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Dynamic programming for optimal packet routing control using two neural networks

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Abstract

We propose a dynamic programming for optimal packet routing control using two neural networks within the framework of statistical physics. An energy function for each neural network is defined in order to express competition between a queue length and the shortest path of a packet to its destination node. We set a dynamics for the thermal average of the state of neuron in order to make the mean-field energy of each neural network decrease as a function of time. By computer simulations with discrete time steps, we show that the optimal control of packet flow is possible by using the proposed method, in which a goal-directed learning has been done for time-dependent environment for packets.

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1. Introduction

Better control of packet flow on large-scale computer networks is needed in the recent internet society. There are routing control, traffic control, congestion control, sequence control and so on as for the packet flow control. Among those kinds of control, the routing control is considered in the present paper. A computer network is assumed to consist of nodes, links and a process. A node is a host computer, a personal

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computer, a work station or something like those. A link is a communication line. A process is a mathematical model for the network layer [1]. There are so many nodes in large-scale computer networks, and hence decentralized, autonomous and adaptive control of packet routing becomes very important in those large-scale computer networks. This situation is completely different from that of small-scale computer networks, in which a central computer controls the packet flow for the whole computer network.

A search of a suitable route (or path) for a packet to be sent from a source node to its destination node is one of the important issues for the control of the packet flow. However, finding of the shortest path is not always the best solution. Next shortest paths may be found as a trade-off with a queue length, a distance from the present node to a destination node of a packet and so on. There are many papers in which the control of the packet flow has been investigated by using neural networks [2–5]. It is known that techniques developed in statistical physics are very useful for optimization problems formulated by using neural networks [6]. Then we have proposed in a previous paper [7] a neural network model for the routing control of packet flow in large-scale computer networks within the framework of statistical physics. There are several situations such that some links have higher reliability than other links as for sending packets, that some links have higher capacity than other links and/or that the ability of processing packets in some nodes is higher than other nodes. In those situations, it is better to avoid using those links with lower reliability and/or with lower capacity for sending packets, and to avoid sending packets to those nodes with lower ability of packet processing. Hence, we have also proposed a neural network model for the routing control of packet flow with the priority links [8,9].

In large-scale computer networks, there is another situation in which nodes, where many packets concentrate, may change as time goes on. Namely, time-dependent environment for packets has to be taken into account for optimal packet flow control. For this aim, we propose a dynamic programming for a goal-directed learning by using two neural networks in the present paper.

In Section 2, we define two neural networks for routing control of packet flow within the framework of statistical physics. We use a mean field approximation for soft control and propose dynamic programming for a goal-directed learning as for optimal packet routing control. We present some of the results obtained by numerical simulations in Section 3. Concluding remarks are given in Section 4.

2. Two neural networks for optimal packet routing control

We define two neural networks for optimal packet routing control in a decentralized, autonomous and adaptive way by dynamic programming. One of the neural networks is used for a communication control neural network (CCNN) and the other is an auxiliary neural network (ANN) used for a goal-directed learning in the CCNN. When nodes concentrated by packets change time-dependently, namely under the time-dependent environment of packets, the optimal packet routing control by the goal-directed learning is important. Hence, in the present paper, we propose the goal-directed learning, which