A HYBRID CRYPTOSYSTEM BASED ON VIGENERE CIPHER AND COLUMNAR TRANPOSITION CIPHER

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Abstract

Privacy is one of the key issues addressed by information Security. Through cryptographic encryption methods, one can prevent a third party from understanding transmitted raw data over unsecured channel during signal transmission. The cryptographic methods for enhancing the security of digital contents have gained high significance in the current era. Breach of security and misuse of confidential information that has been intercepted by unauthorized parties are key problems that information security tries to solve.

This paper sets out to contribute to the general body of knowledge in the area of classical cryptography by developing a new hybrid way of encryption of plaintext. The cryptosystem performs its encryption by encrypting the plaintext using columnar transposition cipher and further using the ciphertext to encrypt the plaintext again using Vigenère cipher. At the end, cryptanalysis was performed on the ciphertext. The implementation will be done using java programming.

Keywords: Cryptography, Encryption, Vigenère, key, columnar transposition

Introduction

The widely handling of digital media for information transmission through secure and unsecured channels exposes messages sent via networks to intruders or third parties. Encryption of messages in this modern age of technology becomes necessary for ensuring that data sent via communications channels become protected and made difficult for deciphering. [1] Enormous number of transfer of data and information takes place through internet, which is considered to be most efficient though it’s definitely a public access medium. Therefore to counterpart this weakness, many researchers have come up with efficient algorithms to encrypt this information from plain text into ciphers [2].

In information security, encryption is the process of transforming information using an algorithm to make it unreadable to anyone except those possessing special knowledge, usually referred to as a key. The result of the process is encrypted information. The reverse process is referred to as decryption [3]. There two main algorithmic approaches to encryption, these are symmetric and asymmetric. Symmetric-key algorithms [4] are a class of algorithms for cryptography that use the same cryptographic keys for both encryption of plaintext and decryption of cipher text. The keys may be identical or there may be a simple transformation to go between the two keys. The keys, in practice, represent a shared secret between two or more parties that can be used to maintain a private information link [5]. This requirement that both parties have access to the secret key is one of the main drawbacks of symmetric key encryption, in comparison to public-key encryption. Typical examples of symmetric algorithms are Advanced Encryption Standard (AES), Blowfish, Triple Data Encryption Standard (3DES) and Serpent [6].

Asymmetric or Public key encryption on the other hand is an encryption method where a message encrypted with a recipient’s public key cannot be decrypted by anyone except a possessor of the matching private key, presumably, this will be the owner of that key and the person associated with the public key used. This is used for confidentiality. [7]. Typical examples of asymmetric encryption algorithms are Rivest Shamir Adleman (RSA), Diffie–Hellman key exchange protocol and Digital Signature Standard(DSS), which incorporates the Digital Signature Algorithm (DSA)

Modern day cryptography entails complex and advance mathematical algorithm are applied to encryption of text and cryptographic techniques for image encryption based on the RGB pixel displacement where pixel of images are shuffled to obtained a cipher image [8].

This research is aimed at contributing to the general body of knowledge in the area of the application of cryptography by employing a hybrid method of encryption. This method combines Vigenère cipher and columnar transposition cipher in its encryption process. The paper has the following structure: section II consist of related works, section III of the methodology, section IV The algorithm section V Implementation, section VI Results and Analysis and section VII concluded the paper.

Related Works

Caesar cipher, also known as the shift cipher, is one of the simplest and most widely known classical encryption techniques. It is a type of substitution cipher in which each letter in the plaintext is replaced by a letter some fixed number of positions down the alphabet. For example, with a shift of 3, A would be replaced by D, B would become E, and so on. The encryption step performed by a Caesar cipher is often

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incorporated as part of more complex schemes, such as the Vigenère cipher, and still has modern application in the ROT13 system. As with all single alphabet substitution ciphers, the Caesar cipher is easily broken and in modern practice offers essentially no communication security.[9]

The encryption can also be represented using modular arithmetic by first transforming the letters into numbers, according to the scheme, A = 0, B = 1... Z = 25. [10] Encryption of a letter by a shift n can be described mathematically as, [11]

En(x) = (x + n) mod 26
Decryption is performed similarly,

Dn (x) = (x - n) mod 26

The Vigenère cipher is a method of encrypting alphabetic text by using a series of different Caesar ciphers based on the letters of a keyword. It is a simple form of polyalphabetic substitution [12][13]. The Cipher spoils the statistics of a simple Caesar cipher by using multiple Caesar ciphers. The technique is named for its inventor, Blaise de Vigenère from the court of Henry III of France in the sixteenth century, and was considered unbreakable for some 300 years [14].

Vigenère can also be viewed algebraically. If the letters A–Z are taken to be the numbers 0–25, and addition is performed modulo 26, then Vigenère encryption E using the key K can be written,

\[ C_i = E_K(P_i) = (P_i + K_i) \mod 26 \]

and decryption D using the key K,

\[ P_i = D_K(C_i) = (C_i - K_i) \mod 26 \]

where, \( P = P_0\ldots P_n \) is the message, \( C = C_0\ldots C_n \) is the ciphertext and \( K = K_0\ldots K_m \) is the used key.

Friedrich Kasiski was the first to publish a successful general attack on the Vigenère cipher. Earlier attacks relied on knowledge of the plaintext, or use of a recognizable word as a key. Kasiski's method had no such dependencies. He published an account of the attack, but it's clear that there were others who were aware of it. Babbage was goaded into breaking the Vigenère cipher when John Hall Brock Thwaites submitted a “new” cipher to the Journal of the Society of the Arts. Thwaites challenged Babbage to break his cipher encoded twice, with keys of different length. Babbage succeeded in decrypting a sample, "The Vision of Sin", by

A modified form of the Vigenère cipher, the alpha-qwerty cipher extended the original 26 character Vigenère cipher to a 92 characters case sensitive cipher including digits and some other symbols commonly used in the English language and can be written from a computer keyboard. The alpha-qwerty cipher also changes the mapping sequence used in the Vigenère cipher. The mapping takes from an extended alphabet sequence to extended qwerty keyboard sequence. To decrypt the code reverse mapping takes place (compliment of encryption) that is from extended QWERTY key-

Figure 1. The Vigenère square

The algebraic description of the extended version is similar to that of the original cipher. It uses modulo 92 instead of modulo and cipher text \( C_i \) is derived using a sequence different from plain text sequence \( P_i \).

\[ C_i = E_K(P_i) = (P_i + K_i) \mod 92 \]

and decryption D,

\[ P_i = D_K(C_i) = (C_i - K_i) \mod 92 \]

where, \( P = P_0\ldots P_n \) is the message, \( C = C_0\ldots C_n \) is the ciphertext and \( K = K_0\ldots K_m \) is the used key.
Alfred Tennyson, encrypted according to the keyword "Emi-
ly", the first name of Tennyson's wife. Studies of Babbage's
notes reveal that he had used the method later published by
Kasiski [10] [17].

In cryptography, a transposition cipher is a process of en-
cryption by which the positions held by units of plaintext are
shifted according to a regular system or pattern, so that the
ciphertext constitutes a permutation of the plaintext. That is,
the order of the units is changed at the end of the shifting
process. Mathematically, a bijective function is used on the
characters' positions to encrypt and an inverse function to
decrypt. The letters themselves are kept unchanged,
which implies that the effect is only on their positions only, making
their order within the message scrambled according to some
well-defined scheme. Many transposition ciphers are done
according to a geometric design [18][19].

In a columnar transposition, the message is written out in
rows of a fixed length, and then read out again column by
column, and the columns are chosen in some scrambled or-
der. Both the width of the rows and the permutation of the
columns are usually defined by a keyword [19]. Advanced
forms of columnar encryption techniques are used for en-
cryption in a matrix representation form [20].

Procedure for single columnar transposition cipher:

1. Chose a key of a fixed length
2. Write the plain text row-by-row in rectangular form
   but with a fixed column which is equal to the cho-
   sen key.
3. Re-arrange the column into alphabetical column using
   the key as the determinant.
4. Read the message column-by-column.
5. The message read becomes the ciphertext.

Example let the key be GERMAN and the plain text be “de-
fend the east wall of the castle”

Then we obtain the following table

| G | E | R | M | A | N |
|---|---|---|---|---|---|
| d | e | f | e | n | d |
| t | h | e | e | a | s |
| t | w | a | l | l | o |
| f | t | h | e | c | a |
| s | t | l | e | x | x |

Re-arranging the above we will obtain

| A | E | G | M | N | R |
|---|---|---|---|---|---|
| n | e | d | e | d | f |

The following ciphertext will be obtained: nalc-
xehwtddtffseleedsaaxfxseahl

Cryptanalysis on both Vigenère cipher and columnar trans-
position cipher in the past shown that, there is a level of dif-
ficulty in breaking the codes. Hence a combination of both
will yield a very complex situation for the various crypto-
graphic techniques. The weakness in Vigenère cipher is that
the key is repeated throughout the encryption and that of
the columnar transposition is that, the same alphabets still re-
 mains in the ciphertext and hence creating possibility for
easy cryptanalysis.

This paper capitalized on the strengths and solved the weak-
ness in the Vigenère cipher by using the strength of the co-
lumnar transposition. In my work the key is used to encrypt
the plaintext using transposition cipher and then the resulting
ciphertext is used as a key to encrypt the plaintext using Vi-
genère cipher. This makes the new method very resistive to
cryptanalysis.

Methodology

The method employs use of both Vigenère cipher and co-
lumnar transposition cipher in its encryption process. The
ciphertext will first be operated on using columnar transposi-
tion cipher. A chosen key out of random will initiate the
transposition process. At the end of the process, the resulting
ciphertext then becomes a key for the Vigenère process.
With the encryption process, a table of Vigenère cipher was
created. The key is then used to operate on the message
which is the plaintext to produce the final ciphertext.

This process will end up making the final ciphertext more
difficult to be broken using existing cryptanalysis processes.
A software program will be written to demonstrate the effec-
tiveness of the algorithm using java programming language
and cryptanalysis will be performed on the ciphertext.

THE MATHEMATICAL ALGO-
RITHM

Let P = plaintext and let X= a character and Xp ∈ X
where $X_p \in P$

Let $K=$ key chosen out of random with a fixed length

where $X_k \in K$

For the columnar transposition:

Let $i=1,2,3\ldots m$

And $X_{p1}=$ first character of the plaintext

Let $P=X_{pi}= \begin{bmatrix} X_{p1} \ldots X_{pm} \end{bmatrix}$

Let $Y_0=$ first position of character $X_k$

Let $Y_l=$ last position of character $X_k$

Let $X_{p0i}=$ first ith position of character $X_p$ with relation to $Y_0$

Let $X_{pli}=$ last ith position of character $X_p$ with relation to $Y_l$

$Ct=$Columnar transposition

Position $X_{p0i} \rightarrow Y_0$ and $X_{pli} \rightarrow Y_l$

\[
Ct = \begin{bmatrix} Y_0 \ldots \ Y_l \\
X_{p01} \ldots X_{pl1} \\
X_{p02} \ldots X_{pl2} \\
\vdots \\
\vdots \\
X_{p0m} \ldots X_{plm}
\end{bmatrix}
\]

Let columns of $Ct$ of $P= CtPi$

Where $i=1,2,3\ldots m$ and $m=$ the last column

The ciphertext, $C_p = \{CtP_1 + CtP_2 + CtP_3 \ldots CtP_m\}$

We then let $C_p =$ the key for the Vigenère cipher

For the Vigenère cipher we have the following process:

If the letters $A–Z$ are taken to be the numbers $0–25$, and addition is performed modulo 26, then Vigenère encryption $E$ using the key $K$ can be written,

\[
C_i = E_k(M_i) = (M_i + K_i) \mod 26
\]

Thus Given $m$, a positive integer,

\[
P = C = (Z_{26})^n,
\]

and

\[
K = (X_{k1}, X_{k2} \ldots X_{km})
\]

Encryption:

\[
e_k(X_{p1}, X_{p2} \ldots X_{pm}) = (X_{p1}+X_{kn0}, X_{p2} + X_{kn1} \ldots X_{pm} + X_{kmn}) \mod 26
\]

where $i=0,1,2\ldots n$

At the end the ciphertext is then obtained as $C_i$.

### IMPLEMENTATION

The algorithm was implemented using java programming.

The plaintext is encrypted using columnar transposition first and the operated on by the Vigenère cipher.

A key of a fixed length was then chosen at random and entered into the system. The plaintext was then transformed row-by-row in rectangular form but with a fixed column which is equal to the chosen key. The columns were then re-arranged alphabetically using the key as the determinant.

The final ciphertext was then obtained by adding column-by-column into a row. The cipher text then becomes a key for the Vigenère process. With the encryption process, a table of Vigenère cipher was created. The key is then used to operate on the message which is the plaintext to produce a ciphertext. Below is the code for the encryption process. Where the user enters a key from the interface and also enters a message at the interface. The encryption is then done based on the predefined mathematical algorithm Witten above. The algorithm was demonstrated using java programming.

```java
Scanner input = new Scanner(System.in);
System.out.println("Enter the plaintext");
String plainText = input.nextLine();
plainText = plainText.toUpperCase();
```
System.out.print("Enter the key: ");
String key = input.nextLine();
key = key.toUpperCase();
String message;
String encryptedMessage;
// Letters in the x-axis
int x=0;
// Letters in the y-axis
int y=0;
message = plainText;
encryptedMessage = "";
// To set the temp as [x][y]
char temp[][]=new char [key.length()][message.length()];
char msg[] = message.toCharArray();
// To populate the array
x=0;
y=0;
// To convert the message into an array of char
for (int i=0; i< msg.length;i++)
{
  temp[x][y]=msg[i];
  if (x==(key.length()-1))
  {
    x=0;
    y=y+1;
  } // Close if
  else
  {
    x++;
  } // Close for loop
// To sort the key
char t[]=new char [key.length()];
t=key.toCharArray();
Arrays.sort(t);
for (int j=0;j<y;j++)
{
  for (int i=0;i<key.length();i++)
  {
    System.out.print(temp[i][j]);
  }
}
System.out.println();

System.out.println("output of the cipher1 "+encryptedMessage);
String Cipher1=encryptedMessage
int tableRowSize = 26;
int tableColumnSize = 26;
vignereTable[][] = new int[26][26];
for (int rows = 0; rows < tableRowSize; rows++){
  for (int columns = 0; columns < tableColumnSize; columns++){
    vignereTable[rows][columns] = (rows + columns) % 26;
  }
}
String plainText = message;
String key1 = Cipher1;
String cipherText = "";
int keyIndex = 0;
for (int ptextIndex = 0; ptextIndex < plainText.length(); ptextIndex++){
  char pChar = plainText.charAt(ptextIndex);
  int asciiVal = (int) pChar;
  if (pChar == ' ')
  {
    cipherText += pChar;
    continue;
  }
  if (asciiVal < 65 || asciiVal > 90)
  {
    cipherText += pChar;
    continue;
  }
  int basicPlainTextValue = ((int) pChar) - 65;
  char kChar = key.charAt(keyIndex);
  kChar+=1;
  int basicKeyValue = ((int) kChar ) - 65;
  int tableEntry = vignereTable[basicPlainTextValue][basicKeyValue];
  char cChar = (char) (tableEntry + 65);
  cipherText += cChar;
  if (keyIndex == key1.length())
  {
    keyIndex = 0;
  }
}
System.out.println(" Final ciphertext is "+cipherText);

Results and Analysis

The program written was used to encrypt a message and the result was analyzed by various methods of cryptanalysis.
The plain text = “IN THE FOREST THERE ARE MANY TREES WITH THE SAME HEIGHT”
The keyword was = “TRUE”

After applying the transposition cipher the result, below was obtained the padded character was the same as the key.

The Cipher1= HRTEMTSHHTNFSERNEIHMITEE-HAARWTAEOTREYETEEGT

Using the above as a key to encrypt the plaintext with the Vigenère cipher yielded the following below.

Final ciphertext= PEMLQGYWZAMUJIREI-UHZGMZHIZWIKDMHILTAXYIGKAX

From the analysis the index of coincidence (IC) of the ciphertext was calculated to be 0.0501. For a normal English text of alphabet of A-Z, the Variance is normally 14.50603 and the standard deviation of 3.80868. The results indicated there is a larger deviation the ciphertext.

Figure 2. The frequency graph of ciphertext

Figure 3. The Percentage of alphabet frequency within the ciphertext

The figure 2 represent the monogram frequency graph of the ciphertext and figure 3 is the percentage of each alphabet within the ciphertext.

Below is the statistical and cryptanalysis results performed on the ciphertext.

Table 1. Cryptanalysis of ciphertext

| Cryptanalysis          | Ciphertext |
|------------------------|------------|
| Incidence Coincidence  | 0.0501     |
| Keyword Length         | 1          |
| Chi-squared statistic against English distribution | 655.8480 |
| Chi-squared statistic against uniform distribution | 38.7778 |
| Statistical data: Variance | 33.9517 |
| Statistical data: Standard deviation | 5.8268 |
| Present alphabet Entropy | 3.3035 |

Conclusion

From the analysis the index of coincidence (IC) between a string and that same string with its first few characters deleted (sometimes called a shift of the string) was obtained for A to be 0.0501 which indicates a stronger approach of the new algorithm. For a normal English text of alphabet of A-Z, the Variance is normally 14.50603 and the standard deviation of 3.80868. But from the results of the cryptanalysis, it was clearly recognized that there was a large deviation and variation from the normal observation. This indicated the strength in the new system is very high due to its hybrid nature.

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