An Overview on Quantum Image Watermarking for Security of COVID-19 Patient Record

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The basics of Quantum Information Processing (QIP) is summarized below, in addition to a comprehensive survey of quantum image-based data hiding techniques. QIP is more efficient and provides higher security than classical information processing. A comparative analysis of the Flexible Representation of Quantum Images (FRQI) and Novel Enhanced Quantum Representation (NEQR) model is also presented. QIP is used in various potential applications, hence offering an interesting and demanding area for researchers [1]. Some of the important applications include medicine, military, environmental monitoring, image processing, communications, computations, and cryptography. This article focusses on the processing of information that can be represented using quantum mechanics [2]. Furthermore, coherence, entanglement, and superposition of quantum states makes quantum computing more suitable to its classical counterpart for information storage and processing [1], [3].

A. An overview of Quantum Information Processing

In QIP, a qubit signifies the smallest data in a quantum system, which is the combination of two ground states, 0 and 1. In addition to representing grounded states, it also represents its superposition [4], [5]. In fact, quantum computation has been identified as a potential solution to the failure of Moore's law [6]. The use of quantum information hiding approaches have recently increased. In many cases, they are leveraged for securing quantum medical images in smart healthcare applications [1], [5]. Protecting patient data that is shared over secure channels, or IoT networks, is very important for data confidentiality, ownership identification, and to help prevent patient identity theft, copyright violations, and illegal distribution [2], [7].

B. Quantum Image Watermarking in the Healthcare Domain

As a result from the COVID-19 pandemic, numerous hospitals and health-centers have been storing patient data and related images on their servers [8]. This provides an additional resource and better references, enabling medical professionals to provide effective treatment. However, it may put the patients' records at a higher risk of falling into the wrong hands. Notable organizations and agencies have provided guidelines and standards for the security of health records, but security and privacy issues still need to be addressed. For example, once data has been retrieved by the authorized personnel, will it be stored? If so, for how long and where? Quantum information hiding involves imperceptibly inserting different kinds of secrete quantum data into a quantum image, which serves as a carrier for maintaining security [3], [5]. In addition, quantum image watermarking can be leveraged in the healthcare domain to reduce bandwidth and storage demands. This would result in more efficient archiving and warrant faster retrieval of data. Fig. 1 below shows the general framework for hiding quantum image(s) for smart healthcare:

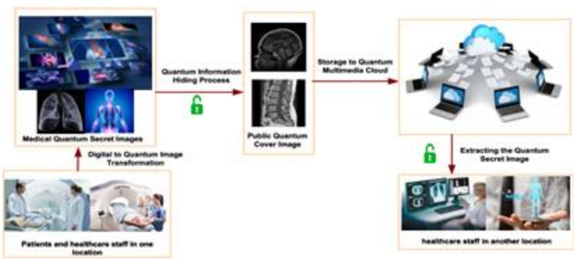

Fig. 1: General framework for hiding quantum image(s)

The urgency of developing efficient quantum image watermarking techniques for use in the healthcare domain is evident. In a recent study, we analyzed various quantum image watermarking techniques, and this paper provides details pertaining to merits and limitations corresponding with each approach. Lastly, we highlighted the significant challenges of the FRQI and NEQR quantum models, along with suggestions for future research studies that may fill in gaps in these domains for both researchers and developers.

C. Notable Contributions from Quantum Models

FRQI [6], NEQR [3], improved NEQR [3] etc. are models with a number of capabilities proficient for transforming digital images into quantum representation quantum state processes. Notable contributions in this area, as reported by potential researchers at national and international levels, are given below:

Abdulrida et al. proposed a robust and secure watermarking scheme for copyright protection and owner validation of quantum images [1]. The aforementioned method uses transformations including, but not limited to, Haar transform and geometric transform, least significant bit (LSB), and quantum techniques. Certain textures of the logo are encoded using quantum entanglement of bell state before being concealed into the cover image.

Another method, suggested by Miyake and Nakamae, involved using NEQR based robust watermarking techniques with lower computational complexity [3]. The watermark is doubled in size, and then scrambled using SWAP gates and confidential keys. For this tactic, CNOT (XOR) gates are used to embed the scrambled watermark into the cover image. However, this technique can be improved by using stabilizer formalism [3].

Several scholarly articles provided an overview, description, and observations from another watermarking approach [6]. In this publication, the authors presented a robust watermarking approach for quantum images based on Quantum Fourier Transform (QFT). Initially, this tactic involves transforming the carrier and watermark images into quantum images using FRQI. In the pre-processing stage, the watermark images are scrambled into meaningless images by quantum circuits. During the embedding procedure, watermark images are ingrained into Fourier coefficients of carrier images. This scheme ensures resistance against noise and cropping attacks. Since Quantum Wavelet Transform (QWT) is fast and has a full circuit of quantum Daubechies wavelet transform, M. Mastriani suggests a QWT-based dynamic watermarking technique with higher embedding capacity [5]. This approach uses FRQI representations for defining digital images. The authors used dynamic vectors based on the carrier and watermark quantum images for choosing the factors while embedding. Compared to similar quantum-based watermarking techniques [2], [6], [9], this watermarking approach demonstrated better results in terms of complexity, imperceptibility, and embedding capacity.

Authors Song, Wang, El-Latif, and Niuof [10] proposed another key dynamic watermarking technique, based on Hadamard transform for quantum images and FRQI representations. This method also uses dynamic vectors based on the quantization and controlling of the embedding factor. S. Wang, X. Song, and X. Niu, in [11], proposed watermarking procedures based on Quantum Cosine Transform (QCT) for quantum images. Initially, carrier and watermark images are converted into quantum images by FRQI. In the embedding procedures, the mark is concealed into a QCT coefficient of the carrier image. Then, in the extraction phase, the dynamic vector is used to control the embedding strength of a watermark system. Therefore, this structure provides better visual quality compared to traditional techniques.

In their publication, Yan et. al [12] described a novel concept for a duple watermarking scheme encompassing multi-channel quantum images (MCQI). This approach was developed for the protection of quantum images. In this strategy, the watermark is embedded into spatial and frequency domains of carrier images, which contributes to the strength of the watermark. In addition, it uses two keys—a Color Information Key (CIK) and a Position Information Key (PIK). The CIK is used to preserve color information, and the PIK scrambles the position of the watermark image. The concealed watermark logo can only be extracted by CIK and PIK in spatial and frequency domains. The implemented scheme provides more protection for quantum data. Panjiyar et. Al [13] proposed a dynamic watermark strategy for quantum images based on two different techniques—Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT).

Another method involves concealing Three Pseudorandom Number (PN) sequences in RGB color space images to provide a higher level of security. The proposed work claims to achieve robustness against almost all attackers. Enhanced robustness and superior security are achieved when this work is separately compared with DCT and DWT-based techniques. In another article [14], two different data hiding approaches were suggested for sharing quantum medical images using NEQR representation. The first recommendation involves Steganography approaches based on chaotic maps. This would provide better security by encrypting the quantum secret-image using a controlled-NOT gate. The encrypted image is concealed in two most and least qubits of the quantum host image. In the second approach, based on quantum image watermarking, involves hiding grey scale quantum images into quantum carrier images. The secret image is scrambled using Arnold’s cat map and is then embedded into the carrier image using XOR operation. In 2021, Qu et al. [15] proposed an efficient quantum steganography scheme using improved-exploiting modification direction techniques. Initially, this scheme considered the NEQR model for converting the digital image into quantum information. Then, qubits of the secrete data are concealed and obtain the marked data via quantum circuits. Then, the same quantum circuit is used to recover the hidden data from the carrier image. This method demonstrated a reasonable relationship between invisibility and capacity, and the result analysis ensured the ssuperiority of the scheme over existing works [16], [17].

D. Conclusion

This paper provides information on the basics of QIP as well as the analyses for a number of data hiding solutions for quantum images. Based on these findings, most of the quantum image watermarking methods are based on the FRQI method. However, the time complexity of FRQI is too high and the compression ratio too poor. Another challenge is the impossibility to achieve accurate image retrieval for the FRQI model—The NEQR model adopted a qubit sequence to store the grey-scale value of all the pixels in the image for the first time, instead of the probability amplitude of a single qubit, as in FRQI. It has been demonstrated that quantum representation by an NEQR model is better in many aspects than an FRQI. Lower time complexity, high compression ratio, and accurate image retrieval properties of the NEQR model make it superior to the FRQI model. In summary, rapid advancement in quantum image processing is experienced; however, there are infinite challenges and problems evident in current trends that need to be addressed.

REFERENCES

1) R. Abdulrida, M. E. A-Monem, and A. M. Jaber, "Quantum image watermarking based on wavelet and geometric transformation," Iraqi J. Sci., vol. 61, no. 1, pp. 153–163, 2020, doi: 10.24996/ijs.2020.61.1.17.
2) A. M. Iliyasu, P. Q. Le, F. Dong, and K. Hirota, "Watermarking and authentication of quantum images based on restricted geometric transformations," Inf. Sci. (Ny)., vol. 186, no. 1, pp. 126–149, 2012, doi: 10.1016/j.ins.2011.09.028.
3) S. Miyake and K. Nakamae, "A quantum watermarking scheme using simple and small-scale quantum circuits," Quantum Inf. Process., vol. 15, no. 5, pp. 1849–1864, 2016, doi: 10.1007/s11128-016-1260-9.
4) J. Zhang, X. Zhou, J. Yang, C. Cao, and J. Ma, "Adaptive Robust Blind Watermarking Scheme Improved by Entropy-Based SVM and Optimized Quantum Genetic Algorithm," Math. Probl. Eng., vol. 2019, 2019, doi: 10.1155/2019/7817809.
5) M. Mastriani, Quantum image processing, vol. 16, no. 1. 2017.
6) W. W. Zhang, F. Gao, B. Liu, Q. Y. Wen, and H. Chen, "A watermark strategy for quantum images based on quantum fourier transform," Quantum Inf. Process., vol. 12, no. 2, pp. 793–803, 2013, doi: 10.1007/s11128-012-0423-6.
7) F. Yaghmaee and M. Jamzad, "Estimating watermarking capacity in gray scale images based on image complexity," EURASIP J. Adv. Signal Process., vol. 2010, 2010, doi: 10.1155/2010/851920.
8) B. de A. Almeida et al., "Personal data usage and privacy considerations in the COVID-19 global pandemic," Cienc. e Saude Coletiva, vol. 25, pp. 2487–2492, 2020, doi: 10.1590/1413-81232020256.1.11792020.

9) F. Zhang, X. Zhang, and H. Zhang, “Digital image watermarking capacity and detection error rate,” Pattern Recognit. Lett., vol. 28, no. 1, pp. 1–10, 2007, doi: 10.1016/j.patrec.2006.04.020.
10) X. Song, S. Wang, A. A. Abd El-Latif, and X. Niu, “Dynamic watermarking scheme for quantum images based on Hadamard transform,” Multimed. Syst., vol. 20, no. 4, pp. 379–388, 2014, doi: 10.1007/s00530-014-0355-3.
11) S. Wang, X. Song, and X. Niu, “Quantum cosine transform based watermarking scheme for quantum images,” Chinese J. Electron., vol. 24, no. 2, pp. 321–325, 2015, doi: 10.1049/cje.2015.04.016.
12) F. Yan, A. M. Iliyasu, B. Sun, and S. E. V. F. Dong, “A duple watermarking strategy for multi-channel quantum images,” Quantum Inf. Process., vol. 14, pp. 1675–1692, 2015, doi: 10.1007/s11128-014-0912-x.
13) T. Panjiyar, N. Sharma, and Y. Katiyar, “A Technical Paper on Quantum Watermarking Techniques Based on DWT- DCT and DCT-DWT Using PN Sequence,” vol. 6, no. 4, pp. 274–283, 2017.
14) A. A. Abd El-Latif, B. Abd-El-Atty, M. S. Hossain, M. A. Rahman, A. Alamri, and B. B. Gupta, “Efficient Quantum Information Hiding for Remote Medical Image Sharing,” IEEE Access, vol. 6, pp. 21075–21083, 2018, doi: 10.1109/ACCESS.2018.2820603.
15) Z. Qu, “An efficient quantum image steganography protocol based on improved EMD algorithm,” Quantum Inf. Process., vol. 20, no. 53, pp. 1–29, 2021, doi: 10.1007/s11128-021-02991-8.
16) Z. Qu, Z. Cheng, and X. Wang, “Matrix Coding-Based Quantum Image Steganography Algorithm,” IEEE Access, vol. 7, pp. 35684–35698, 2019, doi: 10.1109/ACCESS.2019.2894295.
17) W. Hu, R. Zhou, and G. Luo, “Quantum image steganography algorithm based on modified exploiting modification direction embedding,” Quantum Inf. Process., vol. 19, no. 5, pp. 1–28, 2020, doi: 10.1007/s11128-020-02641-5.

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