

Acknowledgments

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المخلص

- يتناول هذا البحث مجال معالجة الصور الكمومية (Quantum Image Processing - QIP) ، الذي يهدف إلى تعزيز تقنيات معالجة الصور الكلاسيكية من خلال استغلال المبادئ الأساسية لميكانيكا الكم، مثل التراكب، والتشابك، والقابلية للعكس. يركز هذا العمل على نموذج التمثيل المرن للصور الكمومية (FRQI)، من خلال دراسة بنيته وكفاءته الحسابية وعدد الكيوبتات اللازمة لتنفيذ عمليات معالجة الصور. - يتضمن هذا العمل تصميم ومحاكاة دوائر كمومية باستخدام إطار العمل Qiskit ، مع التركيز بشكل خاص على تطبيق فلاتر كمومية ومحاكاة الفلتر الكمومية الوسيطة بهدف إزالة الضوضاء من الصور الرقمية. وتشير نتائج التجارب إلى أن تقنيات الفلتر الكمومية تُظهر أداءً متفوقاً مقارنةً بنظيراتها الكلاسيكية من حيث جودة إزالة الضوضاء، وذلك بناءً على مؤشرات تقييم جودة الصور مثل معدل الذروة للإشارة إلى الضوضاء (PSNR) ، ومتوسط مربع الخطأ (MSE) ، ومؤشر التشابه البنيوي (SSIM). - ورغم القيود الحالية التي تفرضها الأجهزة الكمومية، مثل محدودية عدد الكيوبتات والضوضاء الداخلية، تؤكد نتائج هذه الدراسة على الإمكانيات الواعدة التي توفرها تقنيات الفلتر الكمومية لأنظمة معالجة الصور عالية الأداء مستقبلاً، لا سيما في مجالات تقليل الضوضاء وتحسين جودة الصور.

الكلمات المفتاحية: معالجة الصور الكمومية (QIP) ، التمثيل المرن للصور الكمومية (FRQI) ، الفلتر الكمومية الوسيطة، اكتشاف الحواف، Qiskit، معالجة الصور الرقمية، الحوسبة الكمومية، تمثيل الصور الكمومية، فلتر الصور

Abstract

This thesis investigates the domain of Quantum Image Processing (QIP), which seeks to enhance classical image processing techniques by leveraging the fundamental principles of quantum mechanics, including superposition, entanglement, and reversibility. The research centers on the Flexible Representation of Quantum Images (FRQI), examining its structure, computational efficiency, and qubit requirements for implementing image-related operations.

The study involves the design and simulation of quantum circuits using the Qiskit framework, with a particular focus on the application of quantum filters and the simulation of quantum median filtering techniques for noise reduction in digital images. The experimental findings indicate that quantum-based filtering methods can outperform their classical counterparts in terms of denoising performance, as assessed using standard image quality metrics such as Peak Signal-to-Noise Ratio (PSNR), Mean Squared Error (MSE), and Structural Similarity Index (SSIM).

Although current quantum hardware remains constrained by factors such as limited qubit availability and intrinsic system noise, the results of this work highlight the promising potential of quantum filtering techniques for future high-performance image processing systems, particularly in the areas of noise suppression and visual enhancement.

Keywords: Quantum Image Processing (QIP), FRQI, Quantum Median Filtering, Edge Detection, Qiskit, Digital Image Processing, Quantum Computing, Quantum Image Representation, Image Filtering

Résumé

Ce mémoire porte sur le domaine du traitement d'images quantique (Quantum Image Processing – QIP), qui vise à améliorer les techniques classiques de traitement d'images en exploitant les principes fondamentaux de la mécanique quantique tels que la superposition, l'intrication et la réversibilité. L'étude se concentre sur le modèle de Représentation Flexible des Images Quantiques (FRQI), en analysant sa structure, son efficacité computationnelle ainsi que le nombre de qubits requis pour réaliser des opérations liées aux images.

Le travail consiste à concevoir et à simuler des circuits quantiques à l'aide du framework Qiskit, avec un accent particulier sur l'application de filtres quantiques et la simulation de la filtration médiane quantique dans le but de réduire le bruit présent dans les images numériques. Les résultats expérimentaux montrent que les méthodes de filtrage quantique surpassent leurs équivalents classiques en termes de qualité de débruitage, comme l'indiquent les métriques standard d'évaluation de la qualité d'image telles que le PSNR, le MSE et le SSIM.

Malgré les limitations actuelles du matériel quantique notamment le nombre restreint de qubits disponibles et le bruit intrinsèque des systèmes les résultats obtenus soulignent le potentiel prometteur des techniques de filtrage quantique dans les futurs systèmes de traitement d'images à haute performance, notamment pour la suppression du bruit et l'amélioration visuelle.

Mots-clés : Traitement d'images quantique (QIP), FRQI, Filtrage médian quantique, Détection des contours, Qiskit, Traitement d'images numériques, Calcul quantique, Représentation quantique des images, Filtrage d'images

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