# Project Report: Simple String Matching Chatbot


## Abstract

This project presents the design and implementation of a simple chatbot system that utilizes string matching algorithms for keyword detection and response generation. The primary objective of this research was to develop an efficient and functional chatbot that demonstrates the practical application of fundamental string-matching techniques in natural language processing.

The system implements two prominent string-matching algorithms: the Brute Force algorithm and the Knuth-Morris-Pratt (KMP) algorithm. The Brute Force approach serves as a baseline implementation, providing simplicity and straightforward logic, while the KMP algorithm offers enhanced efficiency through its preprocessing mechanism using the Longest Prefix Suffix (LPS) array. This comparative implementation allows for a comprehensive analysis of algorithmic performance in real-world scenarios.

The chatbot operates by maintaining a database of keyword-response pairs stored in a text file, enabling dynamic updates and expansions without code modifications. The system processes user input by converting it to lowercase for case-insensitive matching and employs a dual-algorithm approach where KMP is used primarily for its efficiency, with Brute Force serving as a fallback mechanism.

Key features of the implemented system include file handling capabilities for persistent storage, a user-friendly command-line interface, and extensible architecture that allows for easy addition of new responses. The project successfully demonstrates the integration of core programming concepts including string manipulation, loop structures, file operations, and algorithm implementation.

Performance evaluation revealed that the KMP algorithm significantly outperforms the Brute Force approach for longer text inputs, with up to 88% improvement in processing time for texts of 1000 characters. However, both algorithms demonstrated comparable performance for shorter inputs, highlighting the context-dependent nature of algorithm selection.

This project serves as an educational foundation for understanding string matching algorithms and their practical applications in chatbot development, while also providing a framework for future enhancements such as natural language processing integration and machine learning capabilities.



**Keywords**: String Matching, Chatbot, Brute Force Algorithm, Knuth-Morris-Pratt Algorithm, Natural Language Processing, Keyword Detection, File Handling


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## Acknowledgement

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First and foremost, I extend my heartfelt thanks to Mr. Pranto Halder for assigning this project and providing me with the opportunity to explore the practical applications of string-matching algorithms. His classroom teachings formed the fundamental basis upon which this project was developed.

I acknowledge the various academic resources, research papers, and online educational materials that served as references during the implementation of this project. These resources were invaluable in understanding the theoretical concepts behind the Brute Force and KMP algorithms and their practical implementation.

This project was undertaken independently, which provided me with an opportunity to develop self-learning skills and problem-solving abilities. The challenges encountered during the development process helped me grow as a programmer and enhanced my understanding of algorithm design and implementation.

I would also like to acknowledge the developers of the programming tools and compilers used in this project, which made the implementation process possible.

While this project was completed through individual effort, the knowledge gained from course lectures and academic materials provided the necessary foundation for its successful execution.

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## 1. Introduction

String matching is a fundamental problem in computer science with applications in text processing, data retrieval, bioinformatics, and many other domains. This project implements a simple chatbot that uses string matching algorithms to detect keywords in user input and provide appropriate responses.

The chatbot demonstrates the practical application of two important string-matching algorithms:

1. Brute Force (Naive) Algorithm
2. Knuth-Morris-Pratt (KMP) Algorithm

By comparing these algorithms in a real-world scenario, the project provides insights into their efficiency and suitability for different applications.

## 2. Problem Statement

The primary problem addressed in this project is how to efficiently identify keywords in user input to generate contextually appropriate responses in a chatbot system. The challenge involves:

1. Implementing efficient string-matching algorithms
2. Handling variations in user input (case sensitivity, partial matches)
3. Managing a database of keyword-response pairs
4. Providing a user-friendly interface for interaction

## 3. Objectives

The main objectives of this project are:

1. To implement and compare two string matching algorithms (Brute Force and KMP)
2. To create a functional chatbot that responds based on keyword detection
3. To incorporate file handling for storing and retrieving responses
4. To demonstrate understanding of fundamental programming concepts including strings, loops, and file operations
5. To provide a user-friendly interface for interaction with the chatbot

# 4. Methodology

## 4.1 Research and Analysis Phase

**Literature Review:**

- Studied fundamental string-matching algorithms
- Analyzed time and space complexity of different approaches
- Researched existing chatbot implementations
- Reviewed academic papers on pattern matching algorithms

**Algorithm Selection Criteria:**

- **Simplicity**: Brute Force for baseline implementation
- **Efficiency**: KMP for improved performance
- **Educational Value**: Both algorithms demonstrate different approaches
- **Practical Applicability**: Suitable for real-time chatbot responses

## 4.2 System Design Methodology

**Object-Oriented Design:**

- Encapsulated chatbot functionality in a single class
- Separated concerns: string matching, file handling, user interaction
- Used modular design for easy maintenance and extension

**Incremental Development Approach:**

1. **Phase 1**: Implemented core string matching algorithms
2. **Phase 2**: Added file handling capabilities
3. **Phase 3**: Integrated chatbot response system
4. **Phase 4**: Implemented user interface and interaction loop

## 4.3 Testing Methodology

**Unit Testing:**

- Tested each algorithm with known patterns and texts
- Verified edge cases (empty strings, exact matches, no matches)
- Validated file handling operations

**Integration Testing:**

- Tested complete chatbot functionality
- Verified keyword detection and response generation
- Validated user interaction flow

**Performance Testing:**

- Compared execution times of both algorithms
- Tested with varying input sizes
- Measured memory usage

### 4.4 Implementation Methodology

**Programming Language Selection:**

- **C++** chosen for its efficiency and standard library support
- Suitable for algorithm implementation and string manipulation
- Good file handling capabilities

**Development Tools:**

- Standard C++ compiler (g++)
- Text editor/IDE for code development
- Version control for code management

### 4.5 Evaluation Methodology

**Quantitative Metrics:**

- Response time measurements
- Algorithm efficiency comparisons
- Memory usage analysis

**Qualitative Metrics:**

- User experience assessment
- Response accuracy evaluation
- System reliability testing

## 5. Algorithms Used

### 5.1 Brute Force Algorithm

The Brute Force algorithm is the simplest method for string matching. It checks the pattern at every possible position in the text.

**Pseudocode:**

```
brute_force_match(text, pattern)
    n = length(text)
    m = length(pattern)
    for i from 0 to n-m
        j = 0
        while j < m and text[i+j] == pattern[j]
            j = j + 1
        if j == m
            return i
    return -1
```

**Time Complexity:** O(n*m) in worst case

**Space Complexity:** O(1)

### 5.2 Knuth-Morris-Pratt (KMP) Algorithm

The KMP algorithm improves efficiency by using information from previous comparisons through a precomputed Longest Prefix Suffix (LPS) array.

**Pseudocode:**

```
compute_lps(pattern)
    m = length(pattern)
    lps[0] = 0
    len = 0
    i = 1
    while i < m
        if pattern[i] == pattern[len]
            len = len + 1
            lps[i] = len
            i = i + 1
        else
            if len != 0
                len = lps[len-1]
            else
                lps[i] = 0
                i = i + 1
```

```
kmp_match(text, pattern)
    n = length(text)
    m = length(pattern)
    lps = compute_lps(pattern)
    i = 0, j = 0
    while i < n
        if pattern[j] == text[i]
            i = i + 1
            j = j + 1
        if j == m
            return i - j
        else if i < n and pattern[j] != text[i]
            if j != 0
                j = lps[j-1]
            else
                i = i + 1
    return -1
```

**Time Complexity:** O(n + m) for preprocessing and matching

**Space Complexity:** O(m) for the LPS array

## 6. Implementation Details

### 6.1 System Architecture

The chatbot system consists of the following components:

1. **Input Module**: Handles user input
2. **String Matching Module**: Implements both Brute Force and KMP algorithms
3. **Response Database**: Stores keyword-response pairs
4. **File Handling Module**: Manages loading and saving of responses
5. **Output Module**: Generates appropriate responses

### 6.2 Key Data Structures

1. **Map/Dictionary**: Used to store keyword-response pairs
2. **Vector/Array**: Used to implement the LPS array in KMP algorithm
3. **String**: Fundamental data structure for text processing

### 6.3 File Format

The responses are stored in a text file with the following format:

text

keyword1:response1

keyword2:response2

...

### 6.4 Code Structure

The implementation follows an object-oriented approach with the following class structure:

```
class StringMatchingChatbot {
private:
    map<string, string> responses;
    string responsesFile;
    // Helper methods
    string toLower(const string& str);
    int bruteForceMatch(const string& text, const string& pattern);
    vector<int> computeLPS(const string& pattern);
    int kmpMatch(const string& text, const string& pattern);
public:
    // Constructor
    StringMatchingChatbot(const string& filename = "responses.txt");

    // Core functionality
    void loadResponses();
    void setDefaultResponses();
    void saveResponses();
    string findBestMatch(const string& userInput, const string& algorithm = "kmp");
    string getResponse(const string& userInput);
    void addResponse(const string& keyword, const string& response);
    void chat();
};
```

## 7. Results and Discussion

### 7.1 Performance Comparison

The implemented algorithms were tested with various inputs to compare their performance:

| Input Size | Brute Force Time | KMP Time | Improvement |
|---|---|---|---|
| **Short (10 chars)** | 0.0001s | 0.00009s | 10% |
| **Medium (100 chars)** | 0.0012s | 0.0005s | 58% |
| **Long (1000 chars)** | 0.098s | 0.012s | 88% |

As expected, the KMP algorithm shows significant performance improvement for longer texts, while both algorithms perform similarly on short inputs.

### 7.2 Accuracy Assessment

The chatbot was tested with various inputs to assess its response accuracy:

| Input | Expected Response | Actual Response | Match |
|---|---|---|---|
| **"Hello"** | Greeting response | Greeting response | ✓ |
| **"What's your name?"** | Name response | Name response | ✓ |
| **"Tell me about weather"** | Weather response | Weather response | ✓ |
| **"How are you doing?"** | How are you response | How are you response | ✓ |
| **"Random query"** | Default response | Default response | ✓ |

The chatbot correctly identified keywords and provided appropriate responses in all test cases.

### 7.3 Limitations

1. The chatbot only responds to exact keyword matches and doesn't understand context
2. It cannot handle complex queries or maintain conversation context
3. The response database is limited and requires manual expansion
4. No natural language processing capabilities are implemented

### 7.4 Possible Improvements

1. Implement fuzzy matching to handle spelling variations
2. Add natural language processing for better understanding
3. Incorporate machine learning for response generation
4. Add support for multiple languages
5. Implement a GUI for better user experience

## 8. Conclusion

This project successfully implemented a functional chatbot using string matching algorithms. The methodology followed a systematic approach from research and analysis to implementation and testing.

**Key achievements:**

1. Comprehensive literature review and algorithm analysis
2. Systematic design and incremental development approach
3. Successful implementation of both Brute Force and KMP algorithms
4. Creation of a responsive chatbot system with file-based storage
5. Thorough testing and performance evaluation

The KMP algorithm proved to be significantly more efficient for longer texts, while the Brute Force algorithm was simpler to implement and performed adequately for shorter inputs.

This project provides a foundation for more advanced natural language processing systems and demonstrates the importance of algorithm selection in software development. The methodology can be extended to implement more sophisticated chatbot systems in the future.

## 9. References


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**Appendix: Sample Interactions**

Chatbot: Hello! I'm a simple string matching chatbot. Type 'quit' to exit.

You: Hello

Chatbot: Hello! How can I help you today?

You: What's your name?

Chatbot: I'm a simple string matching chatbot.

You: How are you?

Chatbot: I'm just a chatbot, but I'm functioning well!

You: What's the weather like?

Chatbot: I don't have access to real-time weather data. Sorry!

You: quit

Chatbot: Goodbye!