Chapter 6
Quantum Computation Perspectives in Medical Image Processing

Pedro João Soares Rodrigues
ESTiG Instituto Politécnico de Bragança, Portugal

Manuel João Ferreira
Universidade do Minho, Portugal

João Luís Monteiro
Universidade do Minho, Portugal

ABSTRACT

The need to increase the complexity of computational methods to produce improvements in functional performance, particularly in medical image processing applications, leads to find suitable physical devices. This chapter describes two ways of adapting the techniques of image processing to quantum devices. This kind of computing can achieve, for some problems, unparalleled performance as compared to classic computing. In the first method, using the quantum Grover's algorithm how to implement image processing techniques under quantum rules is shown. In the second method, using diffraction and interference, the possibility of using less complex quantum devices for processing digital images is treated. Using leucocytes images, that mode is tested.

INTRODUCTION

The automatic analysis of medical images is a field whose main goal is to give to machines a high capacity of processing images in the way the human brain does. This capacity is important in multiple directions. In this domain, the automation of human tasks is mainly helpful to conclude tasks in less time and to minimize errors when producing the results of those tasks. The involved tasks in human vision reach a high level of functional complexity. This is particularly true when the objects of processing are medical images. Thus, it is common to use medical image cases to validate models that have the goal to reach the human visual capacity. Nowadays, there is a relative large pool of knowledge about the human visual cortex and this allows having some image processing solutions that present a good per-

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formance over some kinds of visual applications. Furthermore, that knowledge shows the high complexity of structures that are required to achieve systems that are able to reach the human visual cortex performance. However, it is not possible to obtain the complete comprehension of those structures, but even the partial acquirement of that understanding has been important in attaining image processing systems that perform well for some applications. Generally, the effort to increase the capacity of those models runs into limitations of physical support. These limitations are in the relation between the algorithm complexity and the computational capacity that the physical devices state. Moreover, a small increase in functional performance demands a high order complexity algorithm and subsequently demands an exponential capacity of the physical device. Even though there are multiple algorithms of the math base that are constantly improved, the problem remains. Yet in this direction, the implementation using dedicated hardware or using parallel computation is not enough to get the necessary computing acceleration. The need to increase the complexity of image processing algorithms to improve their functional performance leads to the research of new physical supports that fit them.

This chapter will describe two quantum computing methods that can be applied to medical image processing, to reduce some current limitations in the classical techniques. In some applications, quantum computing allows us to reach speedups that are not possible to get in the classical modes. In the first method, how to adapt the Grover quantum algorithm to image processing is shown. In the second method, a speedup method based in quantum interference is proposed. This last solution can be used in some cases of image analysis. The interference is driven from the objects inside the images to handle the description of the image. The main advantage of this method is also the speedup. The first method can only be tested in quantum emulators, since at this moment there are no quantum computers except in laboratories. The second method can actually be implemented. This is possible because the theoretical background of the quantum interference is basically the same as that which supports light interference. Thus, the method can use light rather than quantum particles.

The studied case (namely in the second technique), in order to test the method, was the recognition of leucocyte images.

The observed results in the first method allowed us to consider its suitable use in the acceleration of image processing. This acceleration is quadratic, which is significant when compared with the classical methods.

In the second method the observed results indicate that the process can be used on images with a geometrical content, but it is not so valuable when used in natural images.

The remainder of the chapter is structured as follows: In the next section, we depict some previous work that conducted us to the present work. In the section "Method I", we begin by explaining the fundamental concepts of the quantum computation. In the next subsections we present the quantum algorithm and the quantum Oracle that will permit us to speed up the image processing and allow us to test the process in a quantum emulator. In the last "Method I" subsections, we give details about a quantum process extension that is based in multi-scale segmentation and we present the final comments about the "Method I". In the section "Method II", we start describing the quantum interference phenomena. In the next subsection the wave function of a circular hole is derived. That derivation is the support to the next subsections where the image formation is related to the quantum interference. In the last "Method II" subsections the quantum interference patterns are analyzed to obtain the description of an image. That analysis is driven by a SVM classifier over images of leukocytes. In the very last subsections the results and the conclusions are present.