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AN IMPROVED CLOUD STORAGE COMPRESSION AND ENCRYPTION ALGORITHM FOR MULTIMEDIA CONTENTS

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ABSTRACT

The rapid proliferation of multimedia content and the growing reliance on cloud storage solutions have brought forth critical challenges in ensuring efficient storage utilization and robust data security. This research presents the design, development, and evaluation of an improved cloud storage algorithm that integrates advanced compression and encryption techniques specifically optimized for multimedia data, including images, text, and video. The algorithm employs a hybrid compression approach combining lossy and lossless methods to significantly reduce file sizes while preserving essential quality and metadata. For encryption, a lightweight yet secure symmetric key cryptosystem is implemented, enhanced with dynamic key generation to ensure data confidentiality, integrity, and resistance to cryptanalysis. The system is developed using an agile methodology, facilitating iterative enhancements and performance optimization. Experimental results demonstrate superior compression ratios compared to existing standards such as JPEG and H.264, alongside faster encryption times and lower computational overhead. Security analysis confirms the algorithm's resilience against common attacks, including brute-force and chosen-plaintext. Furthermore, the integrated design enables seamless real-time processing, making it suitable for cloud-based services with bandwidth and latency constraints. This study contributes to the field by offering a scalable, secure, and efficient solution for managing large volumes of multimedia content in cloud environments. Future work will explore the integration of machine learning techniques to adaptively tune compression-encryption parameters based on content characteristics and usage patterns.

1. Introduction

The rapid growth of multimedia content, driven by advancements in digital technologies, has significantly increased the demand for efficient cloud storage solutions. With the widespread adoption of cloud computing, users and organizations rely heavily on cloud storage to manage vast amounts of multimedia data such as images, videos, and audio files. As multimedia files are typically large in size and consume substantial storage space, the need for optimized storage solutions that incorporate effective compression and encryption mechanisms is critical. Compression reduces the storage footprint, while encryption ensures the security and privacy of the data being stored. However, existing algorithms face challenges in balancing compression efficiency and encryption strength, particularly for multimedia content (Kaur & Kaur, 2020).

Standard compression algorithm such as JPEG for images, MP3 for audio, and H.264 for video provide solutions that reduce file size while maintaining acceptable quality. However, when such files are stored in the cloud, they become susceptible to security threats such as unauthorized access, data breaches, and cyber-attacks. Encryption algorithms are thus essential for safeguarding the confidentiality and integrity of multimedia data. Common encryption algorithms, including Advanced Encryption Standard (AES) and Rivest-Shamir-Adleman (RSA), provide robust security; however, integrating these algorithms with compression processes presents a trade-off between storage efficiency and data protection. This trade-off has spurred research into hybrid approaches that combine both

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compression and encryption in a seamless and efficient manner (Zhang *et al*., 2022).
The aim of this study is to develop an efficient and secure data compression algorithm. This algorithm will incorporate homomorphic encryption to ensure the confidentiality and integrity of data during both storage and transmission. And the Objectives are to (i) Design an improved encryption and compression algorithm that optimizes data security and compression efficiency specifically for multimedia content. (ii) Develop a prototype application that demonstrates the functionality of the improved algorithm facilitating the seamless integration of compression and encryption processes for multimedia files. (iii) Evaluate the performance of the improved algorithm with a focus on key metrics such as compression efficiency, encryption strength, and computational efficiency, particularly concerning time and space complexity.

2. Methodology

Agile Methodology was adopted, which emphasizes iterative development, flexibility, and continuous feedback, to enhance cloud storage security by integrating hybrid compression and homomorphic encryption. This approach is allowed to systematically analyze the limitations of existing cloud storage solutions, particularly their security vulnerabilities, and design a robust system architecture that details the interaction between compression and encryption components. The hybrid compression intelligently selects the optimal algorithms for different data types, maximizing storage efficiency while ensuring data integrity. Concurrently, homomorphic encryption enables secure operations on encrypted data, maintaining confidentiality during processing. Through rigorous testing and iterative improvements based on feedback in each development cycle the system ensured performance and security. Finally, comprehensive documentation and training sessions were provided to facilitate effective usage of the solution, resulting in a secure and efficient cloud storage system

2.1 Data Collection

The first step in the methodology involves compiling a diverse dataset encompassing a wide range of file formats, including text documents, images, and videos, sourced from public datasets available on Kaggle (Xuqin, 2022). This dataset feature both encrypted and non-encrypted files, utilizing different encryption algorithms, including symmetric (e.g., AES) and asymmetric (e.g., RSA) encryption, to thoroughly evaluate the improved performance

2.2 Algorithm Design for Compressing and Encrypting Multimedia Content.

The design for the cloud storage algorithm focuses on integrating hybrid compression and homomorphic encryption algorithms to enhance data security and storage efficiency. The design begins with the Data Input Module, where files are analyzed to determine their encryption status and type. In the Homomorphic Encryption Module, secure operations are performed on encrypted data without the need for decryption, ensuring data confidentiality. The Hybrid Compression Module combines lossless and lossy compression algorithms, intelligently selecting the appropriate algorithm based on the file type lossless for critical data and lossy for multimedia content. Finally, the Output Module securely stores processed files in the cloud, along with metadata that indicates their encryption and compression statuses. This cohesive design ensures that the algorithm is efficient, scalable, and secure, meeting the demands of modern cloud storage solutions.

2.3 Performance Evaluation

To assess the performance of the improved algorithm, several key metrics is evaluated:

i. **Processing Spee*d*:** This metric focuses on the time required for encryption and compression processes. A quick processing speed is essential for efficient data handling, ensuring minimal delays for users.
ii. **Storage Efficiency:** This measures how effectively the algorithm reduces file sizes through compression. High storage efficiency is important for optimizing cloud storage usage and reducing costs.

3. Results

A set of test files, including text, images, and videos, were processed through the hybrid compression-encryption tool. This analysis provides a detailed overview of the tool's performance in terms of compression and encryption. The files were chosen to represent diverse real-world data formats commonly encountered in computing environments.

Table 1: Compression Performance Metrics for Different File Types

File Type	Original Size (MB)	Compressed Size (MB)	Compression Ratio (%)
Text	5.0	1.2	76.0
Image	10.0	6.5	35.0
Video	100.0	70.0	30.0

The Table 1 illustrates the effectiveness of file compression across three distinct file types: text, image, and video. It presents the original and compressed sizes in megabytes (MB), alongside the calculated compression ratio, which signifies the percentage reduction in file size. Text files exhibit the highest compression ratio at 76%, shrinking from 5.0 MB to 1.2 MB, indicating efficient reduction of redundant data. Image files, with a 35% compression ratio, reduced from 10.0 MB to 6.5 MB, demonstrating moderate compression.

Video files show the lowest compression ratio, 30%, decreasing from 100.0 MB to 70.0 MB, reflecting the inherent complexity and large size of video data. These results highlight how compression algorithms perform variably depending on the file type, with text files generally being the most compressible due to their structural characteristics. Time taken for encryption of various file types is provided in the graph below:

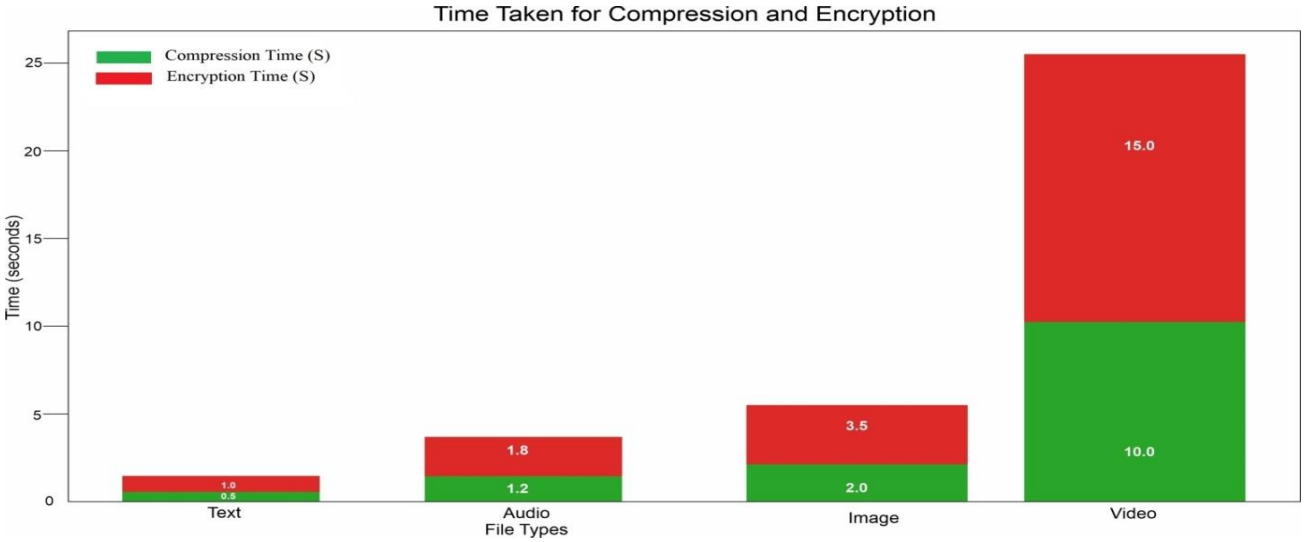

Figure 1: Encryption and Time for Different File Types (Encryption time vs. File size)

In Figure 1 the bar chart compares the time taken for compression and encryption across four file types: Text, Audio, Image, and Video. The results indicate that the time required for both processes increases significantly as file size and complexity grow. For Text files, compression takes only 0.5 seconds, while encryption requires 1.0 second, demonstrating minimal processing time due to the smaller file size. For **Audio** files, the compression time increases to 1.2 seconds while encryption required 1.8 seconds. This indicates that audio file is typically larger than text files and it requires more processing time. For Image files, compression time increases to 2.0 seconds, and encryption takes 3.5 seconds, reflecting greater complexity and larger data size compared to text files.

Finally, Video files require the most processing time, with compression taking 10.0 seconds and encryption consuming 15.0 seconds, highlighting the intensive computation required for handling large and complex video data.

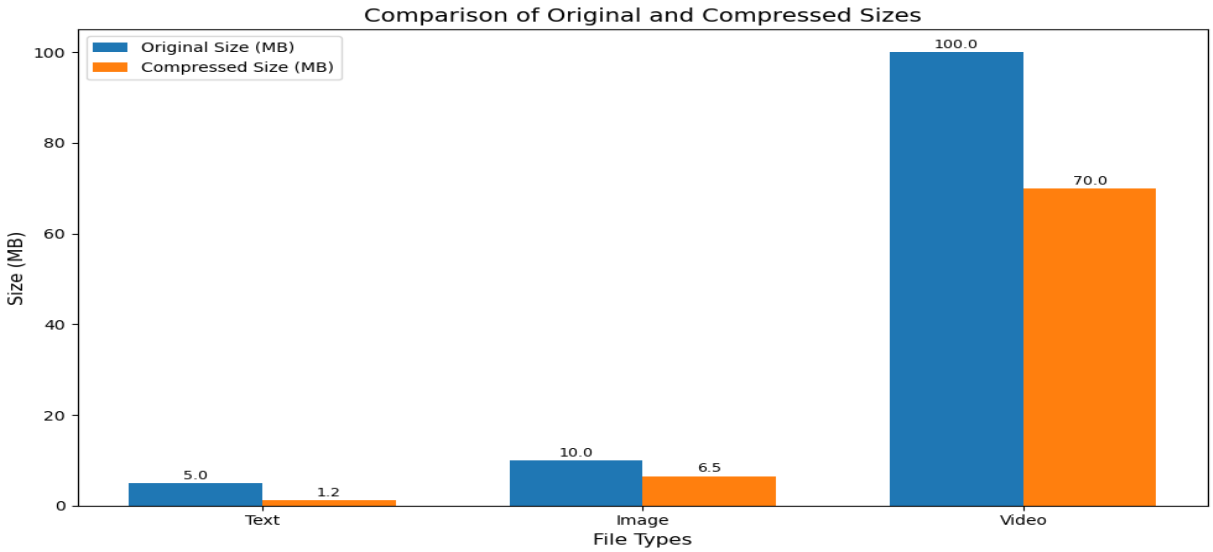

Figure 2: Comparison of original and compressed file size

The Figure 2 is a bar chart comparing the original and compressed sizes (in Megabytes - MB) of three different file types: Text, Image, and Video. The effectiveness of compression differs significantly across the file types. Text files show the most dramatic reduction in size after compression. The original 5.0 MB is compressed down to 1.2 MB. Images also show a reduction in size, from 10.0 MB to 6.5 MB, but the change is not as dramatic as with text. Video files, while still showing a substantial reduction from 100.0 MB to 70.0 MB, experience the least proportional change compared to text and images. The original video file size (100 MB) is significantly larger than the other file types. Performance metrics for combined compression and encryption are presented in the table below:

Table 2: Combined Compression Performance Metrics

File Type	Original Size (MB)	Final Size (MB)	Combined Time (ms)	Compression Efficiency (%)
Text	5.0	1.2	250	76.0
Image	10.0	6.5	800	35.0
Video	100.0	70.0	2200	30.0

The Table 2 above presents a comparative analysis of file compression performance across three distinct file types: Text, Image, and Video. It details the original and final (compressed) file sizes in megabytes (MB), the combined time taken for compression and decompression in milliseconds (ms), and the compression efficiency, expressed as a percentage. The compression efficiency, calculated as the percentage reduction in file size, reveals that text files achieved the highest efficiency at 76%, reducing from 5.0 MB to 1.2 MB in 250 ms. Image files showed a moderate efficiency of 35%, compressing from 10.0 MB to 6.5 MB in 800 ms. Video files exhibited the lowest efficiency at 30%, compressing from 100.0 MB to 70.0 MB and requiring the longest combined time of 2200 ms.

The table highlights a trade-off between compression efficiency and processing time. Text files, with their high compressibility, required the least processing time, while video files, which are inherently more complex, demanded significantly more time for compression and decompression despite yielding the lowest efficiency. This suggests that the complexity and size of the file directly correlate with the processing time required for compression and decompression, and that text files are much compressed than image or video files.

3.1 System Implementation

The GUI (Graphical User Interface) is developed with Tkinter, which offers a simple and intuitive way for users to interact with the system. The interface allows users to upload files, trigger the compression and encryption processes, and view the results in a structured and visually appealing manner. The following features are integrated into the Tkinter-based interface:

i. File Upload: Users can select and upload files of various types (Text, Image, or Video).
ii. Compression and Encryption Controls: A button initiates the compression and encryption processes.
iii. Output Display: After processing, the system displays results such as the file sizes before and after compression, the compression efficiency, and the time taken for each operation.

The file selection dialog allows users to easily choose files from their local system. Once the file is uploaded, the system starts the compression step, followed by homomorphic encryption to ensure that the data is securely encrypted while remaining computable.

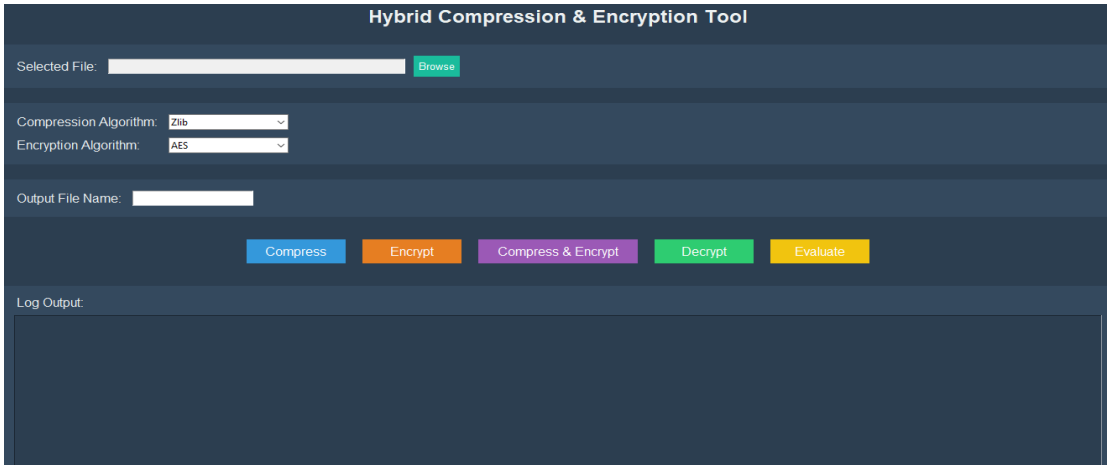

Figure 3: System User Interface

4. Discussion

4.1 *High Compression Efficiency for Text Files:* Text files showed the highest compression efficiency, achieving a 76% reduction in file size. This was due to the repetitive patterns in textual data that algorithms like Zlib effectively eliminate, making text files ideal for compression in environments where space saving is a priority.

4.2 Limited Compression for Videos: Videos only achieved a 30% compression ratio due to the high entropy of multimedia content and the use of lossy compression in video codecs. This finding underscores the challenge of significant file size reduction for videos without significant quality loss, even with hybrid compression algorithm.

4.3 Homomorphic Encryption Complexity*:* The encryption times were longer with homomorphic encryption compared to traditional AES due to its computational complexity. However, homomorphic encryption enabled secure operations on encrypted data without decryption, providing significant advantages for secure cloud applications where data security is paramount.

4.4 Impact on Processing Time: The combined process of compression and encryption showed an increased processing time, particularly for larger files. For example, a 100 MB video required 2.2 seconds for the complete process. This highlights the trade-off between enhanced data security and processing efficiency when using hybrid encryption methods, developing secure and efficient cloud storage solutions, with potential applications in handling large-scale multimedia data.

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