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OBJECTIVE FUNCTION ADJUSTMENT HOPFIELD-TYPE NEURAL NETWORK WITH RESTART TECHNIQUE

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Abstract. *Many techniques with regard to updating parameter have been proposed to help Hopfield neural network (abbr. HNN) escape from the local minimum. In this paper, we propose a new model, objective function adjustment HNN that performs better than other HNN. The proposed algorithm adjusts multipliers of the energy function in gradient ascent direction when the HNN traps in a local minimum. Besides that, another technique is the idea to restart it. The two techniques can help the network to escape from the local minimum. The proposed method was analyzed theoretically and evaluated experimentally through traveling salesman problems simulation. The simulation results obtained from some TSPLIB benchmark problems showed that the proposed algorithm performed better than others and was able to find 100% valid solutions that were optimal or near-optimal solutions.*

Keywords: Hopfield neural network, Local minimum, Lagrange relaxation, The traveling salesman problem, Restart technique

1. **Introduction.** Many problems in science and technology are related to combinatorial optimization problems. A number of combinatorial optimization problems are difficult to deal with because they belong to the NP-hard class [1]. To find an optimal solution for these problems, many methods have been proposed so far. Since Hopfield seminal work [2-4], there has been a growing interest in applying the HNN to solve combinatorial optimization problems. Although the HNN guarantees convergence to a stable equilibrium point due to its gradient descent dynamics, the major weakness is that it often has convergence problems and suffers from the local minimum [5]. Therefore, various modifications have been proposed to overcome the weakness. Work on improving the convergence of the HNN has been carried out by a number of researchers by means of modifying the energy function. Brandt et al. [6] and Aiyer [7] modified the energy function of Hopfield and Tank to improve the convergence to valid solutions. Protzel et al. [8] studied the formulation of Brandt et al. with different parameters. Takefuji and Lee [9] modified the motion equation in order to guarantee the local minimum convergence. But these methods cannot guarantee to escape from the local minimum. Therefore, many other techniques have been combined with HNN to get the optimal or near-optimal solutions. The simulated annealing technique has been introduced into the HNN, and thereby Boltzmann machines were developed [10]. Also several neuron models and heuristics such as hysteresis binary neural model [11], neuron filter [12] and Lagrange relaxation [13] have