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Foreword

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The International Symposium on Artificial Intelligence and Mathematics (ISAIM), has been fostering interactions between research in mathematics, theoretical computer science, and artificial intelligence since 1990. In this special issue, it is our pleasure to present full length, refereed versions of a selection of papers presented at ISAIM 2014. These are some of the best papers from the regular session of the conference and from two special sessions: (1) Boolean and Pseudo-Boolean Functions and (2) Theory of Machine Learning. Several papers are on problems in knowledge representation and reasoning: the topics discussed are decision procedures and their complexity, belief revision, uncertain reasoning, compact representations and satisfiability. There are also papers on learning theory, the cognitive aspects of games and heuristic search.

The following are brief summaries of the papers included in this special issue.

Abramé, Habet, and Toumi present a new local search algorithm, called Ncca+, for solving random satisfiable k-SAT instances. Local search algorithms for k-SAT begin with an initial truth assignment, satisfying some of the clauses, and then try to increase the number of satisfied clauses by iteratively choosing variables to flip. Ncca+, which won the random SAT

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track of the SAT Challenge in 2013, introduces two significant modifications into the Configuration Checking approach used by CCASat, the winning algorithm in 2012. Abramé, Habet, and Toumi demonstrate the effectiveness of Ncca+ through extensive experiments, comparing it to other leading local search solvers on a variety of benchmark problems.

Al-Saedi, Fourdrinoy, Grégoire, Mazure and Saïs extend previous work on identifying tractable cases of the satisfiability problem. Unit propagation is used both for generating new tractable classes, and to preprocess general satisfiability instances in the hope of getting formulas which belong to a tractable class. The technique was applied earlier to Horn formulas, and here it is applied to tractable classes introduced by Tovey and Dalal. The paper studies the relationship between these classes. Experimental results are given about the fraction of benchmark problems that are reduced to tractable cases by this method.

Benferhat, Bouraoui, Papini and Würbel deal with belief revision, the problem of updating a knowledge base when new information is received which may be inconsistent with the current knowledge. In current research on this topic, there is interest in studying this problem for logics that are used in practice. The paper considers belief revision for description logics, a major framework for working with ontologies. It adapts the prioritized removed sets revision (PRSR) approach of Benferhat, Ben-Naim, Papini and Würbel, developed earlier for propositional logic. The revision method is then analyzed from the point of view of its logical properties, by considering which of the belief base revision postulates hold, and from the point of view of its computational complexity.

Flerova, Marinescu, and Dechter extend and evaluate weighted heuristic search strategies for graphical models. Their most promising anytime strategies are experimentally competitive with state-of-the-art branch and bound probabilistic inference methods on many datasets. To help explain their empirical results for best-first and depth-first weighted heuristic search schemes, they introduce the notion of a focused search. They derive a weight value that guarantees running a greedy search with least loss of accuracy and are able to prove additional approximation guarantees.

The paper of Gutfreund, Kontorovich, Levy and Rosen-Zvi tackles the very ambitious multiclass supervised learning problem of learning the full conditional class probability function after seeing data from a distribution. This is more difficult than the more standard problem of simply learning the most likely class. In order to do this, the authors assume that the learner has a training sample consisting of instances and their conditional probabilities. Then, they give a boosting theorem by showing that a learner that can achieve a given loss on average can be converted into a learner that can achieve the same loss with high probability. They also show that it is impossible to achieve the more ambitious goal of achieving arbitrarily low sample errors. They then give several generalization guarantees.

Haus and Michini explore binary decision diagram (BDD) representations of the set of all solutions to 0-1 packing and covering problems. More particularly, they consider BDD representations of the set of solutions $x \in \{0, 1\}^n$ to the packing problem $Ax \leq 1_m$ where $A \in \{0, 1\}^{m \times n}$, or to the covering problem $Ax \geq 1_m$, where $A \in \{0, 1\}^{m \times n}$. Compact BDD representations can yield efficient methods for solving associated combinatorial optimization problems. Haus and Michini give a new method for constructing a BDD representation of an arbitrary independence system. (Erratum: Their algorithm runs in output-polynomial time, assuming the specified oracles. It does not run in output-linear time, as claimed in the introduction and in Lemma 3.) They also show that the above packing and covering problems have a reduced, ordered BDD representing the set of solutions that has size at most $n2^{b(A)-1}$, where $b(A)$ is the bandwidth of A. Finally, they present experimental results demonstrating the computational potential of their BDD methods.

The paper by Kern-Isberner, Wilhelm and Beierle is on uncertain reasoning. They consider knowledge bases given by a set of conditional probabilities of events, formed from some propositional variables. The inference problem is to assign a value to a new conditional probability. This value is not uniquely determined in general. There are several possibilities to determine a unique value; one such possibility is given by the principle of maximum entropy. The computation of the MaxEnt probability is approached by considering a system of polynomial equations, and using concepts and techniques, such as elimination ideals and Gröbner bases, from computational algebra. Methods of uncertain reasoning can be evaluated by considering their general properties as systems of inference. The approach of the paper can also be used to derive some properties of MaxEnt reasoning, such as cautious monotonicity.

Ouchi, Okayama, Otaki, Yoshinaka and Yamamoto study Gold's model of learning in the limit from text. In particular, they look at the relationship between two natural learning strategies for inductive inference. The first strategy, MINL, chooses a minimal concept consistent with the data; the second strategy of refinement operators constructs logic programs as hypotheses. They show that if a certain type of refinement operator exists for a concept class, that class will also be learnable under a MINL strategy. They additionally give a technical condition on a concept class that is sufficient for learning its unbounded finite union. Finally, they give some conditions for polynomial-time learnability.

Qu and Doshi consider data on how subjects play sequential bargaining games (SBG). They evaluate many computational models that integrate choice models with utility functions on SBG data. Their findings include a careful study of whether players engage in what is known as backward induction, which is the game-theoretically optimal solution, or whether they are guided by a sense of fairness. They find that both factors come into play, with backward induction playing a more crucial role in longer games.

Toda considers the dualization of Boolean functions, a basic algorithmic problem for many applications. While the monotone case has been studied extensively both from the theoretical and experimental aspects, including the seminal result of Fredman and Khachiyan, the general case has received less attention. The paper develops new algorithms, formulated as algorithms for generating all minimal directed transversals of directed hypergraphs. The algorithms use variants of ternary decision diagrams, corresponding to binary decision diagrams and their zero-suppressed version. Experimental comparisons are made with BDD-based and other algorithms for the same problem.

The paper of Wojciechowski, Eirinakis and Subramani deals with the computational complexity of decision procedures for various fragments of the theory of real arithmetic, i.e., the theory of real numbers with addition and order, a classical problem for which intractability can be proved without any complexity-theoretic assumption. The fragments considered in this paper are restricted versions of quantified linear programs, where the quantifier-free part is a system of linear inequalities, respectively, quantified linear implications, where the quantifier-free part is an implication between two such systems. The various fragments turn out be in P, respectively, to be complete in levels of the polynomial hierarchy. Some of the fragments can be used as modeling tools for reactive systems and other applications.

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