text")

print("Encoded text with base 64 is")
print(encoded_data)
```

Output

The code for base64 encoding gives you the following output −



Difference between ASCII and base64

You can observe the following differences when you work on ASCII and base64 for encoding data −

- When you encode text in ASCII, you start with a text string and convert it to a sequence of bytes.
- When you encode data in Base64, you start with a sequence of bytes and convert it to a text string.

Drawback

Base64 algorithm is usually used to store passwords in database. The major drawback is that each decoded word can be encoded easily through any online tool and intruders can easily get the information.

In this chapter, let us understand the XOR process along with its coding in Python.

Algorithm

XOR algorithm of encryption and decryption converts the plain text in the format ASCII bytes and uses XOR procedure to convert it to a specified byte. It offers the following advantages to its users −

- Fast computation
- No difference marked in left and right side
- Easy to understand and analyze

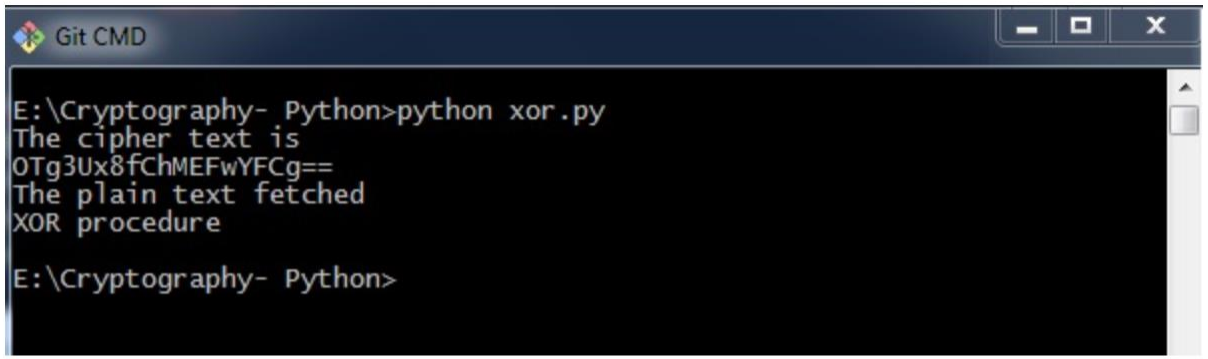
Code

You can use the following piece of code to perform XOR process −

```
def xor_crypt_string(data, key = 'awesomepassword', encode = False, decode = Fal
   from itertools import izip, cycle
   import base64

   if decode:
      data = base64.decodestring(data)
   xored = ''.join(chr(ord(x) ^ ord(y)) for (x,y) in izip(data, cycle(key)))

   if encode:
      return base64.encodestring(xored).strip()
   return xored
secret_data = "XOR procedure"

print("The cipher text is")
print xor_crypt_string(secret_data, encode = True)
print("The plain text fetched")
print xor_crypt_string(xor_crypt_string(secret_data, encode = True), decode = Tr
```

Output

The code for XOR process gives you the following output −



Explanation

- The function **xor_crypt_string()** includes a parameter to specify mode of encode and decode and also the string value.
- The basic functions are taken with base64 modules which follows the XOR procedure/ operation to encrypt or decrypt the plain text/ cipher text.

Note − XOR encryption is used to encrypt data and is hard to crack by brute-force method, that is by generating random encrypting keys to match with the correct cipher text.

While using Caesar cipher technique, encrypting and decrypting symbols involves converting the values into numbers with a simple basic procedure of addition or subtraction.

If multiplication is used to convert to cipher text, it is called a **wrap-around** situation. Consider the letters and the associated numbers to be used as shown below −

0	1	2	3	4	5	6	7	8	9	10	11	12
A	B	C	D	E	F	G	H	I	J	K	L	M
13	14	15	16	17	18	19	20	21	22	23	24	25
N	O	P	Q	R	S	T	U	V	W	X	Y	Z

The numbers will be used for multiplication procedure and the associated key is 7. The basic formula to be used in such a scenario to generate a multiplicative cipher is as follows −

```
(Alphabet Number * key)mod(total number of alphabets)
```

The number fetched through output is mapped in the table mentioned above and the corresponding letter is taken as the encrypted letter.

The number fetched through output is mapped in the table mentioned above and the corresponding letter is taken as the encrypted letter.

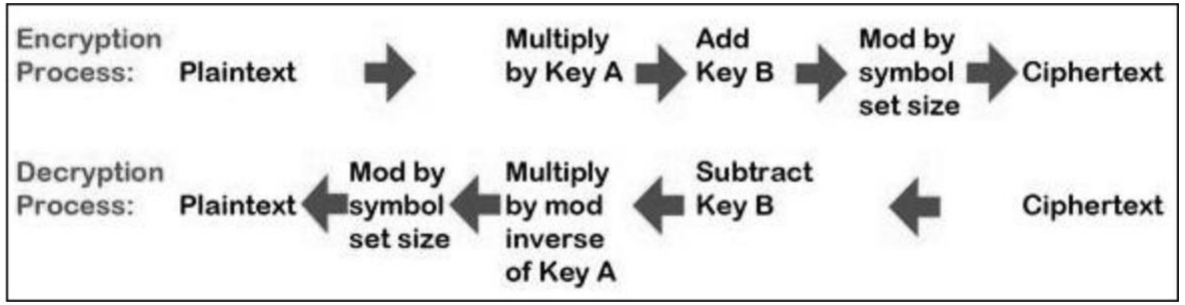
Plaintext Symbol	Number	Encryption with Key 7	Ciphertext Symbol
A	0	(0 * 7) % 26 = 0	A
B	1	(1 * 7) % 26 = 7	H
C	2	(2 * 7) % 26 = 14	O
D	3	(3 * 7) % 26 = 21	V
E	4	(4 * 7) % 26 = 2	C
F	5	(5 * 7) % 26 = 9	J
G	6	(6 * 7) % 26 = 16	Q
H	7	(7 * 7) % 26 = 23	X
I	8	(8 * 7) % 26 = 4	E
J	9	(9 * 7) % 26 = 11	L
K	10	(10 * 7) % 26 = 18	S
L	11	(11 * 7) % 26 = 25	Z
M	12	(12 * 7) % 26 = 6	G
N	13	(13 * 7) % 26 = 13	N
O	14	(14 * 7) % 26 = 20	U
P	15	(15 * 7) % 26 = 1	B
Q	16	(16 * 7) % 26 = 8	I
R	17	(17 * 7) % 26 = 15	P
S	18	(18 * 7) % 26 = 22	W
T	19	(19 * 7) % 26 = 3	D
U	20	(20 * 7) % 26 = 10	K
V	21	(21 * 7) % 26 = 17	R
W	22	(22 * 7) % 26 = 24	Y
X	23	(23 * 7) % 26 = 5	F
Y	24	(24 * 7) % 26 = 12	M
Z	25	(25 * 7) % 26 = 19	T

The basic modulation function of a multiplicative cipher in Python is as follows −

```
def unshift(key, ch):
   offset = ord(ch) - ASC_A
   return chr(((key[0] * (offset + key[1])) % WIDTH) + ASC_A)
```

Note − The advantage with a multiplicative cipher is that it can work with very large keys like 8,953,851. It would take quite a long time for a computer to brute-force through a majority of nine million keys.

Affine Cipher is the combination of Multiplicative Cipher and Caesar Cipher algorithm. The basic implementation of affine cipher is as shown in the image below −



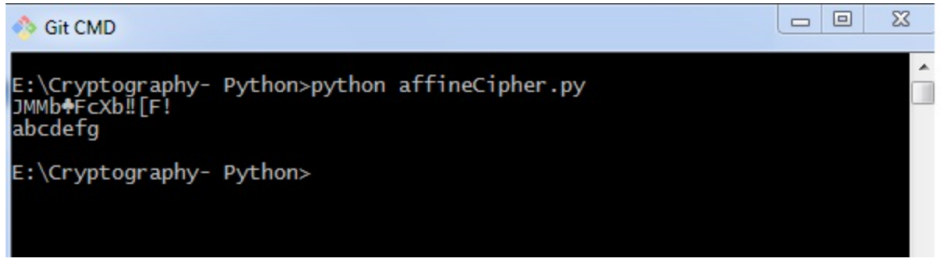
In this chapter, we will implement affine cipher by creating its corresponding class that includes two basic functions for encryption and decryption.

You can use the following code to implement an affine cipher −

```
class Affine(object):
   DIE = 128
   KEY = (7, 3, 55)
   def __init__(self):
      pass
   def encryptChar(self, char):
      K1, K2, kI = self.KEY
      return chr((K1 * ord(char) + K2) % self.DIE)

   def encrypt(self, string):
      return "".join(map(self.encryptChar, string))

   def decryptChar(self, char):
      K1, K2, KI = self.KEY
      return chr(KI * (ord(char) - K2) % self.DIE)

   def decrypt(self, string):
      return "".join(map(self.decryptChar, string))
                affine = Affine()
print affine.encrypt('Affine Cipher')
print affine.decrypt('*18?FMT')
```

Output

You can observe the following output when you implement an affine cipher −



The output displays the encrypted message for the plain text message **Affine Cipher** and decrypted message for the message sent as input **abcdefg.**

Monoalphabetic Cipher

A Monoalphabetic cipher uses a fixed substitution for encrypting the entire message. A monoalphabetic cipher using a Python dictionary with JSON objects is shown here −

```
monoalpha_cipher = {
   'a': 'm',
   'b': 'n',
   'c': 'b',
   'd': 'v',
   'e': 'c',
   'f': 'x',
   'g': 'z',
   'h': 'a',
   'i': 's',
   'j': 'd',
   'k': 'f',
   'l': 'g',
   'm': 'h',
   'n': 'j',
   'o': 'k',
   'p': 'l',
   'q': 'p',
   'r': 'o',
   's': 'i',
   't': 'u',
   'u': 'y',
   'v': 't',
   'w': 'r',
   'x': 'e',
   'y': 'w',
   'z': 'q',
      ' ': ' ',
}
```

With help of this dictionary, we can encrypt the letters with the associated letters as values in JSON object. The following program creates a monoalphabetic program as a class representation which includes all the functions of encryption and decryption.

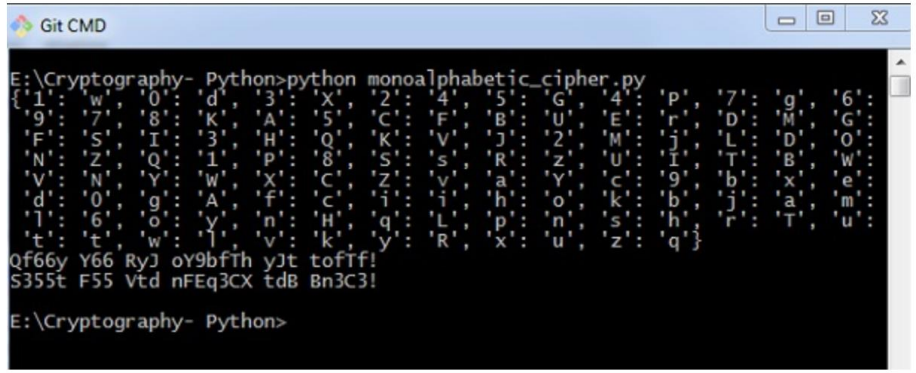
```
from string import letters, digits
from random import shuffle

def random_monoalpha_cipher(pool = None):
   if pool is None:
      pool = letters + digits
   original_pool = list(pool)
   shuffled_pool = list(pool)
   shuffle(shuffled_pool)
   return dict(zip(original_pool, shuffled_pool))

def inverse_monoalpha_cipher(monoalpha_cipher):
   inverse_monoalpha = {}
   for key, value in monoalpha_cipher.iteritems():
      inverse_monoalpha[value] = key
   return inverse_monoalpha

def encrypt_with_monoalpha(message, monoalpha_cipher):
   encrypted_message = []
   for letter in message:
      encrypted_message.append(monoalpha_cipher.get(letter, letter))
   return ''.join(encrypted_message)

def decrypt_with_monoalpha(encrypted_message, monoalpha_cipher):
   return encrypt_with_monoalpha(
      encrypted_message,
      inverse_monoalpha_cipher(monoalpha_cipher)
   )
```

This file is called later to implement the encryption and decryption process of Monoalphabetic cipher which is mentioned as below −

```
import monoalphabeticCipher as mc

cipher = mc.random_monoalpha_cipher()
print(cipher)
encrypted = mc.encrypt_with_monoalpha('Hello all you hackers out there!', cipher
decrypted = mc.decrypt_with_monoalpha('sXGGt SGG Nt0 HSrLXFC t0U UHXFX!', cipher

print(encrypted)
print(decrypted)
```

Output

You can observe the following output when you implement the code given above −



Thus, you can hack a monoalphabetic cipher with specified key value pair which cracks the cipher text to actual plain text.

Simple substitution cipher is the most commonly used cipher and includes an algorithm of substituting every plain text character for every cipher text character. In this process, alphabets are jumbled in comparison with Caesar cipher algorithm.

Example

Keys for a simple substitution cipher usually consists of 26 letters. An example key is −

```
plain alphabet : abcdefghijklmnopqrstuvwxyz
cipher alphabet: phqgiumeaylnofdxjkrcvstzwb
```

An example encryption using the above key is−

```
plaintext : defend the east wall of the castle
ciphertext: giuifg cei iprc tpnn du cei qprcni
```

The following code shows a program to implement simple substitution cipher −

```
import random, sys

LETTERS = 'ABCDEFGHIJKLMNOPQRSTUVWXYZ'
def main():
   message = ''
   if len(sys.argv) > 1:
      with open(sys.argv[1], 'r') as f:
         message = f.read()
   else:
      message = raw_input("Enter your message: ")
   mode = raw_input("E for Encrypt, D for Decrypt: ")
   key = ''

   while checkKey(key) is False:
      key = raw input("Enter 26 ALPHA key (leave blank for random key): ")
```

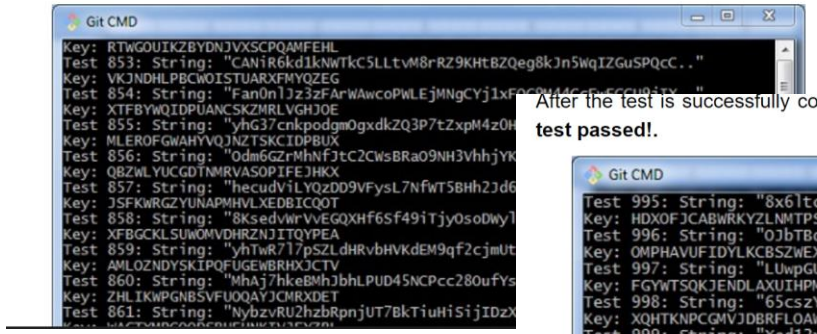
https://www.tutorialspoint.com/cryptography_with_python/cryptography_with_python_simple_substitution_cipher.htm

Testing of Simple Substitution Cipher

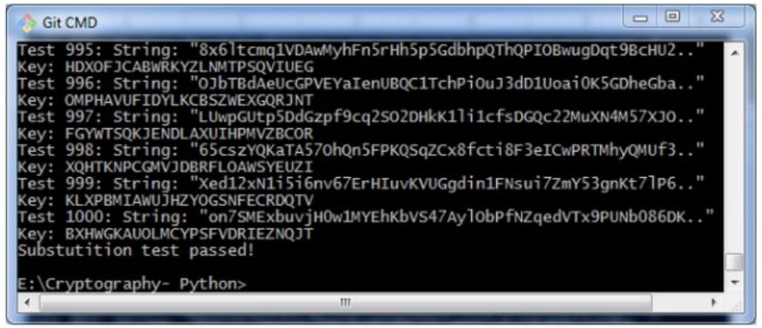
```
import random, string, substitution
def main():
   for i in range(1000):
      key = substitution.getRandomKey()
      message = random_string()
      print('Test %s: String: "%s.."' % (i + 1, message[:50]))
      print("Key: " + key)
      encrypted = substitution.translateMessage(message, key, 'E')
      decrypted = substitution.translateMessage(encrypted, key, 'D')

      if decrypted != message:
         print('ERROR: Decrypted: "%s" Key: %s' % (decrypted, key))
         sys.exit()
      print('Substutition test passed!')

def random_string(size = 5000, chars = string.ascii_letters + string.digits):
   return ''.join(random.choice(chars) for _ in range(size))
if __name__ == '__main__':
   main()
```

Output

You can observe the output as randomly generated strings which helps in generating random plain text messages, as shown below −



After the test is successfully completed, we can observe the output message **Substitution test passed!.**



Thus, you can hack a substitution cipher in the systematic manner.

In this chapter, you can learn about simple implementation of substitution cipher which displays the encrypted and decrypted message as per the logic used in simple substitution cipher technique. This can be considered as an alternative approach of coding.

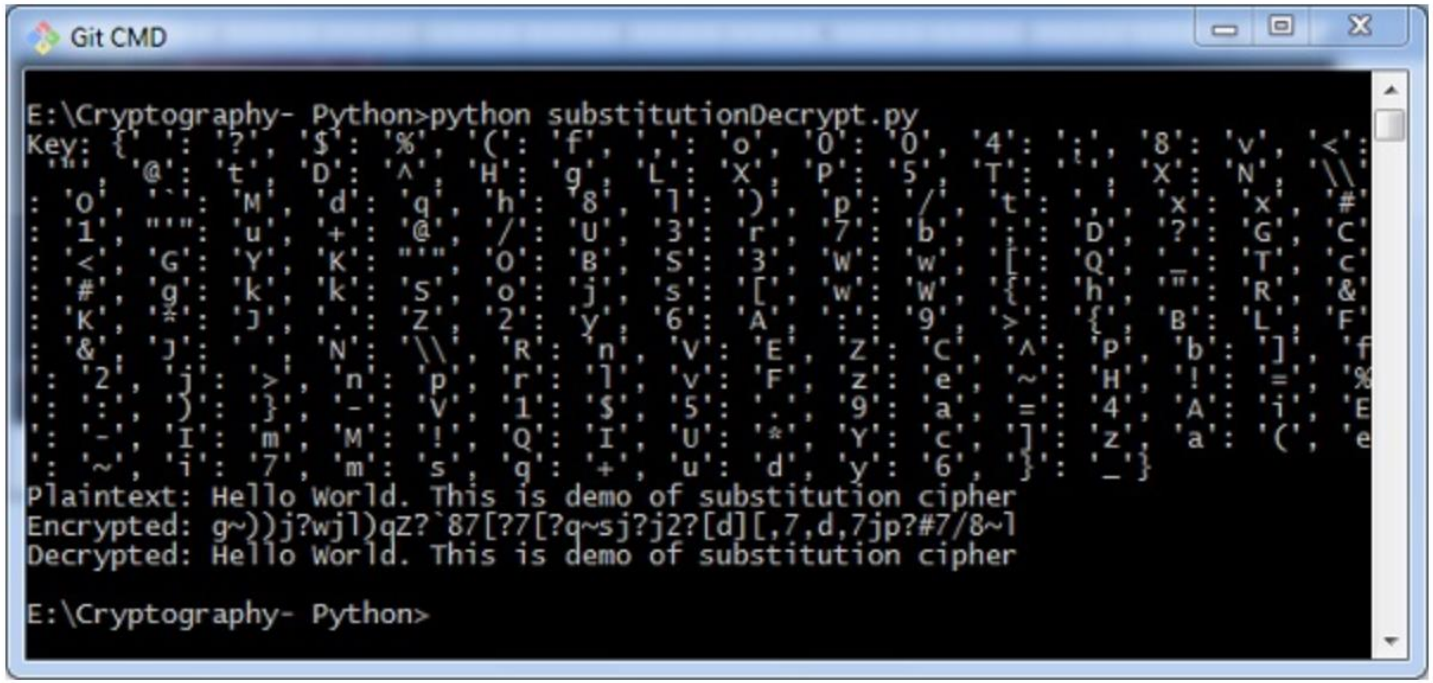
Code

You can use the following code to perform decryption using simple substitution cipher −

```
import random
chars = 'ABCDEFGHIJKLMNOPQRSTUVWXYZ' + \
   'abcdefghijklmnopqrstuvwxyz' + \
   '0123456789' + \
   ':.;,?!@#$%&()+=-*/_<> []{}`~^"\'\\'

def generate_key():
   """Generate an key for our cipher"""
   shuffled = sorted(chars, key=lambda k: random.random())
   return dict(zip(chars, shuffled))

def encrypt(key, plaintext):
   """Encrypt the string and return the ciphertext"""
   return ''.join(key[l] for l in plaintext)

def decrypt(key, ciphertext):
   """Decrypt the string and return the plaintext"""
   flipped = {v: k for k, v in key.items()}
   return ''.join(flipped[l] for l in ciphertext)

def show_result(plaintext):
   """Generate a resulting cipher with elements shown"""
   key = generate_key()
   encrypted = encrypt(key, plaintext)
   decrypted = decrypt(key, encrypted)

   print 'Key: %s' % key
        print 'Plaintext: %s' % plaintext
   print 'Encrypted: %s' % encrypted
   print 'Decrypted: %s' % decrypted
show_result('Hello World. This is demo of substitution cipher')
```

Output

The above code gives you the output as shown here −



Install cryptography module using the following command: pip install cryptography

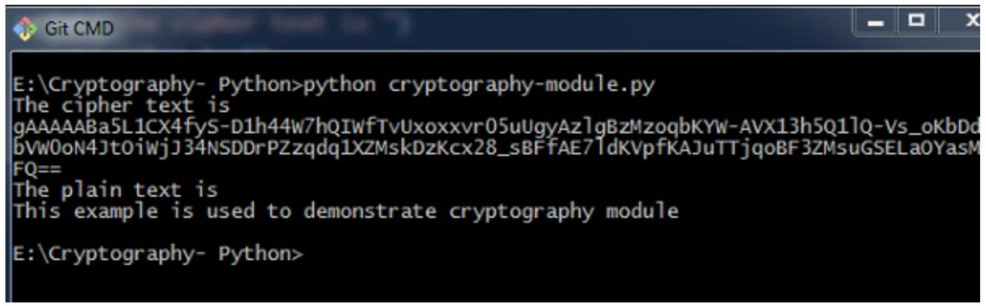
Code

You can use the following code to implement the cryptography module −

```
from cryptography.fernet import Fernet
key = Fernet.generate_key()
cipher_suite = Fernet(key)
cipher_text = cipher_suite.encrypt("This example is used to demonstrate cryptogr
plain_text = cipher_suite.decrypt(cipher_text)
```

Output

The code given above produces the following output −



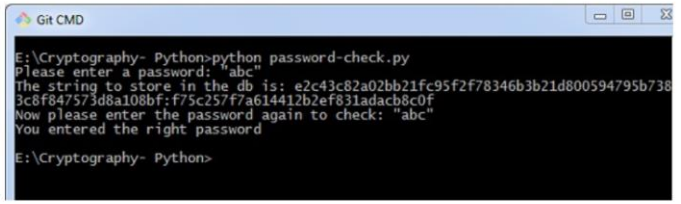
The code given here is used to verify the password and creating its hash. It also includes

The code given here is used to verify the password and creating its hash. It also includes logic for verifying the password for authentication purpose.

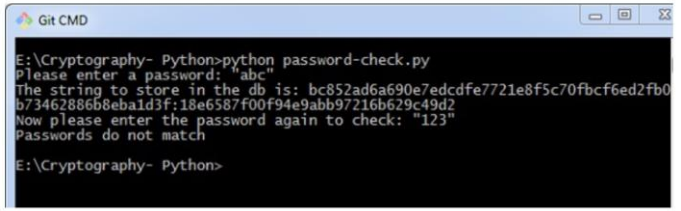
```
import uuid
import hashlib

def hash_password(password):
   # uuid is used to generate a random number of the specified password
   salt = uuid.uuid4().hex
   return hashlib.sha256(salt.encode() + password.encode()).hexdigest() + ':' +

def check_password(hashed_password, user_password):
   password, salt = hashed_password
   return password == hashlib.sha25

new_pass = input('Please enter a pa
hashed_password = hash_password(new
print('The string to store in the d
old_pass = input('Now please enter

if check_password(hashed_password,
   print('You entered the right pas
else:
   print('Passwords do not match')
```

Output

Scenario 1 − If you have entered a correct password, you can find the following output −



Scenario 2 − If we enter wrong password, you can find the following output −



Explanation

Hashlib package is used for storing passwords in a database. In this program, **salt** is used which adds a random sequence to the password string before implementing the hash function.

Vignere Cipher includes a twist with Caesar Cipher algorithm used for encryption and decryption. Vignere Cipher works similar to Caesar Cipher algorithm with only one major distinction: Caesar Cipher includes algorithm for one-character shift, whereas Vignere Cipher includes key with multiple alphabets shift.

Mathematical Equation

For encryption the mathematical equation is as follows −

$$E_k\left(M_i\right) = \left(M_i + K_i\right) \quad mod \;\; 26$$

For decryption the mathematical equation is as follows −

$$D_k\left(C_i\right) = \left(C_i - K_i\right) \quad mod \;\; 26$$

Vignere cipher uses more than one set of substitutions, and hence it is also referred as **polyalphabetic cipher**. Vignere Cipher will use a letter key instead of a numeric key representation: Letter A will be used for key 0, letter B for key 1 and so on. Numbers of the letters before and after encryption process is shown below −

Plaintext Letter	Subkey		Ciphertext Letter
C (2)	P (15)	→	R (17)
O (14)	I (8)	→	W (22)
M (12)	Z (25)	→	L (11)
M (12)	Z (25)	→	L (11)
O (14)	A (0)	→	O (14)
N (13)	P (15)	→	C (2)
S (18)	I (8)	→	A (0)
E (4)	Z (25)	→	D (3)
N (13)	Z (25)	→	M (12)
S (18)	A (0)	→	S (18)
E (4)	P (15)	→	T (19)
I (8)	I (8)	→	Q (16)
S (18)	Z (25)	→	R (17)
N (13)	Z (25)	→	M (12)
O (14)	A (0)	→	O (14)
T (19)	P (15)	→	I (8)
S (18)	I (8)	→	A (0)
O (14)	Z (25)	→	N (13)
C (2)	Z (25)	→	B (1)
O (14)	A (0)	→	O (14)
M (12)	P (15)	→	B (1)
M (12)	I (8)	→	U (20)
O (14)	Z (25)	→	N (13)
N (13)	Z (25)	→	M (12)

The possible combination of number of possible keys based on Vignere key length is given as follows, which gives the result of how secure is Vignere Cipher Algorithm −

Key Length	Equation	Possible Keys
1	26	= 26
2	26 × 26	= 676
3	676 × 26	= 17,576
4	17,576 × 26	= 456,976
5	456,976 × 26	= 11,881,376
6	11,881,376 × 26	= 308,915,776
7	308,915,776 × 26	= 8,031,810,176
8	8,031,810,176 × 26	= 208,827,064,576
9	208,827,064,576 × 26	= 5,429,503,678,976
10	5,429,503,678,976 × 26	= 141,167,095,653,376

https://www.tutorialspoint.com/cryptography_with_python/cryptography_with_python_understanding_vignere_cipher.htm

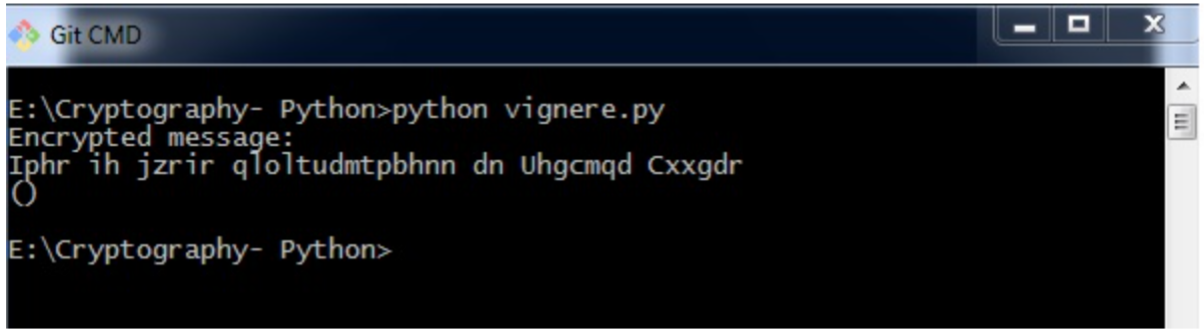
Implementing Vignere Cipher

The possible combinations of hacking the Vignere cipher is next to impossible. Hence, it is considered as a secure encryption mode.

```
import pyperclip

LETTERS = 'ABCDEFGHIJKLMNOPQRSTUVWXYZ'
def main():
   myMessage = "This is basic implementation of Vignere Cipher"
   myKey = 'PIZZA'
   myMode = 'encrypt'

   if myMode == 'encrypt':
      translated = encryptMessage(myKey, myMessage)
   elif myMode == 'decrypt':
      translated = decryptMessage(myKey, myMessage)

   print('%sed message:' % (myMode.title()))
   print(translated)
   print()
def encryptMessage(key, message):
   return translateMessage(key, message, 'encrypt')
def decryptMessage(key, message):
   return translateMessage(key, message, 'decrypt')
def translateMessage(key, message, mode):
   translated = [] # stores the encrypted/decrypted message string
   keyIndex = 0
   key = key.upper()

   for symbol in message:
      num = LETTERS.find(symbol.upper())
      if num != -1:
         if mode == 'encrypt':
            num += LETTERS.find(key[keyIndex])
                              elif mode == 'decrypt':
               num -= LETTERS.find(key[keyIndex])
            num %= len(LETTERS)

            if symbol.isupper():
               translated.append(LETTERS[num])
            elif symbol.islower():
                translated.append(LETTERS[num].lower())
             keyIndex += 1

             if keyIndex == len(key):
                keyIndex = 0
          else:
             translated.append(symbol)
      return ''.join(translated)
if __name__ == '__main__':
   main()
```

Output

You can observe the following output when you implement the code given above −



The possible combinations of hacking the Vignere cipher is next to impossible. Hence, it is considered as a secure encryption mode.

One Time Pad Cipher

One-time pad cipher is a type of Vignere cipher which includes the following features −

- It is an unbreakable cipher.
- The key is exactly same as the length of message which is encrypted.
- The key is made up of random symbols.
- As the name suggests, key is used one time only and never used again for any other message to be encrypted.

Due to this, encrypted message will be vulnerable to attack for a cryptanalyst. The key used for a one-time pad cipher is called **pad**, as it is printed on pads of paper.

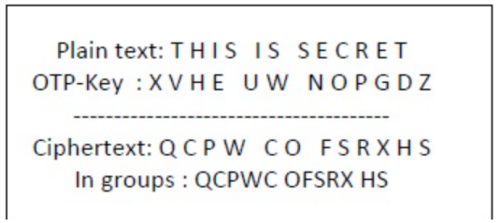
Why is it Unbreakable?

The key is unbreakable owing to the following features −

- The key is as long as the given message.
- The key is truly random and specially auto-generated.
- Key and plain text calculated as modulo 10/26/2.
- Each key should be used once and destroyed by both sender and receiver.
- There should be two copies of key: one with the sender and other with the receiver.

Encryption

To encrypt a letter, a user needs to write a key underneath the plaintext. The plaintext letter is placed on the top and the key letter on the left. The cross section achieved between two letters is the plain text. It is described in the example below −



Decryption

To decrypt a letter, user takes the key letter on the left and finds cipher text letter in that row. The plain text letter is placed at the top of the column where the user can find the cipher text letter.

Implementation of One Time Pad Cipher

Python includes a hacky implementation module for **one-time-pad** cipher implementation. The package name is called One-Time-Pad which includes a command line encryption tool that uses encryption mechanism similar to the one-time pad cipher algorithm.

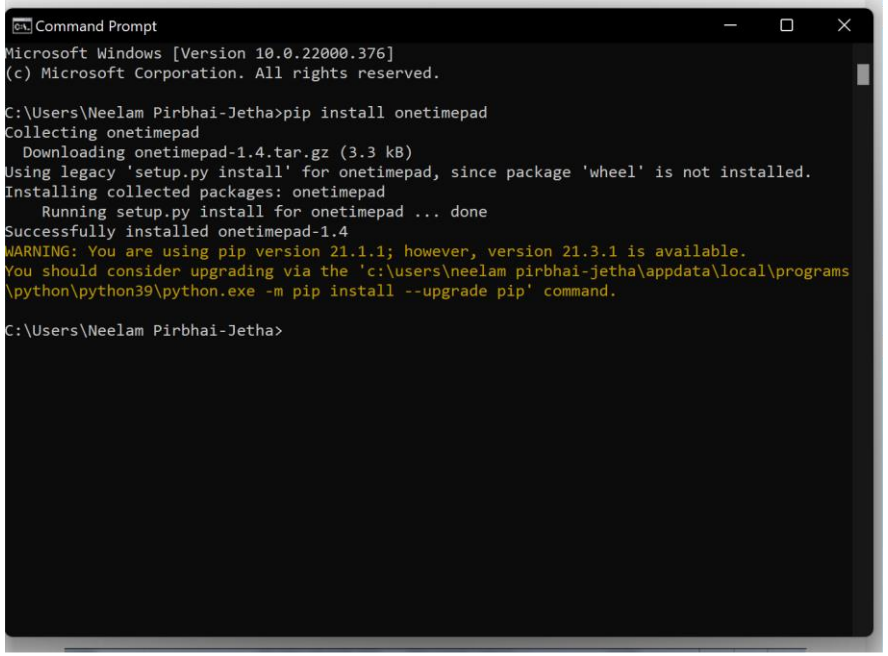
Installation

You can use the following command to install this module −

```
pip install onetimepad
```

If you wish to use it from the command-line, run the following command −

```
onetimepad
```



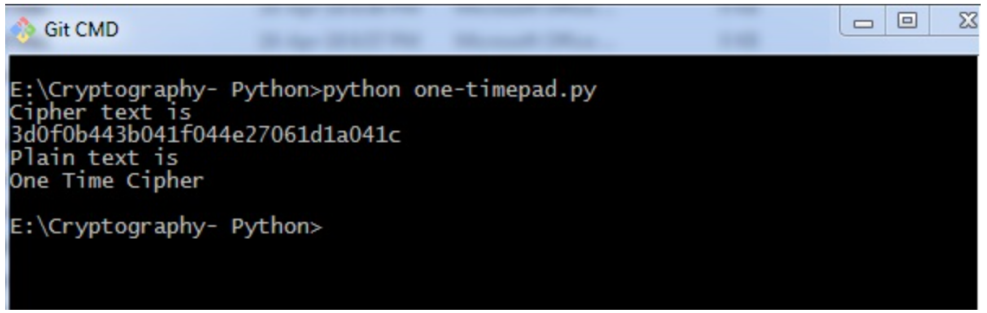
Code

The following code helps to generate a one-time pad cipher −

```
import onetimepad

cipher = onetimepad.encrypt('One Time Cipher', 'random')
print("Cipher text is ")
print(cipher)
print("Plain text is ")
msg = onetimepad.decrypt(cipher, 'random')

print(msg)
```

Output

You can observe the following output when you run the code given above −



Note − The encrypted message is very easy to crack if the length of the key is less than the length of message (plain text).

In any case, the key is not necessarily random, which makes one-time pad cipher as a worth tool.

In this chapter, let us discuss in detail about symmetric and asymmetric cryptography.

Symmetric Cryptography

In this type, the encryption and decryption process uses the same key. It is also called as **secret key cryptography**. The main features of symmetric cryptography are as follows −

- It is simpler and faster.
- The two parties exchange the key in a secure way.

Drawback

The major drawback of symmetric cryptography is that if the key is leaked to the intruder, the message can be easily changed and this is considered as a risk factor.

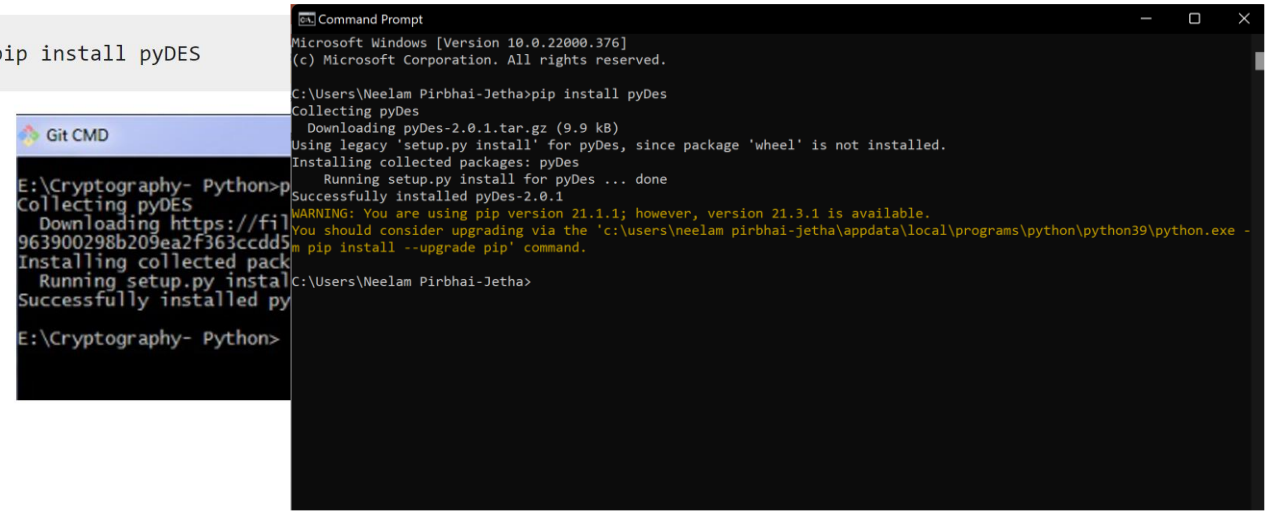
Data Encryption Standard (DES)

The most popular symmetric key algorithm is Data Encryption Standard (DES) and Python includes a package which includes the logic behind DES algorithm.

Installation

The command for installation of DES package **pyDES** in Python is −

```
pip install pyDES
```



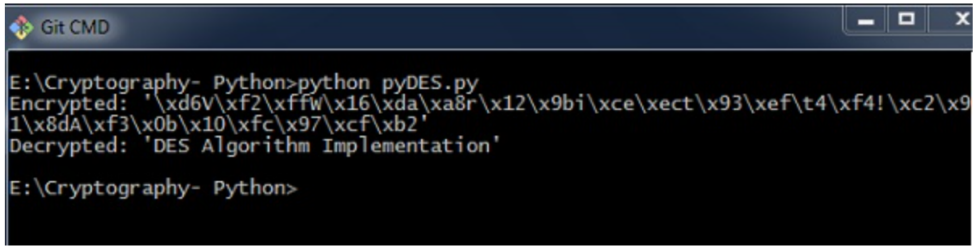
Simple program implementation of DES algorithm is as follows −

```
import pyDes

data = "DES Algorithm Implementation"
k = pyDes.des("DESCRYPT", pyDes.CBC, "\0\0\0\0\0\0\0\0", pad=None, padmode=pyDes
d = k.encrypt(data)

print "Encrypted: %r" % d
print "Decrypted: %r" % k.decrypt(d)
assert k.decrypt(d) == data
```

It calls for the variable **padmode** which fetches all the packages as per DES algorithm implementation and follows encryption and decryption in a specified manner.

Output

You can see the following output as a result of the code given above −



Asymmetric Cryptography

It is also called as **public key cryptography.** It works in the reverse way of symmetric cryptography. This implies that it requires two keys: one for encryption and other for decryption. The public key is used for encrypting and the private key is used for decrypting.

Drawback

- Due to its key length, it contributes lower encryption speed.
- Key management is crucial.

The following program code in Python illustrates the working of asymmetric cryptography using RSA algorithm and its implementation −

```
from Crypto import Random
from Crypto.PublicKey import RSA
import base64

def generate_keys():
   # key length must be a multiple of 256 and >= 1024
   modulus_length = 256*4
   privatekey = RSA.generate(modulus_length, Random.new().read)
   publickey = privatekey.publickey()
   return privatekey, publickey

def encrypt_message(a_message , publickey):
   encrypted_msg = publickey.encrypt(a_message, 32)[0]
   encoded_encrypted_msg = base64.b64encode(encrypted_msg)
   return encoded_encrypted_msg

def decrypt_message(encoded_encrypted_msg, privatekey):
   decoded_encrypted_msg = base64.b64decode(encoded_encrypted_msg)
   decoded_decrypted_msg = privatekey.decrypt(decoded_encrypted_msg)
   return decoded_decrypted_msg
```

https://www.tutorialspoint.com/cryptography_with_python/cryptography_with_python_symmetric_and_asymmetric_cryptography.htm

Understanding RSA Algorithm

RSA algorithm is a public key encryption technique and is considered as the most secure way of encryption. It was invented by Rivest, Shamir and Adleman in year 1978 and hence name **RSA** algorithm.

Algorithm

The RSA algorithm holds the following features −

- RSA algorithm is a popular exponentiation in a finite field over integers including prime numbers.
- The integers used by this method are sufficiently large making it difficult to solve.
- There are two sets of keys in this algorithm: private key and public key.

You will have to go through the following steps to work on RSA algorithm −

Step 1: Generate the RSA modulus

The initial procedure begins with selection of two prime numbers namely p and q, and then calculating their product N, as shown −

```
N=p*q
```

Here, let N be the specified large number.

Step 2: Derived Number (e)

Consider number e as a derived number which should be greater than 1 and less than (p-1) and (q-1). The primary condition will be that there should be no common factor of (p-1) and (q-1) except 1

Step 3: Public key

The specified pair of numbers **n** and **e** forms the RSA public key and it is made public.

Most secure way of encryption

Step 4: Private Key

Private Key **d** is calculated from the numbers p, q and e. The mathematical relationship between the numbers is as follows −

```
ed = 1 mod (p-1) (q-1)
```

The above formula is the basic formula for Extended Euclidean Algorithm, which takes p and q as the input parameters.

Encryption Formula

Consider a sender who sends the plain text message to someone whose public key is **(n,e).** To encrypt the plain text message in the given scenario, use the following syntax −

```
C = Pe mod n
```

Decryption Formula

The decryption process is very straightforward and includes analytics for calculation in a systematic approach. Considering receiver **C** has the private key **d**, the result modulus will be calculated as −

```
Plaintext = Cd mod n
```

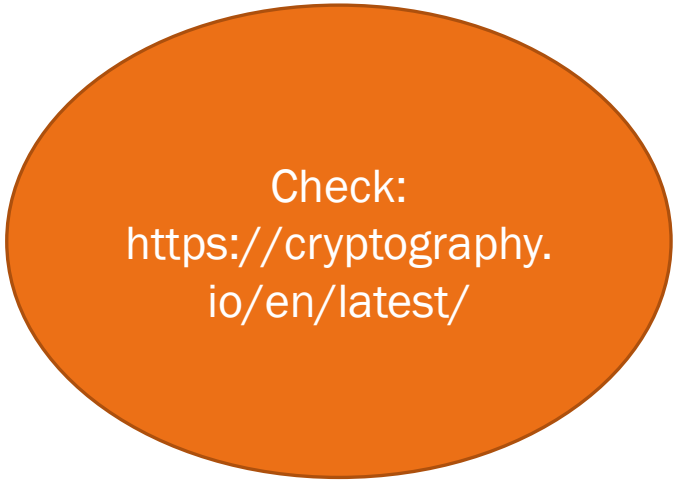
To implement RSA in Python, click on the link below for the codes:
https://www.tutorialspoint.com/cryptography_with_python/cryptography_with_python_creating_rsa_keys.htm
And
https://www.tutorialspoint.com/cryptography_with_python/cryptography_with_python_rsa_cipher_encryption.htm
And
https://www.tutorialspoint.com/cryptography_with_python/cryptography_with_python_rsa_cipher_decryption.htm

Hacking RSA cipher is possible with small prime numbers, but it is considered impossible if it is used with large numbers. The reasons which specify why it is difficult to hack RSA cipher are as follows −

- Brute force attack would not work as there are too many possible keys to work through. Also, this consumes a lot of time.
- Dictionary attack will not work in RSA algorithm as the keys are numeric and does not include any characters in it.
- Frequency analysis of the characters is very difficult to follow as a single encrypted block represents various characters.
- There are no specific mathematical tricks to hack RSA cipher.

The RSA decryption equation is −

```
M = C^d mod n
```



https://www.tutorialspoint.com/cryptography_with_python/cryptography_with_python_hacking_rsa_cipher.htm