

## Documents

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#### Abstract

The importance of image security in the field of medical imaging is challenging. Several research works have been conducted to secure medical healthcare images. Encryption, not risking loss of data, is the right solution for image confidentiality. Due to data size limitations, redundancy, and capacity, traditional encryption techniques cannot be applied directly to e-health data, especially when patient data are transferred over the open channels. Therefore, patients may lose the privacy of data contents since images are different from the text because of their two particular factors of loss of data and confidentiality. Researchers have identified such security threats and have proposed several image encryption techniques to mitigate the security problem. However, the study has found that the existing proposed techniques still face application-specific several security problems. Therefore, this paper presents an efficient, lightweight encryption algorithm to develop a secure image encryption technique for the healthcare industry. The proposed lightweight encryption technique employs two permutation techniques to secure medical images. The proposed technique is analyzed, evaluated, and then compared to conventionally encrypted ones in security and execution time. Numerous test images have been used to determine the performance of the proposed algorithm. Several experiments show that the proposed algorithm for image cryptosystems provides better efficiency than conventional techniques. © 2013 IEEE.

#### Author Keywords

Internet of Medical Things; lightweight encryption; medical image encryption

#### Index Keywords

Health care, Hospital data processing, Image enhancement, Medical image processing, Privacy by design; Application specific, Conventional techniques, Encryption technique, Healthcare industry, Image encryptions, Lightweight encryption, Medical image security, Permutation technique; Cryptography

#### References

- Porras, J., Pänkäläinen, J., Knutas, A., Khakurel, J.  
**January security in the Internet of Things-A systematic mapping study**  
(2018) *Proc. 51st Hawaii Int. Conf. Syst. Sci.*, pp. 3750-3759.
- Alsubaei, F., Abuhussein, A., Shiva, S.  
**Security and privacy in the Internet of medical things: Taxonomy and risk assessment**  
(2017) *Proc. IEEE 42nd Conf. Local Comput. Netw. Workshops (LCN Workshops)*, pp. 112-120.  
Oct
- Elhoseny, M., Ramirez-Gonzalez, G., Abu-Elnasr, O.M., Shawkat, S.A., Arunkumar, N., Farouk, A.  
**Secure medical data transmission model for IoT-based healthcare systems**  
(2018) *IEEE Access*, 6, pp. 20596-20608.

- Hasan, M.K., Ismail, A.F., Islam, S., Hashim, W., Ahmed, M.M., Memon, I.  
**A novel HGBBDSA-CTI approach for subcarrier allocation in heterogeneous network**  
(2019) *Telecommun. Syst.*, 70 (2), pp. 245-262.  
Feb
- Hasan, M.K., Ismail, A.F., Abdalla, A.H., Abdullah, K., Ramli, H., Islam, S., Saeed, R.A.  
**Inter-cell interference coordination in LTE-A HetNets: A survey on self organizing approaches**  
(2013) *Proc. Int. Conf. Comput., Electr. Electron. Eng. (ICCEEE)*, pp. 196-201.  
Aug
- Elhoseny, M., Shankar, K., Lakshmanaprabu, S.K., Maseleno, A., Arunkumar, N.  
**Hybrid optimization with cryptography encryption for medical image security in Internet of Things**  
(2020) *Neural Comput. Appl.*, 32 (15), pp. 10979-10993.  
Aug
- Turjman, F.A., Alturjman, S.  
**Context-sensitive access in industrial Internet of Things (IIoT) healthcare applications**  
(2018) *IEEE Trans. Ind. Informat.*, 14 (6), pp. 2736-2744.  
Jun
- Restuccia, F., D'Oro, S., Melodia, T.  
**Securing the Internet of Things in the age of machine learning and software-defined networking**  
(2018) *IEEE Internet Things J.*, 5 (6), pp. 4829-4842.  
Dec
- Hasan, M.K., Saeed, R.A., Alsaqour, R.A., Ismail, A.F., Aisha, H.A., Islam, S.  
**Cluster-based time synchronisation scheme for femtocell network**  
(2015) *Int. J. Mobile Commun.*, 13 (6), pp. 567-598.
- Islam, S., Abdalla, A.H., Khalifa, M.K.H.O.O., Mahmoud, O., Saeed, R.A.  
**Macro mobility scheme in NEMO to support seamless handoff**  
(2012) *Proc. Int. Conf. Comput. Commun. Eng. (ICCCE)*, pp. 234-238.  
Jul
- Hasan, M.K., Ismail, A.F., Islam Hashim, W.S., Pandey, B.  
**Dynamic spectrum allocation scheme for heterogeneous network**  
(2017) *Wireless Pers. Commun.*, 95 (2), pp. 299-315.  
Jul
- Hasan, M.K., Saeed, R.A., Abdalla, A.-H., Islam, S., Mahmoud, O.  
**An investigation of femtocell network synchronization**  
(2011) *Proc. IEEE Conf. Open Syst.*, pp. 202-207.  
Sep
- Shankar, K., Elhoseny, M., Perumal, E., Ilayaraja, M., Sathesh Kumar, K.  
**An efficient image encryption scheme based on signcryption technique with adaptive elephant herding optimization**  
(2019) *Proc. Adv. Sci. Technol. Secur. Appl.*, pp. 31-42.
- Araghi, T.K., Manaf, A.A.  
**An enhanced hybrid image watermarking scheme for security of medical and non-medical images based on DWT and 2-D SVD**  
(2019) *Future Gener. Comput. Syst.*, 101, pp. 1223-1246.  
Dec
- Ghadirli, H.M., Nodehi, A., Enayatifar, R.  
**An overview of encryption algorithms in color images**

- (2019) *Signal Process.*, 164, pp. 163-185.  
Nov
- Wan, Y., Gu, S., Du, B.  
**A new image encryption algorithm based on composite chaos and hyperchaos combined with DNA coding**  
(2020) *Entropy*, 22 (2), p. 171.  
Feb
  - Cavuoglu, Ü., Kacar, S., Pehlivan, I., Zengin, A.  
**Secure image encryption algorithm design using a novel chaos based S-box**  
(2017) *Chaos, Solitons Fractals*, 95, pp. 92-101.  
Feb
  - Mitra, A., Rao, Y.V.S., Prasanna, S.R.M.  
**A new image encryption approach using combinational permutation techniques**  
(2006) *Int. J. Electr. Comput. Eng.*, 1 (2), pp. 127-131.
  - Shackelford, S.J., Mattioli, M., Myers, S., Brady, A., Wang, Y., Wong, S.  
**Securing the Internet of healthcare**  
(2018) *Minn. J. L. Sci. Tech.*, 19, p. 405.  
Feb
  - Pishva, D.  
**Internet of Things: Security and privacy issues and possible solution**  
(2017) *Proc. 19th Int. Conf. Adv. Commun. Technol. (ICACT)*, pp. 797-808.
  - Sun, W., Cai, Z., Li, Y., Liu, F., Fang, S., Wang, G.  
**Security and privacy in the medical Internet of Things: A review**  
(2018) *Secur. Commun. Netw.*, 2018.  
Mar
  - Shaktawat, V.A.R., Rs, S., Lakshmi, N., Panwar, A.  
**A hybrid technique of combining AES algorithm with block permutation for image encryption**  
(2020) *Rel., Theory Appl.*, 15 (1), p. 15.
  - Pareek, N.K., Patidar, V.  
**Medical image protection using genetic algorithm operations**  
(2016) *Soft Comput.*, 20 (2), pp. 763-772.  
Feb
  - Nematzadeh, H., Enayatifar, R., Motameni, H., Guimaraes, F.G., Coelho, V.N.  
**Medical image encryption using a hybrid model of modified genetic algorithm and coupled map lattices**  
(2018) *Opt. Lasers Eng.*, 110, pp. 24-32.  
Nov
  - Sun, T.Y., Gu, X.B., Chen, X., Yang, Y.  
**A survey on the new development of medical image security algorithms**  
*Cloud Computing and Security (Lecture Notes in Computer Science)*, 11065.  
X. Sun, Z. Pan, and E. Bertino, Eds. Cham, Switzerland: Springer
  - Acharya, B., Panigrahy, S.K., Patra, S.K., Panda, G.  
**Image encryption using advanced hill cipher algorithm**  
(2010) *ACEEE Int. J. Signal Image Process*, 1 (1), pp. 663-667.
  - Aswatha, A.R., Sasi, S., Santhosh, B., Mehta, D., Babuprasad, S.  
**Design and implementation of unreliable CFDP protocol over elliptic curve cryptography**

- (2020) *Smart Innov., Syst. Technol.*, 160, pp. 627-638.  
Dec
- Banik, A., Shamsi, Z., Laiphrakpam, D.S.  
**An encryption scheme for securing multiple medical images**  
(2019) *J. Inf. Secur. Appl.*, 49.  
Dec
  - Liu, H., Kadir, A., Li, Y.  
**Asymmetric color pathological image encryption scheme based on complex hyper chaotic system**  
(2016) *Optik*, 127 (15), pp. 5812-5819.  
Aug
  - Dai, Y., Wang, H., Wang, Y.  
**Chaotic medical image encryption algorithm based on bit-plane decomposition**  
(2016) *Int. J. Pattern Recognit. Artif. Intell.*, 30 (4), pp. 1-15.
  - Avudaiappan, T., Balasubramanian, R., Pandiyan, S.S., Saravanan, M., Lakshmanaprabu, S.K., Shankar, K.  
**Medical image security using dual encryption with oppositional based optimization algorithm**  
(2018) *J. Med. Syst.*, 42 (11), pp. 1-11.  
Nov
  - Kanso, A., Ghebleh, M.  
**An efficient and robust image encryption scheme for medical applications**  
(2015) *Commun. Nonlinear Sci. Numer. Simul.*, 24 (1-3), pp. 98-116.  
Jul
  - Lima, J.B., Madeiro, F., Sales, F.J.R.  
**Encryption of medical images based on the cosine number transform**  
(2015) *Signal Process., Image Commun.*, 35, pp. 1-8.  
Jul
  - Mukhedkar, M., Powar, P., Gaikwad, P.  
**Secure non real time image encryption algorithm development using cryptography & steganography**  
(2015) *Proc. Annu. IEEE India Conf. (INDICON)*, pp. 1-6.  
Dec
  - Jia, M., Yin, Z., Guo, Q., Liu, G., Gu, X.  
**Downlink design for spectrum efficient IoT network**  
(2018) *IEEE Internet Things J.*, 5 (5), pp. 3397-3404.  
Oct
  - Laiphrakpam, D.S., Khumanthem, M.S.  
**Medical image encryption based on improved ElGamal encryption technique**  
(2017) *Optik*, 147, pp. 88-102.  
Oct
  - Cao, W., Zhou, Y., Chen, C.L.P., Xia, L.  
**Medical image encryption using edge maps**  
(2017) *Signal Process.*, 132, pp. 96-109.  
Mar
  - Pal, S.K., Anand, S.  
**Cryptography based on RGB color channels using ANNs**  
(2018) *Int. J. Comput. Netw. Inf. Secur.*, 10 (5), pp. 60-69.  
May

- Rarhi, K., Saha, S.  
**Image encryption in IoT devices using DNA and hyperchaotic neural network**  
(2020) *Lect. Notes Netw. Syst.*, 82, pp. 347-375.
- Hamza, R., Yan, Z., Muhammad, K., Bellavista, P., Titouna, F.  
**A privacy-preserving cryptosystem for IoT E-healthcare**  
(2020) *Inf. Sci.*, 527, pp. 493-510.  
Jul
- Ghazal, T.M., Hasan, M.K., Hassan, R., Islam, S., Abdullah, S.N.H.S., Kalra, A.A.D.  
**Security vulnerabilities, attacks, threats and the proposed countermeasures for the Internet of Things applications**  
(2020) *Solid State Technol.*, 63 (1 S), pp. 2513-2521.
- Hassan, R., Qamar, F., Hasan, M.K., Aman, A.H.M., Ahmed, A.S.  
**Internet of Things and its applications: A comprehensive survey**  
(2020) *Sym-metry*, 12 (10), p. 1674.  
Oct
- Varish, N., Pal, A.K., Hassan, R., Hasan, M.K., Khan, A., Parveen, N., Banerjee, D., Memon, I.  
**Image retrieval scheme using quantized bins of color image components and adaptive tetrolet transform**  
(2020) *IEEE Access*, 8, pp. 117639-117665.
- Albahri, O.S., Albahri, A.S., Zaidan, A.A., Zaidan, B.B., Alsalem, M.A., Mohsin, A.H., Mohammed, K.I., Shareef, A.H.  
**Faulttolerant mHealth framework in the context of IoT-based real-time wearable health data sensors**  
(2019) *IEEE Access*, 7, pp. 50052-50080.
- Misran, N., Islam, M.S., Beng, G.K., Amin, N., Islam, M.T.  
**IoT based health monitoring system with LoRa communication technology**  
(2019) *Proc. Int. Conf. Electr. Eng. Informat. (ICEEI)*, pp. 514-517.  
Jul
- Safavi, S., Meer, A.M., Keneth Joel Melanie, E., Shukur, Z.  
**Cyber vulnerabilities on smart healthcare, review and solutions**  
(2018) *Proc. Cyber Resilience Conf. (CRC)*, pp. 1-5.  
Nov
- Hua, Z., Yi, S., Zhou, Y.  
**Medical image encryption using highspeed scrambling and pixel adaptive diffusion**  
(2018) *Signal Process.*, 144, pp. 134-144.  
Mar
- Ke, G., Wang, H., Zhou, S., Zhang, H.  
**Encryption of medical image with most signi-cant bit and high capacity in piecewise linear chaos graphics**  
(2019) *Measurement Vol. 135*, pp. 385-391.  
Mar
- Khond, S., Vijayakumar, B.  
**Secure medical image processing using chaos and DNA encryption enhanced using reversible data hiding**  
(2019) *Int. J. Eng. Adv. Technol. Vol. 8*, pp. 1062-1067.  
Feb
- Priya, S., Santhi, B.  
**A novel visual medical image encryption for secure transmission of authenticated watermarked medical images**

(2019) *Mobile Netw. Appl.*,  
Feb

- Raja, S.P.  
**Joint medical image compression-encryption in the cloud using multiscale transform-based image compression encoding techniques**  
(2019) *Sadhana*, 44 (2), p. 28.  
Feb
- Raja, S.P.  
**Multiscale transform-based secured joint efficient medical image compression-encryption using symmetric key cryptography and ebcot encoding technique**  
(2019) *Int. J. Wavelets, Multiresolution Inf. Process.*, 17 (5).  
Sep
- Salama, A., Mokhtar, A., Tayel, M.  
**A triple-layer encryption-based watermarking technique for improving security of medical images**  
(2019) *J. Med. Imag. Health Inf.*, 9 (3), pp. 610-619.
- Dang, P.P., Chau, P.M.  
**Image encryption for secure Internet multimedia applications**  
(2000) *IEEE Trans. Consum. Electron.*, 46 (3), pp. 395-403.  
Aug
- Kamil, S., Ayob Siti, M., Ahmad, Z.  
**Lightweight and optimized multilayer data hiding using video steganography paper**  
(2018) *Int. J. Adv. Comput. Sci. Appl.*, 9 (12), pp. 256-262.
- Kamil, S., Ayob, M., Sheikh Abdullah, S.N.H., Ahmad, Z.  
**Challenges in multi-layer data security for video steganography revisited**  
(2018) *Asia-Paci-c J. Inf. Technol. Multimedia*, 7 (2), pp. 53-62.  
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