BOOK REVIEW

PROCEEDINGS OF THE FIRST INTERNATIONAL WORKSHOP ON MULTISTRATEGY LEARNING

edited by **Ryszard S. Michalski and Gheorghe Tecuci**

Artificial Intelligence Center, George Mason University,
Fairfax, VA 22030, (1991) 435 p.

The evolution of the Machine Learning field is characterized by a great expansion and diversification of learning methods. Most of the research has been orientated toward *single-strategy* learning methods that apply one primary type of inference, such as induction, deduction or analogy, and one representational mechanism, such as predicate calculus or neural network. Such methods include those for empirical inductive generalization, explanation-based learning, learning by abduction, case-based learning, qualitative methods for law discovery, conceptual clustering, neural network learning, and others.

Despite the great diversity of these learning strategies, they share two common features that limit their applications to complex, real-world problems. First of all, in order to be applicable, each of these learning strategies requires a certain type of input and of background knowledge. For instance, empirical induction requires many input examples and a small amount of background knowledge. Explanation-based learning requires one input example and complete background knowledge. Learning by analogy and case-based learning require background knowledge analogous to the input. Learning by abduction requires causal background knowledge related to the input. Secondly, the result of the single-strategy learning process is very limited. This is a hypothetical generalization of several input examples (in the case of empirical induction), or an operational generalization of an input example (in the case of explanation- based learning), or new knowledge about the input (in the case of learning by analogy or case-based learning), or new background knowledge (in the case of learning by abduction). From these characterizations, one may however notice the complementarity of the requirements and of the results of the single-strategy learning methods. Naturally, this suggests that by properly integrating them, one could obtain a synergistic effect in which different strategies mutually support each other, and compensate for each other's weaknesses. This is the motivation for developing multistrategy learning systems.

Multistrategy learning systems integrate two or more inference types and/or representational mechanisms. These systems take advantage of the strengths of individual learning strategies, and therefore can be applied to a wider range of problems. Human learning is clearly not limited to any single strategy, but can involve any type of strategy, or a combination of them, depending on the task at hand. Research on multistrategy learning is therefore a key to understanding learning processes in general, to making progress in machine learning, as well as to extending the applicability of current machine learning methods to new practical domains.

The Proceedings of the First International Workshop on Multistrategy Learning

(MSL-91), edited by Ryszard S. Michalski and Gheorghe Tecuci, is the first collection of papers on multistrategy learning. It contains 33 papers grouped into six categories, according to their primary theme:

I. Theoretical and General Issues

II. Theory Revision

III. Strategy Selection

IV. Integration of Symbolic and Subsymbolic Methods

V. Cognitive Models

VI. Special Topics and Applications.

The seven papers in Part I address the underlying principles and theoretical issues in multistrategy learning. For instance, the paper "Inferential Learning Theory as a Basis for Multistrategy Task-Adaptive Learning", by R.S. Michalski, presents some results on a new theory of learning which allows the analysis of different learning processes in terms of high level patterns of inference, called knowledge transmutations, and facilitates multistrategy learning. Also, the paper "Learning as Understanding the External World", by G.Tecuci, describes a general approach to multistrategy learning that consists of a dynamic integration of the elementary inferences (like deduction, analogy, abduction, generalization, specialization, abstraction, concretion, etc.) that generate the individual single-strategy learning methods. The paper "Balanced Cooperative Modeling", by K.Morik, presents a multistrategy approach to domain modelling that is based on a balanced interaction between the system and the user where learning contributes to the preparation of the background knowledge, to enhancing the domain knowledge, and to inspecting the knowledge. The paper of Y. Kodratoff entitled "Induction and the Organization of Knowledge" analyses different forms of induction and their role in the organization of the knowledge bases.

The seven papers in Part II describe methods and systems performing theory revision through multistrategy learning. The paper "A Multistrategy Approach to Theory Refinement",by R.J. Mooney and D. Ourston, describes the system EITHER that employs independent modules for deductive, abductive and inductive reasoning to revise an arbitrarily incorrect Horn-clause domain theory to fit a set of preclassified training instances. L. De Raedt and M. Bruynooghe describe the multistrategy interactive concept learner and theory revisor CLINT which is a representative of the Inductive Logic Programming Paradigm. Other representative systems described are WHY (of L. Saitta, M. Botta, S. Ravoto and S.B. Sporetto), KBL (of B.L. Whitehall, S.C-Y Lu and R.E. Stepp), and GEMINI (of A.P. Danyluk).

Part III contains three papers that present architectures for multistrategy learners that emphasize the selection of learning strategies according to the task to be performed. For instance, the paper "Using Introspective Reasoning to Select Learning Strategies", by M. Cox and A. Ram, presents an approach based on explanation structures that help the system to identify different types of failures and to choose the appropriate learning strategies in order to avoid similar mistakes in the future.

Part IV, which contains seven papers, discusses issues of integrating symbolic and subsymbolic learning, and compares the performances of these two paradigms on a selected class of learning problems. The paper of G.G. Towell and J.W. Shavlik, "Refining Symbolic Knowledge Using Neural Networks", addresses the problem of

integrating an artificial neural network into a multistrategy learning system. The authors present a three-step approach in which symbolic rules are translated into a neural network, the neural network is improved through learning, and the final network is translated back into symbolic rules. J.Zhang presents the system FCLS that learns flexible concepts through an integration of symbolic and subsymbolic learning methods. H. Vafaie and K. DeJong present a rule learning system that integrates a genetic algorithm based learner with an empirical inductive learner. The paper of J.Wnek and R.S Michalski, "An Experimental Comparison of Symbolic and Subsymbolic Learning Paradigms: Phase I - Learning Logic-style Concepts", discusses and experimentally compares five methods for concept learning from examples.

Part V contains two papers related to human learning, which is intrinsically multistrategy. The paper of E.J. Wisniewski and D.L. Medin investigates how multiple sources of knowledge influence feature construction processes in human learning and compare these processes with those found in constructive inductive systems and explanation-based learning systems. The paper of M. Gams addresses the problem of human multistrategy learning at two levels, in a group of experts, and at the human brain level.

The last part of the Proceedings contains seven papers addressing special topics and applications of multistrategy learning. The paper of M. Veloso and J. Carbonell, "Automating Case Generation, Storage and Retrieval in PRODIGY", presents the derivational analogy reasoner of the multistrategy learner PRODIGY. The paper "Method Integration for Experience-Based Learning", by J. Gould and R. Levinson, describes how a variety of machine learning methods can be combined synergistically to produce an adaptive pattern-oriented chess program. L.Hunter presents a multistrategy approach to predicting protein structure. J. Segen presents the GEST system that integrates six learning strategies in order to learn to recognize nonrigid visual shapes from real images. G. Widmer presents a multistrategy learning method based on qualitative reasoning and its application to a musical problem.

Undoubtedly, the Proceedings of the First International Workshop on Multistrategy Learning is currently the most important bibliographic reference to Multistrategy Learning, one of the most significant new developments in Machine Learning, that becomes a central research theme in the field.

To make this valuable source of information available to a large community, Morgan Kaufmann will publish (toward the end of 1992) the book "Machine Learning: A Multistrategy Approach", edited by R.S. Michalski and G. Tecuci. Individual chapters of this book are updated versions of the papers that have been selected from those of the MSL-91 Proceedings. This will be the fourth volume in a sequel of books on Machine Learning that aim at contributing to a global perspective of the progress in this field. The first two volumes were edited by R.S. Michalski, J. Carbonell and T. Mitchell (in 1983 and 1986, respectively) and the third volume was edited by Y. Kodratoff and R.S. Michalski (in 1990).

Dan Tufis