Image Encryption Using RSA

Major project report submitted in partial fulfilment of the requirement for the degree of Bachelor of Technology

in

Computer Science Engineering & Information Technology

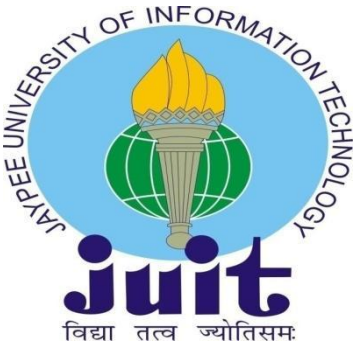
By

SALIL VERMA (191514)

SAHIL (191443)

UNDER THE SUPERVISION OF

Dr. Pankaj Dhiman



Department of Computer Science & Engineering and Information Technology

Jaypee University of Information Technology, Waknaghat, 173234, Himachal Pradesh, INDIA

CERTIFICATE

Candidate's Declaration

I hereby declare that the work presented in this report entitled " **Image Encryption using RSA**" in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Computer Science and Engineering/Information Technology submitted in the department of Computer Science & Engineering and Information Technology, Jaypee University of Information Technology Waknaghat is an authentic record of my own work carried out over a period from August 2022 to December 2022 under the supervision of **Dr. Pankaj Dhiman (Assistant Professor SG with CSE & IT)**. I also authenticate that I have carried out the above mentioned project work under the proficiency stream **Information Security**.

The matter embodied in the report has not been submitted for the award of any other degree or diploma.

Sahil
(191443) (……..)
Salil Verma
(191514) (……..)

This is to certify that the above statement made by the candidate is true to the best of my knowledge.

(.....)
Dr. Pankaj Dhiman
Assistant Professor (SG)
CSE & IT
Dated: 17/11/2022

PLAGIARISM CERTIFICATE

ACKNOWLEDGEMENT

Firstly, I express my heartiest thanks and gratefulness to almighty God for His divine blessing makes it possible for us to complete the project work successfully.

I am really grateful and wish my profound indebtedness to Supervisor **Dr. Pankaj Dhiman** Department of CSE Jaypee University of Information Technology, Waknaghat. Deep Knowledge & keen interest of my supervisor in the field of "**Image Security**" to carry out this project. Her endless patience, scholarly guidance, continual encouragement, constant and energetic supervision, constructive criticism, valuable advice, reading many inferior drafts and correcting them at all stages have made it possible to complete this project.

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Finally, I must acknowledge with due respect the constant support and patients of my parents.

Salil Verma (191514)
Sahil (191443)

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ABSTRACT

In today's world, secure online data transmission takes precedence over other activities. Various algorithms exist to provide the computational difficulty that makes cracking the key to identify a unique message difficult. Many researchers have applied various cryptographic algorithms for secure data transmission, and various hybrid cryptographic algorithms have been proposed to improve the level of information security. Key management plays an important role in implementing cryptographic algorithms. For this reason, we applied image encryption technology that uses a random image as a key. I used a random image as a key and encrypted another image as information using the RSA algorithm. The proposed method is compared with conventional approaches and concludes that encryption algorithms implemented using images as keys offer more security in terms of encryption and decryption times.

Chapter 01: INTRODUCTION

1.1 Introduction

Information is presented in a variety of formats, including text, images, audio, and video. Security and authentication are becoming increasingly important when transferring data over the Internet. Therefore, different researchers use large keys while implementing different encryption algorithms to increase the level of data security. The larger the key, the more sensitive the data, but the management of the key becomes a tedious task. Using images as keys instead of large format keys makes key management easier and improves information security. Encryption technology is widely used to achieve information security. Image encryption is the process of transforming the actual image into a different, secure format. As a result, the information is relatively difficult to access and destroy without the decryption key. RSA is one of the recognized public-key cryptographic algorithms that facilitates encryption and authentication of information.

There are different uses for image encryption and decryption in digital communications. Image security is often used in other areas such as medical imaging, military information multimedia structures, and telemedicine. In hospitals, finance, government, defence and other sectors, images are used as keys to provide a higher level of data protection than information is the key. Stealing personal information is an illegal duty for any kind of institution. Therefore, stronger methods of encrypting images or data are required to ensure that data is transmitted securely and cannot be easily hacked by attackers. On the receiving side, you can find the actual image after decoding. The receiving end can easily access the data or image using the private key.

Basic Terms Used in Cryptography

Plain Text: The original message that the person wants to convey to the other party is defined as plain text. In encryption, the actual message that needs to be sent to the remote station is specially named as plain text.

Cipher Text: A meaningless message that no one can understand is called a ciphertext. Encryption converts the original message into a readable message before sending the actual message.

Encryption: The process of converting plaintext into ciphertext is called encryption. Encryption uses cryptographic techniques to send confidential messages over insecure channels. The encryption process requires two things: an encryption algorithm and a key. Cryptographic Algorithm means the technology used for encryption. Encryption is done at the sender.

Decryption: The reverse encryption process is called decryption. This is the process of converting ciphertext to plaintext. In encryption, the receiver uses decryption techniques to retrieve the original message from a readable message (the ciphertext). The decryption process requires two things: a decryption algorithm and a key. A decryption algorithm describes the technique used for decryption. In general, encryption and decryption algorithms are the same.

Key: Keys can be numeric or alphanumeric text, or special symbols. Keys are used when plaintext is encrypted and ciphertext is decrypted. The choice of keys in cryptography is very important because the security of encryption algorithms directly depends on the keys.

Purpose of Cryptography

Encryption offers many security goals to ensure privacy, tamper-proofing of data, etc. It is widely used today due to the great security benefits of encryption. Below are the different goals of encryption.

Confidentiality: Information in your computer is transmitted and should only be retrieved by authorised parties and not by others.

Authentication: Information received by each system must verify the identity of the sender, whether that information is from an authorised person or a false identity.

Integrity: Only authorised parties may change submitted information. A given message cannot be changed between sender and recipient.

Non Repudiation: Prevents senders and recipients of messages from refusing forwarding.

Access Control: Only authorised parties can access the information provided.

Classification of Cryptography

Cryptography technique is used when secret messages are transferred from one party to another over a communication line.
There are two main types of cryptography:

1. **Symmetric key cryptography**
   In this type of encryption, both sender and receiver know the same secret code called key. Messages are encrypted with a key by the sender and decrypted with the same key by the recipient. Keys play a very important role in symmetric cryptography. This is because its security directly depends on the type of key, i.e. key length etc..

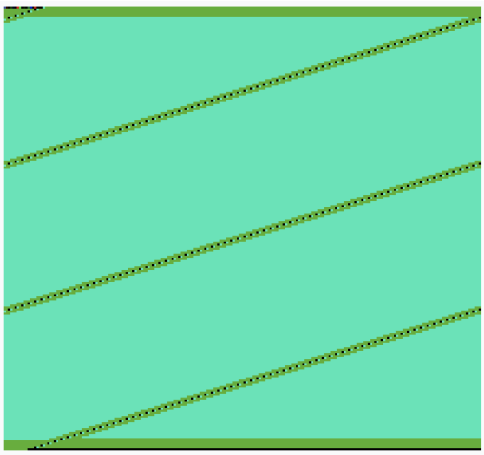
2. **Asymmetric key cryptography**
   Asymmetric key cryptography is used as a pair of encryption and decryption algorithms. In public-key cryptography, a key works with a corresponding public-private key pair.

1.2 Problem Statement

Modern age with advanced technology. Most people prefer to use the internet as their primary means of transferring data from one end to the other over the internet. There are many ways to send data over the Internet, including: Send emails, texts and images. Images are widely used in the modern world of telecommunications. However, one of the main concerns when sending data over the Internet is "security" and reliability. Data security basically means protecting data from unauthorised users and intruders. Encryption is a method of protecting information. Image coding is the technique of transforming an original image into another, less comprehensible form. No one can access the content without knowing the decryption key.

1.3 Objectives

Digital images are widely disseminated on the Internet. With the development of Internet technology, digital images containing a lot of visual information are transmitted and stored over the Internet and can be copied, manipulated, and illegally used by unauthorised users, especially in the military, commercial, and medical fields. and image security incidents can occur. Many governments, businesses and individuals are beginning to pay attention to privacy issues. Therefore, protecting your images is very important. Digital image security is an essential and difficult task over common communication channels. Various techniques are used to protect digital images, including encryption, steganography, and watermarking. These are ways to protect digital images to meet your security goals. Confidentiality, Integrity and Availability (CIA). The RSA algorithm is the foundation of cryptosystems (a set of cryptographic algorithms used for a particular security service or purpose), enables public-key cryptography, and is widely used to protect sensitive data. such as the Internet. The purpose of image encryption schemes is to obtain the highest quality hidden image to keep the information secret.



Original Image

Encrypted Image

1.4 Methodology

RSA is a cryptographic algorithm used to encrypt and decrypt data. This algorithm was developed by Ron Rivest, Adi Shamir, and Leonard Adleman in 1977. The RSA cryptosystem is also known as the public key cryptosystem. RSA is commonly used for secure data transfer. According to the RSA algorithm, encryption starts with choosing two large prime numbers and an auxiliary value as the public key. Prime numbers are kept secret. The public key is used to encrypt messages and the private key is used to decrypt messages or information. The RSA algorithm encrypts the original image and uses a different key to decrypt the image. This is illustrated in the following diagram.

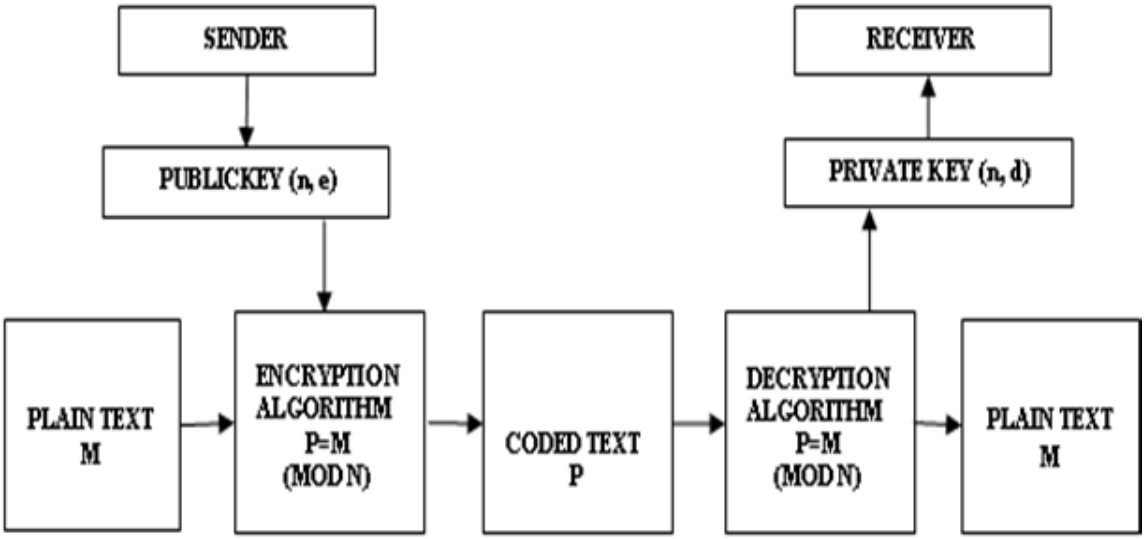


Fig 1: Methodology of RSA

1.4 Organisation

Chapter 1: Introduction

Covers the various project related things such as, introduction, Problem statement, motivation and tells us about the reasons behind the choice of this project.

Chapter 2: Literature Survey

Covers the literature surveyed as well as tells about the concepts that have been studied and understood.

Chapter 3: System Development

Covers the tools and technologies that are used. It also tells about the System Design- various design diagrams.

Chapter 4: Performance analysis

It covers the implementation of the project and the project snapshots.

Chapter 5: Conclusion

Chapter 02: LITERATURE SURVEY

Information security is a serious issue for modern online applications. When data is transmitted via online media, it must be protected against unauthorised access. Many researchers have proposed many security algorithms and hybrid approaches to information security. Faster algorithms and high-performance computing techniques provide ways to decrypt data even after security algorithms are implemented. Therefore, various researchers are interested in image security. Analysing network traffic involves managing various resources where bandwidth plays a critical role. Researchers have proposed a dynamic bandwidth management technique for on-demand services. Since images require more bandwidth than textual information, the proposed operations can be integrated with dynamic resource management technology to provide faster and more secure services. Today, mixed media data travels extensively across the web in various structures such as images, audio, video, and text. Computer communication via the Internet makes all information transparent and available to all customers. Data security is therefore an important and critical task. As data moves from one place to another over the Internet, it must be protected from unauthorised access. So the most important thing is to transfer your photos safely. There are multiple ways to store images, including encryption, watermarking, custom watermarking, cryptanalysis, and steganography.

A. **A New Image Encryption Technique Based On Combination of Block Displacement and Block Cipher Technique 2013**.

In this article, we propose a new image encryption algorithm. Algorithm security is already known to depend on key length. That is, longer key lengths always support better security features, and the proposed algorithm uses a key length of 128 bits. proposed algorithm. It would take him 2128 times to crack the key to access the cryptanalysis of the original or proposed key, which is almost impossible for a hacker. The proposed algorithm does not apply such kind of formulas, so floating point errors are not possible. Correlation coefficients and entropy values of the proposed algorithm were calculated.

B. Permutation based Image Encryption Technique, 2011

Sesha Pallavi Indrakanti and P.S.Avadhani introduced an algorithm based on random pixel replacement with the motivation of preserving image quality. He had three stages in the encryption process. Phase 1 was image encryption. Phase 2 was the key generation phase. Phase 3 was the identification process. This ensures confidentiality of colour images with less computation.

C. Image Encryption Based on Explosive Inter-pixel Displacement of the RGB Attributes of a Pixel, 2011

Proposed in 2011, this paper focused on manipulating the RGB values of pixels and shifting them according to predefined keys. A circular shift is applied to the three components of a pixel using different keys so that the R, G, and B values of one pixel are blended with the R, G, and B values of another pixel. pixel shift.

D. Image Encryption based on the RGB PIXEL Transposition and Shuffling 2013.

In this paper, a method of gradually transposing and remixing the RGB values of an image was proposed, which proved to be very effective in terms of security analysis. His additional swapping of RGB values in the image file after the RGB component shift made the image more secure against all currently available attacks.

Chapter 03: SYSTEM DEVELOPMENT

3.1 RSA Algorithm

Developed by Ron Rivest, Adi Shamir, and Leonard Adleman in 1977, the RSA algorithm is one of the most widely used asymmetric key encryption algorithms. Naming is based on the last name of the developer. This algorithm enables both information security and authentication.

Public key cryptosystems are primarily used to protect data in transit. RSA is an asymmetric key encryption algorithm that uses a public/private key pair. The sender encrypts the message with the public key and the recipient decrypts the message with the recipient's private key.

The reason for using the RSA algorithm is the main problem with factoring large integers. Security comes from the product of two large prime numbers in implementing the algorithm. The most complicated part of RSA encryption is the generation of public and private keys. Two prime numbers, p and q, are generated using the Rabin-Miller primality test algorithm. The connection between private and public keys is established by two prime numbers. Key sizes are often expressed in bits.

3.2 Steps of RSA Algorithm

The RSA algorithm involves three major steps during implementation. They are as follows:

A. Generation of key
B. Encryption
C. Decryption.

A. Key Generation

The first stage of the RSA algorithm is key generation, which includes public and private generation. As the name suggests, the public key is the public key that is visible to everyone and is used to participate in encrypting messages. Image transmissions are encrypted with your public key and can be decrypted with your private key. A key for the RSA algorithm can be created using the following steps:

1. First, we have to select the two different prime numbers that are p and q.

2. For safety, prime integers p and should be selected with the same bit-length. Prime integers are efficiently found by primality testing.

3. Then, we have to calculate the value of n that is n=pq.

4. n is the modulus that is used for equally the public and private keys. Its length is known as key length that is usually stated in bits.

5. We have to compute Euler's totient of n.
   $\phi(n)=\phi(p)\phi(q) =(p-1)(q-1) =n-(p+q-1);$
   here, $\phi$is Euler's totient function. This rate is kept private

6. Then, we have to choose an integer e that $1 <e<\phi(n)$ and

gcd(e,ϕ(n))=1; i.e., e and ϕ(n) are coprime.

e is out as a key which is kept public.

e has a brief bit-length and slight Hamming weight outcomes in more effective encryption. However, much minor e values have been published to become less locked in some settings.

7. Determine d as d≡e−1(modϕ(n)),

   i.e., d which is the modular multiplicative inverse of e(modulo ϕ(n)).

   This is performed as, solve d given by d·e≡1(mod ϕ(n)).

   That is calculated using an extended Euclidean algorithm. It uses the pseudo-code in the modular integers section; inputs a and n correspond to e and ϕ(n), respectively.

   Evaluate the value of d which is kept as the private key. Public key involves the modulus of n and e. The private key has the modulus of n and d, and it is kept secret. p,q, and ϕ(n) values are kept secret because these values can be used for calculating d.

B. Encryption

c≡me(mod n)

c=cipher text

m=plain text

e=public key

d=private key

C. Decryption

m≡cn(mod n)

c=cipher text

m=plain text

e=public key

d=private key

3.3 RSA Algorithm Illustration

This method is the traditional method used for encryption and decryption using text or numeric keys. Here I proposed the same algorithm as the previous one with the simple modification of using images as keys instead of text or numbers as keys.

The following is our proposed algorithm:

Let's take some example of RSA encryption algorithm:

Example 1:

This example shows how we can encrypt plaintext 9 using the RSA public-key encryption algorithm. This example uses prime numbers 7 and 11 to generate the public and private keys.

Explanation:

Step 1: Select two large prime numbers, p, and q.

p = 7

q = 11

Step 2: Multiply these numbers to find n = p x q, where n is called the modulus for encryption and decryption.

First, we calculate

n = p x q

n = 7 x 11

n = 77

Step 3: Choose a number e less than n, such that n is relatively prime to (p - 1) x (q -1). It means that e and (p - 1) x (q - 1) have no common factor except 1. Choose "e" such that $1<e < \varphi(n)$, e is prime to $\varphi(n)$, gcd (e, d (n)) =1.

Second, we calculate

$\varphi(n) = (p - 1) \times (q-1)$

$\varphi(n) = (7 - 1) \times (11 - 1)$

$\varphi(n) = 6 \times 10$

$\varphi(n) = 60$

Let us now choose the relative prime e of 60 as 7.

Thus the public key is <e, n> = (7, 77)

Step 4: A plaintext message m is encrypted using public key <e, n>. To find ciphertext from the plain text following formula is used to get ciphertext C.

To find ciphertext from the plain text following formula is used to get ciphertext C.

$C = m^e \bmod n$

$C = 9^7 \bmod 77$

$C = 37$

Step 5: The private key is <d, n>. To determine the private key, we use the following formula d such that:

$D_e \bmod \{(p - 1) \times (q - 1)\} = 1$

$7d \bmod 60 = 1$, which gives $d = 43$

The private key is <d, n> = (43, 77)

Step 6: A ciphertext message c is decrypted using the private key <d, n>. To calculate plain text m from the ciphertext c the following formula is used to get plain text m.

$m = c^d \bmod n$

$m = 37^{43} \bmod 77$

$m = 9$

In this example, Plain text = 9 and the ciphertext = 37

Example 2:

In an RSA cryptosystem, a particular A uses two prime numbers, 13 and 17, to generate the public and private keys. If the public of A is 35. Then the private key of A is ……?.

Explanation:

Step 1: in the first step, select two large prime numbers, p and q.

p = 13

q = 17

Step 2: Multiply these numbers to find n = p x q, where n is called the modulus for encryption and decryption.

First, we calculate

n = p x q

n = 13 x 17

n = 221

Step 3: Choose a number e less than n, such that n is relatively prime to (p - 1) x (q -1). It means that e and (p - 1) x (q - 1) have no common factor except 1. Choose "e" such that 1<e < φ (n), e is prime to φ (n), gcd (e, d (n)) =1.

Second, we calculate

φ (n) = (p - 1) x (q-1)

φ (n) = (13 - 1) x (17 - 1)

φ (n) = 12 x 16

φ (n) = 192

g.c.d (35, 192) = 1

Step 3: To determine the private key, we use the following formula to calculate the d such that:

Calculate $d = d_e \bmod \varphi(n) = 1$

$d = d \times 35 \bmod 192 = 1$

$d = (1 + k.\varphi(n))/e$ [let k =0, 1, 2, 3……]

Put k = 0

$d = (1 + 0 \times 192)/35$

$d = 1/35$

Put k = 1

$d = (1 + 1 \times 192)/35$

$d = 193/35$

Put k = 2

$d = (1 + 2 \times 192)/35$

$d = 385/35$

$d = 11$

The private key is <d, n> = (11, 221)

Hence, private key i.e. d = 11

Example 3:

A RSA cryptosystem uses two prime numbers 3 and 13 to generate the public key= 3 and the private key = 7. What is the value of cipher text for a plain text?

Explanation:

Step 1: In the first step, select two large prime numbers, p and q.

p = 3

q = 13

Step 2: Multiply these numbers to find n = p x q, where n is called the modulus for encryption and decryption.

First, we calculate

n = p x q

n = 3 x 13

n = 39

Step 3: If n = p x q, then the public key is <e, n>. A plaintext message m is encrypted using public key <e, n>. Thus the public key is <e, n> = (3, 39).

To find ciphertext from the plain text following formula is used to get ciphertext C.

$C = m^e \bmod n$

$C = 5^3 \bmod 39$

C = 125 mod 39

C = 8

Hence, the ciphertext generated from plain text, C = 8.

Example 4:

A RSA cryptosystem uses two prime numbers, 3 and 11, to generate private key = 7. What is the value of ciphertext for a plain text 5 using the RSA public-key encryption algorithm?

Explanation:

Step 1: in the first step, select two large prime numbers, p and q.

p = 3

q = 11

Step 2: Multiply these numbers to find n = p x q, where n is called the modulus for encryption and decryption.

First, we calculate

n = p x q

n = 3 x 11

n = 33

Step 3: Choose a number e less than n, such that n is relatively prime to (p - 1) x (q -1). It means that e and (p - 1) x (q - 1) have no common factor except 1. Choose "e" such that 1< e < φ (n), e is prime to φ (n), gcd (e, d (n)) =1.

Second, we calculate

φ (n) = (p - 1) x (q-1)

φ (n) = (3 - 1) x (11 - 1)

φ (n) = 2 x 10

φ (n) = 20

Step 4: To determine the public key, we use the following formula to calculate the d such that:

Calculate e x d = 1 mod φ (n)

e x 7 = 1 mod 20

e x 7 = 1 mod 20

e = (1 + k. φ (n))/ d [let k =0, 1, 2, 3……]

Put k = 0

e = (1 + 0 x 20) / 7

e = 1/7

Put k = 1

e = (1 + 1 x 20) / 7

e = 21/7

e = 3

The public key is <e, n> = (3, 33)

Hence, public key i.e. e = 3

3.4 Proposed Algorithm

The proposed algorithm considered an image as information rather than text or numbers, and another image as a key to implement the RSA algorithm.

The steps of the proposed algorithm are as follows:

1. Consider the image and find out the array format.
2. Finding the length of an array.
3. Consider the key image and find out the corresponding array format.
4. From the key image, any random prime number will be considered as key (For simplicity, we have considered the first prime number as key among the key image array).
5. Then, the same key generation, encryption, decryption process can be done as the traditional one.

3.4.1 Key generation

1. Choose two numbers p and q that are prime and distinct in nature.
2. For high security purposes, the prime numbers p and q should be randomly taken and must have the same bit-length.
3. Compute n=pq, where n is used for modulus of both the public and private keys. Its size is expressed in bits which is known as key length.
4. Compute $\phi(n)=\phi(p)\phi(q)=(p-1)(q-1) =n-(p+q-1)$, where $\phi$is Euler's totient function.
5. Choose an integer e such that $1 <e<\phi(n)$ and $\gcd(e,\phi(n)) =1$, i.e., e and $\phi(n)$ are coprime.
6. Determine das $d\equiv e-1(\text{mod } \phi(n))$;
   i.e., d is the multiplicative inverse of e(modulo $\phi(n)$).
   Solve d given $d\cdot e\equiv 1(\text{mod}\phi(n))$.

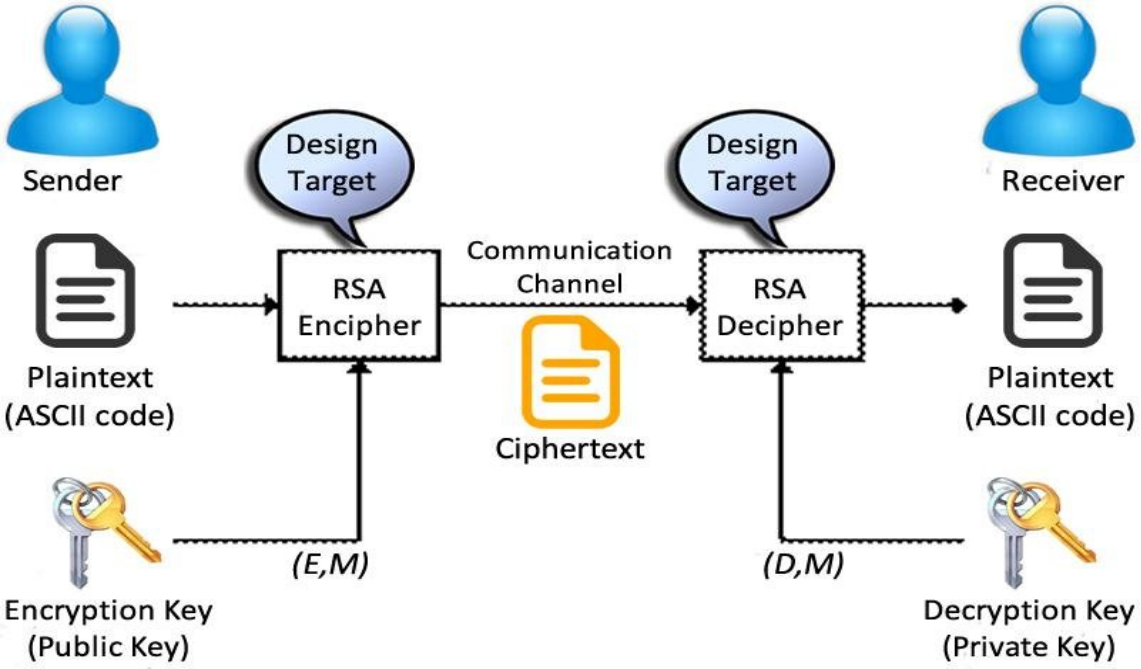


Fig 2:Encryption Decryption

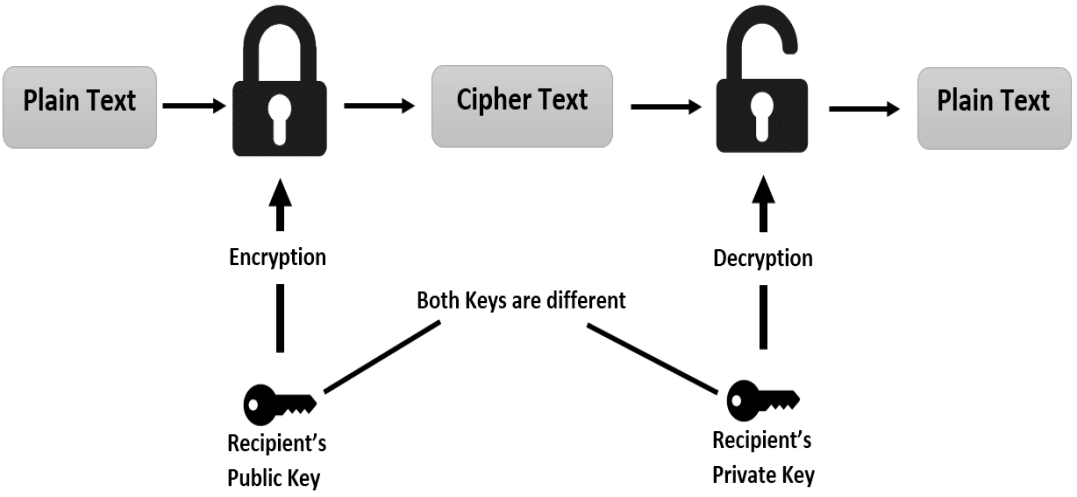


Fig 3: Plain text to Cipher text

3.5 Advantages of RSA Algorithm

- No Key Sharing: RSA encryption depends on using the receiver's public key, so you don't have to share any secret key to receive messages from others.
- Proof of Authenticity: Since the key pairs are related to each other, a receiver can't intercept the message since they won't have the correct private key to decrypt the information.
- Faster Encryption: The encryption process is faster than that of the DSA algorithm.
- Data Can't Be Modified: Data will be tamper-proof in transit since meddling with the data will alter the usage of the keys. And the private key won't be able to decrypt the information, hence alerting the receiver of manipulation.

Chapter 04: PERFORMANCE ANALYSIS

- Choose two numbers p and q that are prime and distinct in nature.
- For high security purposes, the prime numbers p and q should be randomly taken and must have the same bit-length.
- Compute n=pq, where n is used for modulus of both the public and private keys. Its size is expressed in bits which is known as key length.
- Compute $\phi(n)=\phi(p)\phi(q)=(p-1)(q-1) =n-(p+q-1)$, where $\phi$is Euler's totient function.
- Choose an integer e such that $1 <e<\phi(n)$ and $\gcd(e,\phi(n)) =1$, i.e., e and $\phi(n)$ are coprime.
- Determine das $d\equiv e-1(\text{mod } \phi(n))$;
- i.e., d is the multiplicative inverse of e(modulo $\phi(n)$).
- Solve d given $d\cdot e\equiv 1(\text{mod}\phi(n))$.

4.1 Practical Work

As mentioned earlier, there are two different primes P and Q used to generate n. Write code to generate them. As the length increases, it takes longer to generate the relative primes e and d. The following table shows the relationship between the numbers chosen for P and Q and the time allotted to generate them.

Table 1: Prime Number Time Establishment

Chosen Numbers		Time Established (seconds)
P	Q	
7	5	0.010387
11	13	0.040969
17	23	0.124453
29	53	0.964863
47	59	3.504031
113	71	18.675820
239	173	590.455964

Now we use digital images as data to be encrypted. We used an image with size 612 X 612.

PC specifications are:

System: Windows 10 Home Single Language

Processor: Intel(R) Core(TM) i3-6100U CPU @ 2.30GHz 2.30 GHz

RAM: 4 GB

System Type: 64-bit operating system, x64-based processor

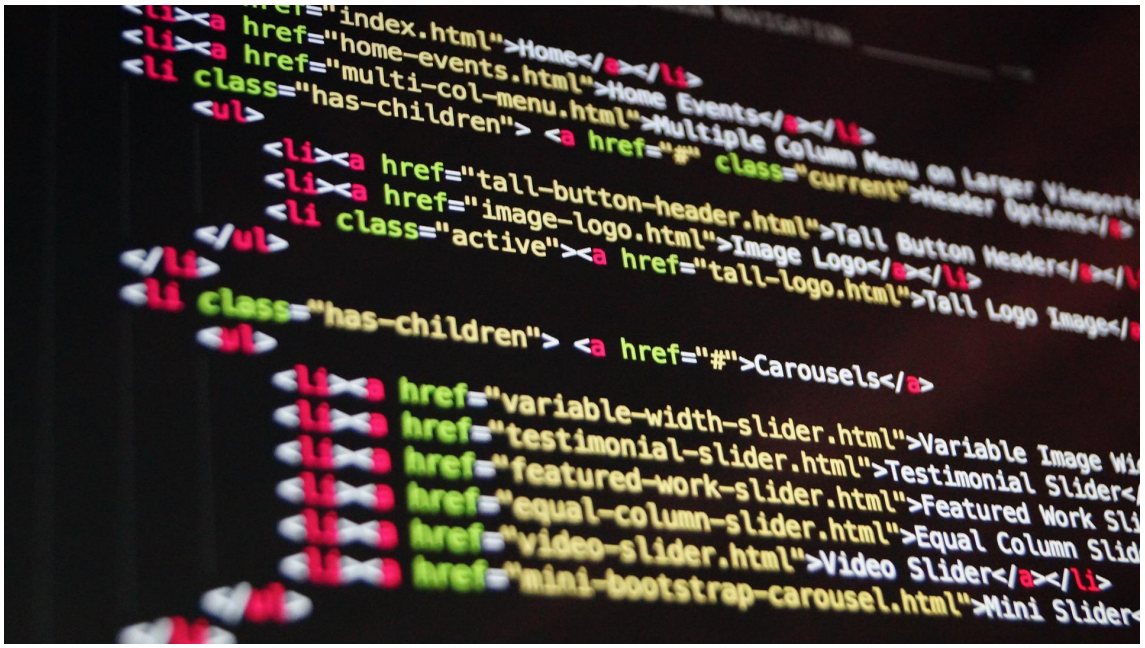


Fig 4:The image used for encryption

A relative prime e was chosen with different values and the following is the result:

Screenshots Of Implementation

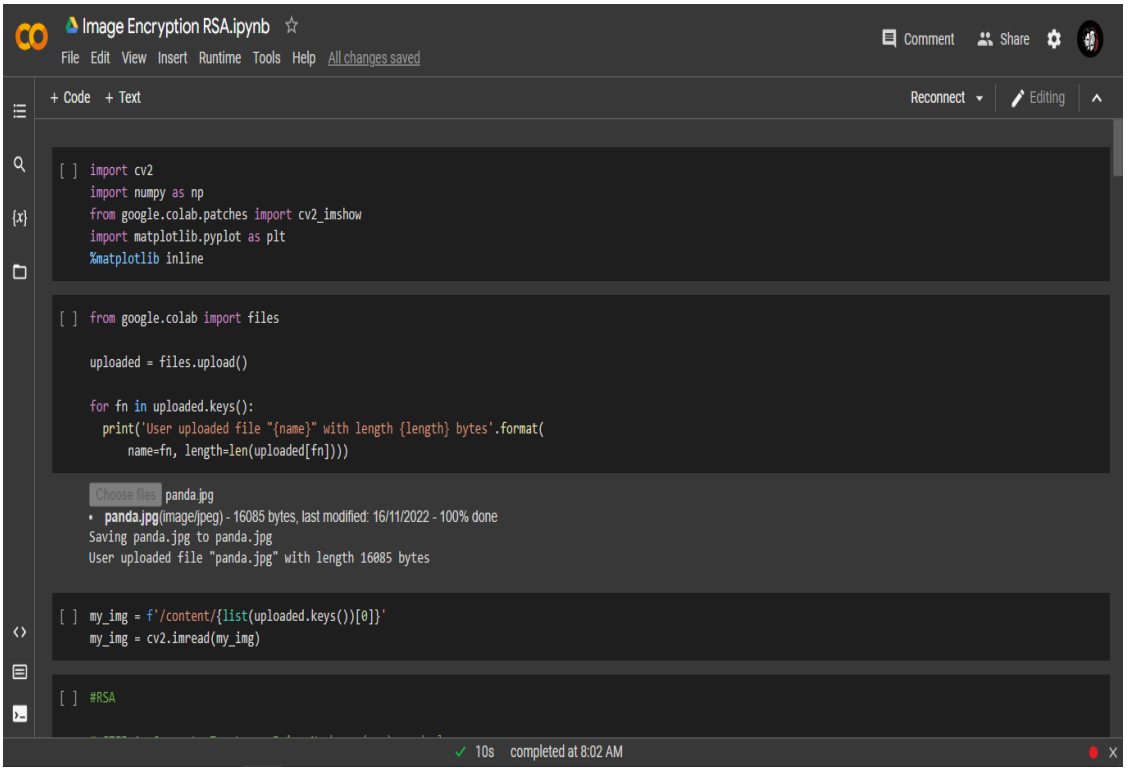


Fig 5: Implementing Code

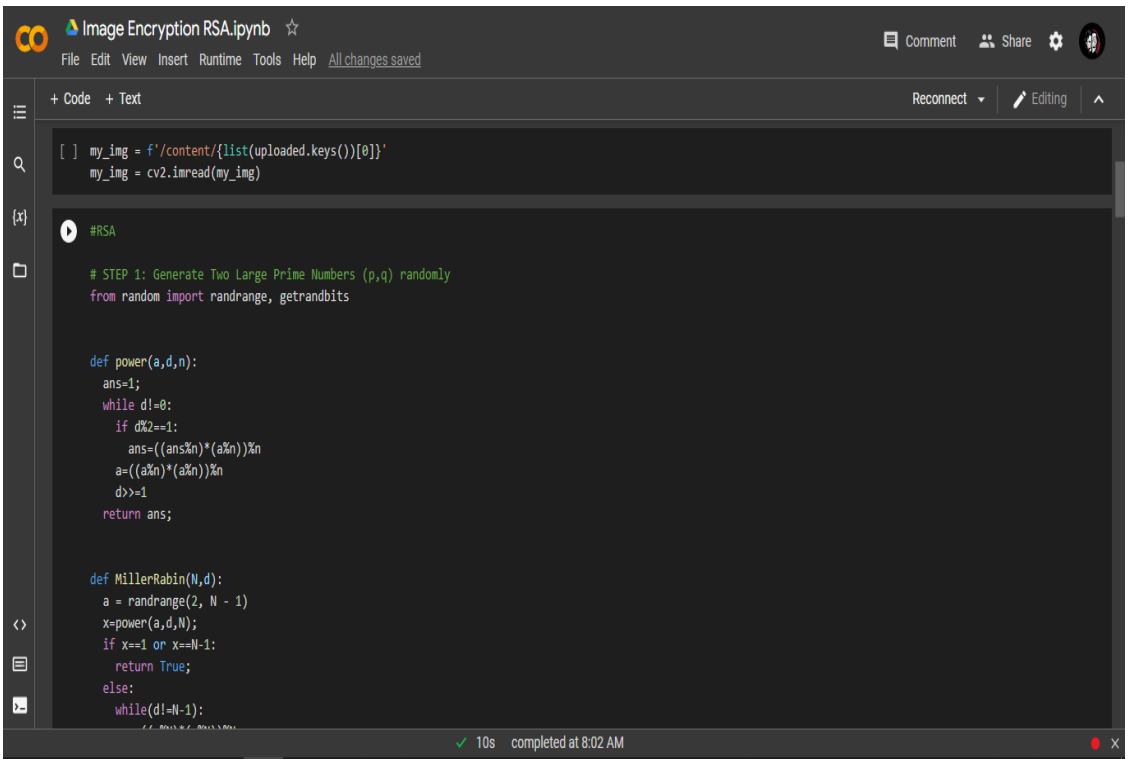


Fig 6: Implementing Code

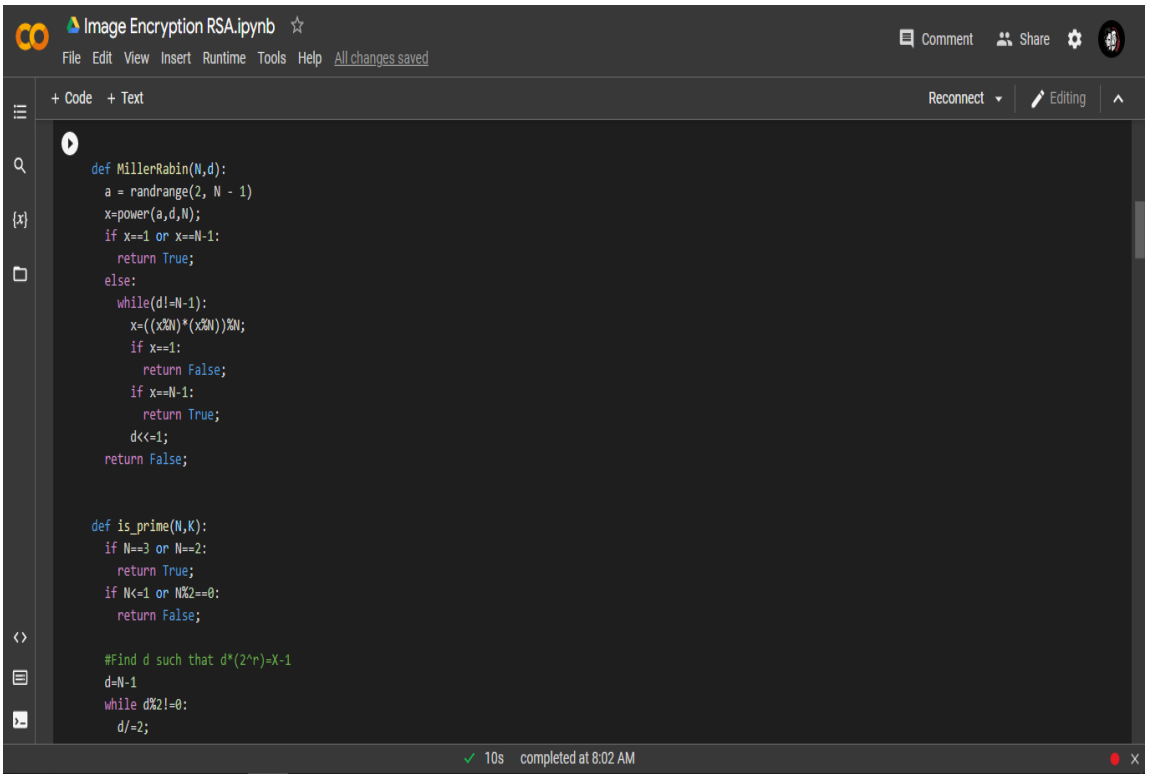


Fig 7: Implementing Code

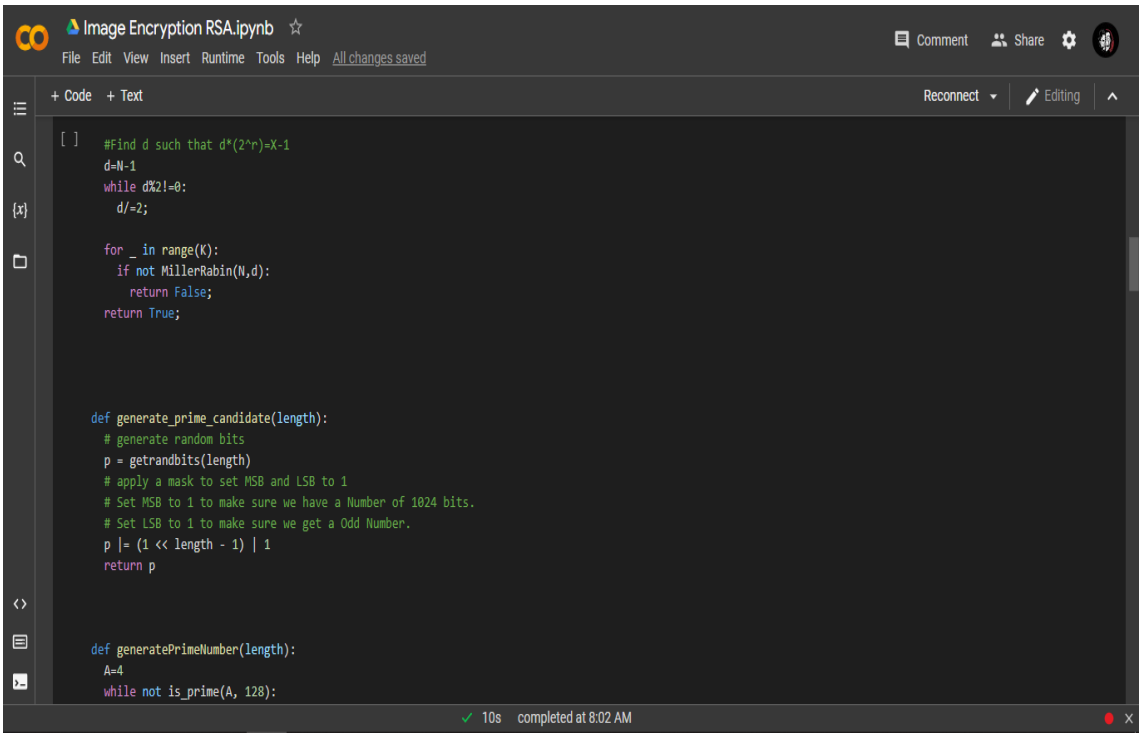


Fig 8: Implementing Code

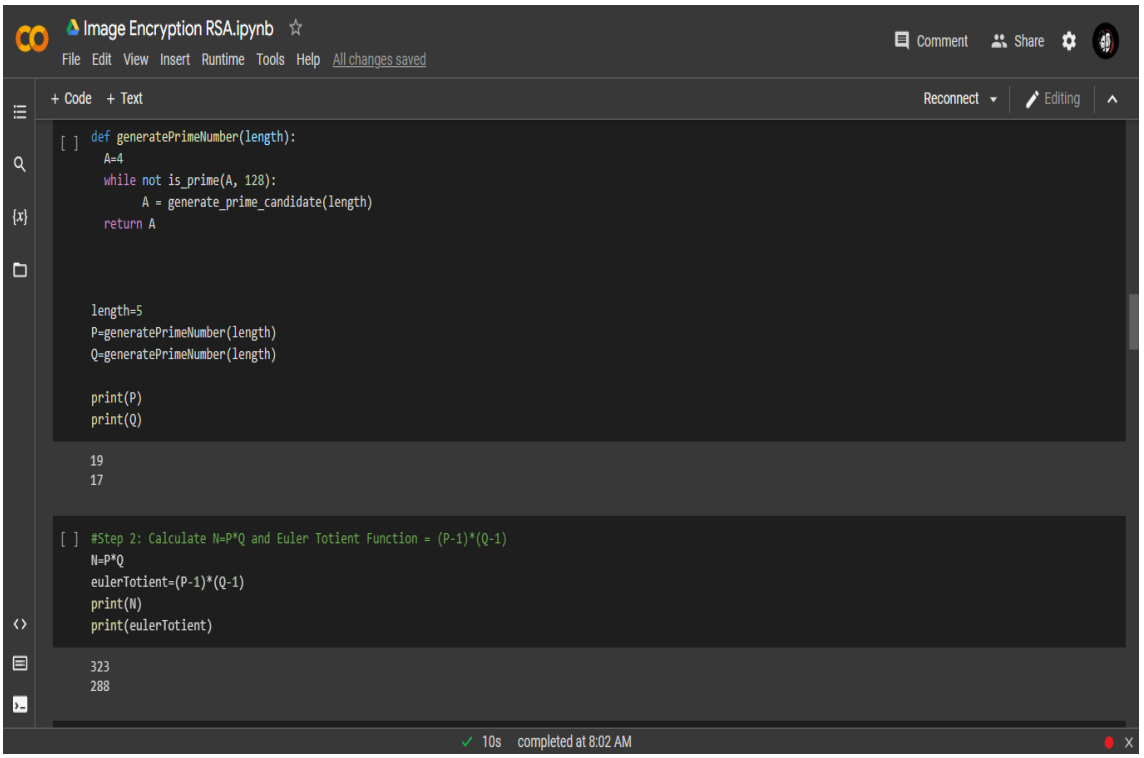


Fig 9: Implementing Code

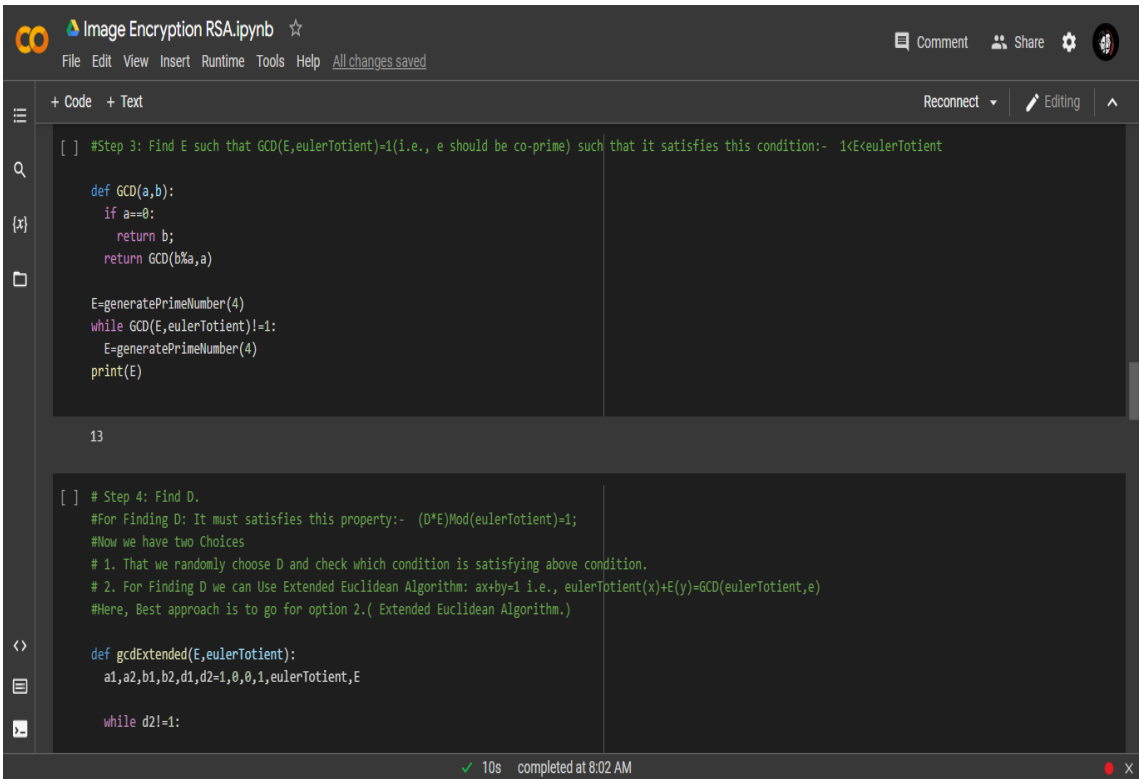


Fig 10: Implementing Code

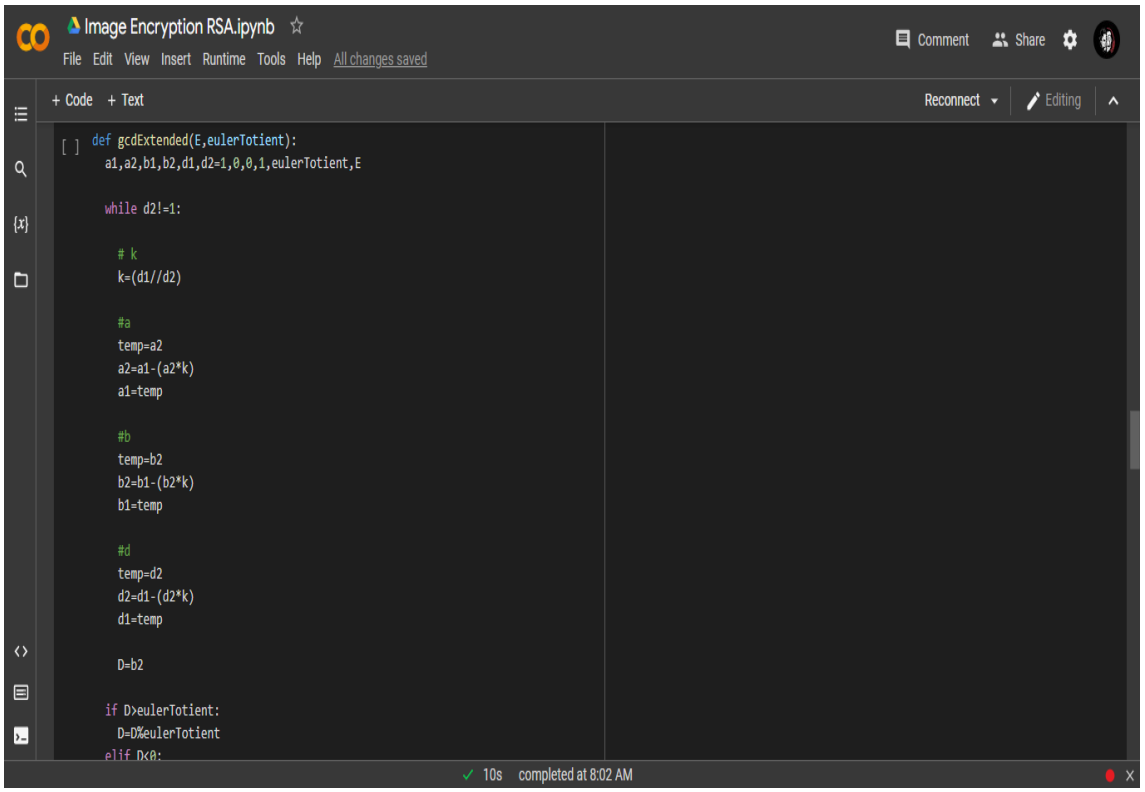


Fig 11: Implementing Code

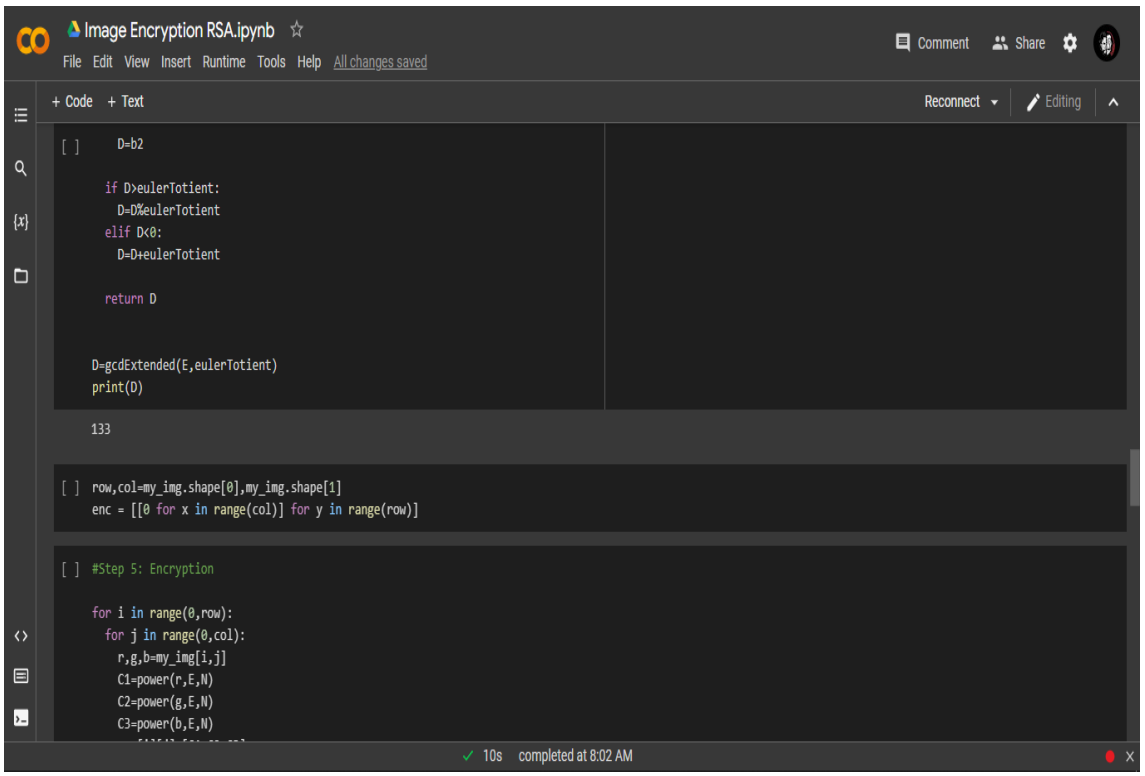


Fig 12: Implementing Code

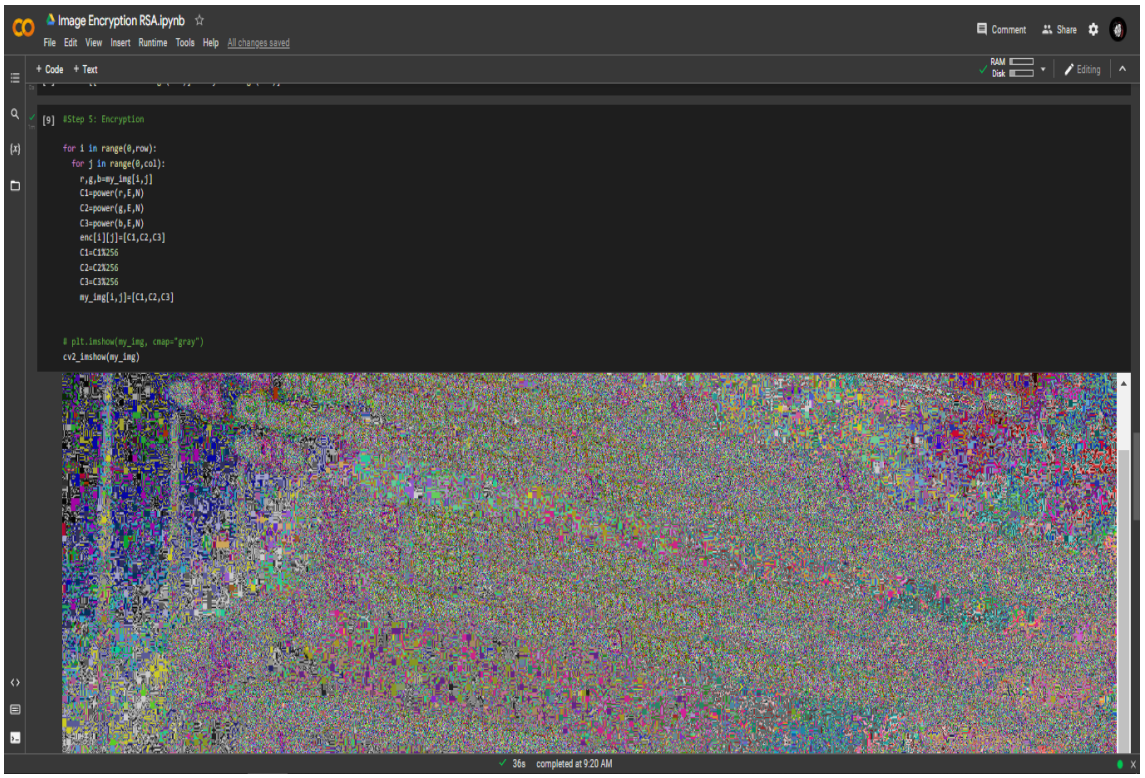


Fig 13: Implementing Code

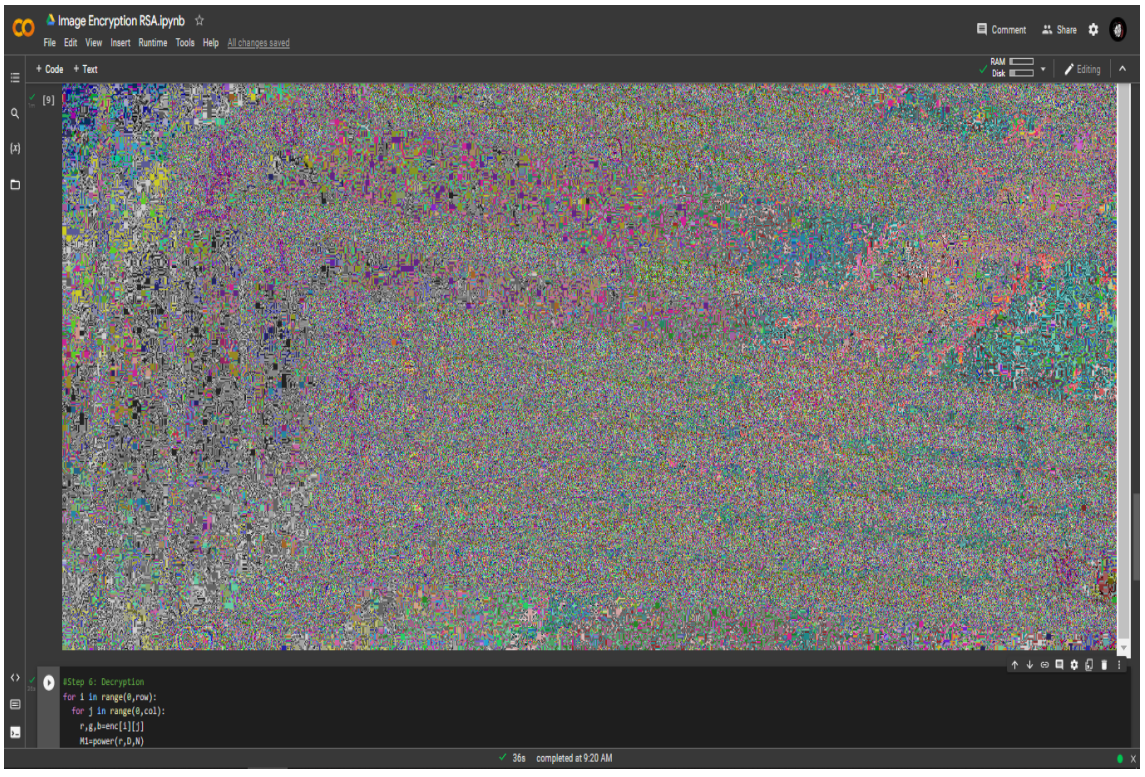


Fig 14: Encrypted Image

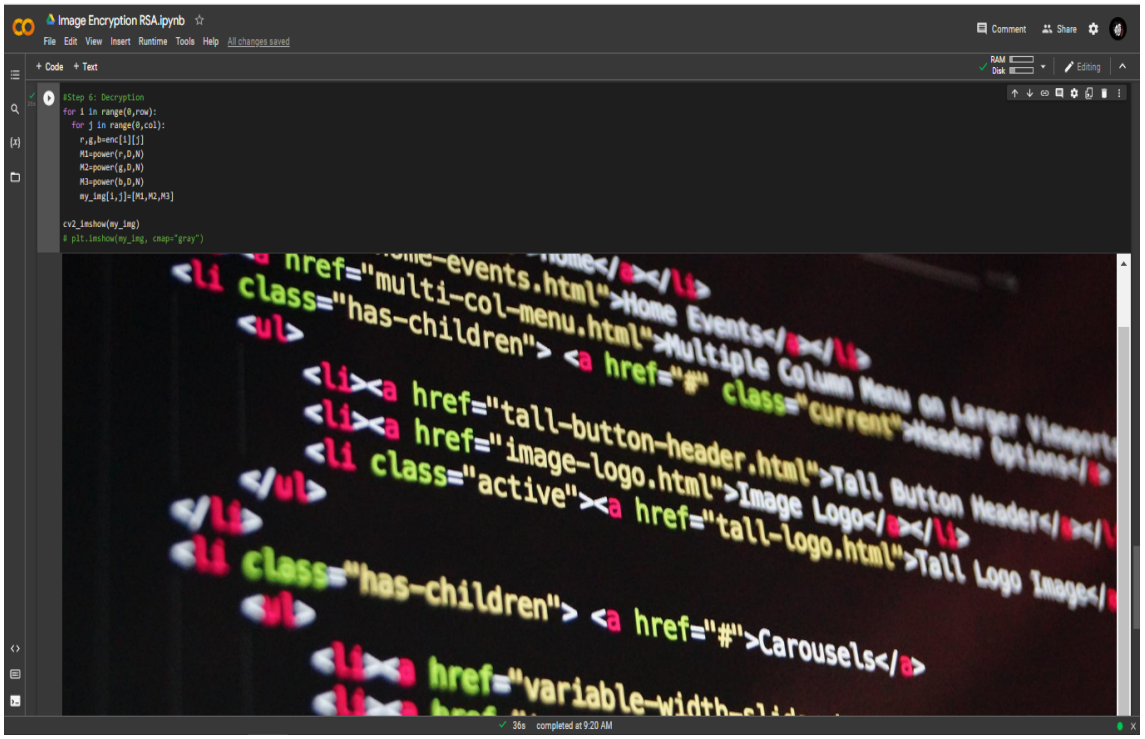


Fig 15: Decrypted Image

Outputs with different inputs

Table 2: P, Q, E, D, Time

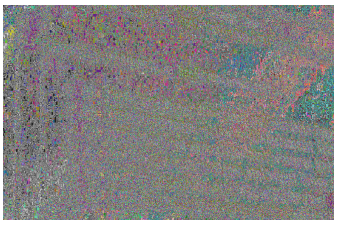
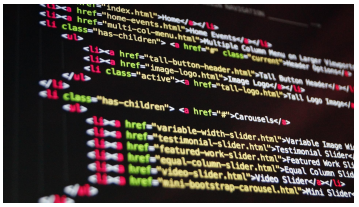
P	**239**	
Q	**173**	
E	**27**	
D	**30323**	
Time	**3.774115**	

Table 3: P, Q, E, D, Time

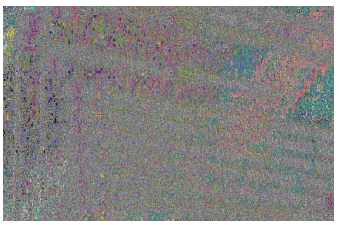
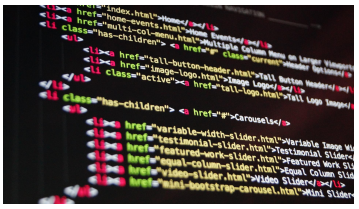
P	**113**	
Q	**71**	
E	**6469**	
D	**589**	
Time	**4.240226**	

Table 4: P, Q, E, D, Time

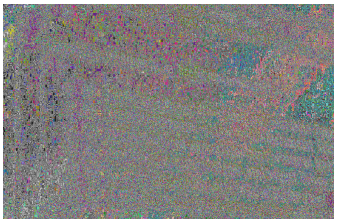
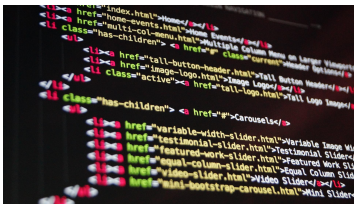
P	**47**	
Q	**59**	
E	**21**	
D	**23885**	
Time	**3.762528**	

Table 5: P, Q, E, D, Time

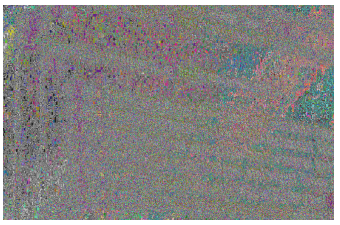
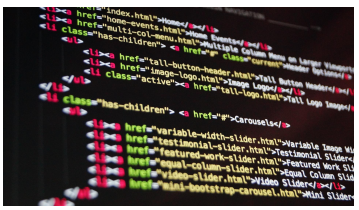
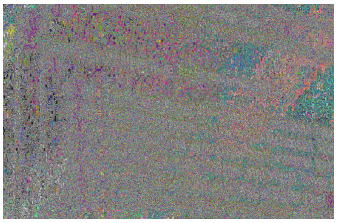
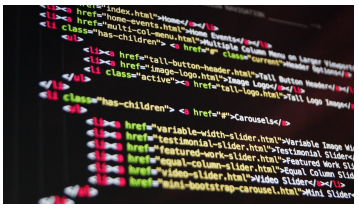
P	**17**	
Q	**23**	
E	**109**	
D	**2661**	
Time	**3.681188**	

Table 6: P, Q, E, D, Time

P	**11**	
Q	**13**	
E	**47**	
D	**743**	
Time	**3.691191**	

Chapter 05: CONCLUSIONS

5.1 Conclusions

RSA is the most commonly used encryption algorithm today, but there are certain limitations that must be considered in order for RSA to remain the best, and research needs to be done to make RSA anti-quantization . As the current
the encryption system will soon be replaced, research in the area of quantum computer-resistant quantum encryption methods is needed more than ever. Developing qCrypt isn't enough, but it's a starting point.
However, more research is needed on post-quantum cryptosystems.

5.2 Recommendations

A few recommendations should be emphasised regarding RSA encryption. RSA's strength lies in its large prime-based keys, but RSA is slow to generate keys compared to other algorithms.

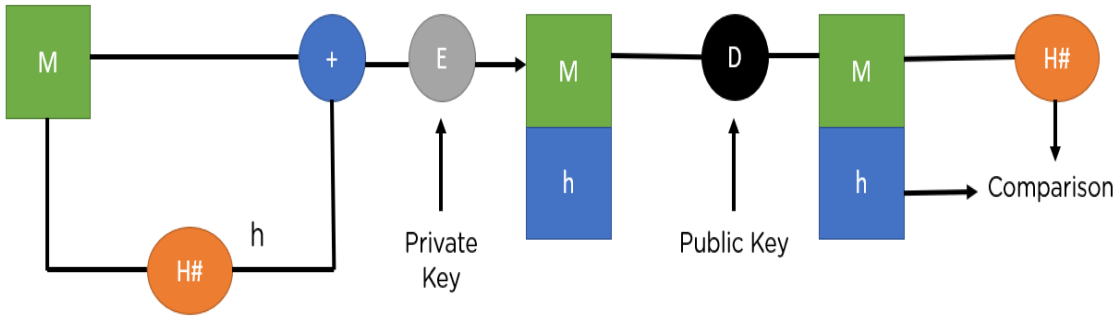
5.3 Applications

RSA encryption is generally used in combination with other encryption schemes, or for digital signatures which can validate the authenticity and integrity of a message. It cannot be used to encrypt entire messages or files, because it is less effective and more resource-heavy than symmetric-key encryption.

What Are Digital Signatures?

Digital signatures serve the purpose of authentication and verification of documents and files. This is crucial to prevent tampering during official papers' transmission and prevent digital manipulation or forgery.

They work on the public key cryptography architecture, barring one small caveat. Typically, the asymmetric key system uses a public key for encryption and a private key for decryption. However, when dealing with digital signatures, it's the opposite. The private key is used to encrypt the signature, and the public key is used to decrypt it. Since the keys work in tandem with each other, decrypting it with the public key signifies it used the correct private key to sign the document, hence authenticating the origin of the signature.



M - Plaintext

H - Hash function

h - Hash digest

'+' - Bundle both plaintext and digest

E - Encryption

D - Decryption

The image above shows the entire process, from the signing of the key to its verification. So, go through each step to understand the procedure thoroughly.

- Step 1: M denotes the original message It is first passed into a hash function denoted by H# to scramble the data before transmission.
- Step 2: It then bundles the message together with the hash digest, denoted by h, and encrypts it using the sender's private key.
- Step 3: It sends the encrypted bundle of the message and digest to the receiver, who decrypts it using the sender's public key.
- Step 4: Once decrypted, it passes the message through the same hash function (H#) to generate the hash digest again.
- Step 5: It compares the newly generated hash with the hash received in the decrypted bundle. If they match, it verifies the data integrity.

There are two industry-standard ways to implement the above methodology. They are:

1. RSA Algorithm
2. DSA Algorithm

Both have the same goal, but they approach encryption and decryption in different ways.

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APPENDICES

Code :

```
import cv2
import numpy as np
from google.colab.patches import cv2_imshow
import matplotlib.pyplot as plt
%matplotlib inline
```

```
from google.colab import files

uploaded = files.upload()

for fn in uploaded.keys():
  print('User uploaded file "{name}" with length {length} bytes'.format(
      name=fn, length=len(uploaded[fn])))
```

```
my_img = f'/content/{list(uploaded.keys())[0]}'
my_img = cv2.imread(my_img)
```

```
#RSA

# STEP 1: Generate Two Large Prime Numbers (p,q) randomly
from random import randrange, getrandbits



def power(a,d,n):
  ans=1;
  while d!=0:
    if d%2==1:
      ans=((ans%n)*(a%n))%n
    a=((a%n)*(a%n))%n
```

```
   d>>=1
 return ans;
def MillerRabin(N,d):
 a = randrange(2, N - 1)
 x=power(a,d,N);
 if x==1 or x==N-1:
   return True;
 else:
   while(d!=N-1):
     x=((x%N)*(x%N))%N;
     if x==1:
       return False;
     if x==N-1:
       return True;
     d<<=1;
 return False;



def is_prime(N,K):
 if N==3 or N==2:
   return True;
 if N<=1 or N%2==0:
   return False;

 #Find d such that d*(2^r)=X-1
 d=N-1
 while d%2!=0:
   d/=2;

 for _ in range(K):
   if not MillerRabin(N,d):
     return False;
 return True;




def generate_prime_candidate(length):
```

```
 # generate random bits
 p = getrandbits(length)
 # apply a mask to set MSB and LSB to 1
 # Set MSB to 1 to make sure we have a Number of 1024 bits.
 # Set LSB to 1 to make sure we get a Odd Number.
 p |= (1 << length - 1) | 1
 return p
def generatePrimeNumber(length):
 A=4
 while not is_prime(A, 128):
       A = generate_prime_candidate(length)
 return A



length=5
P=generatePrimeNumber(length)
Q=generatePrimeNumber(length)

print(P)
print(Q)
```

```
#Step 2: Calculate N=P*Q and Euler Totient Function = (P-1)*(Q-1)
N=P*Q
eulerTotient=(P-1)*(Q-1)
print(N)
print(eulerTotient)
```

```
#Step 3: Find E such that GCD(E,eulerTotient)=1(i.e., e should be co-prime) such that it satisfies this condition:-  1<E<eulerTotient

def GCD(a,b):
 if a==0:
   return b;
 return GCD(b%a,a)
```

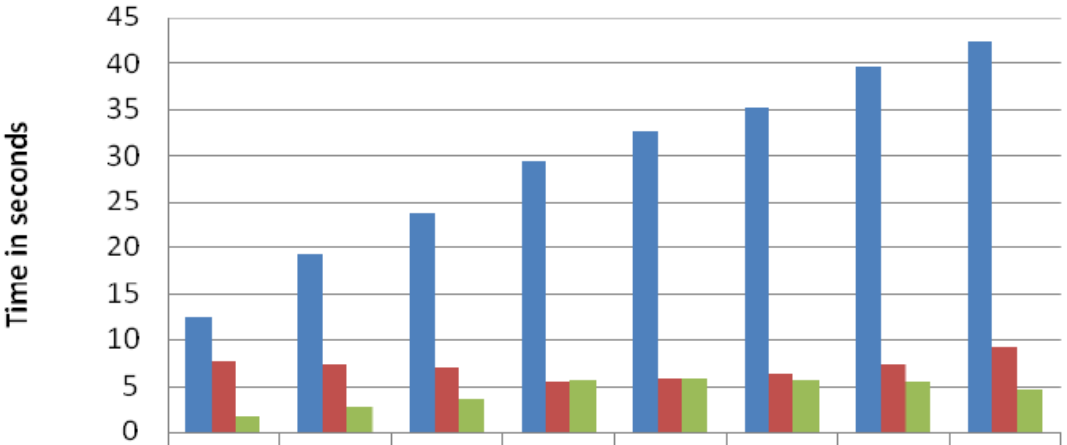
```
E=generatePrimeNumber(4)
while GCD(E,eulerTotient)!=1:
  E=generatePrimeNumber(4)
print(E)
```

```
# Step 4: Find D.
#For Finding D: It must satisfies this property:-  (D*E)Mod(eulerTotient)=1;
#Now we have two Choices
# 1. We randomly choose D and check which condition satisfies the above condition.
# 2. For Finding D we can Use Extended Euclidean Algorithm: ax+by=1 i.e.,
eulerTotient(x)+E(y)=GCD(eulerTotient,e)
#Here, Best approach is to go for option 2.( Extended Euclidean Algorithm.)

def gcdExtended(E,eulerTotient):
  a1,a2,b1,b2,d1,d2=1,0,0,1,eulerTotient,E

  while d2!=1:

    # k
    k=(d1//d2)

    #a
    temp=a2
    a2=a1-(a2*k)
    a1=temp

    #b
    temp=b2
    b2=b1-(b2*k)
    b1=temp

    #d
    temp=d2
```

```
    d2=d1-(d2*k)
    d1=temp

    D=b2

  if D>eulerTotient:
    D=D%eulerTotient
  elif D<0:
    D=D+eulerTotient

  return D

D=gcdExtended(E,eulerTotient)
print(D)
row,col=my_img.shape[0],my_img.shape[1]
enc = [[0 for x in range(col)] for y in range(row)]
```

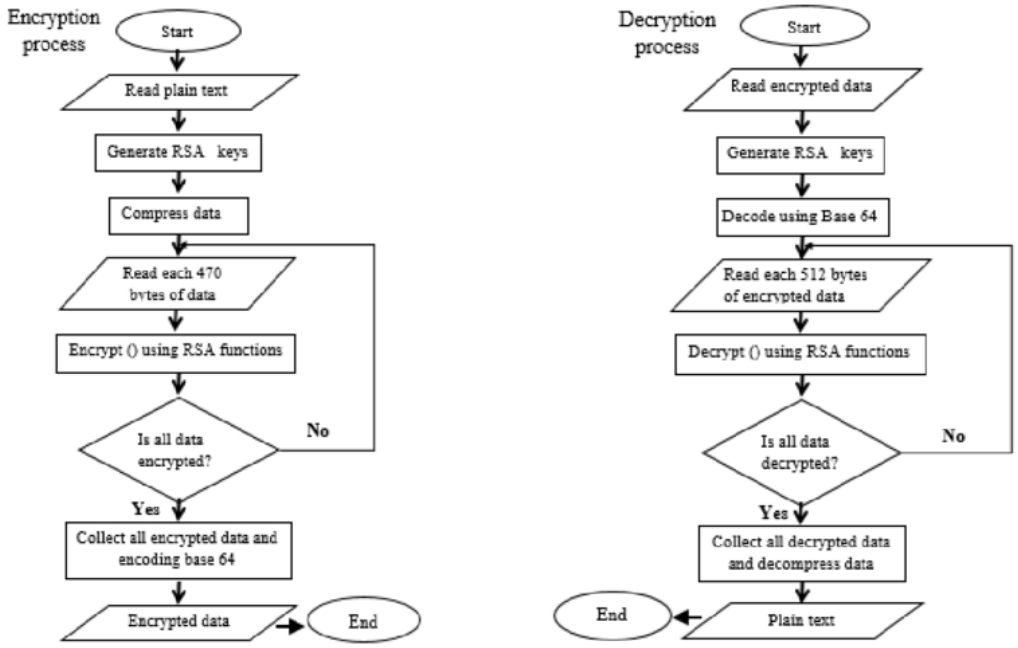
```
#Step 5: Encryption

for i in range(0,row):
  for j in range(0,col):
    r,g,b=my_img[i,j]
    C1=power(r,E,N)
    C2=power(g,E,N)
    C3=power(b,E,N)
    enc[i][j]=[C1,C2,C3]
    C1=C1%256
    C2=C2%256
    C3=C3%256
    my_img[i,j]=[C1,C2,C3]



# plt.imshow(my_img, cmap="gray")
cv2_imshow(my_img)
```

```
#Step 6: Decryption
for i in range(0,row):
  for j in range(0,col):
    r,g,b=enc[i][j]
    M1=power(r,D,N)
    M2=power(g,D,N)
    M3=power(b,D,N)
    my_img[i,j]=[M1,M2,M3]

cv2_imshow(my_img)
# plt.imshow(my_img, cmap="gray")
```

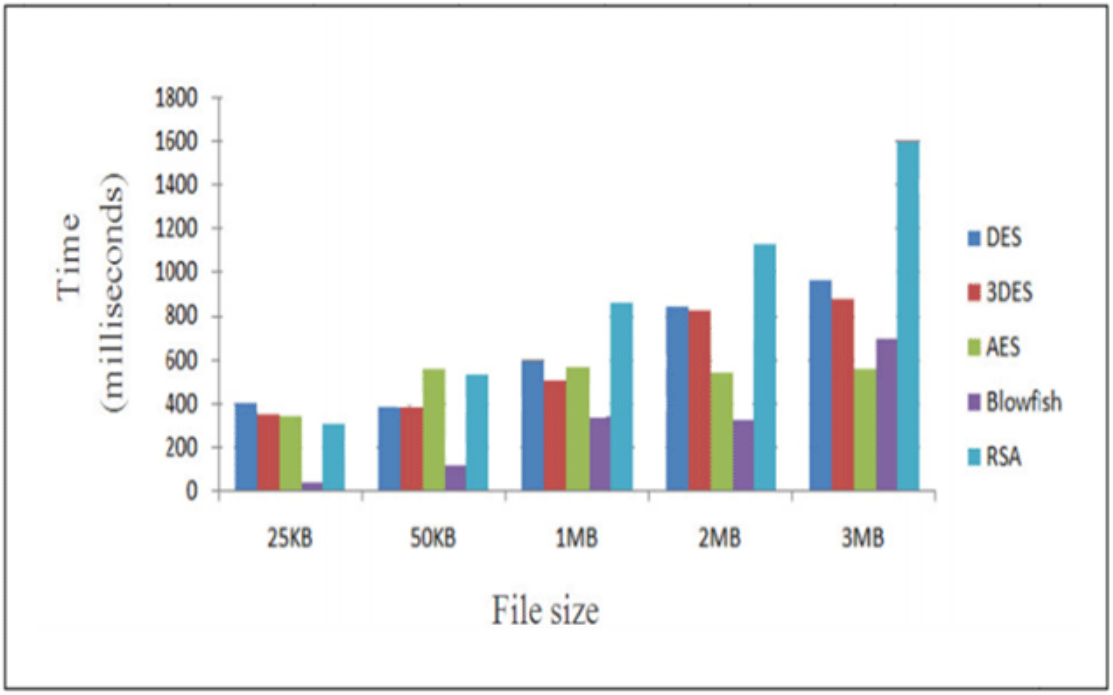


	256	512	1024	2048	4096	8192	16392	32784
CPU RSA	12.56	19.14	23.6	29.33	32.64	35.16	39.66	42.37
GPU RSA	7.56	7.25	6.86	5.38	5.68	6.27	7.21	9.25
Speedup	1.66	2.65	3.44	5.51	5.74	5.6	5.5	4.58

Graph 1:Graph showing effect of data input on CPU-RSA and GPU-RSA along with the Speedup



Graph 2:Flowchart-of-RSA-encryption-and-decryption-operations



Graph 3:Graph showing various encryption methods with time