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QUANTUM FOURIER TRANSFORM OF IMAGES

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Abstract
This paper presents an approach to applying quantum Fourier transform (QFT) to image processing using quantum computing. The use of quantum computing for image analysis and processing is becoming increasingly relevant in modern science and technology. A quantum QFT circuit is presented, implemented using the Qiskit framework, which is a tool for programming quantum computers. The paper presents the basic steps of QFT and their application to a state vector representing the pixel intensities of an image. We explore the impact of quantum transformation on image structure and present the results in the form of graphs and visualizations. In addition, we are introducing the ability to infer the QFT quantum circuit for a more visual representation of the algorithm. The results highlight the potential of quantum computing in the field of image processing and open new prospects for the use of quantum technologies in the field of computer vision.

Keywords. *Quantum computing, Fourier transform, image processing, quantum circuit.*

1. Introduction. *With the development of quantum technologies, new opportunities appear for solving computational problems, including in the field of image processing. Traditional image processing methods often face limitations in speed and efficiency, especially when dealing with large volumes of data. In this context, the application of quantum computing for image processing represents a promising research direction. Quantum algorithms, such as the Quantum Fourier Transform (QFT), can provide more efficient data processing by using the principles of quantum mechanics. With the development of quantum computing and the expansion of its scope, new opportunities in the field of data processing arise. One exciting area of research is the application of quantum methods to image processing. Traditional methods, although effective, often face limitations, especially when working with large amounts of information [1].*

The purpose of this work is to review and analyze the application of QFT to images using quantum computing. We explore the key steps of quantum transformation in the context of image processing and consider the impact of this method on the structure of images. We also present a new aspect in the form of the output of the QFT quantum circuit for a clear demonstration of the algorithm. This work aims to expand understanding of the capabilities of quantum computing in the field of image processing and contribute to the development of new data analysis methods using quantum technologies [2].

2.Materials and methods.

To conduct the study, a digital image of interest for analysis was selected. The image can be either monochrome or color to view the effect of quantum transformation on different types of data. The image is converted into a format suitable for processing, such as black and white. The image size can also be reduced to the nearest lesser power of two for ease of application of the Quantum Fourier Transform (QFT). Each pixel in the image is converted to intensity and a state vector is generated. This vector is prepared for use in a quantum circuit. A quantum circuit is implemented to apply QFT to the image state vector. The Qiskit library for the Python programming language is used for this. Each element of the state vector represents the probability amplitude on the corresponding qubit [3].

The impact of QFT on image structure is studied. State vectors before and after transformation, as well as the resulting images, are analyzed. Visualization of results is used for a clearer understanding of the process. To visually represent the QFT algorithm in a quantum circuit, the Qiskit library is used. A quantum circuit is derived by applying QFT to the input data. The experiment is carried out with various variants of images and QFT parameters to identify the features and influence of quantum transformation on the structure of the input data [4].

To implement a quantum circuit, the program uses the Qiskit library, which provides the ability to work with quantum circuits in the Python programming language. Quantum bits are created that will be used to represent the input image state vector. The number of qubits is equal to the nearest lesser power of two to the image size (for example, if the image size is 64x64, then 6 qubits are used). The quantum

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circuit presented in this program performs the Fourier transform on quantum bits (quantum qubits). The Fourier transform is a mathematical transformation that has applications in various fields, including classical and quantum information science [5].

3. Results. *A quantum circuit uses quantum bits, which are the quantum analogues of classical bits. Qubits can be in a linear combination of the states ∣0⟩∣0⟩ and ∣1⟩∣1⟩ due to the phenomenon of quantum interference. The Fourier transform in this context is performed on quantum bits. This transform is the quantum analogue of the classical Fourier transform, which is applied to a sequence of values. The circuit uses quantum gates such as Hadamard gates H, controlled phase gates Rϕ), and controlled phase gates C (Fig.1).*

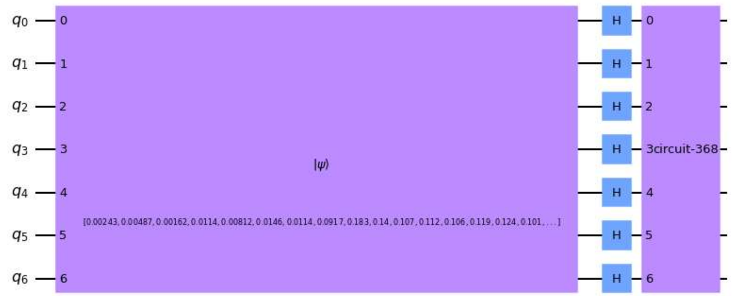

Fig.1. Quantum circuit Fourier transform to qubit state

The initial state of the quantum system is initialized with an image, and then a quantum transformation is performed. After this, qubits are measured to obtain classical information. The results of quantum transformation are visualized using graphs, allowing you to see how the state vector and image change after the transformation (Fig.2).

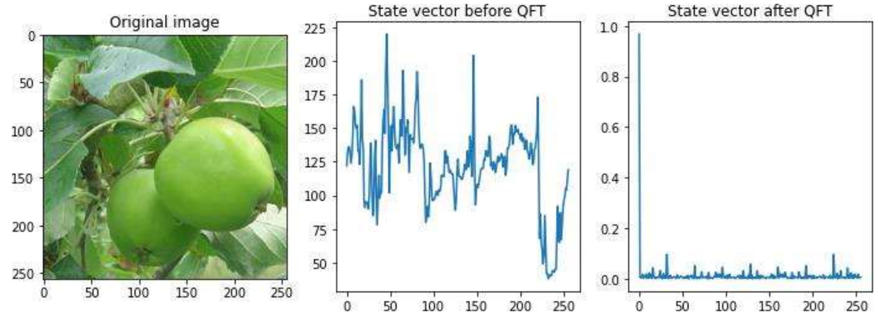

Fig.2. State vector before and after QFT

Such a quantum circuit can be used to study quantum transformations in images and in the context of quantum data processing algorithms.

4.Conclusion. *In this work, the application of Quantum Fourier Transform (QFT) in the context of image processing was analyzed. Experimental results show that quantum transformation can affect the structure of images, leading to changes in pixel amplitudes. The efficiency of quantum conversion was assessed using images using different numbers of quantum bits. Increasing the number of bits resulted in higher transformation granularity, but required more computational resources.*

The amplitude histogram after QFT can serve as an indicator of important image characteristics. However, it must be taken into account that the results can greatly depend on the image itself and the parameters of the quantum circuit. It also highlighted areas of application where quantum image processing techniques could be most useful, such as highlighting singular points and patterns. However, it should be noted that quantum image processing methods have their limitations, and the performance *of such approaches can be improved with further research and optimization. These results highlight the promise of using quantum approaches in image processing, providing new opportunities for analyzing and modifying visual data. Further research in this area will help optimize the parameters of quantum circuits and expand the scope of their application in practical image processing problems.*

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