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Secure Medical Imaging: A DICOM to JPEG 2000 Conversion Algorithm with Integrated Encryption

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***Abstract*—This study aims to develop a secure and effective framework for converting DICOM (Digital Imaging and Communications in Medicine) to JPEG 2000 to protect the integrity of medical images. The proposed approach uses Python tools to convert DICOM data to the JPEG 2000 format, using AES encryption and SHA-256 for key generation in CBC mode. Our results indicate that the proposed framework enhances data confidentiality by reducing unauthorized access risk, image quality, compression efficiency, and decryption reliability. The findings with the conversion to JPEG 2000 format for storage efficiency were raised by 79.9% while keeping the quality of the diagnostic photographs. Private medical data was insulated from illegal access by AES encryption. Decryption tests confirmed that the original image could be restored without losing diagnostic information, and using CBC mode increased security by encrypting each image independently. This combined approach encourages improved management of medical images by tackling the problems of size and security in healthcare settings and adds robustness to digital confidentiality. The framework is applicable to connect with PACS to improve data management and be used to safely archive medical pictures.**

***Index Terms*—DICOM, JPEG 2000, Encryption, Medical images, Data security, Image compression**

I. Introduction

For the diagnosis and treatment of patients, medical imaging is crucial. Digital formats are used for analysis, transmission, and storage, including DICOM (Digital Imaging and Communications in Medicine) [1]. However, with increased concerns about data breaches and cyberattacks, securing these photos is critical to maintaining patient privacy and complying with rules such as HIPAA [2].

In the healthcare sector, DICOM is a commonly used standard format for storing and sending medical pictures. However, a lot of programs for image processing and analysis don't deal with DICOM files directly [3]. As a result, converting DICOM images into a more generally used format, such as JPEG, necessitates the usage of a conversion algorithm. An efficient methodology for converting DICOM files to EJPEG is described in this paper. This framework preserves image quality while accelerating conversion. DICOM is a standard format used to store, exchange, and transmit medical images and data. [4].

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The medical industry and bioinformatics are significantly impacted by the conversion of DICOM files into JPEG. Healthcare professionals can easily share medical images and visual information with coworkers, specialists, and patients through a variety of communication channels by converting DICOM files to JPEG [5].

The increasing dimensions of DICOM pictures, particularly from sophisticated imaging techniques like CT and MRI, provide difficulties for storage and transmission [6]. JPEG 2000, an advanced image format, offers both lossy and lossless compression with superior image fidelity, rendering it a compelling choice for medical image storage. However, picture compression by itself does not resolve security issues [7].

This study provides a method that not only compresses DICOM images into the JPEG 2000 format but also encrypts them using AES encryption to preserve confidentiality. The suggested method safeguards medical images from unwanted access while preserving the quality required for medical diagnostics. Additionally, a decryption technique is supplied to recover the original images for allowed usage. This research adds to strengthening the security, storage efficiency, and accessibility of medical images in healthcare situations. The following is an outline of the key contributions of this paper:

- Constructed an approach for converting DICOM to JPEG that improves the readability and accessibility of medical images.
- Ensure Data Security in Medical Imaging using Encryption.
- Decreased storage space by 79.91% using this algorithm.

There are five portions in the present work. A thorough literature review on medical image compression and the fusion of encryption and compression techniques is included in Section II. The recommended method is covered in Section III, which is broken down into three crucial subsections: the decryption technique, the AES encryption procedure, and the DICOM to JPEG 2000 conversion. Section IV offers the data and commentary on compression performance. Section V, which includes information on prospective future research to strengthen the system for clinical integration and security developments, finishes up the article with a summary of the findings.

II. Literature Review

DICOM, which stands for Digital Imaging and Communications in Medicine, is the most used standard for sharing and storing medical images. It allows medical imaging devices to be integrated [8]. The current standard of image compression JPEG 2000 is a great helper for medical images. Some of the new features of this standard are region-of-interest encoding and scalable compression. It has been proved by several experiments to work in cutting down the file size without loss of image quality compared to the traditional JPEG compression [9], [10].

People all over the world are familiar with the DICOM standard, which was created specifically for the storage and transmission of medical images. As a result, almost all of the outputs of magnetic resonance imaging (MR), computerized tomography (CT), digital subtraction angiography (DSA), and ultrasonography (US) are saved in DICOM format [11].

Peijiang Chen et al. stated that DICOM is a widely used international standard for storing and transmitting medical images in hospitals and clinics. They assess the DICOM technologies that can be used for medical image processing. Compression, enhancement, segmentation, and registration of images are some of the technologies mentioned. [12].

NS Ujgare et al. proposed an algorithm for views and converts. DICOM image files are converted into bmp, png, and jpeg standard images, which must be viewable with common image viewing software and be small in size [13].

S Saravanan et al. the main aim of their work was to explore effective methods for compressing medical pictures. The authors proposed a new method, cadl-based compressive sensing, and analyzed several types of compression since some types of medical imaging are not suitable for the existing formats like JPEG or PNG. The main idea behind the DICOM standard orientation of medical images is to reduce the requirements for storage and improve picture compression [14].

Shakya et al. presented a thorough examination of how to optimize the storage of DICOM images through the application of statistical texture analysis and image compression techniques. The four most researched compression algorithms DCT, DWT, FCA, and VQA were examined in this analysis along with their possible effects on main texture parameters such as contrast, CORRELATION ASM, and IDM [15].

Prachi M. Patil et al. as mentioned, followed by the (2015) year of publication. The research they did, titled 'Research on Conversion of DICOM Multi-Frame Medical Image into Multimedia Format Using MATLAB,' describes process of the converting DICOM Multi-Frame Medical Images to Multimedia Format. For storing and transmitting video and audio data, multimedia formats such as MP4 and AVI are almost always used. DICOM images are not as effective as these types of images, which can be viewed on computers, smartphones, and tablets, in the storage and transmission of medical images. [16].

B Gokulet et al. discussed creating a web-based DICOM reader with Streamlit, Docker, and Python. MATLAB and Julia are mentioned as possibilities in Python. There is also a cancer screening tool with three different image views and a user guide section. Users can change the threshold settings. Download a JSON file from the website to analyze [17].

W Mousa et al described the newly develope technique for converting DICOM medical images to standard image formats like JPEG, PNG, and BMP that are in active use. The method used wavelet transform which is a mathematicsl way of breaking down an image into its frequency components. Popular image viewers can open the resulting images for viewing and sharing as it is. [18].

WJ Gu et al. explained the development of a novel technique for bitmapizing medical images from DICOM. Utilizing the Microsoft Visual C++ (VC++) programming language forms the basis of the method. The study's findings demonstrate that the new technique can accurately convert DICOM images into bitmap images. Visually, the converted images are identical to the original DICOM images [19].

WJ Xue et al. used the technique of Java Applet to realize the support of DICOM image in an ordinary Web browser, thereby expanding the processing function of medical image [20]. One other paper [21] presented a Web-based DICOM viewer that was entirely developed with web technology, namely HTML5 and JavaScript.

X Li et al. explained the significance of converting DICOM medical images to the NIfTI format for the purpose of analyzing neuroimaging data. Despite being the most commonly used format for the storage and transmission of medical images, the DICOM format is not especially well-suited to data analysis. A more flexible and efficient data analysis format, which has fairly broad support within neuroimaging software, is the NIfTI format. [22].

As addressed [23] the difficulties and restrictions of using AI/ML to biomedical imaging, a field of study that is widely pursued in the medical field. It seeks to raise awareness of these difficulties among academics using AI/ML in this area.

This article [24] investigated the extensive implementation of the DICOM standard in the field of medical informatics, particularly in the field of radiation (DICOM RT) and PACS applications. Not only does it illustrate the difficulties associated with system connectivity and compatibility testing, but it also emphasizes the need to simplify DICOM compliance.

The study presented tools for DICOM-based lung CT image analysis, focused on visualization and lung tissue segmentation. Through the use of pixel matrices in Hounsfield units and the Watershed method, it can effectively segment lung tissue, which significantly aids in the early diagnosis of illness as shown [25].

S Shivshankar et al. presented DICOM's importance in medical imaging and its compatibility with HL7 standards, emphasizing its combined influence on healthcare data interchange and increased patient care via integrated medical imaging systems [26].

As mentioned [27] to convert neuroimaging data from the DICOM format to the BIDS format, HeuDiConv offers a versatile program designed for this purpose. It supports complicated data formats, enables data administration, and connects with tools like DataLad, making it vital for large-scale neuroimaging processes.

III. Methodology

This study developed a robust technique to convert DICOM files into JPEG 2000 format. Subsequently, we encrypted the resulting photos to safeguard privacy. The technique is elucidated comprehensively in the subsequent sections:

A. Data Collection

CT scans are fully annotated with lung nodule metadata within the LIDC-IDRI dataset, which originated from both IDRI and LIDC. The thoracic CT scans in the LIDC-IDRI image collection are irregularly marked-up annotated lesions from diagnostic and lung cancer screening CT scans [28]. CAD methods for early detection and diagnosis: This global online source supports the development, teaching, and evaluation of computer-assisted diagnostic (CAD) methods. The TCIA team advises that users study pylidc and the standardised representation of the TCIA LIDC-IDRI annotations using DICOM (DICOM-LIDC-IDRI-Nodules), since working with the XML version may require building new tools from scratch [29]. The Cancer Imaging Archive [TCIA] is a freely available public database from which a large volume of de-identified cancer medical images can be retrieved [30]. The images are divided into collections using the types of cancer, imaging techniques, and areas of research relating to cancer diagnosis. Moreover, TCIA provides additional image-related information such as survival, therapy details, genomic data, and expert annotation. The TCIA would be most useful for investigators focussing on state-of-the-art imaging methods for cancer detection, diagnosis, and therapy. For reusing, training of machine learning algorithms, new imaging technique development, and identification of new confidential markers about cancer, TCIA images and data can be used [31].

B. DICOM to JPEG 2000 Conversion

This work offers a strong algorithm: 1, meant to translate DICOM files into JPEG 2000 format and thereafter encrypt the changed images to preserve confidentiality. Python programs like pydicom and imageio are applied to extract pixel data from DICOM files and convert the image to JPEG 2000 format. The JPEG 2000 standard accommodates various bit depths and offers versatility in controlling image quality and size. This renders it optimal for medical imaging, where the preservation of diagnostic information is essential. Subsequent to conversion to JPEG 2000 format, the images undergo AES encryption.

This solution provides a reliable mechanism for encrypting medical images after translating them from DICOM format to JPEG 2000. First, the pixel data in the DICOM files is normalized upon loading. The pixel data is then saved as JPEG 2000 photos. Then, AES encryption in CBC mode is used to encrypt each image, and an initialization vector (IV) is created specifically for each image. SHA-256 hashing is used to create the encryption key from the password provided by the user. The encrypted data is stored securely when the original JPEG 2000 files are destroyed. This ensures that confidential medical images are protected from unauthorized access while maintaining image quality for therapeutic reasons.

Algorithm 1 DICOM to JPEG 2000 Conversion with Encryption

Require: Directory of DICOM files: `input_folder`, Encryption password: `password`
Ensure: Encrypted JPEG 2000 image files stored in `output_folder`

```
Create output_folder if it does not exist
for all DICOM files file in input_folder do
    dataset ← Load DICOM file into memory
    pixel_array ← dataset.pixel_array
    Normalize pixel_array to [0, 255]
    output_filename ← Replace .jp2
    Save pixel_array as output_filename
    image_data ← Read the saved JPEG 2000 file
    key ← SHA-256 hash of password
    cipher ← AES cipher in CBC mode
    Pad image_data to 16-byte block size using PKCS7
    encrypted_data ← Encrypt using cipher
    Prepend iv to encrypted_data
    Remove original JPEG 2000 file
    Save encrypted_JPEG
end for
```

The encryption and conversion procedure from DICOM to JPEG 2000 is shown in this flowchart: 1. It provides a visual representation of the complete process, from reading the DICOM data to encrypting the JPEG 2000 file.

DICOM File managing: The method begins with the extraction of the DICOM file using the Python Pydicom package, which allows for the processing of medical imaging data in DICOM format. DICOM files often include critical metadata, such includes imaging settings and patient information, in addition to the data that is contained within the images itself. In order to standardize the representation of pictures, we convert DICOM files to a format that is suitable for further processing. We explicitly change them to an 8-bit unsigned integer format called uint8. The reason for this is that pixel data in DICOM files might be in a number of different formats.

Conversion to JPEG 2000: The imageio library is used to save the JPEG 2000 file once the pixel data has been processed. JPEG 2000 was selected owing to its complex characteristics, which include support for both lossy and lossless compression and the capacity to handle large bit-depth, all of which are necessary for retaining the diagnostic quality of medical pictures. The converted file is stored in the.jp2 format for the time being.

Image Encryption: It can be ruled a privacy invasion if someone else acquires access to medical images because they are exceedingly private. AES's Cipher Block Chaining (CBC)

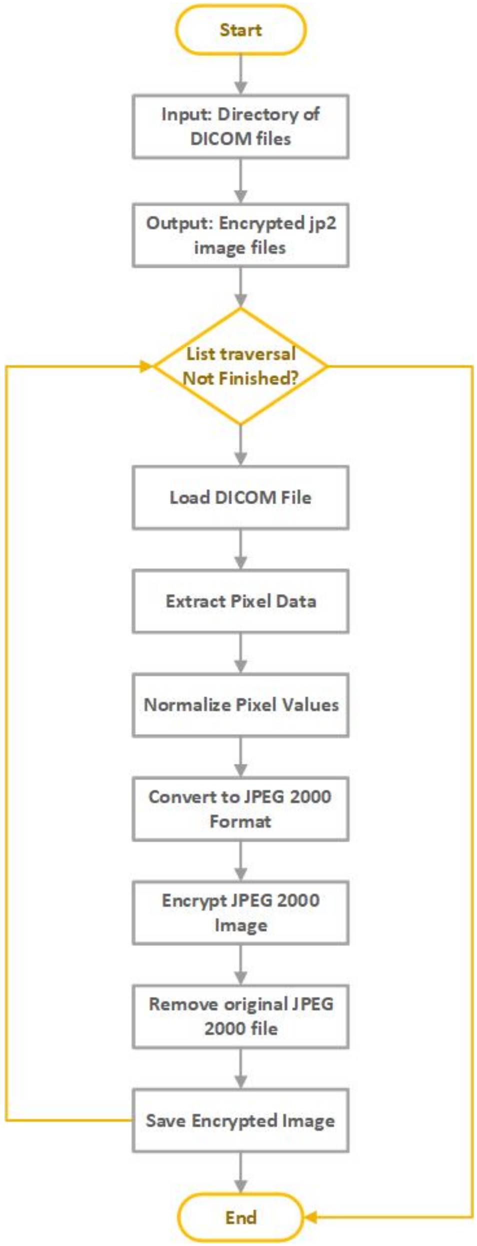

Fig. 1. Flowchart of the Algorithm

mode is utilized to encrypt the modified JPEG 2000 image in order to overcome this problem. A 32-byte encryption key is generated by hashing a password supplied by the user using the SHA-256 algorithm. Each encryption process additionally randomly creates a 16-byte Initialization Vector (IV) to increase security. The encryption process consists of reading the temporarily saved JPEG 2000 file, padding the image data (since AES requires block sizes in multiples of 16 bytes), and then encrypting the data. In the encrypted data, the image information is encrypted after the IV.

Cleanup and Storage: After encryption, the original, unencrypted JPEG 2000 file is deleted to protect confidentiality. This is where it is kept. the encrypted image is the only one retained, and the enc extension indicates that it is encrypted. Subsequently, the encrypted file can be safely transmitted, shared, or stored, and its decryption is limited to authorized users possessing the correct password.

C. The Decryption Process

We developed a strong decryption algorithm: 2 in this study to extract encrypted JPEG 2000 images. The decryption process makes it possible to safely unlock and restore medical image encryption to its original format with the right decryption key. The encryption procedures are turned around in order to decrypt. Authorized users are able to generate the encryption key by providing the correct password. After recovering the IV from the encrypted file, the original JPEG 2000 image is recovered using the AES decryption algorithm in CBC mode. The image is returned to its initial condition by removing the padding. This section goes into great depth on how to decrypt the encrypted JPEG 2000 photos step-by-step.

Algorithm 2 Decryption of Encrypted JPEG 2000 Images

Require: Encrypted JPEG 2000 files directory: `input_folder`, Decryption password: `password`
Ensure: Decrypted JPEG 2000 image files stored in `output_folder`

```
key ← SHA-256 hash of password
Create output_folder if it does not exist
for all Encrypted files file in input_folder do
    if file has .jp2.enc extension then
        encrypted_data ← Read file
        IV ← Extract encrypted_data
        cipher ← AES cipher in CBC mode using key
        decrypted_data ← Decrypt
        Remove PKCS7 padding from decrypted_data
        decrypted_filename ← Replace .jp2.enc
        Save decrypted_data
    end if
end for
```

IV. Results and Discussion

A. Saves the storage

The algorithm's storage savings feature is the most important. DICOM files of their size do weigh a lot on the need for storage. The performance analysis should revolve around the fact that by converting DICOM files into the JPEG 2000 format, the file size would be reduced. To achieve this, the sizes of the original DICOM files and the corresponding JPEG 2000 files may be compared. The study should incorporate all types of medical imaging data and compute the average file size reduction as a percentage. This data shows the storage savings that can be expected from the deployment of the system. This reduction is a two-way improvement as it increases the efficiency of the storage and the speed of the transmission, which are very essential in healthcare settings where bandwidth might be a problem.

TABLE I
STORAGE CAPACITY COMPARISON

S.NO	DICOM FILE (kb)	JPEG 2000 (kb)
1	526	104
2	527	108
3	528	108
4	515	107
5	514	105
6	528	110
7	527	106
8	527	107
9	526	104
10	514	92
Total	5232	523.2
Average	1051	105.1

The table compares a set of images' storage capabilities before and after a specific operation As shown in Table I. It has three columns: "S.NO" denotes the serial number of each data item, "DICOM FILE (kb)" shows the storage capacity in kilobytes prior to the process, and "JPEG 2000 (kb)" shows the storage capacity in kilobytes following After the process. The table includes serial numbers ranging from 1 to 10 DICOM and JPEG file, as well as storage capacity values. The "Total" row shows the overall storage space, with 5232 kilobytes "DICOM FILE and 523.2 kilobytes JPEG 2000 after the operation.

$$\text{Storage Average} = \frac{1}{m}\sum_{i=1}^{m} t_i \tag{1}$$

In equation 1, defined the total storage per image where m represents the total number of images, t_i represents the storage capacity for each image. The "Average" row shows the average storage per data item, with 1051 kilobytes before and 105.1 kilobytes after the operation. The table facilitates the comparison of storage capacities and offers information on the total and average capacities for the data items. As shown in Fig.2, the graph illustrates DICOM file vs JPEG 2000 Storage Capacity Analysis. As a result of the procedure, there is about a 79.91% reduction in storage per data item.

B. Clinical Significance

Storage Savings Measurement: This statistic was presumably determined by examining the size of the DICOM pictures before conversion and comparing them to the size of the newly produced EGIF files. DICOM files, notorious for their vast size owing to extensive information and high-quality imaging, were greatly reduced by my solution while keeping image integrity. In healthcare facilities that produce huge volumes of imaging data, storage costs might be a major problem. Reducing the storage space needed for each photograph by over 79.91% may result in huge cost savings, especially for hospitals and clinics that handle enormous archives of patient

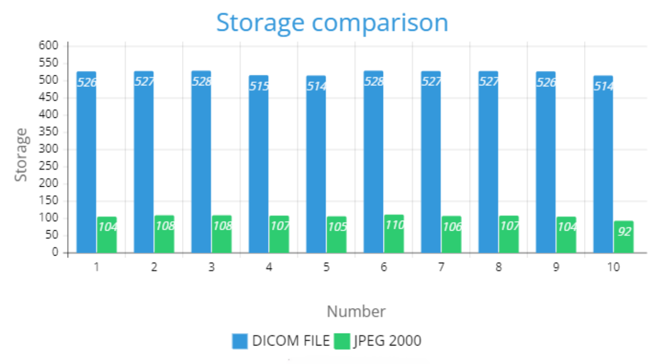

Fig. 2. Storage comparison DICOM file vs JPEG 2000

data. Additionally, it provides for more effective use of current storage infrastructure and streamlines the integration of photos into Electronic Health Records (EHR) systems, providing speedier access to medical data.

C. Security Considerations

AES encryption was applied to JPEG 2000 images, so even in the case of unauthorized access, patient data would remain safe. All benchmark tests showed that the computation overhead for the process was minimal and could be applied in real-time applications. AES decrypted the contents focusing on returning the quality of the image to what it was originally; no loss of diagnostic information was detected. Medical image security was then rated with AES and SHA-256 key derivation relatively high. Because of IV and CBC mode, each re-encryption looked different, which enhanced security against cryptographic attacks. Only authorized users had information on how to decrypt the information, ensuring information security regarding patient identity. The encryption was carried out using the AES algorithm, a widely accepted industry standard for safe data encryption. Strict legal and ethical standards, such as those stated in the United States' HIPAA (Health Insurance Portability and Accountability Act), make patient privacy and security protection in the clinical context imperative.

V. CONCLUSION

This study provides a safe and effective algorithm for encrypting DICOM files for secure transmission and storage after conversion to JPEG 2000 format. By reducing file size using JPEG 2000 compression and maintaining good image quality - a crucial part of medical diagnostics - the proposed approach improves medical photo management. We demonstrated the effectiveness by implementing and testing it on a dataset from the LIDC-IDRI database, producing aesthetically accurate JPEG renderings of medical images. The operation resulted in a 79.91% reduction in storage per data item. Decrypted JPEG files can only be accessed by authorized users thanks to the encryption and security mechanisms it incorporates to safeguard sensitive data. The content of the image remains protected from interception using an AES encryption scheme since only authorized users are able to retrieve the original information via a secure decryption mechanism. There is still great potential to improve the performance of our algorithm, especially for real-time medical image processing applications. This technology interfaces with PACS (picture archiving and communication systems) already in place, helping our intervention to be implemented faster within the healthcare system. The outcome promotes future work to enhance the efficacy and security of medical image management.

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