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APPLICATION OF QUANTUM ALGORITHMS IN IMAGE PREPROCESSING

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Abstract
This article discusses the problem of using quantum algorithms for image processing. The main emphasis is on converting classical images into a quantum state. Methods for converting images using quantum computing are considered, and the prospects and possibilities of using quantum algorithms in image processing problems are also explored. The advantages and limitations of this approach are discussed, and ways forward for further development and research in this area are suggested.

Keywords: *Quantum computing, image processing, image transformation, quantum state, classical images, image processing algorithms.*

1. Introduction. *Modern problems in image processing pose new challenges for the scientific community that require innovative approaches. In recent years, the research topic of using quantum algorithms for image processing has become increasingly relevant. This approach offers the potential to significantly improve the efficiency and accuracy of image processing by applying the principles of quantum mechanics. One of the key aspects of this topic is the transformation of classical images into a quantum state. This allows image information to be transferred to a quantum format that can be processed using quantum algorithms. This approach opens up new possibilities for solving image processing problems, such as edge detection, segmentation, object recognition and others [1].*

In this context, it becomes important to research and develop methods, algorithms and models that can effectively take advantage of quantum computing for image processing. In addition to converting classical images into a quantum state, the possibilities of using quantum algorithms for edge detection, converting halftone images to binary, and other image processing tasks are also considered. The purpose of this work is to study the prospects for using quantum algorithms for image processing, as well as to develop effective methods and models for solving related problems. The results of this research may lead to the development of new approaches in the field of image processing based on the principles of quantum mechanics, and open up new opportunities for solving complex problems in this field [2].

2. Materials and methods. *The process of forming a set of qubits is a key step in preparing a quantum system for computation or information processing. The initial step is to select the physical system that will be used to implement the qubits. The formation of the basic state usually begins with the state |0⟩. The next step is to use quantum gates or other operations to manipulate qubits and create states corresponding to the desired quantum states. These operations can include rotations on the Bloch sphere, the application of guided operations, superpositions, and quantum interactions between qubits. Next, control and measurement are carried out. Controlling the state of qubits using measurements and feedback allows you to perform operations on qubits with high accuracy and control the process of formation of quantum states. Error correction mechanisms, such as quantum error codes, are enabled to reduce the impact of errors on the state of the qubits and improve the reliability of the quantum system. The next stage is the preparation of the quantum state to perform specific calculations or information processing. This may include the creation of superpositions, quantum inversion, and other operations necessary to implement quantum algorithms. The process of forming a set of qubits requires strict control and manipulation of quantum states to ensure their stability and accuracy [3].*

Measuring each qubit |q(i,j)⟩ of the entire pixel set of the image allows us to form a matrix of the pixel system. In this case, the correspondence of quantum states 0 and 1 to pixel values at the output leads to a binary object at the output. Figure 2 shows the developed model of a quantum computing device and the result of executing a quantum algorithm for transforming a set of pixels. The result of transforming a pixel set of a photograph using a quantum algorithm can be illustrated as a binary image, where each pixel takes on the value 0 or 1 depending on the quantum state of the corresponding qubit. This approach makes it possible to efficiently represent an image using quantum information and process it using quantum algorithms. The qubit measurement process in this context is based on the use of random numbers from the interval [0, 1]. When measuring the qubit |q(i,j)⟩ , where c1 is the amplitude

of the state |1⟩, a random number from this interval is played. If the random number falls in the interval [0, |c1|^2], then the output value of the measurement is the basis state |0⟩. Otherwise, if the random number falls in the interval [|c1|^2, 1], the output value of the measurement will be the quantum state |1⟩. Thus, this process allows one to probabilistically determine the state of the qubit after measurement, taking into account the amplitude of its state and the random nature of the measurement [4].

3. Computational experiment. *Performing a transformation from a classical image to a quantum superposition state requires several steps, including image preparation, information encoding, and creation of the quantum superposition. The classic image is loaded into the image processing program. The image must be represented as a matrix of pixels, where each pixel is characterized by intensity or color. Each pixel in the image is encoded into a quantum state. This can be achieved using amplitude quantization, where the intensity of each pixel is represented by the probability amplitude on a quantum bit. If you have a monochrome image with 8-bit color depth (256 intensity levels), each pixel can be encoded on a single 8-qubit or on multiple qubits with a lower color depth. Next, apply the superposition operation to the qubits representing the pixels of the image. This makes it possible to create a quantum superposition of different pixel states. For example, one can use the Hadamard operation to create a superposition of the |0⟩ and |1⟩ states on each qubit, allowing all possible combinations of pixel states to be represented in a single quantum state. After creating a quantum superposition, the measurement of quantum states is performed (Fig.1).*

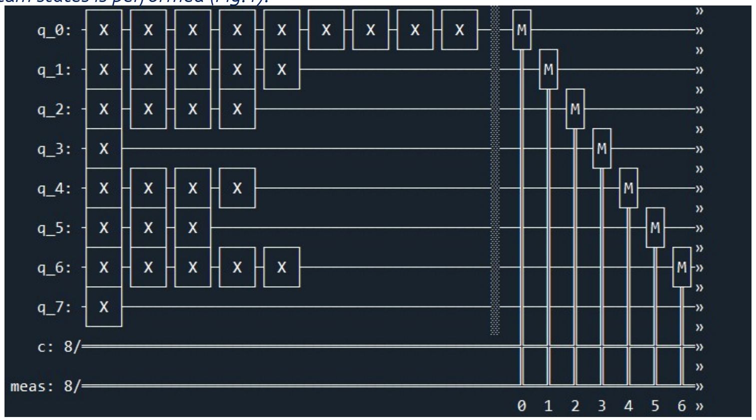

Fig.1. Quantum contrast enhancement circuit

This will lead to the collapse of the superposition into one of the states in accordance with the probability distribution of amplitudes. The resulting state will be a quantum version of the classical image (Fig.2).

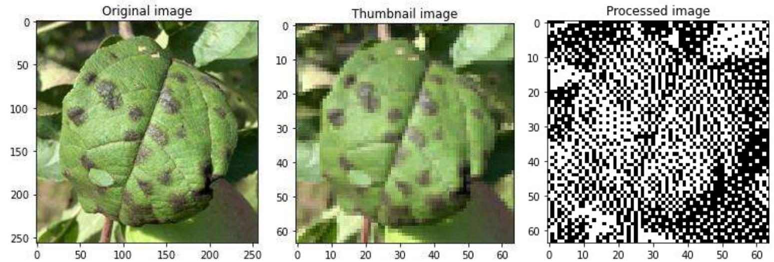

Fig.2. Original and processed image

Performing the transformation of a classical image into a quantum superposition state requires combining image processing techniques with the principles of quantum mechanics to create and analyze the quantum states that represent the image.

4. Conclusion. *The application of quantum algorithms in image processing is a promising direction, opening up new opportunities for solving complex problems and improving the performance of image processing systems. The use of quantum algorithms can significantly speed up the computational process by applying the principles of quantum mechanics, such as quantum superposition and quantum parallelism. This allows you to efficiently process large volumes of data and perform complex operations such as filtering, segmentation, and object recognition more quickly and efficiently than classical methods. One of the key advantages of using quantum algorithms in image processing is their ability to provide stability under different angles of an object and its movement. This makes it possible to create more reliable and accurate image processing systems that can work in various conditions and provide a high degree of accuracy in object recognition.*

In addition, the use of quantum algorithms in image processing can also improve the level of cryptographic noise immunity, which is an important aspect in modern information processing and data privacy protection systems. Thus, the application of quantum algorithms in image processing represents a promising direction that can lead to more efficient, faster and more accurate image processing systems, opening up new opportunities for innovation in this field.

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