Hierarchical Distributed Search in a Routing Problem of Communication Networks

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In many researches on artificial intelligence, the process of problem solving was often formulated as a search on the solution space. Similarly, distributed problem solving can be treated as a distributed search. Distributed problem solving is one of important research topics in artificial intelligence, and it aims to solve a problem using interaction between loosely-coupled and cooperative agents. Most researches on distributed problem solving were application oriented. That is, given some specific system or application, interaction between agents is represented by some abstract model, and new theory and results are derived through simulations. However, since these researches focused on practical use of a specific field, formalization of the problem is insufficient and lacks generality.

In recent years, the method of formalizing a problem solving as a search on the state space graph is extended to distributed problem solving. A problem solving can be formulated as a search on the state space graph, starting from the initial-state and finishes at the goal-state. In this search, each agent can search only in a subgraph. Therefore, when the problem is too hard to be solved by each individual agent, cooperation between multiple agents is necessary to solve it. There are two kinds of problems in distributed search. One is a static problem in which link-costs are assumed to be constants, and the other is a dynamic problem in which link-costs vary during the search.

The diffusing search and the multiple agents search are well-known as distributed searches. Both methods deal with only static problems, and do not work effectively for dynamic problems in which the quality of solutions(i.e. the sum of costs) is significant. In the diffusing search, when the number of agents increases, its performance drops because of the communication overhead. On the other hand, communication between agents is done through a hash table commonly shared by all agents, but this is impractical to implement.

The routing problem of communication networks is knows as one of typical dynamic problems. The purpose of this problem is to find a route with minimal communication delay(cost) which is used for transfer messages from each communication node to a given destination. Since the delay of each link changes according to the amount of communication traffic on the link, this problem is a dynamic problem.

In case of solving this problem with a distributed search, each communication agent administrates each node together with connected links. The administration includes monitoring generation of messages, switching messages, and monitoring the delay of connected links. Since each agent can monitor the delay of connected links only, it uses estimated values for the delay of unconnected links when a route is selected. Each agent selects a route to an adjacent node, and the selection of the route after that is left to the agent administrating the adjacent node. This dynamic routing strategy works effectively for dynamic change of communication delay.

To improve accuracy of solution, each agent needs to exchange frequently information of the delay, because estimated delay of unconnected links are used for routing. However, this causes communication overhead, and the performance drops as a whole. In other words, there is a trade-off between accuracy of solution and an increase of traffic. In a larger communication network containing many agents, communication traffic necessarily increases, and therefore there exists a limitation on the size of networks to be solved.

So, this paper adopts the routing problem of communication networks as a dynamic search problem, and aims to analyze quantitatively the problem of communication traffic on distributed searches. Moreover, the hierarchical distributed search is proposed to solve search problems of large size. In the hierarchical distributed search, a new type of agents is introduced, which administrate subgraphs adjacent to them and exchanges information of the delay only on these subgraphs. This is effective in reducing the amount of communication used for exchanging the information. The queuing theory is used for analyzing communication traffic on the distributed search and the hierarchical distributed search. Based on these results, we have made simulations on communication networks and have analyzed the obtained results.