# "Evolution of Coding Techniques: From Morse code to Matrix-Based Cryptography for Secure Communication"

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**Abstract**: This paper investigates different coding and decoding techniques, from classic methods such as Morse code to more sophisticated methods using matrix multiplication and inversion. The simplicity and effectiveness of Morse code are being evaluated as a reliable form of basic communication, especially in low-tech environments. Yet, its basic nature also constrains its safety in contemporary uses. On the other hand, the article explores the application of matrix multiplication for encrypting messages, converting information into a safe form through mathematical procedures. The decryption procedure, which involves accurately calculating the inverse matrix, introduces a strong level of protection, rendering it an effective tool in cryptography. By extensively comparing these methods, the paper showcases how coding techniques have evolved from basic to advanced, mirroring the increasing need for secure communication in the digital age. The results highlight the significance of choosing suitable encoding and decoding techniques according to the specific requirements of the communication, be it for simplicity, speed, or security.

KEY WORDS: Coding, Decoding, Morse code, Matrices

Why I chose this topic:

## 1. Introduction:

The common concept of coding and decoding to the forms of changing over data from one organize into another (coding) and after that changing over it back to its unique frame (translating). This concept is essential in different areas, such as communication, computing, information handling, and phonetics.

- Coding Definition: Coding is the method of transforming information or data into a distinctive arrange employing a particular strategy or calculation. This prepare is regularly done to plan the information for transmission, capacity, or handling.
  Examples:
  1. Content Encoding: Changing over characters into parallel information utilizing designs like ASCII or UTF-8.
  2. Encryption: Changing over plain content into a ciphertext to ensure the data (e.g., utilizing calculations like AES or RSA).
  3. Information Compression: Decreasing the measure of information for capacity or transmission (e.g., using ZIP or MP3 groups).
- Decoding: Decoding is the method of changing over coded or encoded information back into its unique organize. This permits the data to be caught on or handled as planning.
  Examples:
  1. Content Interpreting: Changing over twofold information back into discernable content.
  2. Unscrambling: Changing over cipher text back into the initial plain content.
  3. Information Decompression: Growing compressed information back to its original measure and organize.
- Applications
  1. Communication: In advanced communication, information is regularly encoded to guarantee that it can be transmitted proficiently and safely. At the receiver's conclusion, the information is decoded to its unique frame.
  2. Computing: In computers, various forms of encoding (e.g., machine code) are utilized to permit the processor to execute enlightening. Interpreting is vital for deciphering those enlightening.
  3. Multi media: Sound and video records are encoded to diminish record measure for capacity or gushing. Playback gadgets translate the records to render the media appropriately.
     Significance: Coding and Decoding are basic for guaranteeing that information remains intaglio, secure, and usable all through its travel from creation to end-user. Whether in computing, communication, or information capacity, these forms play a vital part in present day innovation.

## 2. Computer Programming:

Computer programming is the art of writing instructions for a computer. These instructions are called “programs.” As “smart” as they seem to the layperson, computers can’t do anything on their own. Everything a computer does is the result of programs people develop to solve problems, meet needs, or achieve goals.

Coding is a combination of sequences that you give to your computer for it to perform various tasks. What excites me about coding is how a random sequence of characters can create multi million worth of websites and applications. It is a way to communicate with your machines. Coding plays a huge impact on our day to day lives. Traffic lights, Calculators, smartTV and even some cars use internal coding. All the top running businesses around the globe require an application that can run in as many platforms as possible, which is again only possible because of coding. Programming is more fun and astonishingly useful as it build your creativity and creates new career doors for those passionate about it. Learning to code has been an empowering experience for me. As it helped me create things that once lived in my imagination.

It wouldn’t be easy to imagine things we use today that do not rely either fully or partially on software in one form or another. Code powers the world we live in today. Coding has a widespread use in multiple areas such as automation of repetitive tasks, software development, complex problem solving, data management, web development, and innovation of new technologies such as artificial intelligence and machine learning. A SaaS application, smartphone apps, desktop productivity tools, an apple watch, and even microwave and washing machines rely on code written by software programmers in order to operate. Even when jobs of repetitive nature would be replaced by more strategic jobs as a result of widespread automation, coders would ultimately control what is to be automated and code the machines accordingly. In the next phase of AI evolution, when machines learn and begin to “code” themselves, humans will create and programme the next generation of artificial intelligence. Hence coding is going to stay forever and remain as important as it is today, if not more.

Since computers do not communicate like humans, coding acts as a translator. Code converts human input into numerical sequences that computers understand. Once computers receive these messages, they complete assigned tasks such as changing font colors or centering an image.

## 3. Coding Decoding in Different Sectors:

A. CODING IN MILITARY SECTOR

Computer systems are a critical component in the Military. Computer programming principles implemented today influence how technologies, such as 3D printing and artificial intelligence, will support future Military operations. Computer programmers and developers write, analyze, design, and develop programs that are critical to war-fighting capabilities. From maintenance tracking programs to programs that organize and display intelligence data, they ensure that the Military has the software and programs needed to complete missions efficiently and effectively.

B. CODING IN AVIATION

Without software programming, modern aviation would not exist. It wouldn’t be possible to manage flight plans, air traffic control, autopilot systems and complex maintenance routines. There are a lot of automated software systems that aviation currently relies on.

Computers software are crucial to an airport's air traffic control services. While the communication between air traffic controllers and pilots occurs through radio, the system by which this communication is synthesized with radar and weather data is based on computers.

C. HEALTHCARE ADVANCEMENTS

The Biotech industry is leaning more and more on code as time passes. AI, bioinformatics, and data analysis made possible the fastest-in-history development of the COVID-19 vaccine. In addition, patient management systems make it easier for patients to find healthcare providers and maintain clinic operations. Healthcare information management also used to require shocking amounts of paperwork. Still, those days are no more, now that information about medical visits can be easily encoded and stored in patient databases.

D. GOVERNMENT SERVICES

Code-based interfaces have made student loan applications, vaccine registrations, filing taxes, income assistance, and many other services easier. Facial recognition is being increasingly used when scanning passports in international airports, which has helped make the verification process 90% faster.

E. CLIMATE CHANGE

Coding continues to play a vital role in developing new technologies to address global challenges like climate change. Carbon emissions data is often stored and sorted manually, which can be taxing due to its magnitude. Automating this can increase data accuracy, improving the resolutions that can be obtained.

F. MEDIA AND COMMUNICATION

Coding is the key to the development of social media platforms. Coding is needed to build the entire infrastructure of social media platforms, creating a user friendly interface, content management, networking, data analytics and personalisation, and fixing bugs to ensure smooth operation and user satisfaction.

G. CODING IN SPACECRAFT

Programming allows us to design and develop cutting-edge systems that power rockets, satellites, and spacecraft. We may imagine complex mathematical equations and cutting-edge technologies when we think of space exploration. However, at the heart of every space mission lies the code that controls the spacecraft, its sensors, and its instruments. Various coding programs are used in spacecraft innovation to improve performance, efficiency, reliability and safety of the spacecraft. Coding also plays a crucial role in mission control, allowing operators to interact with space systems, analyze data, and make informed decisions.

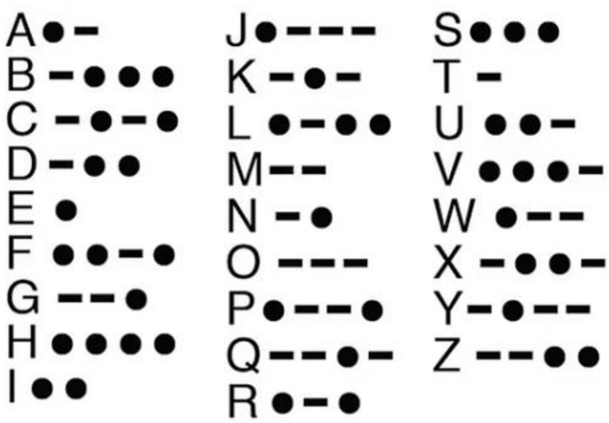
## 4. Types of Coding and Decoding:

A. BINARY CODE

- Coding: Represents data using two symbols, typically 0 and 1. Binary code is the foundation of all modern computing and digital communication.
- Decoding: Converts binary data back into its original form, such as text, images, or executable instructions.
- Example: The letter "A" in binary is 01000001.

B. MORSE CODE

- Coding: Uses a series of dots (short signals) and dashes (long signals) to represent letters, numbers, and punctuation. Originally designed for telegraph communication.
- Decoding: Converts the sequence of dots and dashes back into readable text.
- Example: The letter "A" in Morse code is . -.




Source

Fiq 1: Morse code

C. ASCII (American Standard Code for Information Interchange)

- Coding: Encodes text characters into a 7-bit or 8-bit binary number, allowing computers to store and communicate text data.
- Decoding: Converts the binary numbers back into text characters.
- Example: The character "A" in ASCII is 65 in decimal, which corresponds to 01000001 in binary.

D. UNICODE

- Coding: Extends ASCII to support a vast array of characters from various languages and symbol sets, using a variety of encoding forms (UTF-8, UTF-16, etc.).
- Decoding: Converts the encoded Unicode data back into characters that can be displayed on the screen.
- Example: The character "A" in Unicode can be U+0041.

E. HEXADECIMAL CODE

- Coding: Represents binary data in a more human-readable format using base-16 numbering (0-9 and A-F).
- Decoding: Converts hexadecimal numbers back into binary or other data forms.
- Example: The binary 01000001 is 41 in hexadecimal.

| Binary | Hexadecimal | Binary | Hexadecimal | Binary | Hexadecimal |
|---|---|---|---|---|---|
| 0 0 0 0 | 0 | 0 1 0 1 | 5 | 1 0 1 0 | A |
| 0 0 0 1 | 1 | 0 1 1 0 | 6 | 1 0 1 1 | B |
| 0 0 1 0 | 2 | 0 1 1 1 | 7 | 1 1 0 0 | C |
| 0 0 1 1 | 3 | 1 0 0 0 | 8 | 1 1 0 1 | D |
| 0 1 0 0 | 4 | 1 0 0 1 | 9 | 1 1 1 0 | E |
| | | | | 1 1 1 1 | F |

Fiq 2 : Binary, Hexadecimal codes

F. BASE64 ENCODING

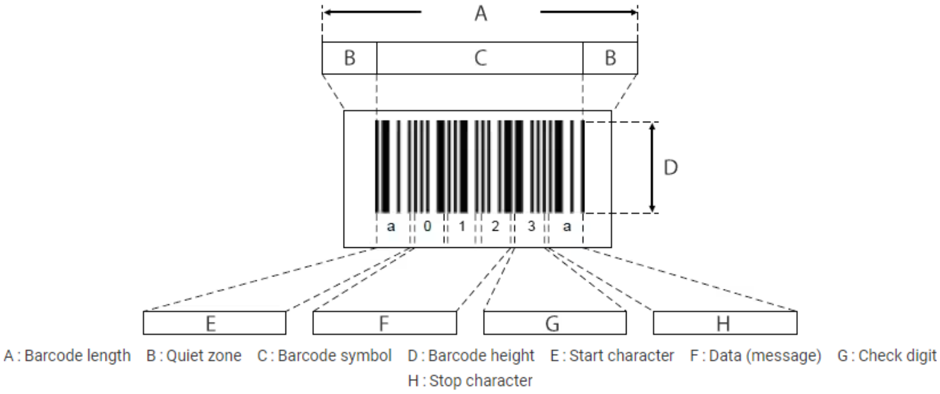
- Coding: Converts binary data into a text string using 64 different ASCII characters (A-Z, a-z, 0-9, +, /). Often used to encode binary files like images for transmission over text-based protocols (e.g., email).
- Decoding: Converts the Base64-encoded text back into binary data.
- Example: The text "Hello" in Base64 is SGVsbG8=.

G. QR CODES

- Coding: Encodes text, URLs, or other data into a two-dimensional matrix of squares, which can be scanned by a QR code reader.
- Decoding: The QR code reader interprets the pattern of squares to retrieve the original data.
- Example: A QR code might encode a URL like https://example.com.

H. BARCODES

- Coding: Uses a series of vertical bars of varying widths and spaces to represent numbers or other data, typically for product identification.
- Decoding: Barcode scanners interpret the pattern of bars to retrieve the encoded data.
- Example: A UPC barcode encodes a product number like 012345678905.




Fiq 3: Bar code

I. HUFFMAN CODING
- Coding: A compression technique that uses variable-length codes for different characters, with more common characters receiving shorter codes.
- Decoding: The encoded data is expanded back into the original form using the Huffman tree.
- Example: In a text file, common letters like "e" might be encoded with a shorter bit sequence than less common letters like "z".

J. GRAY CODE
- Coding: A binary numeral system where two successive values differ in only one bit, often used in error correction in digital communication.
- Decoding: Converts Gray code back into standard binary or decimal form.
- Example: The binary number 0011 (3 in decimal) is 0010 in Gray code.

K. REED-SOLOMON CODE
- Coding: Used in error correction to detect and correct errors in data transmission or storage, particularly in CDs, DVDs, and QR codes.
- Decoding: The Reed-Solomon algorithm corrects errors and retrieves the original data.
- Example: Used to correct up to two erroneous symbols in a sequence of 255 symbols.

L. CAESAR CIPHER
- Coding: A simple encryption technique where each letter in the text is shifted by a fixed number of places in the alphabet.
- Decoding: Shifts the letters back by the same number to retrieve the original text.
- Example: The text "HELLO" shifted by 3 becomes "KHOOR".

M. RUN-LENGTH ENCODING (RLE)
- Coding: A simple form of data compression where sequences of the same data value are stored as a single data value and count.
- Decoding: Expands the compressed data back into its original form.
- Example: The string AAAAAABBBB could be encoded as 6A4B.

These are just some of the many coding and decoding systems used in various applications, each with its own purpose and advantages.

## 5. Matrix in Coding Decoding:

**Matrix coding and decoding** typically refers to the process of encoding data into a matrix format and then decoding it back to its original form. This technique is commonly used in various fields, including error correction, cryptography, and digital communications. Here are some of the key concepts related to matrix coding and decoding:

A. Error-Correcting Codes (ECC)

Matrix coding is often used in error-correcting codes, which are designed to detect and correct errors in data transmission or storage. Some common types of matrix-based error-correcting codes include:

- **Hamming Code**:
  - Coding: Data is arranged in a matrix, and parity bits are added in specific positions to detect and correct single-bit errors.
  - Decoding: The received data is checked against the parity bits to identify and correct any errors.
  - Example: A 7-bit Hamming code can correct a single-bit error and detect two-bit errors.
- **Reed-Solomon Code**:
  - Coding: Data is encoded into a matrix, and extra rows or columns are added with redundant information to correct multiple errors.
  - Decoding: The matrix is analyzed to identify and correct errors using the redundant information.
  - Example: Used in QR codes, CDs, and DVDs to correct burst errors.
- **LDPC (Low-Density Parity-Check) Code**:
  - Coding: Data is represented in a sparse matrix with a low density of 1s, which helps in efficiently detecting and correcting errors.
  - Decoding: Iterative algorithms are used to decode the data by checking parity constraints.
  - Example: Used in modern communication systems like Wi-Fi and satellite communications.

B. Block Codes

In block coding, data is divided into fixed-size blocks, and each block is encoded separately. The encoding and decoding processes often involve matrix operations.

- **Generator Matrix (G)**:
  - Coding: The original data vector is multiplied by a generator matrix (G) to produce a codeword.
  - Decoding: The received codeword is multiplied by the inverse or transpose of the generator matrix (if applicable) to retrieve the original data.
  - Example: In a simple (7,4) block code, 4 bits of data are encoded into a 7-bit codeword.
- **Parity-Check Matrix (H)**:
  - Decoding: The received codeword is multiplied by a parity-check matrix (H) to detect and possibly correct errors.
  - Example: If the result of the multiplication is zero, the codeword is valid; otherwise, errors are present.

C. Matrix-Based Cryptography

Matrix coding and decoding are also used in cryptographic algorithms, where matrices are employed to transform plaintext into ciphertext and vice versa.

- Hill Cipher:
  - Coding: The plaintext is divided into blocks, each block is treated as a vector, and then multiplied by an encryption matrix to produce the ciphertext.
  - Decoding: The ciphertext is multiplied by the inverse of the encryption matrix to retrieve the plaintext.
  - Example: If the encryption matrix is AAA and the plaintext vector is XXX, the ciphertext YYY is Y=AXY = AXY=AX.

D. Matrix Coding in Digital Communications

Matrix coding is used in digital communication systems to improve data transmission reliability.

- **MIMO (Multiple Input Multiple Output)**:
  - Coding: Data is transmitted over multiple antennas using matrix-based algorithms to increase throughput and reliability.
  - Decoding: The receiver uses matrix decoding techniques to separate the signals and retrieve the original data.
  - Example: MIMO technology is used in 4G and 5G wireless communication systems.

E. Reed-Muller Codes

- Coding: Data is encoded using a matrix-based approach where the generator matrix is derived from Boolean functions. This allows the creation of long, complex codes that can correct multiple errors.
- Decoding: Specific algorithms are used to decode the received data and correct any errors based on the structure of the code.
- Example: Reed-Muller codes are used in deep-space communication and other applications requiring high reliability.

Summary

Matrix coding and decoding involve representing data as matrices and using matrix operations to encode and decode information. These techniques are widely used in error correction, cryptography, and digital communication to ensure data integrity, security, and reliability.

## 6. Coding Decoding basic sentences using Matrices:

Let's code and Decode basic sentences using matrices in mathematics.

Giving numbers to all the Alphabets.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| P | Q | R | S | T | U | V | W | X | Y | Z |
| 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |

Taking a basic sentence to code:

1. "MY NAME IS SANA"

Giving numbers to each alphabet of sentence:

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M | Y | | N | A | M | E | | I | S | | S | A | N | A |
| 13 | 25 | | 14 | 1 | 13 | 5 | | 9 | 19 | | 19 | 1 | 14 | 1 |

If I write in numbers, anyone can decode it by using numbers given to the alphabets.

So for code language, I have to use matrix multiplication method.

Let's consider any multiplication matrix as, A = $\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$
This matrix will be known to receiver only so that he can decode it.

So, let's code MY out of the whole sentence:
$\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} * \begin{bmatrix} 13 \\ 25 \end{bmatrix} = \begin{bmatrix} 13+50 \\ 39+100 \end{bmatrix} = \begin{bmatrix} 63 \\ 139 \end{bmatrix}$ (for MY, where M= 13 and Y = 25)
Let's code for other alphabets to,
$\begin{matrix} N \\ A \end{matrix} \begin{bmatrix} 14 \\ 1 \end{bmatrix}, \begin{matrix} M \\ E \end{matrix} \begin{bmatrix} 13 \\ 5 \end{bmatrix}, \begin{matrix} I \\ S \end{matrix} \begin{bmatrix} 9 \\ 19 \end{bmatrix}, , \begin{matrix} S \\ A \end{matrix} \begin{bmatrix} 19 \\ 1 \end{bmatrix}, , \begin{matrix} N \\ A \end{matrix} \begin{bmatrix} 14 \\ 1 \end{bmatrix}$

For NAME,
$\begin{bmatrix} N \\ A \end{bmatrix} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} * \begin{bmatrix} 14 \\ 1 \end{bmatrix} = \begin{bmatrix} 14+2 \\ 42+4 \end{bmatrix} = \begin{bmatrix} 16 \\ 46 \end{bmatrix}$
$\begin{bmatrix} M \\ E \end{bmatrix} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} * \begin{bmatrix} 13 \\ 5 \end{bmatrix} = \begin{bmatrix} 13+10 \\ 39+20 \end{bmatrix} = \begin{bmatrix} 23 \\ 59 \end{bmatrix}$
For IS,
$\begin{bmatrix} I \\ S \end{bmatrix} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} * \begin{bmatrix} 9 \\ 19 \end{bmatrix} = \begin{bmatrix} 9+38 \\ 27+76 \end{bmatrix} = \begin{bmatrix} 47 \\ 103 \end{bmatrix}$
For SANA,
$\begin{bmatrix} S \\ A \end{bmatrix} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} * \begin{bmatrix} 19 \\ 1 \end{bmatrix} = \begin{bmatrix} 14+2 \\ 57+4 \end{bmatrix} = \begin{bmatrix} 21 \\ 61 \end{bmatrix}$
$\begin{bmatrix} N \\ A \end{bmatrix} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} * \begin{bmatrix} 14 \\ 1 \end{bmatrix} = \begin{bmatrix} 14+2 \\ 42+4 \end{bmatrix} = \begin{bmatrix} 16 \\ 46 \end{bmatrix}$

Coded Message,

| M | Y | | N | A | M | E | | I | S | | S | A | N | A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 | 139 | | 16 | 46 | 23 | 59 | | 47 | 103 | | 21 | 61 | 16 | 46 |

For decoding the current message, we will use inverse of matrix,
For finding inverse of A, we need adj A,
For 2x2 matrix we can interchange diagonal elements and changing signs of diagonal elements to get adj A,
So adj A = $\begin{bmatrix} 4 & -2 \\ -3 & 1 \end{bmatrix}$
Determinant of A = 1*4 – 2*3 = -2

So. Inverse of A, $A^{-1}$ = $\begin{bmatrix} 4 & -2 \\ -3 & 1 \end{bmatrix}$ / -2 = $\begin{bmatrix} -2 & 1 \\ -3/2 & -1/2 \end{bmatrix}$
To get original message, we have to multiply $A^{-1}$ and coded message,

For MY,
$\begin{bmatrix} I \\ S \end{bmatrix} = \begin{bmatrix} -2 & 1 \\ -3/2 & -1/2 \end{bmatrix} * \begin{bmatrix} 63 \\ 139 \end{bmatrix} = \begin{bmatrix} -126+139 \\ (189-139)/2 \end{bmatrix} = \begin{bmatrix} 13 \\ 25 \end{bmatrix}$
For NAME,
$\begin{bmatrix} N \\ A \end{bmatrix} = \begin{bmatrix} -2 & 1 \\ -3/2 & -1/2 \end{bmatrix} * \begin{bmatrix} 16 \\ 46 \end{bmatrix} = \begin{bmatrix} -32+46 \\ (48-46)/2 \end{bmatrix} = * \begin{bmatrix} 14 \\ 1 \end{bmatrix}$
$\begin{bmatrix} M \\ E \end{bmatrix} = \begin{bmatrix} -2 & 1 \\ -3/2 & -1/2 \end{bmatrix} * \begin{bmatrix} 23 \\ 59 \end{bmatrix} = \begin{bmatrix} -46+59 \\ (69-59)/2 \end{bmatrix} = \begin{bmatrix} 13 \\ 5 \end{bmatrix}$
For IS,
$\begin{bmatrix} I \\ S \end{bmatrix} = \begin{bmatrix} -2 & 1 \\ -3/2 & -1/2 \end{bmatrix} * \begin{bmatrix} 47 \\ 103 \end{bmatrix} = \begin{bmatrix} -94+103 \\ (141-103)/2 \end{bmatrix} = \begin{bmatrix} 9 \\ 19 \end{bmatrix}$
For SANA,
$\begin{bmatrix} S \\ A \end{bmatrix} = \begin{bmatrix} -2 & 1 \\ -3/2 & -1/2 \end{bmatrix} * \begin{bmatrix} 21 \\ 61 \end{bmatrix} = \begin{bmatrix} -42+61 \\ (63-61)/2 \end{bmatrix} = \begin{bmatrix} 19 \\ 1 \end{bmatrix}$
$\begin{bmatrix} N \\ A \end{bmatrix} = \begin{bmatrix} -2 & 1 \\ -3/2 & -1/2 \end{bmatrix} * \begin{bmatrix} 16 \\ 46 \end{bmatrix} = \begin{bmatrix} -32+46 \\ (48-46)/2 \end{bmatrix} = \begin{bmatrix} 14 \\ 1 \end{bmatrix}$

Decode message,

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M | Y | | N | A | M | E | | I | S | | S | A | N | A |
| 13 | 25 | | 14 | 1 | 13 | 5 | | 9 | 19 | | 19 | 1 | 14 | 1 |

2. <u>"BELIEVE IN YOURSELF"</u>

Let's consider a quote "Believe in yourself"

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B | E | L | I | E | V | E | | | I | N | | Y | O | U | R | S | E | L | F | |
| 2 | 5 | 12 | 9 | 5 | 22 | 5 | 0 | 0 | 9 | 14 | 0 | 25 | 12 | 21 | 18 | 19 | 5 | 12 | 6 | 0 |

We will break the words into 3 alphabets groups,
Like B E L = [2, 5, 12]
For space we will consider it as 0.

Let's consider multiplication matrix as, A = $\begin{bmatrix} 1 & 2 & 3 \\ -1 & 4 & 5 \\ 7 & -6 & 8 \end{bmatrix}$

For BELIEVE,

$$\begin{bmatrix} B \\ E \\ L \end{bmatrix} = \begin{bmatrix} 1 & 2 & 3 \\ -1 & 4 & 5 \\ 7 & -6 & 8 \end{bmatrix} * \begin{bmatrix} 2 \\ 5 \\ 15 \end{bmatrix} = \begin{bmatrix} 2+10+36 \\ -2+20+60 \\ 14-30+72 \end{bmatrix} = \begin{bmatrix} 48 \\ 78 \\ 80 \end{bmatrix}$$

$$\begin{bmatrix} I \\ E \\ V \end{bmatrix} = \begin{bmatrix} 1 & 2 & 3 \\ -1 & 4 & 5 \\ 7 & -6 & 8 \end{bmatrix} * \begin{bmatrix} 9 \\ 5 \\ 22 \end{bmatrix} = \begin{bmatrix} 85 \\ 121 \\ 209 \end{bmatrix}$$

$$\begin{bmatrix} E \\ \\ \end{bmatrix} = \begin{bmatrix} 1 & 2 & 3 \\ -1 & 4 & 5 \\ 7 & -6 & 8 \end{bmatrix} * \begin{bmatrix} 5 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 5 \\ 5 \\ 35 \end{bmatrix}$$

For IN,

$$\begin{bmatrix} I \\ N \\ \end{bmatrix} = \begin{bmatrix} 1 & 2 & 3 \\ -1 & 4 & 5 \\ 7 & -6 & 8 \end{bmatrix} * \begin{bmatrix} 9 \\ 14 \\ 0 \end{bmatrix} = \begin{bmatrix} 37 \\ 47 \\ -21 \end{bmatrix}$$

For YOURSELF,

$$\begin{bmatrix} Y \\ O \\ U \end{bmatrix} = \begin{bmatrix} 1 & 2 & 3 \\ -1 & 4 & 5 \\ 7 & -6 & 8 \end{bmatrix} * \begin{bmatrix} 25 \\ 15 \\ 21 \end{bmatrix} = \begin{bmatrix} 55 \\ 35 \\ 85 \end{bmatrix}$$

$$\begin{bmatrix} R \\ S \\ E \end{bmatrix} = \begin{bmatrix} 1 & 2 & 3 \\ -1 & 4 & 5 \\ 7 & -6 & 8 \end{bmatrix} * \begin{bmatrix} 18 \\ 19 \\ 5 \end{bmatrix} = \begin{bmatrix} 71 \\ 83 \\ 52 \end{bmatrix}$$

$$\begin{bmatrix} L \\ F \\ \end{bmatrix} = \begin{bmatrix} 1 & 2 & 3 \\ -1 & 4 & 5 \\ 7 & -6 & 8 \end{bmatrix} * \begin{bmatrix} 12 \\ 6 \\ 202 \end{bmatrix} = \begin{bmatrix} 24 \\ 12 \\ 48 \end{bmatrix}$$

Coded message,

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B | E | L | I | E | V | E | | | I | N | | Y | O | U | R | S | E | L | F | |
| 48 | 78 | 80 | 85 | 121 | 209 | 5 | 5 | 35 | 37 | 47 | -21 | 55 | 35 | 85 | 71 | 83 | 52 | 24 | 12 | 48 |

Decoding,
For decoding we need to find $A^{-1}$,
For calculating A-1 by adjoint method, we need to find cofactors,
$A_{11}$=32+30 = 62
$A_{12}$ =-(8-35) = 43
$A_{13}$ = 6-28 = -22
$A_{21}$ = - (16+18) = -34
$A_{22}$ = 8-21 = -13
$A_{23}$ = - (6-26) = 20
$A_{31}$ = 10-12 = -2
$A_{32}$ = - (5+3) = -8

$A_{33}$ = 4+2 = 6

Co-factor matrix = $\begin{bmatrix} 62 & 43 & -22 \\ -34 & -13 & 22 \\ -2 & -8 & 6 \end{bmatrix}$

|A| = 1*62 + 2*43 + 38*(-22) = 82

Adj A = (cofactor) $^{transpose}$ = $\begin{bmatrix} 62 & 24 & -2 \\ 43 & -13 & -8 \\ -22 & 22 & 6 \end{bmatrix}$

$A^{-1}$ = adj A/|A| = 1/82 * $\begin{bmatrix} 62 & 24 & -2 \\ 43 & -13 & -8 \\ -22 & 22 & 6 \end{bmatrix}$

$A^{-1} = \begin{bmatrix} 31/41 & -17/41 & -1/41 \\ 43/82 & -12/82 & -4/41 \\ 11/41 & 10/41 & 3/41 \end{bmatrix}$

For BELIEVE,

$$\begin{bmatrix} B \\ E \\ L \end{bmatrix} = \begin{bmatrix} 31/41 & -17/41 & -1/41 \\ 43/82 & -12/82 & -4/41 \\ 11/41 & 10/41 & 3/41 \end{bmatrix} * \begin{bmatrix} 48 \\ 78 \\ 80 \end{bmatrix} = \begin{bmatrix} 82/41 \\ 410/82 \\ 492/41 \end{bmatrix} = \begin{bmatrix} 2 \\ 5 \\ 12 \end{bmatrix}$$

$$\begin{bmatrix} I \\ E \\ V \end{bmatrix} = \begin{bmatrix} 31/41 & -17/41 & -1/41 \\ 43/82 & -12/82 & -4/41 \\ 11/41 & 10/41 & 3/41 \end{bmatrix} * \begin{bmatrix} 85 \\ 121 \\ 209 \end{bmatrix} = \begin{bmatrix} 9 \\ 5 \\ 22 \end{bmatrix}$$

$$\begin{bmatrix} E \\ \\ \end{bmatrix} = \begin{bmatrix} 31/41 & -17/41 & -1/41 \\ 43/82 & -12/82 & -4/41 \\ 11/41 & 10/41 & 3/41 \end{bmatrix} * \begin{bmatrix} 5 \\ -5 \\ 35 \end{bmatrix} = \begin{bmatrix} 5 \\ 0 \\ 0 \end{bmatrix}$$

For IN,

$$\begin{bmatrix} I \\ N \\ \end{bmatrix} = \begin{bmatrix} 31/41 & -17/41 & -1/41 \\ 43/82 & -12/82 & -4/41 \\ 11/41 & 10/41 & 3/41 \end{bmatrix} * \begin{bmatrix} 37 \\ 47 \\ -21 \end{bmatrix} = \begin{bmatrix} 9 \\ 14 \\ 0 \end{bmatrix}$$

For YOURSELF,

$$\begin{bmatrix} Y \\ O \\ U \end{bmatrix} = \begin{bmatrix} 31/41 & -17/41 & -1/41 \\ 43/82 & -12/82 & -4/41 \\ 11/41 & 10/41 & 3/41 \end{bmatrix} * \begin{bmatrix} 55 \\ 47 \\ 85 \end{bmatrix} = \begin{bmatrix} 25 \\ 15 \\ 21 \end{bmatrix}$$

$$\begin{bmatrix} R \\ S \\ E \end{bmatrix} = \begin{bmatrix} 31/41 & -17/41 & -1/41 \\ 43/82 & -12/82 & -4/41 \\ 11/41 & 10/41 & 3/41 \end{bmatrix} * \begin{bmatrix} 71 \\ 83 \\ 52 \end{bmatrix} = \begin{bmatrix} 18 \\ 19 \\ 5 \end{bmatrix}$$

$$\begin{bmatrix} L \\ F \\ \end{bmatrix} = \begin{bmatrix} 31/41 & -17/41 & -1/41 \\ 43/82 & -12/82 & -4/41 \\ 11/41 & 10/41 & 3/41 \end{bmatrix} * \begin{bmatrix} 24 \\ 12 \\ 48 \end{bmatrix} = \begin{bmatrix} 12 \\ 6 \\ 0 \end{bmatrix}$$

## 7. Conclusion:

Ultimately, studying different coding and decoding methods, such as Morse code and matrix operations, offers a holistic perspective on secure information transmission and retrieval. Depending on the situation and the desired level of security, each approach has its own set of benefits and difficulties.

Morse code, a prime example, depends on a basic but efficient method of using dots and dashes for encoding data. Its longevity is attributed to its simplicity and user-friendliness, especially in scenarios with limited technology or when quick communication is essential. Nevertheless, its straightforwardness also renders it vulnerable to current decoding methods, emphasizing the necessity for more sophisticated approaches in specific situations.

On the flip side, employing matrix multiplication and matrix inverses brings a more advanced strategy to coding and decoding. This approach encodes messages in a manner that is hard to decode without understanding the specific matrix by representing messages as vectors and utilizing matrices for transformation. Decoding includes calculating the matrix inverse, providing an extra layer of security by only revealing the original message with the correct inverse matrix.

Matrix-based methods are especially important in cryptography, where ensuring the security of transmitted information is crucial. Comparing these methods to Morse code shows how coding and decoding strategies have evolved, highlighting the demand for increasingly secure and intricate systems in the digital era.

Overall, this discussion underscores the importance of choosing the appropriate method based on the specific requirements of the communication process, whether it be the simplicity and reliability of Morse code or the mathematical rigor of matrix operations. The continued study and development of these methods are crucial for advancing secure communication in an increasingly interconnected world.

## 8. Biographies :

**Saba:**

- High school graduate 2024, 'Blue Star Senior Secondary Public School, Hamirpur'
- Discipline captain in the school cabinet.
- President of Cultural Activities Club(2023-24)
- Founder of coding club at my school, as an initiative to help young students build programming skills.
- Organised Symposium-2024 for pharmacy and pharmaceutics.
- Organised a spring cleaning drive in my community. (2024)
- IBM Full Stack Developer Professional Certification (2023-24)
- Volunteer at regional hospital for covid vaccination(2021)
- First in environment day poster making competition (2022)
- Second in inter school landscape painting competition (2023)
- 1st in classical music competition(synthesizer) (2022)
- Participated in regional and state level Table Tennis tournaments (2021-24)
- Participated in national and state level Karate-Kumite by KIO(Karate India Organisation)(2021-24)
- First in regional MTB tournament(2023)
- Intermediate Course in snow skiing (2020)
- Advance course in snow skiing(2021)
- Winter ice skating course (2021-24)
- Advance mountaineering course(2022)
- First in school level march-past competition (2021)
- Organised and participated in blood donation camp (2024) and donated blood twice in the same year.

Under the guidance of:

***Dr. Mamta Jain***

- M.Sc (Mathematics) (Double gold medalist)
- M.Phil (Computer Applications) with honors From University of Roorkee (now IIT Roorkee)
- PhD (Mathematics) -Various papers published in international journals
- Former Lead Auditor ISO 9001,ISO -22000 School Accreditation Examiner by QCI
- 26 years of teaching experience
- Various Research Paper Published

***Er. Raunaq Jain***

- B.E Mechanical Engineering From Thapar Institute of Engineering and Technology
- District Physics Topper
- Content Writer and graphic designer
- Mechanical Mentor from session 2019-2020
- Technical Data Analyst at Deloitte