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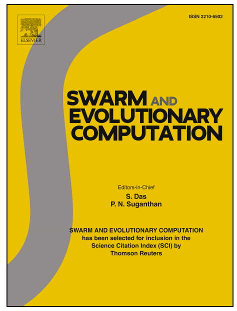

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Quantum rotation gate in quantum-inspired evolutionary algorithm: a review, analysis and comparison study

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ABSTRACT

Quantum-inspired Evolutionary Algorithm (QEA) is a kind of intelligent algorithm which widely and effectively used in many fields. In QEA, the basic and common operations usually include quantum chromosome observation and quantum gate update. Quantum rotation gate (QRG) is the most commonly used operator for the operation of quantum gate update, which has a significant influence on the performance of QEA. Many kinds of QRGs have been proposed with different methods to set the only parameter of QRG, i.e., rotation angle. In this paper, a study on classification of QRG is first conducted with respect to rotation direction and magnitude of rotation angle by analyzing and summarizing various kinds of QRGs in literature, and then the corresponding definitions, descriptions and analyses are presented. Furthermore, in order to investigate and compare performances of different QRGs, we set 21 kinds of QRG schemes based on the classification of rotation direction and magnitude of rotation angle. Four typical complex function optimization problems and a 0-1 knapsack problem are selected as experiment objects to test the 21 kinds of schemes. Comprehensive processing and analyzing for the experiment data are conducted, which draws some valuable conclusions for the more reasonable and more effective applications of QEA.

***Keywords*:** Quantum-inspired evolutionary algorithm, Quantum rotation gate, Function optimization problem, Knapsack problem. *

1. Introduction

Quantum-inspired Evolutionary Algorithm (QEA), proposed by Han and Kim [1,2], is widely and effectively used in many fields. In QEA, a solution individual is encoded by quantum bit, which expressed as a pair of normalized probability amplitude. Quantum bit coding represents 0-1 linear superposition and has abundant diversity. This enables QEA obtain a large search solution space even under a small population size, and get the global optimum with great probability. QEA usually includes two operations, quantum chromosome observation and quantum gate update. The former make an uncertain quantum bit code to be a determinate binary 0 (or 1) in the probability of its corresponding probability amplitude; the operation of quantum gate update plays a role of updating the quantum chromosomes, makes quantum chromosomes evolve from generation to generation and converge to the optimal solution of the problem gradually.

Quantum rotation gate (QRG) is the most commonly used quantum gate in QEA. In 2000, Han and Kim [1] proposed a genetic quantum algorithm to solve knapsack problems and gave the definition and operation method of QRG, in which directions and magnitudes of the rotation angle, the only operation parameter, are given by a lookup table. For the sake of simplicity, a determination method of directions and magnitudes of the rotation angle is termed as a QRG scheme in this paper hereafter. Many different QRG schemes are proposed in QEA-related literature since then. In [3], a more concise QRG scheme with only two nonzero rotation angle conditions was proposed, which is also used to convergence Analysis [4], multiple-Fault diagnosis [5], global numerical optimization [6] and solving economic dispatch problem [7]. QRG schemes with dynamically changing rotation angles are often used in literature. Bin et al. [8] proposed a quantum-inspired binary gravitational search algorithm to handle thermal unit commitment with wind power integration problem, the corresponding QRG scheme characterized by evolutionary generation-dependent rotation angles. The similar QRG schemes are also found in [9-11]. Apart from the evolutionary generation, the object function value is often used to adaptively adjust the rotation angles. Vlachogiannis and Østergaard [12] proposed a general quantum genetic algorithm, in which the rotation angle is related to the normalized difference of object functional value, to determine the optimal settings of control variables for optimal reactive power and voltage control. The algorithms proposed in [13,14] also adopted the dynamically changing rotation angles according to functional values. In the algorithms presented by [15] and [16], rotation angles adaptively change with the gradient information of object function. Another kind of parameter, the difference of binary chromosome individual, is also used to adjust rotation angles, the corresponding method can be found in [17], in which the individual difference is evaluated by Hamming distance. In contrast to a lot of literature which present various QRG schemes, on the other hand, there seems no one focus in comprehensive analysis and comparison of those QRG schemes, which is the motivation for us to conduct the work in this paper.

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