Randomized Key-based GMO-BCS Image Encryption for Securing Medical Image

Vineet Kumar Singh, Achintya Singhal, K.N. Rai, Abhishek Kumar, A.N.D. Dwivedi

Abstract*: An essential security requirement while transmitting and receiving medical images is to maintain confidentiality and authorization of these medical images. This paper contains a proposal of an enhanced lossless image encryption algorithm that provides security to Digital Imaging and Communications in Medicine (DICOM) images by producing a random key with using enhanced group modulo based bit circular shift (GMO-BCS) technique. Random key production is the backbone of this technique to provide robust security of medical images that transfer over a network. In the encryption process, we randomly generate a key for each and every pixel of the DICOM image. Group theory is used in this process to create circular shifting in 8-bit pixel values while the security enhancement employs the random key for encryption. This technique is more suitable for medical image encryption either by direct transmission or multimedia app-based transmission under telemedicine and others.

***Keywords:* Random key security, medical image encryption, GMO-BCS, encryption, decryption.**

I. INTRODUCTION

Images play an important role in our daily life to convey information either for entertainment or for communication purpose. Security is also important for images to easily transferring with authentication. Medical images also play an important role in the diagnosis. Medical Imaging is a technique for the visualization of the interior structure of the body for analysis and diagnoses the disease or damage [1]. DICOM stands for Digital Imaging and Communication in Medicine. It has a special type of file format extension that is filename.dcm. These type of images having extension .dcm does not easily open anywhere without a supporting software or viewer. DICOM images standard maintained by NEMA (National Electrical Manufacturers Association) and transmit over a medium such as wired (like copper wire, optical fiber) or wireless communication, storage devices, etc [1, 2].

Some DICOM images that hold different file types, parameter, and size. It may be either 8 Bpp (Bit per pixel) or 12 Bpp or 16 Bpp. 8 Bpp DICOM images are color Doppler, DSA (Digital Subtraction Angiography) and ultrasound images [3]. Compound radiography and digital radiography have 12 Bpp. Mammography images holds the 12 Bpp while X-ray angiography, MRI and CT (Computed Tomography) images have 16 Bpp and large in size especially CT [3]. This work is an advanced and enhanced version of GMO-BCS proposed in [4]. This paper have a proposal of randomized key based enhanced lossless image encryption algorithm that successfully works with DICOM images and provides security to it. During processing, a random key sequence generated and employed with enhanced group modulo based bit circular shift (GMO-BCS) technique. GMO-BCS image encryption is the base of this technique whereas random key generation and association with each pixel are the advanced features that provide robust security to medical images. Group theory is used in this process to create circular shifting in 8-bit pixel values whereas the random key utilized for bit rotation for security enhancement in encryption.

II. LITERATURE REVIEW

The base work proposed in [4] where the key-value assigned by the user which fixed for each channel of the image. When the assessment of image quality is required, there is no exact principal to chose the SSIM [5]. Triple image encryption using one-time keystream scheme is proposed in [6]. Medical image encryption based on multiple chaotic mapping proposed in [7] and using edge map a medical image encryption technique proposed in [8]. Improved padding based GGH encryption algorithm for medical image encryption is proposed in [9]. The masking algorithm technique is proposed in [10] for medical image encryption and compression both. A 3-Dimensional chaotic system is proposed for medical image encryption in [11]. For encryption purpose, 3D Lorenz map governs DNA rules proposed in [12]. Some other image encryption techniques of hybrid, frequency and spatial domains are discussed in [13]. To secure internet multimedia application, image encryption is proposed in [14] for image transmission using the internet. Based on variable circular shift an image encryption algorithm is proposed in [15]. The telemedicine information system is discussed in [16] for diagnosis. In this paper, the proposed technique applicable to telemedicine purpose for secure image transmission without any loss of data.

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The security is essential to maintain integrity and authentication of medical images that have critical data used for diagnosis and treatment. A proposal to maintain the integrity and authenticity of multi-frame DICOM images using digital signature proposed in [17]. Some advances of medical image analysis with examples are discussed in [18].

III. PURPOSE

A. Submission of the paper

Data loss in medical image processing can create a serious problem which can cause a lot of risk to the patient. To achieve security goal about information privacy of data or non-altered data of medical images that transfers for telemedicine purpose, we propose a Randomized key-based GMO-BCS algorithm. The transmission process includes the information to transmit by computers than can be accessed only by an authorized person not by others (anyone else).

IV. METHODOLOGY

The encryption process includes the initial GMO-BCS algorithm proposed in [4]. The critical value used to rotate bits circularly according to group modulo operation i.e., in between 0 to 7 means 8, but the generation is of the key is random. The fixed only one-time key is used in initial GMO-BCS algorithm for encryption and decryption while in the proposed algorithm the random key is generated for each pixel individually. This feature of the algorithm makes it unique and more secure from initial GMO-BCS. By using the random key for every pixel of each channel of DICOM image generates new pixels for encrypted channel matrix. After converge or overlapped to all encrypted channel matrixes, we got a cipher image. For decryption, the reverse process of encryption is used and the encrypted DICOM image is used as the input image of the decryption process. According to the random key value used in the encryption process subtracted from 8 for the reverse circular shifting of bits in the decryption process. In this paper, the posed algorithm is advanced from the earlier one and easily works with the DICOM images file formats.

A. Encryption Algorithm: The encryption algorithm is an enhanced version of [4] and as following:

Step 1: Begin.
Step 2: Read the medical image.
Step 3: Extract RGB (Red, Green, and Blue) channels.
Step 4: Find the size in number of rows and columns of all (RGB) channel
Step 5: Find the seed value to generate a random key sequence generation to all (RGB) channels.
Step 6: Generate a random key sequence to all (RGB) channels by using seed value.
Step 7: Apply random key to circular shift rotation at the bit level with initial shifting d=x<8 and increment value of d by 1 for every next row.
Step 8: Generate an encrypted channel R matrix.
Step 9: Repeat Step 6 to Step 7 for channel G with d=x+y<8 in step 6.
Step 10: Repeat Step 6 to Step 7 for channel B with d=x+y+z<8 in step 6.
Step 11: Combine all channels (RGB) matrix.
Step 12: Find the encrypted medical image.
Step 13: End

B. Decryption Algorithm: The decryption algorithm is an enhanced version of [4] and as following:

Step 1: Begin.
Step 2: Read the encrypted medical image.
Step 3: Extract RGB (Red, Green, and Blue) channels.
Step 4: Find the size in number of rows and columns of all (RGB) channel
Step 5: Use the last value of random key sequence as a key to all (RGB) channels.
Step 6: Apply random key to circular shift rotation at the bit level with initial shifting d=(8-x)<8 and increment value of d by 1 for every next row.
Step 7: Generate an encrypted channel R matrix.
Step 8: Repeat Step 6 to Step 7 for channel G with d=(8-x+y)<8 in step 6.
Step 9: Repeat Step 6 to Step 7 for channel B with d=(8-x+y+z)<8 in step 6.
Step 10: Combine all channels (RGB) matrix.
Step 11: Find the Decrypted medical image.
Step 12: End

V. EXPERIMENTAL RESULTS

The result is shown here for DICOM encryption and decryption. This algorithm smoothly works with the medical image file format (.dcm) without any loss of data. The PSNR and MSE calculated as per the formula described in [4, 5]. Structural similarity index measure (SSIM) is calculated as discussed in [5].

A. Encryption Result

The DICOM image encryption result is depicted in Table 1. Medical images that are used in this paper are color Doppler (ultrasound) image of the abdomen that contains some information about the disease of the patient. This image is the original images of the patient. The other information about these images from where I have taken is discussed in the acknowledgment section. In this image, we removed the personal information of the patient.

First of all, we have read the DICOM image and extract their RGB channels then apply randomized GMO-BCS algorithm to encrypt all three RGB channels. After finding the encrypted RGB channels, converge all them to get the final encrypted image. All encryption process result is shown in Table 1. The PSNR and MSE of the encryption process are depicted in the encryption section Table 3. The PSNR value of all RGB channels and average PSNR value is acceptable.

B. Decryption Result

The decryption process results are depicted in Table 2. This process is the same as the reverse process of encryption. The significant random value is subtracted from 8, which used for rotation in encryption and hold the property of group modulo operation that is 0 to 7. This advanced feature makes it more robust. As discussed in [4], the randomized GMO-BCS technique is also an utterly lossless technique. The infinite PSNR value and zero MSE value prove that the proposed randomized GMO-BCS encryption-decryption algorithm is lossless. The PSNR and MSE of the decryption process are depicted in the decryption section of Table 3. After decryption, the infinite PSNR and zero MSE shows the error-free decryption.

Table 1 Result of Randomized GMO-BCS of DICOM Encryption Process

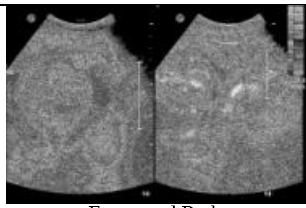
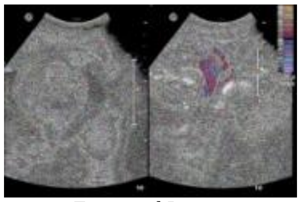
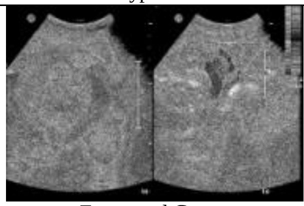
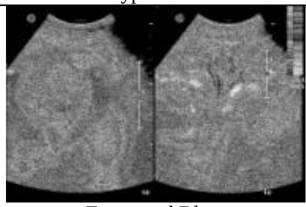
Randomized GMO-BCS Encryption Results			
Original Medical Image (OMI)	**Extracted Channels of OMI**	**Encrypted Channels of OMI**	**Encrypted Medical Image (EMI)**
 Original Image	 Red	 Encrypted Red	 Encrypted Image
	 Green	 Encrypted Green	
	 Blue	 Encrypted Blue	

Table 2 Result of Randomized GMO-BCS of DICOM Decryption Process

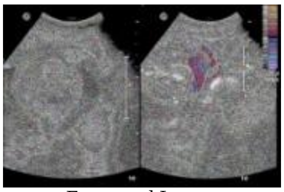
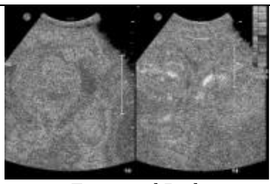
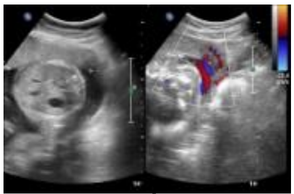
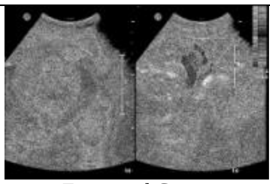
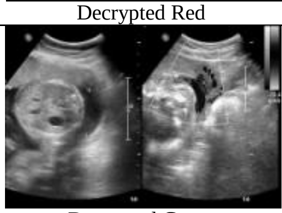
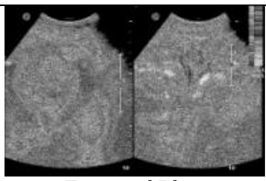
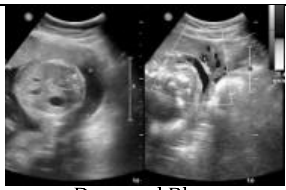
Randomized GMO-BCS Decryption Results			
Encrypted Medical Image (EMI)	**Extracted Channels of EMI**	**Decrypted Channels of EMI**	**Decrypted Medical Image (DMI)**
 Encrypted Image	 Encrypted Red	 Decrypted Red	 Decrypted Image
	 Encrypted Green	 Decrypted Green	
	 Encrypted Blue	 Decrypted Blue	

Table 3 Result of Randomized GMO-BCS of DICOM Encryption Process

Randomized GMO-BCS Medical Image Results				
Channels ↓	**Encryption**		**Decryption**	
	PSNR	**MSE**	**PSNR**	**MSE**
Red Channel	30.9219257	52.59	Inf dB	0.00
Green Channel	30.7291756	54.97	Inf dB	0.00
Blue Channel	30.6820139	55.57	Inf dB	0.00
Average →	**30.7777051**	**54.38**	**Inf dB**	**0.00**

C. Encryption and Decryption Result (Comparison): After the randomized GMO-BCS Experiment, we have seen that the average encryption result is much better than the basic GMO-BCS algorithm proposed in [4]. The proposed randomized GMO-BCS encryption results are depicted in Table 4. The random key value is used for bit circular shift performed in 8-bit binary values of each pixel according to the random key. The basic GMO-BCS encryption results are shown in Table 5. The image and experimental platform are the same for both techniques.

The main aspect i.e. security is also better than GMO-BCS. Basic GMO-BCS uses fixed precise key values for each channel whereas the random-key GMO-BCS generates the random key for each pixel of each channel of the original image randomly.

D. Decryption Result

In reference to the comparison, the decryption process is the reverse process of encryption for both techniques. The decryption process of randomized GMO-BCS technique and basic GMO-BCS technique is completely lossless. To avoid repetition, we have not shown the figure of the decryption results of basic GMO-BCS decryption discussed in [4].

Table 4 Result of GMO-BCS Encryption Process

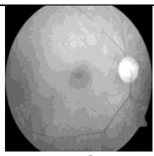
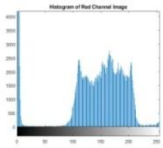
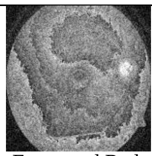
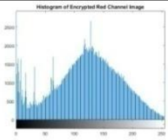
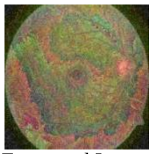
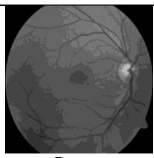
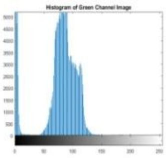
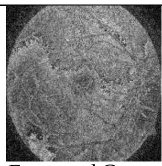
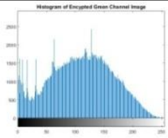
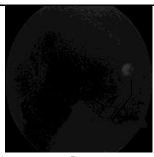
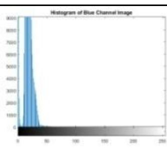
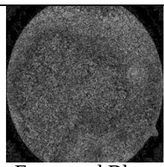
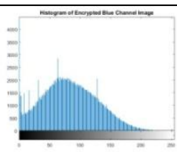
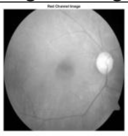
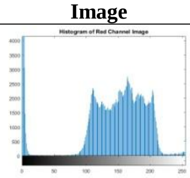
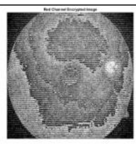
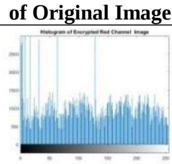
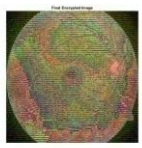
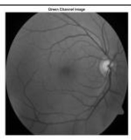
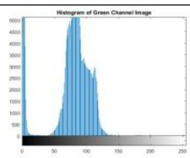
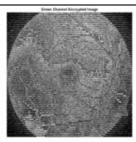
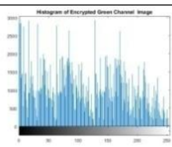
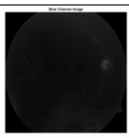
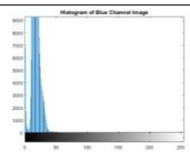
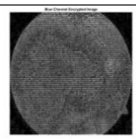
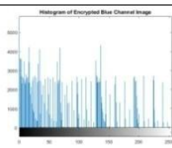
Randomized GMO-BCS Processing Results					
Original Image	**Extracted Channels of Original Image**	**Histogram of Extracted Channels of Original Image**	**Encrypted Channels of Original Image**	**Histogram of Encrypted Channels of Original Image**	**Encrypted Image**
 Original Image	 Red	 Hist. of Red	 Encrypted Red	 Hist. of Enc. Red	 Encrypted Image
	 Green	 Hist. of Green	 Encrypted Green	 Hist. of Enc. Green	
	 Blue	 Hist. of Blue	 Encrypted Blue	 Hist. of Enc. Blue	

Table 5 Result of GMO-BCS Encryption Process

GMO-BCS Process Results					
Original Image	**Extracted Channels of Original Image**	**Histogram of Extracted Channels of Original Image**	**Encrypted Channels of Original Image**	**Histogram of Encrypted Channels of Original Image**	**Encrypted Image**
 Original Image	 Red	 Hist. of Red	 Encrypted Red	 Hist. of Enc. Red	 Encrypted Image
	 Green	 Hist. of Green	 Encrypted Green	 Hist. of Enc. Green	
	 Blue	 Hist. of Blue	 Encrypted Blue	 Hist. of Enc. Blue	

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VI. Result Discussion

The PSNR and MSE based result comparison between initial GMO-BCS discussed in [4] with the proposed randomized key-based GMO-BCS image encryption algorithm is depicted in Table 7.

In comparison to both techniques, the PSNR value for the red channel after randomized GMO-BCS encryption slightly differs with 0.2898516 and MSE is better with difference 7.03. As shown in Table 7. Initial GMO-BCS algorithm is slightly better for the red channel but the Random GMO-BCS in terms of Green and Blue channels is much better.

Infinite PSNR and 0.00 MSE of the Decryption section of Table 7 prove that both techniques are completely lossless. The graph related to the PSNR value of red, green and blue channels for both techniques is depicted in Fig. 1. As shown in Fig. 1 the PSNR value of Rand-GMO-BCS scheme is better than the initial GMO-BCS proposed in [4].

Table 6 Result of Randomized GMO-BCS Decryption Process

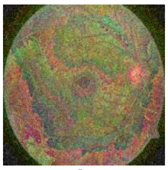
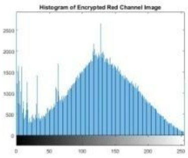
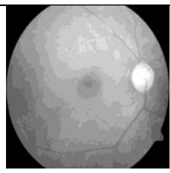
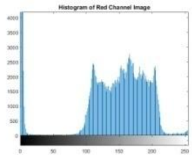
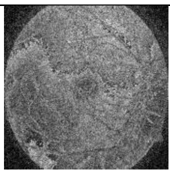
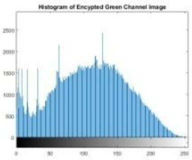
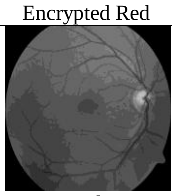
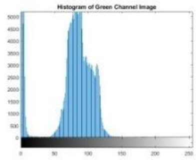
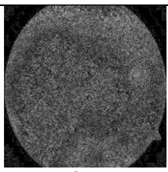
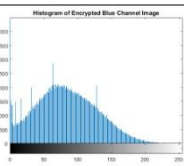
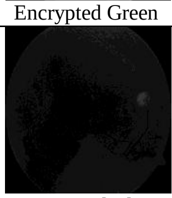
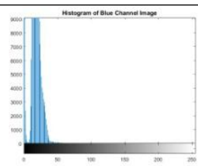
Randomized GMO-BCS Decryption Results					
Encrypted Image	**Extracted Channels of Original Image**	**Histogram of Extracted Channels of Original Image**	**Encrypted Channels of Original Image**	**Histogram of Encrypted Channels of Original Image**	**Original Image**
 Original Image	 Red	 Hist. of Red	 Encrypted Red	 Hist. of Enc. Red	 Encrypted Image
	 Green	 Hist. of Green	 Encrypted Green	 Hist. of Enc. Green	
	 Blue	 Hist. of Blue	 Encrypted Blue	 Hist. of Enc. Blue	

Table 7 Result of Randomized GMO-BCS Decryption Process

Channels	Basic GMO-BCS Results				Randomized GMO-BCS Results			
	Encryption		Decryption		Encryption		Decryption	
	PSNR	MSE	PSNR	MSE	PSNR	MSE	PSNR	MSE
Red	27.7568075	108.99	Inf dB	0.00	28.0466591	101.96	Inf dB	0.00
Green	30.5184775	57.71	Inf dB	0.00	29.4064576	74.55	Inf dB	0.00
Blue	36.4481037	14.73	Inf dB	0.00	33.5188256	28.92	Inf dB	0.00
Average	**31.5744629**	**60.4767**	**Inf dB**	**0.00**	**30.3239808**	**68.4767**	**Inf dB**	**0.00**

Fig. 2 concluded the comparison of MSE between both techniques. In basic GMO-BCS, MSE is better for red channel encryption. It means that the PSNR value of randomized GMO-BCS technique is higher in comparison to basic GMO-BCS. The MSE is higher for green and blue channels mean PSNR is better in case of Randomized GMO-BCS for the green and blue channel. In the average case higher MSE and lower PSNR is shown in Table 7 for proposed random GMO-BCS. This is the reason that decided that the proposed technique is better. In Randomized GMO-BCS, the average MSE is much better than initial GMO-BCS after encryption.

The SSIM index value is 0.2941, and SSIM index value map is depicted in Fig. 3. After random GMO-BCS decryption, we found the standard SSIM index value is 1.0000. It means that the quality of decryption is outstanding.

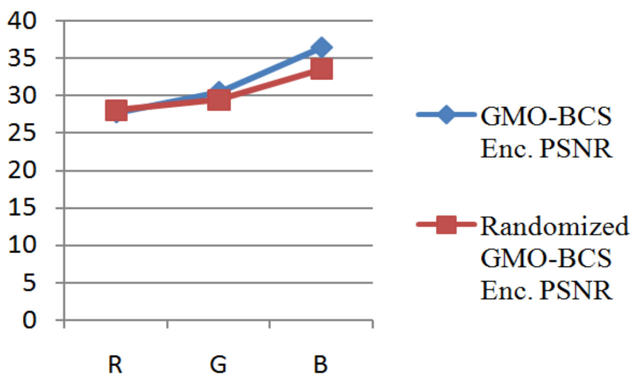


Fig. 1 PSNR comparison between GMO-BCS and Randomized GMO-BCS Encryption

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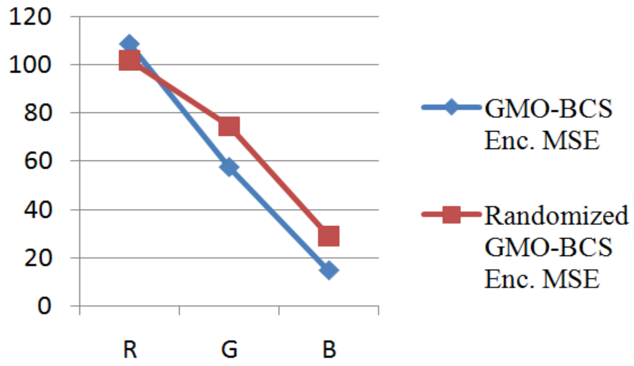
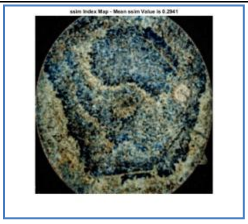


Fig. 2 MSE comparisons between GMO-BCS and Randomized GMO-BCS Encryption

Table 8 SSIM Index Value Map after Encryption and Decryption

SSIM Value After Encryption = 0.2941	 SSIM Index Value Map After Encryption
SSIM Value After Decryption = 1.0000	 SSIM Index Value Map After Decryption

VII. CONCLUSION

In this paper, A random key sequence produces for each pixel of all channels of the medical images based on initial GMO-BCS. Security included in the encryption process is not easily cracked without finding the exact random key sequence and seed value, which has taken for key generation in the encryption process. Because of this, the proposed technique is robust than the initial GMO-BCS. The results are shown above where the rotation keys are generated randomly that makes the high level of encryption standard. The lossless feature of proposed technique makes it more suitable for medical image encryption and transmission under Telemedicine. In the future, to enhance the security of the medical image we can use the extensive group higher than 8-bit for the circular shift in pixel bit values using group modulo operation.

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