

# Learning from Problem Solving and Communication: A Computational Model for Distributed Knowledge Systems

Takao TERANO

Graduate School of Systems Management, The University of Tsukuba, Tokyo

Email: terano@gssm.otsuka.tsukuba.ac.jp

## Abstract<sup>1</sup>

This paper addresses the issues of machine learning in distributed knowledge systems, which will consist of distributed software agents with problem solving, communication and learning functions. To develop such systems, we must analyze the roles of problem solving and communication capabilities among individual agents or knowledge systems.

To facilitate the analyses, we propose a computational model: LPC. In the model, we assume that (1) a set of problems is given to one of the agents, (2) any single agent cannot solve the problems, thus, the agents must communicate each other, and (3) the agents have abilities to learn from both problem solving results and communications.

The model consists of a set of agents with (a) a knowledge base for learned concepts, (b) a knowledge base for the problem solving, (c) a prolog-based inference mechanism, and (d) a set of beliefs on the reliability of the other agents. Each agent can improve its own problem solving capabilities by inductive and/or deductive learning on the given problems and by reinforcement learning on the reliability of communications among the other agents.

The problems given to LPC consist of a set of tuples:  $\{(G, E)\}$ , where  $G$  is the goal of the problem, and  $E$  is a set of examples. The information of  $E$ s are used to improve the learning performance in similar manners found in *multi-strategy learning systems*. If  $E$  is empty, the problems become the same as the ones in distributed problem solving. If  $E$  contains plural examples, the agents can utilize them for inductive learning, and  $E$  contains only one example, the agents can use it for deductive learning, when the agents have sufficient domain knowledge.

The agents of LPC solve a given problem in part by using their own problem solving knowledge and learned results. If they cannot solve the whole problem, they decompose it into sub-problems, and then request the other agents to solve them. The requests are done based on the memory of the other agents' information. In order to improve the problem solving performance for a set of given similar problems, the agents of LPC organize themselves by changing the information on which agents they should request to solve the (sub-)problems.

An experimental system of the model has been implemented in Prolog language. The feasibility of the proposed model has been validated using a *list replacement problem* to decompose and delete list elements in given tasks. The problem aims to simulate cooperative work on manufacturing processes, office works, and so on. The experimental results suggest that the proposed model is simple and executable for analyzing the learning mechanisms applicable to distributed knowledge systems.

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<sup>1</sup>A full version of the paper will be available as GSSM Research Report, the University Tsukuba, until the end of 1994.