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Robust Quantum Image Encryption Algorithm Leveraging 3D-BNM Chaotic Maps and Controlled Qubit-Level Operations

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Abstract : This study presents a novel quantum image encryption algorithm, using a 3D chaotic map and controlled qubit-level scrambling operations. The newly proposed 3D-BNM chaotic map effectively reduces the degradation of chaotic dynamics resulting from the finite word length effect. It facilitates the generation of highly unpredictable random sequences and enhances chaotic performance. The system's efficacy is additionally enhanced by the inclusion of a SHA-256 hash function. Initially, classical plain images are converted into their quantum equivalents using the Novel Enhanced Quantum Representation (NEQR) model. The Generalized Quantum Arnold Transformation (GQAT) is then applied to disrupt the coordinate information of the quantum image. Subsequently, to diffuse the pixel values of the scrambled image, XOR operations are performed using pseudorandom sequences generated by the 3D-BNM chaotic map. Furthermore, to enhance the randomness and reduce the correlation among the pixels in the resulting cipher image, a controlled qubit-level scrambling operation is employed. The encryption process utilizes fundamental quantum gates such as C-NOT and CCNOT. Both theoretical and numerical simulations validate the effectiveness of the proposed algorithm against various statistical and differential attacks. Moreover, the proposed encryption algorithm operates with low computational complexity.

Keywords : 3D Chaotic map, SHA-256, quantum image encryption, Qubit level scrambling, NEQR
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