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Dagstuhl Seminar 41/1992

Workshop on Analogical and Inductive Inference

5. bis 9. Oktober 1992

Organized by:
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Preface

Learning is obviously an important phenomenon of natural intelligence. Therefore, despite diverging specifications of the area of artificial intelligence, learning is a central issue of artificial intelligence research. There is abundant evidence of the human ability to learn from possibly incomplete information. In human communication, one usually provides only incomplete information with respect to some target phenomenon to be described or specified, or even to be learned. Algorithmic or computational learning theory is the theoretical division of machine learning research dealt with those problems. Analogical reasoning and inductive inference are typical research areas faced to the central problem of processing possibly incomplete information.

Nowadays, there are three international conference series in the area of algorithmic or computational learning theory. The youngest one is ALT (Algorithmic Learning Theory) established in Japan in 1990 and held annually since then. Two years earlier, there has been started the annual workshop series COLT (Computational Learning Theory) in the USA. Already in 1986, a workshop series called AII (Analogical and Inductive Inference) has been established in Germany. Compared to ALT and COLT, the AII events are distinguished by a considerably smaller number of participants as well as by putting much more emphasis on longer talks and room for discussions. So, the International Research and Conference Center at Dagstuhl Castle seemed particularly tailored to host AII'92. The organizers gratefully acknowledge the excellent working conditions provided for this third event in the AII series.

The AII workshos are focussed on all formal approaches to algorithmic resp. computational learning particularly emphasising settings faced to processing incomplete information. Both analogical reasoning and inductive inference are currently attracting a considerable interest. Analogical reasoning plays a crucial role in the currently booming field of case-based reasoning. In the field of inductive logic programming, for instance, a couple of new techniques have been developed for inductive inference. Moreover, AII events are always intended to bridge the gap between several research communities. The basic areas of concern are theoretical computer science, artificial intelligence, and cognitive sciences. The scientific programme of AII'92 reflects the endeavour to support communication between specialists of these areas quite well.

An international programme committee has been working to prepare AII'92, the Dagstuhl Seminar # 9241, scientifically. Members of the programme committee are Setsuo Arikawa (Fukuoka, Japan), Janis Barzdins (Riga, Latvia), Bruce Buchanan (Pittsburgh, PA, USA), Robert P. Daley (Pittsburgh, PA, USA). Luc De Raedt (Leuwen, Belgium), Ulrich Furbach (Koblenz, Germany), Douglas R. Hofstadter (Bloomington, IN, USA), Bipin Indurkhya (Boston, MA, USA), Klaus P. Jantke (Leipzig, Germany), Carl H. Smith (College Park, MD, USA), Manfred Warmuth (Santa Cruz, CA, USA), and Stefan Wrobel (St. Augustin, Germany).

The conference programme contains presentations of different type. First, there are invited talks by distinguished scientists reporting on essential contributions to the area. Second, there are submitted papers which have been processed in a reviewing and selection process as usual. Third, there have been invited two talks of a very special type to be presented and discussed at evening sessions. Fourth, according to the policy of Dagstuhl Seminars to provide every participants the opportunity to present her/his recent work, there are so-called supplementary talks. The programme attached at the end of this collection allows to get an overview of these categories of contributions. The invited talks and the submitted papers which passed the reviewing process successfully are published in the proceedings volume Analogical and Inductive Inference, Klaus P. Jantke (ed.), Lecture Notes in Artificial Intelligence, Springer-Verlag, 1992. Readers interested in the proceedings of the former AII workshops may consult Springer-Verlag Lecture Notes in Computer Science 265 and Lecture Notes in Artificial Intelligence 397. Selected contributions will appear in a revised form in a special issue of the Journal of Experimental and Theoretical Artificial Intelligence (JETAI). This will be volume 5 (1993), issue 2.

As usually behind the scene, the work of a number of colleagues contributed essentially to the success of the workshop. I want to express my sincere gratitude to all of them. The Algorithmic Learning Group of Leipzig University of Technology, in particular Andreas Albrecht, Ulf Goldammer, Steffen Lange, and Eberhard Pippig, provided continous assistance. Steffen Lange did a particularly important work as organizing secretary of AII'92. Last but not least, Thomas Zeugmann (Darmstadt) has intensively pushed forward the assembly of the present publication.

Klaus P. Jantke

Unions of Identifiable Classes of Total Recursive Functions

Kalvis Apsītis, Rūsiņš Freivalds, Mārtiņš Kriķis
Raimonds Simanovskis and Juris Smotrovs
University of Latvia, Riga

J. Barzdin (1974) has proved that there are classes of total recursive functions which are EX–identifiable but their union is not. We prove that there are no 3 classes U_1, U_2, U_3 such that $U_1 \cup U_2$, $U_1 \cup U_3$, and $U_2 \cup U_3$ would be in EX but $U_1 \cup U_2 \cup U_3 \notin EX$. For FIN–identification there are 3 classes with the above–mentioned property and there are no 4 classes U_1, U_2, U_3, U_4 such that all 4 unions of triples of these classes would be identifiable but the union of all 4 classes would not. For identification with no more than p mindchanges a $(2^{p+2} - 1)$–tuple of such classes do exist but there is no (2^{p+2})–tuple with the above mentioned property.

A Language Learning Characterization of the Hypersimple Sets

Ganesh Baliga and John Case
University of Delaware, Newark

Hypersimple sets were introduced by Emil Post in his attempt to resolve what is now known as Post's problem. We present a characterization of hypersimple sets in terms of the well–known language learning criterion $TxtEx^*$ (see Case and Lynes (1982) for the definitions of $TxtEx^*$ and $TxtBc^*$). This characterization yields, as a corollary, a strikingly simple language class contained in $TxtBc^* \setminus TxtEx^*$.
References:

Case, J., and Lynes, C. (1982), Machine inductive inference and language identification, *in* "Proceedings Automata, Languages and Programming, 9th Colloquium, Aarhus, Denmark," (M. Nielsen and E.M. Schmidt, Eds.), Lecture Notes in Computer Science 140, pp. 107 - 115, Springer-Verlag, Berlin.

Learning from Multiple Sources of Inaccurate Data

Ganesh Baliga, University of Delaware, Newark
Sanjay Jain, National University of Singapore, Singapore
and
Arun Sharma, University of New South Wales, Sydney

Most theoretical studies of inductive inference model a situation involving a machine

M learning its environment E on following lines. M, placed in E, receives data about E, and simultaneously conjectures a sequence of hypotheses. M is said to learn E just in case the sequence of hypotheses conjectured by M stabilizes to a final hypothesis which correctly represents E.

The above model makes the idealized assumption that the data about E that M receives is from a *single* and *accurate* source. An argument is made in favor of a more realistic learning model which accounts for data emanating from *multiple* sources, some or all of which may be *inaccurate*. Motivated by this argument, the present paper introduces and theoretically analyzes a number of inference criteria in which a machine is fed data from multiple sources, some of which could be infected with inaccuracies. The main parameters of the investigation are the number of data sources, the number of faulty data sources, and the kind of inaccuracies.

Efficient Inference of Formulas from I/O Examples

Guntis Barzdins
Latvian University, Riga

In the talk an efficient method for inferring formulas constructed from the set of known functions and satisfying several input-output examples is considered. The method is based on the use of hypergraphs to represent the sets of valid formulas. The hypergraph transformations are used to filter these sets against the provided I/O examples more efficiently than just one formula at a time as it would be in the case of pure exhaustive search. In comparison with the earlier reports about the method, here we present a generalization witch allows to consider not only discrete functions, but also continuous functions. The computer experiments illustrating the use of the generalized method for inferring the formula for computing the volume of the frustum of the square pyramid are presented.

Infinitary Self-Reference in Learning Theory

John Case, University of Delaware, Newark

Kleene's Second Recursion Theorem provides a means for transforming any program p into a program $e(p)$ which first creates a quiescent self copy and then runs p on that self copy together with any externally given input. $e(p)$, in effect, has perfect self-knowledge and p represents how $e(p)$ uses its self knowledge (and its knowledge of the external world). Infinite regress paradoxes are avoided since $e(p)$ creates its self copy outside of itself. One mechanism to achieve this creation is a self-replication trick isomorphic to that employed by single-celled organisms. Another is for $e(p)$ to look in a mirror to see which program it is. In 1974 I published an infinitary generalization of Kleene's theorem which I called the Operator Recursion Theorem. It provides a means for obtaining an (algorithmically) growing network of programs which, in effect, share a common (also growing) mirror from which they can obtain perfect models of themselves and the other programs in the network. This and other recursion theorems have found many applications in, among other domains, Gold style computational learning theory. I will present and explain several examples intended to teach the use of infinitary (and other) recursion theorems in learning theory.

Representing the Spatial/Kinematik Domain and Lattice Computers

John Case, Dayanand S. Rajan and Anil M. Shende
University of Delaware, Newark

An approach to analogical representation for objects and their motions in space is proposed.

This approach involves lattice computer architectures and associated algorithms and is shown to be abstracted from the behavior of human beings mentally solving spatial/kinematic puzzles. There is also discussion of where in this approach the modeling of human cognition leaves off and the engineering begins.

The possible relevance of the approach to a number of issues in Artificial Intelligence is discussed. These issues include efficiency of sentential versus analogical representations, common sense reasoning, update propagation, learning performance tasks, diagrammatic representations, spatial reasoning, metaphor, human categorization, and pattern recognition.

Lastly there is a discussion of the somewhat related approach involving cellular automata applied to computational physics.

Strong Separation of Learning Classes

John Case, University of Delaware, Newark
Keh-Jiann Chen Academica Sinica, Taipei, Republic of China
and
Sanjay Jain, National University of Singapore, Singapore

Suppose $\mathbf{LC}_1$ and $\mathbf{LC}_2$ are two machine learning classes each based on a criterion of success. Suppose, for every machine which learns a class of functions according to the $\mathbf{LC}_1$ criterion of success, there is a machine which learns this class according to the $\mathbf{LC}_2$ criterion. In the case where the converse does *not* hold $\mathbf{LC}_1$ is said to be *separated* from $\mathbf{LC}_2$. It is shown that for many such separated learning classes from the literature a much *stronger* separation holds: $(\forall \mathcal{C} \in \mathbf{LC}_1)(\exists \mathcal{C}' \in (\mathbf{LC}_2 - \mathbf{LC}_1))[\mathcal{C}' \supset \mathcal{C}]$. It is also shown that there is a pair of separated learning classes from the literature for which the stronger separation just above does not hold. A philosophical heuristic toward the design of artificially intelligent learning programs is presented with each strong separation result.

A Solution of the Credit Assignment Problem in the Case of Learning Rectangles

Zhixiang Chen, Boston University and
Wolfgang Maass, TU Graz

The talk has been given by Peter Auer, TU Graz.

We present a paper of Zhixiang Chen and Wolfgang Maass which solves the following open problem: Is there an algorithm for on-line learning of rectangles $\prod_{i=1}^{d}\{a_i, a_i + 1, \ldots, b_i\}$ over the discrete domain $\{1, \ldots, n\}^d$ whose error bound is polylogarithmic in the size n^d of the domain? They give a positive answer by solving the well known "credit assignment problem" introducing a new error tolerant binary search strategy which tolerates certain types of wrong "credit assignments".

We also present a tight lower bound on the learning complexity of the above learning problem not given in the paper. Furthermore we present some new results on the learning of rectangles in noisy environments which give sharp bounds on the tolerable noise.

Desiderata for Generalization-to-N Algorithms

William W. Cohen, AT & T Bell Labs., Murray Hill

Systems that perform "generalizations-to-N" in explanation–based learning generalize a proof tree by generalizing the *shape* of the tree, rather than simply changing constants to variables. This paper introduces a formal framework which can be used either to characterize or to specify the outputs of an algorithm for generalizing number. The framework consists of two desiderata, or desired properties, for generalization-to-N algorithms. In the paper, we first motivate and define these desiderata, the review one of several alternative frameworks for generalizing number: an automata–based approach first described in Cohen (1988). Finally, we describe a generalization-to-N technique that provably meets these desiderata. As an illustration of the operation of the new algorithm, an implementation of it is applied to a number of examples from the literature on generalization-to-N.

The Power of Probabilism in Popperian FINite Learning

Robert Daley Bala Kalyanasundaram
University of Pittsburgh, Pittsburgh
Mahe Velauthapillai
Georgetown University, Washington, D.C.

We consider the capabilities of probabilistic *FIN*-type learners who must always produce programs (i.e., hypotheses) that halt on every input. We show that the structure of the learning capability of probabilistic and team learning with success ratio above $\frac{1}{2}$ in *PFIN*-type learning is analogous to the structure observed in *FIN*-type learning. On the contrary, the structure of probabilistic and team learning with success ratio at or below $\frac{1}{2}$ is more sparse for *PFIN*-type learning than *FIN*-type learning. For $n \geq 2$, we show that the probabilistic hierarchy below $\frac{1}{2}$ for *PFIN*-type learning is defined by the sequence $\frac{4n}{9n-2}$, which has an accumulation point at $\frac{4}{9}$. We also show that the power of redundancy at the accumulation point $\frac{4}{9}$ is different from the one observed at $\frac{1}{2}$. More interestingly, for the first time, we show the power of redundancy even at points that are not accumulation points.

An Analysis of Various Forms of 'Jumping to Conclusions'

Peter A. Flach, Tilburg University

In this paper, I discuss and relate characterisations of different forms of 'jumping to conclusions': Kraus, Lehmann & Magidor's analysis of plausible reasoning (1990), my own characterisation of inductive reasoning (Flach, 1991), Zadrozny's account of abductive reasoning (1991), and Gardenfors' theory of belief revision (1988). My main claims are that (i) inductive reasoning can be characterised in a way simlar to plausible reasoning; (ii) inductive and abductive reasoning are special cases of explanatory reasoning; and (iii) there are strong relations between belief revision and explanatory reasoning. The ultimate goal of this research is a general account of jumping to conclusions.

References

P.A. Flach (1991), The role of explanations in inductive learning, ITK Research Report no. 30, Institute for Language Technology & Artificial Intelligence, Tilburg University, the Netherlands.

P. Gardenfors (1988), Knowledge in flux, MIT Press, Cambridge MA.

Kraus, D. Lehmann, and M. Magidor (1990), Nonmonotonic reasoning, preferential-models and cumulative logics, Artificial Intelligence 44, pp. 167-207.

W. Zadrozny (1991), On rules of abduction, IBM Research Report, August 1991.

Synthesis of Logic Programs from Examples and Properties

Pierre Flener and Yves Deville, Universite de Louvain

In view of the synthesis of recursive (logic) programs whose intended relation is known, we introduce "properties" as a specification formalism. Properties help overcome the limited expressive power and the ambiguity of examples, and yet preserve their naturalness and conciseness. The promise is faster and more reliable synthesis of (logic) programs from such augmented incomplete specifications than from examples alone. Viewing recursive (logic) programs as very special concept descriptions, we advocate a departure from "traditional" inductive learning techniques. Thus, within our general framework of stepwise synthesis of logic programs from examples and properties, we opt for a non-incremental synthesis that is moreover guided by a divide-and-conquer (logic) program schema. Also, rather than inferring hypotheses from one specification source, and rejecting hypotheses using the other one, our synthesis mechanism makes a "constructive" usage of both: it performs inductive inferences from examples, and deductive inferences from properties. ¿From a toolbox of interchangeable methods that synthesize instantiations of predicate variables of a program schema, we develop such a logic program synthesis mechanism.

An Inductive Inference Approach to Classification

Rusins Freivalds, University of Latvia, Riga
and
Achim G. Hoffmann, Technische Universität Berlin

In this paper, we introduce a formal framework for investigating the relationship of inductive inference and the task of classification. We give the first results on the relationship between functions that can be identified in the limit and functions that can be acquired from unclassified objects only. Moreover, we present results on the complexity of classification functions and the preconditions necessary in order to allow the computation of such functions.

Asking Questions Versus Verifiability

William Gasarch, University of Maryland, College Park
and
Mahendran Velauthapillai, Georgetown University, Washington, DC

Case smith studied learning machines whose conjectures are verifiable (i.e. the conjectures are total programs). They discovered that such machines are weaker than

whose conjectures are not verifiable. Gasarch and Smith studied learning machines that ask questions. They discovered that such machines are stronger than passive machines. We raise the question "Can the weakness of verifiability be overcome by the strength of asking queries. We answer many interesting questions along the way. They include a full examination of PEX and the resolution of some open problems of Gasarch Smith. The motivating question has two answers: if unbounded mind changes are allowed then the queries do not increase learning power of verifiable machines, where in the bounded case they do.

Learning Decision Strategies with Genetic Algorithms

John J. Grefenstette, Naval Research Laboratory, Washington, DC

Machine learning offers the possibility of designing intelligent systems that refine and improve their initial knowledge through their own experience. This article focuses on the problem of learning sequential decision rules for multi-agent environments. We describe the SAMUEL learning system that uses genetic algorithms and other competition based techniques to learn decision strategies for autonomous agents. One of the main themes in this research is that the learning system should be able to take advantage of existing knowledge where available. This article describes some of the mechanisms for expressing existing knowledge in SAMUEL, and explores some of the issues in selecting constraints for the learning system.

A Model of the "Rediscription" Process in the Context of Geometric Proportional Analogy Problems

Scott O'Hara, Boston University, Boston

It has been recognized for some time that analogies can rediscribean object or situation sometimes resulting in a radically new point of view. While thiscreative aspect of analogy is often cited as a reason for its study, AI approaches to analogy have, for the most part, ignored this phenomenon and instead have focused on computing similarities between fixed descriptions. To study this "rediscription" process by which new points of view can be created, we seek a micro-world in which the rediscription phenomenon occurs in its fully subtletly but in which in can be isolated from extraneous and ill-understood factors. Proportinal analogies (i.e., analogies of the form: A is to B as C is to D) in the abstract domain of geometric figures form just such a micro-world. In this paper, we describe an algebraic formulation of the rediscription process in the context of of geometric proportional analogies. We then discuss the design of a computer programm called PAN which rediscribes geometric figures while solving proportional analogy problems. Finally, we briefly discuss our plans for future work in this area.

Wittgenstein on Analogical and Inductive Inference

Achim G. Hoffmann
Technische Universität Berlin

In Wittgenstein's philosophy there are two rather controversial viewpoints. In his early philosophy (Tractatus-Logico Philosophicus) he advocated the model-theoretic view of the world.

His late philosophy (Philosophical Investigations $\approx$ 1950) rejects this model–theoretic view, where linguistic terms have a fixed ontological reference. Instead he argued that the meaning of linguistic terms can only be determined as its use.

But the use of linguistic terms in any reasonable way (i.e. in order to communicate) presupposes a certain intuitive ability to recognize and employ regularities, which are connected with the kind of regularities other people recognize.

Moreover, regularities in using linguistic terms may change through the use of a term. These regularities and the way of changing these regularities seems also to be the basis for inductive and analogical inference.

Wittgenstein's late considerations has been taken as an indication that human analogical and inductive reasoning requires a rather extensive description. Hence, for research in algorithmic induction one should rather assume an extensive body of knowledge which acquires a limited amount of knowledge from the environment, instead learning with a very small algorithm an unbounded amount of knowledge.

Why one Researcher Concluded that Formal Methods are Inappropriate for Realistically Modelling Sequence Extrapolation and Analogy-making

Douglas R. Hofstadter, Indiana University, Bloomington

Among my earliest research projects in Artificial Intelligence was the "Seek Whence" project, a computer program whose goal was to observe a sequence of integers as it was presented term by term, and to "seek whence" the sequence was originating - - i.e., to seek the underlying rule of the sequence. I describe my initial approach which was based on "natural" computer-science methods, such as recursion and tree search, and I describe my gradual disenchantment with such techniques and my reasons for eventually concluding that formal mathematical approaches to sequence extrapolation, despite their elegance and appeal, are psychologically unrealistic and therefore constitute a misleading avenue to follow.

I then show how the Seek-Whence project convinced me that the key to sequence extrapolation is abstract perception of complex hierarchical structures, which led me to the modelling of analogy-making. I describe the Artificial-Intelligence research project that ensued - - namely, the Copycat Project - - and I describe its architecture, which attempts to model the fluidity and plasticity of human concepts and human perception. The Copycat architecture is both parallel and non-deterministic, and accordingly its behavior is emergent and unpredictable. I will attempt to make clear my reasons for believing in the necessity of this type of approach for realistically modelling human insight and creativity.

Predictive Analogy and Cognition

Bipin Indurkhya, Northeastern University, Boston

Abstract: The most prevalent sense of 'analogy' in cognitive science and AI literature, which I refer to as 'predictive analogy', is the process of inferring further similarities between two given situations based on some existing similarities. Though attempts to validate predictive analogy on logical grounds have been singularly unsuccessful, it is claimed that all the empirical evidence points to the usefulness of predictive analogy in cognition. In this talk I critically analyze this claim. I argue that the classroom experiments by cognitive psychologists to demonstrate predictive analogy as a problem-solving heuristic do not really do so. Moreover, the few studies of real-world problem-solving situations definitely point away from predictive analogy. I present some examples where predictive analogy prevents one from seeing things as they are, thereby hindering cognition. Having exposed its 'dark side', I argue for a balanced perspective where predictive analogy is best seen as a psychological process that is as likely to be a liability as an asset to cognition.

Learning a Class of Regular Expressions via Restricted Subset Queries

Efim Kinber, University of Latvia, Riga

A wide class of regular expressions non–representable as unions of "smaller" expressions is shown to be polynomial–time learnable via restricted subset queries from arbitrary representative examples "reflecting" the loop structure and a way the input example is obtained from the unknown expression. The corresponding subclass of regular expressions of loop depth at most 1 is shown to be learnable from representive examples via membership queries. A wide class of expressions with loops $\mathcal{A}^+$ of arbitrary loop depth is shown to be learnable via restricted subset queries from arbitrary examples.

A Unifying Approach to Monotonic Language Learning

Steffen Lange, TH Leipzig and Thomas Zeugmann, TH Darmstadt

The present paper deals with monotonic and dual monotonic language learning from positive and negative examples. The three notions of monotonicity reflect different formalizations of the requirement that the learner has to produce always better and better generalizations when fed more and more data on the concept to be learnt.

The three versions of dual monotonicity describe the concept that the inference device has to produce exclusively specializations that fit better and better to the target language. We characterize strong-monotonic, monotonic, weak-monotonic, dual strong-monotonic, dual monotonic and dual weak-monotonic as well as finite language learning from positive and negative data in terms of recursively generable finite sets. Thereby, we elaborate a unifying approach to monotonic language learning by showing that there is exactly one learning algorithm which can perform any monotonic inference task.

Background Knowledge and Declarative Bias in Inductive Concept Learning

Nada Lavrač and Sašo Džeroski
Jožef Stefan Institute, Jamova

There are two main limitations of classical inductive learning algorithms: the limited capability of taking into account the available background knowledge and the use of limited knowledge representation formalism based on propositional logic. The paper presents a method for using background knowledge effectively in learning both attribute and relational descriptions. The method, implemented in the system LINUS, uses propositional learners in a more expressive logic programming framework. This allows for learning of logic programs in the form of constrained deductive hierarchical database clauses. The paper discusses the language bias imposed by the method and shows how a more expressive language of determinate logic programs can be used within the same framework.

Analogical Reasoning Based on Typical Examples

Erica Melis
Universität des Saarlandes, Saarbrücken

Our starting points for investigating analogical reasoning with typical examples were some interesting results on concept structures and distinguished examples in congnitive psychology and our experience with a certain kind of analog asoning relying on

typical examples, and the general insight that hybrid models of reasoning are the more adequate ones in computationally modeling of human reasoning. Reasoning by typical examples is developed as a special case of analogical reasoning using semantic information contained in the concept structures. The corresponding inference rule is derived by replacing explicit information about connections and similarity in a general pattern of analogical inference by information about the relationship to typical examples. Using the new inference rule analogical reasoning proceeds by checking a related example. This procedure is simpler than ordinary knowledge based analogical inference. Finally the connections to learning of pattern languages and "good" examples in inductive learning are presented.

Equivalence and Refinement for First-order Predicates

Stephen Muggleton
The Turing Institute, Glasgow G1 2AD

A number of authors within the Inductive Logic Programming literature have investigated the problem of introducing novel terms into the learner's vocabulary. This process is known as *predicate invention.* There is a growing need for a theoretical framework for predicate invention. We describe a first attempt at such a framework in an attempt to answer when predicate invention is necessary and from which universe these predicates are chosen. The framework uses the notion of a lattice of predicate utility. Some results of an initial implementation are given.

Characterization of Finite Identification

Yasuhito Mukouchi
Kyushu University 39, Kasuga 816

A majority of studies on inductive inference of formal languages and models of logic programming have mainly used Gold's identification in the limit as a correct inference criterion. In this criterion, we can not decide in general whether the inference terminates or not, and the results of the inference necessarily involve some risks. In this paper, we deal with finite identification for a class of recursive languages. The inference machine produces a unique guess just once when it is convinced the termination of the inference, and the results do not involve any risks at all. We present necessary and sufficient conditions for a class of recursive languages to be finitely identifiable from positive or complete data. We also present some classes of recursive languages that are finitely identifiable from positive or complete data.

On Learning Certain Classes of Pictures Languages

Rani Siromoney
Madras Christian College, Madras

Learning sets of strings generated by grammars or accepted by automata have been studied extensively. But not much work has been done on the learning of picture languages (rectangular arrays in two dimensions), even though these models have been of interest in applications to syntactic pattern recognition and recently, to problems of tiling. Siromoney matrix array grammars were introduced in the seventies, as a parallel/sequential model for generating rectangular digitized pictures. One class can be considered as a special case of pattern languages and such techniques applied for the learning. Another class is an extension of equal matrix grammar to two dimensions and techniques for learning an EML adopted. Finally, a linear time algorithm is given for identifying an unknown local picture language from positive data. For the efficient learning of recognizable picture languages from positive data, restricted subset queries are needed.

Inductive Inference and Machine Learning

Carl H. Smith
University of Maryland, College Park

In this short talk, intended to promote discussion, an attempt will be made to relate inductive inference with machine learning. Essentially, both fields have the same, perhaps unreachable, grand goal of being able to understand human learning sufficiently well so as to be able to program a computer to learn. The machine learning community has decided to start directly with implementations, while the inductive inference community is examining the boundary of the algorithmically learnable. All other relationships between the two fileds may be mere serendipity.

On Identifying DNA Splicing Systems from Examples

Yuji Takada, FUJITSU and Rani Siromoney, Madras Christian College

DNA sequences are recombined with restriction enzymes and ligases. Splicing systems, generative devices introduced by Head, represent this DNA recombinant behaviors as operations on pairs of strings over a finite alphabet. Culik II and Harju proved that a language generated by a splicing system is regular. We give a method to construct a splicing system from deterministic finite state automaton. By combining a conventional inductive inference/learning method for deterministic finite state automata with our method, we have an effective inductive inference/learning method for splicing systems.

Ignoring Data May be the Only Way to Learn Efficiently

Rolf Wiehagen, Humboldt–Universität Berlin
and
Thomas Zeugmann, TH Darmstadt

In designing learning algorithms it seems quite reasonable to construct them in a way such that all data the algorithm already has obtained are correctly and completely reflected in the hypothesis the algorithm outputs on these data. However, this approach may totally fail, i.e., it may lead to the unsolvability of the learning problem, or it may exclude any efficient solution of it. In particular, we present a natural learning problem and prove that it can be solved in polynomial time if and only if the algorithm is allowed to ignore data.

On the Notion of Minimal Correcting Specializations in Machine Learning

Stefan Wrobel
GMD, St. Augustin 1

Generalization and specialization are the central operations examined in Machine Learning. Where generalization addresses the problem of extending an incomplete theory (inductive hypothesis), specialization is necessary whenever the existing theory is incorrect, i.e., produces incorrect inferences. In this talk, we will discuss the issue of what properties such a specialization operation should have. In particular, we will take issue with the claim that specialization operations should be minimal, as it has been put forth by some authors in Machine Learning, and argue that in many contexts, this is not desirable.

Our argument is based on the standard definition of generality based on logical derivability, i.e., one theory is said to be more general than another if the latter can be derived from the former ($\Gamma_1 \geq_g \Gamma_2$ iff $\Gamma_1 \vdash \Gamma_2$). This definition of generality immediately implies that the notion of minimal specialization is one that is decided on the *knowledge level*, i.e., on the closures of the respective theories. This, however, means that we can build on work on the logic of theory change, where the properties of minimal specialization operations on closed theories have been studied under the name of *theory contraction*. We point out that minimal specializations can be obtained only with *maxi-choice* contractions, and identify the undesirable properties of such operations with respect to theory completion and reason maintenance.

We conclude with more practical aspects of specialization, and briefly present the specialization algorithm used in the knowledge revision tool KRT (a part of the MOBAL system) that was developed based on the results of work on finite base contraction. We will also contrast this algorithm with other methods that have been proposed to obtain minimal specializations.

Appendix

The invited papers as well as the submitted ones in the following conference programme have been published in: K.P. Jantke (Ed.), Analogical and Inductive Inference, Lecture Notes in Artificial Intelligence 642, 1992, Springer-Verlag, Berlin.

Conference Programme

Monday, October 5

09:30 Opening

10:00 Coffee Break

10:30 Invited Talk
Rolf Wiehagen, Thomas Zeugmann
Too Much Information can be Too Much for Learning Efficiently
(recommended by Klaus P. Jantke)

12:00 Lunch

15:00 Coffee Break

15:30 Submitted Paper
Bipin Indurkhya
Predictive Analogy and Cognition

16:00 Submitted Paper
Scott O'Hara
A Model of the 'Redescription' Process in the Context of Geometric Proportional Analogy Problems

18:00 Dinner

19:30 Special Session I
Douglas R. Hofstadter
Why one Researcher Concluded that Formal Methods are Inappropriate for Realistically Modelling Sequence Extrapolation and Analogy-Making

Tuesday, October 6

09:00 Invited Talk
John J. Grefenstette
Learning Decision Strategies with Genetic Algorithms
(recommended by Robert P. Daley)

10:00 Coffee Break

10:30 Invited Talk
Nada Lavrac, Saso Dzeroski
Background Knowledge and Declarative Bias in Inductive Concept Learning
(recommended by Luc De Raedt)

12:00 Lunch

15:00 Coffee Break

15:30 Submitted Paper
William W. Cohen
Desiderata for Generalization-to-N Algorithms

16:00 Submitted Paper
Peter A. Flach
An Analysis of Various Forms of 'Jumping to Conclusions'

16:30 Supplementary Talk
Douglas R. Hofstadter
A Sketch of an Emergent & Parallel Architecture for Analogy-making

16:50 Supplementary Talk
Erica Melis
Analogical Inference Based on Typical Examples

17:10 Supplementary Talk
Stefan Wrobel
On the Notion of Minimal Specializations in Machine Learning

18:00 Dinner

19:30 GOSLER Project Meeting

Wednesday, October 7

09:00 Invited Talk
John Case, Dayanand S. Rajan, Anil M. Shende
Representing the Spatial/Kinematic Domain and Lattice Computers
(recommended by Carl H. Smith)

10:00 Coffee Break

10:30 Submitted Paper
Yasuhito Mukouchi
Characterization of Finite Identification

11:00 Submitted Paper
Steffen Lange, Thomas Zeugmann
A Unifying Approach to Monotonic Language Learning on Informant

12:00 Lunch

15:00 Coffee Break

15:30 Submitted Paper
Ganesh Baliga, Sanjay Jain, Arun Sharma
Learning from Multiple Sources of Inaccurate Data

16:00 Submitted Paper
William I. Gasarch, Mahendran Velauthapillai
Asking Questions Versus Verifiability

16:30 Submitted Paper
Efim Kinber
Learning a Class of Regular Expressions via Restricted Subset Queries

17:00 MOBAL-Demo
Stefan Wrobel

18:00 Dinner

19:30 Special Session II
John Case
Infinitary Self-Reference in Learning Theory

Thursday, October 8

09:00 Invited Talk
Zhixiang Chen, Wolfgang Maass
A Solution of the Credit Assignment Problem in the Case of Learning Rectangles
(recommended by Manfred Warmuth)

10:00 Coffee Break

10:30 Submitted Paper
Rusins Freivalds, Achim G. Hoffmann
An Inductive Inference Approach to Classification

11:00 Submitted Paper
John Case, Keh-Jiann Chen, Sanjay Jain
Strong Seperation of Learning Classes

12:00 Lunch

15:00 Coffee Break

15:30 Submitted Paper
Robert P. Daley, Bala Kalyanasundaram, Mahendran Velauthapillai
The Power of Probabilism in Popperian Finite Learning

16:00 Submitted Paper
Kalvis Apsitis, Rusins Freivalds, Martins Krikis, Raimonds Simanovskis, Juris Smotrovs
Unions of Identifiable Classes of Total Recursive Functions

16:30 Submitted Paper
Yuji Takada, Rani Siromoney
On Identifying DNA Splicing Systems from Examples

17:15 Supplementary Talk
Achim Hoffmann
Wittgenstein on Analogical and Inductive Inference

17:35 Supplementary Talk
Carl H. Smith
Inductive Inference and Machine Learning: A Tenuous Relationship

18:00 Conference Dinner

Friday, October 9

09:00 Invited Talk
Stephen Muggleton
Equivalence and Refinement for First-Order Predicates
(recommended by Stefan Wrobel)

10:00 Coffee Break

10:30 Supplementary Talk
Rani Siromoney
On Learning Certain Classes of Picture Languages

10:50 Supplementary Talk
Ganesh R. Baliga, John Case
A Language Learning Characterization of the Hypersimple Sets

11:10 Supplementary Talk
Guntis Barzdins
Efficient Inference of Formulas from Input/Output Examples

11:30 Supplementary Talk
Pierre Flener, Yves Deville
Synthesis of Logic Programs From Examples and Properties

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