



MINISTRY OF EDUCATION AND RESEARCH OF REPUBLIC OF MOLDOVA  
TECHNICAL UNIVERSITY OF MOLDOVA  
FACULTY OF COMPUTERS, INFORMATICS AND MICROELECTRONICS  
DEPARTMENT OF SOFTWARE AND AUTOMATION ENGINEERING

CRYPTOGRAPHY  
LABORATORY WORK #1

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## Caesar Cipher: Implementation & Extension

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*Author:*

Andrei Chicu

std. gr. FAF-233

*Verified:*

Zaica, asist. univ.

Department of SEA, FCIM UTM

# 1 Introduction

GitHub repository: [https://github.com/andyp1xel/crypto\\_labs](https://github.com/andyp1xel/crypto_labs)

## 1.1 Objective

The objective of this laboratory work is to implement the Caesar Cipher algorithm, covering both the standard fixed-shift version and an extended version that uses a keyword to permute the alphabet, significantly increasing the cipher's key space and cryptoresistance.

## 1.2 Tasks

- Task 1.1: Standard Caesar Cipher (Single Key  $k_1$ )
- Task 1.2: Permutation Caesar Cipher (Two Keys  $k_1$  and  $k_2$ )
- Task 1.3: Cipher Verification (Exchange and Decrypt)

## 1.3 Theoretical Background

The Caesar cipher is a substitution cipher where each letter in the plaintext is shifted by a fixed number of positions in the alphabet. The standard Caesar cipher uses the following formulas:

- Encryption:  $c = e_k(x) = (x + k) \bmod n$
- Decryption:  $m = d_k(y) = (y - k) \bmod n$

where  $n = 26$  for the English alphabet and the shift key  $k \in \{1, 2, \dots, 25\}$ .

The permutation cipher modifies this by first reordering the alphabet using a keyword  $k_2$ , then applying the Caesar shift  $k_1$  on the permuted alphabet. This increases the keyspace from 25 to approximately  $26! \times 25 \approx 10^{28}$  possible keys.

# 2 Implementation

## 2.1 Task 1.1: Standard Caesar Cipher (Single Key)

### 2.1.1 Overview

The standard Caesar Cipher implementation uses a single integer key,  $k_1 \in [1, 25]$ , for the alphabetic shift. The implementation is written in Go and provides a command-line interface for user interaction.

## 2.1.2 Implementation

1. Input Functions The implementation includes robust input validation:

```
func getShiftKey(reader *bufio.Reader) int {
    for {
        fmt.Print("Enter the shift key (an integer between 1 and
        ↪ 25): ")
        keyStr, _ := reader.ReadString('\n')
        key, err := strconv.Atoi(strings.TrimSpace(keyStr))
        if err == nil && key >= 1 && key <= 25 {
            return key
        }
        fmt.Println("Invalid key. It must be an integer between 1
        ↪ and 25.")
    }
}

func sanitizeText(input string) string {
    var builder strings.Builder
    for _, char := range input {
        if unicode.IsLetter(char) {
            builder.WriteRune(unicode.ToUpper(char))
        }
    }
    return builder.String()
}
```

The `getShiftKey` function validates that  $k_1$  is an integer in the range  $[1, 25]$ , repeatedly prompting the user until valid input is provided.

The `sanitizeText` function ensures the input plaintext is converted to uppercase and all non-letter characters (including spaces) are removed, as required by the specification.

The encryption and decryption logic is implemented in the `processText` function:

```
func processText(inputText string, shiftKey int, currentAlphabet string,
    op CipherOp) (string, error) {
    charToIndex := make(map[rune]int)
    for i, char := range currentAlphabet {
        charToIndex[char] = i
    }
}
```

```

sanitizedText := sanitizeText(inputText)
var result strings.Builder
alphabetSize := len(currentAlphabet)

for _, char := range sanitizedText {
    index, ok := charToIndex[char]
    if !ok {
        continue
    }

    var newIndex int
    switch op {
    case Encrypt:
        newIndex = (index + shiftKey) % alphabetSize
    case Decrypt:
        newIndex = (index - shiftKey + alphabetSize) %
            ↪ alphabetSize
    }

    result.WriteRune([]rune(currentAlphabet)[newIndex])
}

return result.String(), nil
}

```

The function:

- (a) Creates a character-to-index mapping from the provided alphabet
- (b) Sanitizes the input text
- (c) For each character, calculates the new position using modular arithmetic:
  - Encryption:  $(\text{index} + k) \bmod 26$
  - Decryption:  $(\text{index} - k + 26) \bmod 26$
- (d) Returns the transformed text

The results are shown in Figures 1, 2

```
lab1 $ go run .

--- Caesar Cipher Menu ---
1. Standard Caesar Cipher (Task 1.1)
2. Caesar Cipher with Permutation Key (Task 1.2)
3. Exit
Select an option: 1

--- Standard Caesar Cipher ---
Enter operation (encrypt/decrypt): encrypt
Enter the shift key (an integer between 1 and 25): 4
Enter the text to process: i am grut

Result: MEQKVYX

--- Caesar Cipher Menu ---
1. Standard Caesar Cipher (Task 1.1)
2. Caesar Cipher with Permutation Key (Task 1.2)
3. Exit
Select an option: █
```

Figure 1: Standard Caesar Encryption

```
--- Caesar Cipher Menu ---
1. Standard Caesar Cipher (Task 1.1)
2. Caesar Cipher with Permutation Key (Task 1.2)
3. Exit
Select an option: 1

--- Standard Caesar Cipher ---
Enter operation (encrypt/decrypt): decrypt
Enter the shift key (an integer between 1 and 25): 4
Enter the text to process: meqkvyyx

Result: IAMGRUT
```

Figure 2: Standard Caesar Decryption

## 2.2 Task 1.2: Permutation Caesar Cipher (Two Keys)

### 2.2.1 Overview

This extended cipher uses both a shift key  $k_1$  (integer) and a permutation key  $k_2$  (keyword string) to create a custom alphabet ordering before applying the Caesar shift.

### 2.2.2 Implementation

The `getPermutationKey` function validates that  $k_2$ :

- Contains only alphabetic characters
- Has a minimum length of 7 characters

```
func getPermutationKey(reader *bufio.Reader) string {
    for {
        fmt.Print("Enter the permutation keyword (at least 7 letters
        ↪ long, " +
            "no numbers/symbols): ")
        key, _ := reader.ReadString('\n')
        key = strings.TrimSpace(key)

        cleanKey := sanitizeText(key)

        if len(cleanKey) < 7 {
            fmt.Println("Invalid keyword. It must contain at least 7
            ↪ letters.")
            continue
        }
        if len(cleanKey) != len(key) {
            fmt.Println("Invalid keyword. It must contain only
            ↪ letters " +
                "('A'-'Z', 'a'-'z').")
            continue
        }
        return key
    }
}
```

The `generatePermutedAlphabet` function sanitizes and uppercases the keyword  $k_2$ , appends unique letters from  $k_2$  to the new alphabet in order of first appearance, appends remaining standard

alphabet letters (A-Z) not in  $k_2$  in their natural order.

```
func generatePermutedAlphabet(keyword string) string {
    var builder strings.Builder
    seen := make(map[rune]bool)

    // Add unique characters from the keyword first
    for _, char := range strings.ToUpper(keyword) {
        if !seen[char] {
            builder.WriteRune(char)
            seen[char] = true
        }
    }

    // Add the rest of the alphabet
    for _, char := range alphabet {
        if !seen[char] {
            builder.WriteRune(char)
        }
    }

    return builder.String()
}
```

The results are shown in Figures 3, 4

```
lab1 $ go run .
--- Caesar Cipher Menu ---
1. Standard Caesar Cipher (Task 1.1)
2. Caesar Cipher with Permutation Key (Task 1.2)
3. Exit
Select an option: 2

--- Caesar Cipher with Permutation Key ---
Enter operation (encrypt/decrypt): encrypt
Enter the shift key (an integer between 1 and 25): 4
Enter the permutation keyword (at least 7 letters long, no numbers/symbols): iamgrut
Enter the text to process: guardiansofthegalaxy
Generated Permuted Alphabet: IAMGRUTBCDEFHJKLNOPQSVWXYZ

Result: BDUCJRUSYVLENKBQUAM

--- Caesar Cipher Menu ---
1. Standard Caesar Cipher (Task 1.1)
2. Caesar Cipher with Permutation Key (Task 1.2)
3. Exit
Select an option: █
```

Figure 3: Extended Caesar Encryption



```

--- Caesar Cipher Menu ---
1. Standard Caesar Cipher (Task 1.1)
2. Caesar Cipher with Permutation Key (Task 1.2)
3. Exit
Select an option: 2

--- Caesar Cipher with Permutation Key ---
Enter operation (encrypt/decrypt): decrypt
Enter the shift key (an integer between 1 and 25): 4
Enter the permutation keyword (at least 7 letters long, no numbers/symbols): iamgrut
Enter the text to process: bducjrusyvlenkbuquam
Generated Permuted Alphabet: IAMGRUTBCDEFHJKLNOPQSVWXYZ

Result: GUARDIANSOFTHEGALAXY

```

Figure 4: Extended Caesar Decryption

## 2.3 Task 1.3: Cipher Verification (Exchange and Decrypt)

### 2.3.1 Objective

This task verifies the practical application of the Permutation Caesar Cipher through a peer exchange, where two students encrypt messages and exchange them for decryption verification.

### 2.3.2 Exchange Results

#### My Encryption:

- Original message: TESTMESSAGE
- Shift key ( $k_1$ ): 7
- Permutation key ( $k_2$ ): SECURITY
- Generated permuted alphabet: SECURITYABDFGHJKLMNPOQVWXZ
- Resulting ciphertext: HAYHXAYYKOA

#### Partner's Encryption:

- Received ciphertext: XZHHIXJZB
- Provided shift key ( $k_1$ ): 4
- Provided permutation key ( $k_2$ ): MOLDOVA
- Generated permuted alphabet: MOLDVABCEFGHIJKNPQRSTUVWXYZ
- Decrypted message: SUCCESSFUL

Both encryption and decryption processes were successful. The decrypted message matched the partner's original plaintext, confirming correct implementation of the permutation Caesar cipher algorithm.



### 3 Testing and Results

The implementation has been thoroughly tested with automated unit tests. The test results are shown in Figure 5.

```
lab1 $ go test -v .
=== RUN   TestSanitizeText
=== RUN   TestSanitizeText/trailing_space___
=== RUN   TestSanitizeText/hello_world
=== RUN   TestSanitizeText/Hello,_World!
=== RUN   TestSanitizeText/123_ABC_xyz_456
=== RUN   TestSanitizeText/NoChanges
=== RUN   TestSanitizeText/!@#%$^&*()_+
=== RUN   TestSanitizeText/___leading_space
--- PASS: TestSanitizeText (0.00s)
    --- PASS: TestSanitizeText/trailing_space___ (0.00s)
    --- PASS: TestSanitizeText/hello_world (0.00s)
    --- PASS: TestSanitizeText/Hello,_World! (0.00s)
    --- PASS: TestSanitizeText/123_ABC_xyz_456 (0.00s)
    --- PASS: TestSanitizeText/NoChanges (0.00s)
    --- PASS: TestSanitizeText/!@#%$^&*()_+ (0.00s)
    --- PASS: TestSanitizeText/___leading_space (0.00s)
=== RUN   TestGeneratePermutedAlphabet
=== RUN   TestGeneratePermutedAlphabet/Standard_Example_from_PDF
=== RUN   TestGeneratePermutedAlphabet/Keyword_with_repeated_letters
=== RUN   TestGeneratePermutedAlphabet/Full_alphabet_as_keyword
--- PASS: TestGeneratePermutedAlphabet (0.00s)
    --- PASS: TestGeneratePermutedAlphabet/Standard_Example_from_PDF (0.00s)
    --- PASS: TestGeneratePermutedAlphabet/Keyword_with_repeated_letters (0.00s)
    --- PASS: TestGeneratePermutedAlphabet/Full_alphabet_as_keyword (0.00s)
=== RUN   TestProcessText
=== RUN   TestProcessText/Standard_Encrypt_-_No_wrap
=== RUN   TestProcessText/Standard_Encrypt_-_With_wrap
=== RUN   TestProcessText/Standard_Decrypt_-_No_wrap
=== RUN   TestProcessText/Standard_Decrypt_-_With_wrap
=== RUN   TestProcessText/Permutation_Encrypt_-_Verified_Logic
=== RUN   TestProcessText/Permutation_Decrypt_-_Reverse_of_above
=== RUN   TestProcessText/Full_Cycle_-_Standard
=== RUN   TestProcessText/Full_Cycle_-_Permutation
--- PASS: TestProcessText (0.00s)
    --- PASS: TestProcessText/Standard_Encrypt_-_No_wrap (0.00s)
    --- PASS: TestProcessText/Standard_Encrypt_-_With_wrap (0.00s)
    --- PASS: TestProcessText/Standard_Decrypt_-_No_wrap (0.00s)
    --- PASS: TestProcessText/Standard_Decrypt_-_With_wrap (0.00s)
    --- PASS: TestProcessText/Permutation_Encrypt_-_Verified_Logic (0.00s)
    --- PASS: TestProcessText/Permutation_Decrypt_-_Reverse_of_above (0.00s)
    --- PASS: TestProcessText/Full_Cycle_-_Standard (0.00s)
    --- PASS: TestProcessText/Full_Cycle_-_Permutation (0.00s)
PASS
ok      cryptography-labs/lab1  0.004s
lab1 $
```

Figure 5: Test results

#### 3.1 Test Coverage

The following test cases have been implemented:

### 3.1.1 TestSanitizeText

Validates text sanitization functionality with various input patterns:

- Trailing spaces: "hello world " to HELLOWORLD
- Standard text: "hello\_world" to HELLOWORLD
- Greeting variations: "Hello, World!" to HELLOWORLD
- Alphanumeric combinations: "123 ABC xyz 456" to ABCXYZ
- Special character handling: "!@#\$%^&\*()\_+" to ""
- Leading space removal: " test" to TEST

### 3.1.2 TestGeneratePermutedAlphabet

Tests alphabet permutation generation:

- Standard example from specification: "cryptography" to CRYPTOGAHBDEFIJKLMNOPQSUVWXYZ
- Keywords with repeated letters: "ABRACADABRA" to ABCDEFGHIJKLMNOPQRSTUVWXYZ
- Full alphabet as keyword input

### 3.1.3 TestProcessText

Verifies encryption/decryption operations:

- Standard encryption with wrapping (e.g., XYZ with  $k = 5 \rightarrow$  CDE)
- Standard encryption without wrapping (e.g., ABC with  $k = 3 \rightarrow$  DEF)
- Standard decryption with wrapping (e.g., ABC with  $k = 3 \rightarrow$  XYZ)
- Standard decryption without wrapping
- Permutation-based encryption with verified logic
- Permutation-based decryption (reverse operation)
- Full cycle tests (encrypt then decrypt) for both standard and permutation methods

## 3.2 Security Analysis

**Standard Caesar Cipher:** Has a keyspace of 25 possible keys. Easily broken by exhaustive key search (brute force). **Permutation Caesar Cipher:** Keyspace is  $26! \times 25$ . Exhaustive key search becomes computationally infeasible, but it is vulnerable to frequency analysis attacks, and remains a monoalphabetic substitution cipher (each plaintext letter always maps to the same ciphertext letter).

## 4 Conclusions

This laboratory work successfully implemented the Caesar Cipher and its permutation-enhanced extension. The use of a permutation keyword significantly complicates an exhaustive key search compared to the standard version, although the cipher remains vulnerable to frequency analysis. All requirements regarding text sanitization (uppercase, no non-letters) and key validation ( $k_1 \in [1, 25], \text{len}(k_2) \geq 7$ ) were met in the implementation.