International Journal of Innovative
Computing, Information and Control
Volume **5**, Number **12(B)**, December **2009**

ICIC International ©2009 ISSN 1349-4198
pp. **5051–5060**

A NEW TYPE OF HOPFIELD NETWORK WITH CONTROLLABLE SYNAPTIC WEIGHTS FOR SOLVING COMBINATORIAL OPTIMIZATION PROBLEMS

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Received July 2008; revised December 2008

Abstract. *A virtual magnetic diminuendo (VMD) method proposed recently is a new search algorithm for combinatorial optimization problems. It is originally inspired by the analogy between the Hopfield network and the spin glass system, and its essence is to change a configuration of the energy function by controlling a threshold corresponding to a virtual magnetic parameter. As there is another variable parameter in the Hopfield network, synaptic weight, so it is expected that controlling the synaptic weights, named a controlling synaptic weights (CSW) method, must be another candidate of new search methods. In order to investigate its effectiveness, some computer simulations are tried with an N queens problem. As a result, it is found that the proposed CSW method shows better score than the conventional standard Hopfield network.*

Keywords: Hopfield network, Virtual magnetic diminuendo (VMD) method, Controlling synaptic weights (CSW) method, Combinatorial optimization problem, N queens problem

1. **Introduction.** There are numerous tasks with a number of constraints in this world. Under such circumstances, we are sometimes requested to find out a solution which satisfies as many constrains as possible. It is called a combinatorial optimization problem. At the research level, some simple tasks such as an N queens problem, a four colors problem, and a travelling salesman problem (TSP) have been adopted to evaluate the efficiency of the proposed methods.

A Hopfield network [1] is known as a good tool based on the neural information technology to handle this kind of tough problems. It is a neural network inspired by the spin glass system consisting of many spins with mutual interactions as mentioned further in the next section. Following the theory developed in the field of the spin glass system, the Hopfield network ideally reaches an optimal solution after the repetition of state transitions. But one of its major drawbacks is the existence of energy local minima, because iterative state transitions are carried out just reducing the energy defined in advance. In order to avoid such poor solutions, many kinds of methods have been proposed by a lot of researchers.

In general, above-mentioned techniques are divided into two major groups. One is an idea based on an analogy between the Hopfield network and the spin glass system, and the other is just an operation to get better solutions without any physical background. For example, simulated annealing [2], Boltzmann machines [3], Gaussian machines [4], quantum annealing [5], and a virtual magnetic diminuendo (VMD) method [6] belong to the former category. Among them, the VMD method and its advanced version are discussed mainly in this paper.