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CNS - Experiment 1

Aim: Breaking the Mono-alphabetic Substitution Cipher using Frequency analysis method.

Theory:

Mono-alphabetic Substitution Cipher:

A mono-alphabetic substitution cipher is a type of substitution cipher where each letter of the plaintext is replaced with a fixed corresponding letter from the cipher alphabet. In other words, it involves mapping each letter of the alphabet to a different letter. The key to the cipher is the mapping between the plaintext alphabet and the cipher alphabet.

For example, using a simple mono-alphabetic substitution cipher with a fixed key, the mapping might look like this:

Plaintext: ABCDEFGHIJKLMNOPQRSTUVWXYZ

Cipher: XYZABCDEFGHIJKLMNOPQRSTUVW

Advantages of Mono-alphabetic Substitution Cipher:

Ease of Implementation: Mono-alphabetic ciphers are relatively easy to implement and understand, making them accessible for educational purposes or simple encryption needs.

Initial Security: Mono-alphabetic ciphers can provide some basic level of security against casual attempts at decryption, especially if the cipher alphabet is randomly generated.

Disadvantages of Mono-alphabetic Substitution Cipher:

Vulnerable to Frequency Analysis: The biggest weakness of mono-alphabetic substitution ciphers is that each letter in the plaintext is always mapped to the same letter in the ciphertext. This leads to patterns in the ciphertext, making it susceptible to frequency analysis.

Limited Key Space: The key space of mono-alphabetic substitution ciphers is relatively small since there are only 26! (factorial) possible key combinations. This makes brute-force attacks feasible, especially with the aid of frequency analysis.

Lack of Perfect Secrecy: Unlike more complex ciphers like the one-time pad, mono-alphabetic substitution ciphers do not provide perfect secrecy. Once the key is discovered, the entire message can be decrypted.

Frequency Analysis Method:

Frequency analysis is a technique used to break mono-alphabetic substitution ciphers or ciphers with relatively weak encryption methods. It takes advantage of the fact that certain letters or combinations of letters occur with predictable frequency in natural languages like English.

The steps in a frequency analysis attack are as follows:

Collect Ciphertext: Obtain the encrypted message that you want to decrypt.

Analyze Frequency: Count the occurrences of each letter in the ciphertext. Certain letters will have higher frequencies due to their prevalence in the language.

Map Frequencies: Map the most frequently occurring letters in the ciphertext to the most frequently occurring letters in the language (e.g., 'E' in English).

Compare Context: Use the context of the message to identify other words and patterns to gradually piece together the key and the original plaintext.

Trial and Error: In more complex cases, frequency analysis may not fully decrypt the entire message, but it can significantly reduce the key space, allowing for manual trial and error to find the correct decryption.

Frequency analysis is particularly effective against longer ciphertexts because it provides more data for analyzing letter frequencies. To counter frequency analysis, more secure ciphers, such

as poly-alphabetic ciphers or modern cryptographic algorithms like AES, were developed, which are not vulnerable to this type of attack.

Answer in brief for the below questions:

1. What is the primary weakness of monoalphabetic cipher?

The main weakness of a monoalphabetic cipher lies in its vulnerability to frequency analysis. In this kind of substitution cipher, each letter in the plaintext is always replaced by the same letter in the ciphertext throughout the message. Because of this fixed relationship, the statistical frequency of letters and common letter patterns of the plaintext language are preserved in the encoded message. For example, if 'E' is the most common letter in English, whatever letter replaces 'E' in the cipher will also be the most common letter in the ciphertext. Cryptanalysts can study these patterns and compare them to known letter frequencies in the target language to break the code without needing to know the key. This is why monoalphabetic ciphers, while simple, are considered insecure for protecting information.

2. How can you decode a message encrypted with a monoalphabetic cipher without knowing the key?

Decoding a message encrypted with a monoalphabetic cipher without knowing the key typically involves a technique called frequency analysis. This method takes advantage of the fact that every language has characteristic letter frequencies. For instance, in English, some letters like 'E', 'T', and 'A' appear more often than others. By analyzing the frequency of each character in the ciphertext and matching these frequencies to those found in the target language, a cryptanalyst can make educated guesses about which ciphertext letters correspond to which plaintext letters. Over time, by also spotting common patterns and digraphs (i.e., two-letter combinations like 'TH' or 'HE'), the attacker can usually reconstruct the entire substitution table and fully decode the message.

- Ciphertext: "XLI UYMGO XLI QEPR"
- Suppose in English, “E” is the most common letter, and "X" appears frequently in the ciphertext.
- By matching the frequency of letters in the ciphertext with frequencies of letters in English, a cryptanalyst might guess that “X” corresponds to “T”, “L” to “H”, and so on, gradually revealing the original phrase: "THE QUICK THE BROWN".

3. Can a monoalphabetic cipher be used to encode numbers and symbols as well as letters?

Yes, a monoalphabetic cipher scheme can be extended beyond just letters to include numbers and special symbols. Traditional monoalphabetic substitution ciphers only operate on letters (usually the 26 letters of the English alphabet), but there's nothing in principle preventing the extension of the substitution rule to cover other characters. To do this, you would simply expand the substitution table so that every symbol in your plaintext alphabet—including digits, punctuation marks, and other symbols—has a unique substitute in the ciphertext alphabet. Each number or symbol would be consistently replaced according to this expanded mapping, granting flexibility, though it does not increase security against frequency analysis by much.

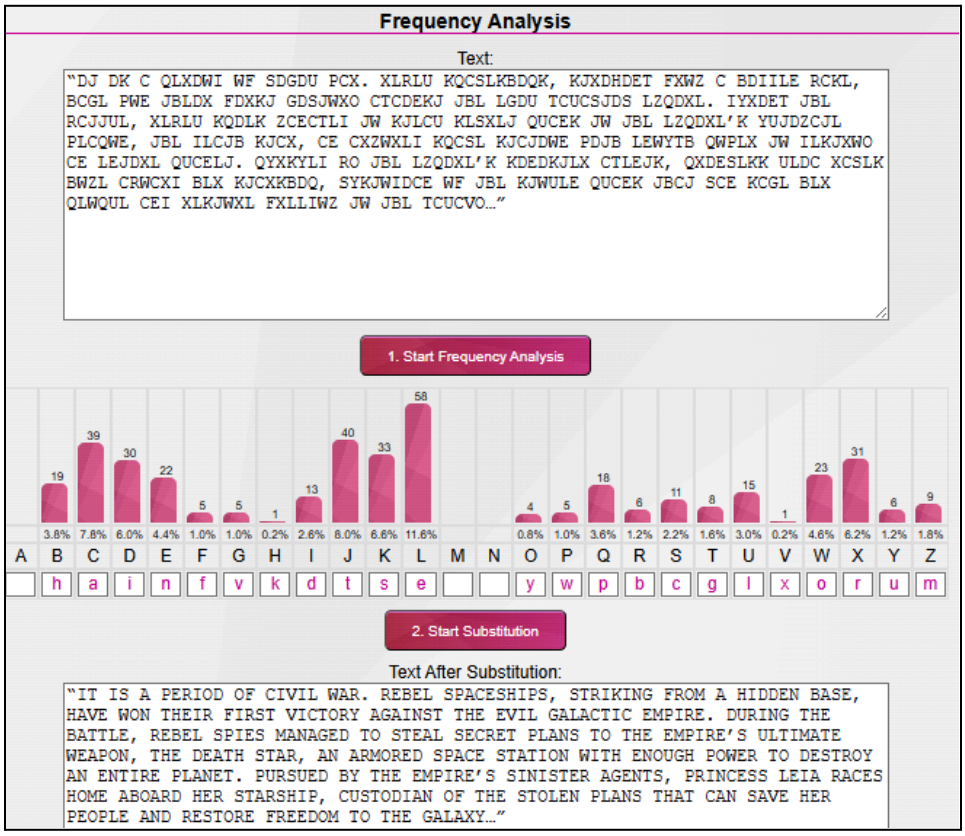
- Let's say the plaintext is "MEET AT 10:00!"
- A substitution table assigns "M" → "Q", "E" → "R", "T" → "Y"; "1" → "5", "0" → "3", ":" → "#", "!" → "@".
- The ciphertext becomes: "QRR YQ 53#33@"

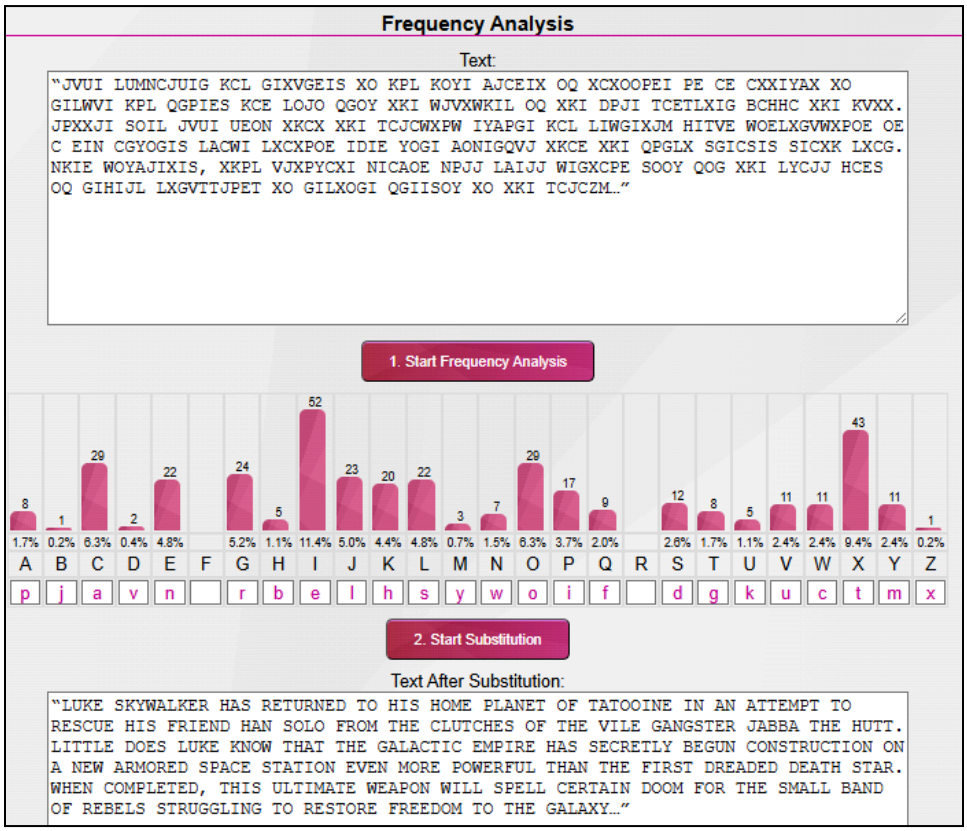
4. What is substitution table, and how is it used in monoalphabetic ciphers?

A substitution table in the context of monoalphabetic ciphers is essentially a reference chart or mapping that defines how each character from the plaintext alphabet is converted into a character in the ciphertext alphabet. The table contains two rows: one for all possible plaintext symbols and one for their corresponding ciphertext substitutes. During encryption, the sender looks up each character of the plaintext in the table and replaces it with the mapped character to form the ciphertext. Similarly, for decryption, the receiver uses the table in reverse to recover the original message. The substitution table is the 'key' to the cipher, and both the sender and receiver must agree upon it—and keep it secret—to successfully communicate using this technique.

- Suppose the English alphabet is mapped to another sequence:
    - Plaintext: A B C D E F G ... Z
    - Ciphertext: Q W E R T Y U ... M
- To encrypt "CAB", use the table:
    - "C" → "E", "A" → "Q", "B" → "W"
    - Result: "EQW"

Screenshots:



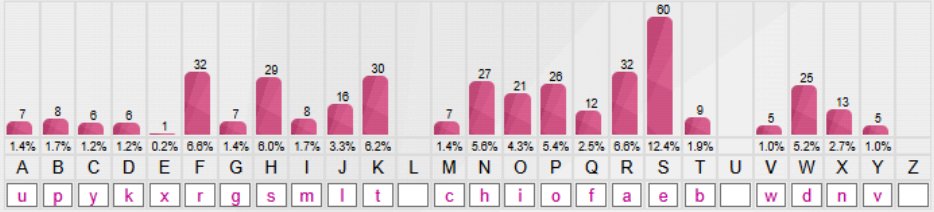


Frequency Analysis

Text:

"OK OH R WRFD KOIS QPF KNS FSTSJJOPX. RJKNPAGN KNS WSRKN HKRF NRH TSSX WSHKFPCSW,
OIBSFORJ KFPPBH NRYS WFOYSX KNS FSTSJ QPFMSH QFPI KNSOF NOWWSX TRHS RXW BAFHASW
KNSI RMFPHH KNS GRJREC.
SYRWOXG KNS WFSRWSW OIBSFORJ HKRFQJSSK, R GFPAB PQ QFSSWPI QOGNKSFH JSW TC JADS
HDCVRJDSF NRH SHKRTJOHNSW R XSV HSMFSK TRHS PX KNS FSIPKS OMS VPFJW PQ NPKN.
KNS SYOJ JPFW WRFKN YRWSF, PTHSHHSW VOKN QOXWOXG CPAXG HDCVRJDSF, NRH WOHBRKMNSW
KNPAHRXWH PQ FSIPKS BFPTSH OXKP KNS QRF FSRMNSH PQ HBRMS…"

1. Start Frequency Analysis



2. Start Substitution

Text After Substitution:

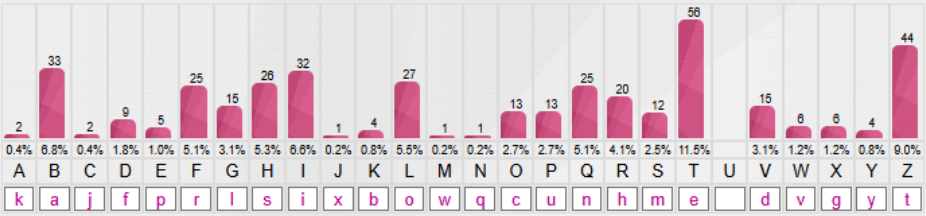
"IT IS A DARK TIME FOR THE REBELLION. ALTHOUGH THE DEATH STAR HAS BEEN DESTROYED,
IMPERIAL TROOPS HAVE DRIVEN THE REBEL FORCES FROM THEIR HIDDEN BASE AND PURSUED
THEM ACROSS THE GALAXY.
EVADING THE DREADED IMPERIAL STARFLEET, A GROUP OF FREEDOM FIGHTERS LED BY LUKE
SKYWALKER HAS ESTABLISHED A NEW SECRET BASE ON THE REMOTE ICE WORLD OF HOTH.
THE EVIL LORD DARTH VADER, OBSESSED WITH FINDING YOUNG SKYWALKER, HAS DISPATCHED
THOUSANDS OF REMOTE PROBES INTO THE FAR REACHES OF SPACE…"

Frequency Analysis

Text:

"ZRTFT IH PQFTHZ IQ ZRT XBGBOZIO HTQBZT. HTWTFBG ZRLPHBQV HLGBF HYHZTSH RBWT
VTOGBFTV ZRTIF IQZTQZILQH ZL GTBWT ZRT FTEPKGIO.
ZRIH HTEBFBZIHZ SLWTSTQZ, PQVTF ZRT GTBVTFHRIE LD ZRT SYHZTFILPH OLPQZ VLLAP, RBH
SBVT IZ VIDDIOPGZ DLF ZRT GISIZTV QPSKTF LD CTVI AQIXRZH ZL SBIQZBIQ ETBOT BQV
LFVTF IQ ZRT XBGBJY.
HTQBZLF BSIVBGB, ZRT DLFSTF NPTTQ LD QBKLL, IH FTZPFQIQX ZL ZRT XBGBOZIO HTQBZT
ZL WLZT LQ ZRT OFIZIOBG IHHPT LD OFTBZIQX BQ BFSY LD ZRT FTEPKGIO ZL BHHIHZ ZRT
LWTFMRTGSTV CTVI…"

1. Start Frequency Analysis



2. Start Substitution

Text After Substitution:

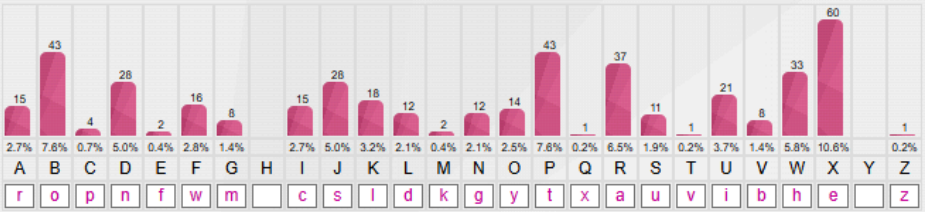
"THERE IS UNREST IN THE GALACTIC SENATE. SEVERAL THOUSAND SOLAR SYSTEMS HAVE
DECLARED THEIR INTENTIONS TO LEAVE THE REPUBLIC.
THIS SEPARATIST MOVEMENT, UNDER THE LEADERSHIP OF THE MYSTERIOUS COUNT DOOKU, HAS
MADE IT DIFFICULT FOR THE LIMITED NUMBER OF JEDI KNIGHTS TO MAINTAIN PEACE AND
ORDER IN THE GALAXY.
SENATOR AMIDALA, THE FORMER QUEEN OF NABOO, IS RETURNING TO THE GALACTIC SENATE
TO VOTE ON THE CRITICAL ISSUE OF CREATING AN ARMY OF THE REPUBLIC TO ASSIST THE
OVERWHELMED JEDI…"

Frequency Analysis

Text:

"FX IWBBJX PB NB PB PWX GBBD. VSP FWO, JBGX JRO, PWX GBBD? FWO IWBBJX PWUJ RJ BSA NBRK? RDL PWXO GRO FXKK RJM FWO IKUGV PWX WUNWXJP GBSDPRUD? FWO, 35 OXRAJ RNB, EKO PWX RPKRDPUI? FWO LBXJ AUIX CKRO PXQRJ? FX IWBBJX PB NB PB PWX GBBD UD PWUJ LXIRLX RDL LB PWX BPWXA PWUDNJ, DBP VXIRSJX PWXO RAX XRJO, VSP VXIRSJX PWXO RAX WRAL, VXIRSJX PWRP NBRK FUKK JXATX PB BANRDUZX RDL GXRJSAX PWX VXJP BE BSA XDXANUXJ RDL JMUKKJ, VXIRSJX PWRP IWRKKXDNX UJ BDX PWRP FX RAX FUKKUDN PB RIIXCP, BDX FX RAX SDFUKKUDN PB CBJPCBDX, RDL BDX FWUIW FX UDPXDL PB FUD, RDL PWX BPWXAJ, PBB."

1. Start Frequency Analysis



2. Start Substitution

Text After Substitution:

"WE CHOOSE TO GO TO THE MOON. BUT WHY, SOME SAY, THE MOON? WHY CHOOSE THIS AS OUR GOAL? AND THEY MAY WELL ASK WHY CLIMB THE HIGHEST MOUNTAIN? WHY, 35 YEARS AGO, FLY THE ATLANTIC? WHY DOES RICE PLAY TEXAS? WE CHOOSE TO GO TO THE MOON IN THIS DECADE AND DO THE OTHER THINGS, NOT BECAUSE THEY ARE EASY, BUT BECAUSE THEY ARE HARD, BECAUSE THAT GOAL WILL SERVE TO ORGANIZE AND MEASURE THE BEST OF OUR ENERGIES AND SKILLS, BECAUSE THAT CHALLENGE IS ONE THAT WE ARE WILLING TO ACCEPT, ONE WE ARE UNWILLING TO POSTPONE, AND ONE WHICH WE INTEND TO WIN, AND THE OTHERS, TOO."