Contents

Abstracts

Automata Theory and Applications: Games, Learning and Structures

20–24 Sep 2021

1 George Barmpalias

Chinese Academy of Sciences, China
Equivalences between learning of data and probability distributions, and their applications

Abstract

Algorithmic learning theory traditionally studies the learnability of effective infinite binary sequences (reals), while recent work by (Vitanyi and Chater 2017) and (Bienvenu et al. 2014) has adapted this framework to the study of learnability of effective probability distributions from random data. We prove that for certain families of probability measures that are parametrized by reals, learnability of a subclass of probability measures is equivalent to learnability of the class of the corresponding real parameters. This equivalence allows to transfer results from classical algorithmic theory to learning theory of probability measures. We present a number of such applications, providing many new results regarding EX and BC learnability of classes of measures, thus drawing parallels between the two learning theories.

Joint work with Fang Nan and Frank Stephan.
Arxiv: http://arxiv.org/abs/1801.02566

2 Dmitry Berdinsky

Mahidol University, Thailand
FA-presentations of Cayley graphs of groups

Abstract

Groups admitting FA-presentations of its Cayley graphs naturally extend the class of automatic groups retaining its fundamental algorithmic properties. In this talk I will discuss properties of normal forms obtained from FA-presentations of such groups from at least two different perspectives: geometric and computational.

References:

- https://arxiv.org/abs/2008.02381
- https://arxiv.org/abs/2008.02511
- https://arxiv.org/abs/2001.04743
- https://arxiv.org/abs/1902.00652
- https://arxiv.org/abs/1804.02548

3 Volker Diekert

FMI, Universität Stuttgart, Germany
Regular matching problems for infinite trees

Abstract

My lecture reports on results which appeared on arXiv with my former student Carlos Camino (Stuttgart) and my colleagues Besik Dundua, (Kutaisi International University and Tbilisi State University, Georgia), Mircea Marin (West University of Timişoara, Romania), and Géraud Sénizergues (Université de Bordeaux, France).

We study the matching problem of regular tree languages, that is, "$\exists\sigma : \sigma(L) \subseteq R$?" where L, R are regular tree languages over the union of finite ranked alphabets Σ and $\mathcal{X}$ where $\mathcal{X}$ is an alphabet of variables and σ is a substitution such that $\sigma(x)$ is a set of trees in $T(\Sigma \cup H) \setminus H$ for all $x \in \mathcal{X}$. Here, H denotes a set of "holes" which are used to define a "sorted" concatenation of trees. Conway studied this problem in the special case for languages of finite words in his classical textbook *Regular algebra and finite machines* published 1971. He showed that if L and R are regular, then the problem "$\exists\sigma\forall x \in \mathcal{X} : \sigma(x) \neq \emptyset \wedge \sigma(L) \subseteq R$?" is decidable. Moreover, there are only finitely many maximal solutions, the maximal solutions are regular substitutions, and they are effectively computable.

We extend Conway's results when L, R are regular languages of finite and infinite trees, and language substitution is applied inside-out, in the sense of Engelfriet and Schmidt (1977/78). More precisely, we show that if $L \subseteq T(\cup\mathcal{X})$ and $R \subseteq T(\Sigma)$ are regular tree languages over finite or infinite trees, then the problem "$\exists\sigma\forall x \in \mathcal{X} : \sigma(x) \neq \emptyset \wedge \sigma_{\mathrm{io}}(L) \subseteq R$?" is decidable. Here, the subscript "io" in $\sigma_{\mathrm{io}}(L)$ refers to "inside-out". Moreover, there are only finitely many maximal solutions σ, the maximal solutions are regular substitutions and effectively computable. The corresponding question for the outside-in extension σ_{oi} remains open, even in the restricted setting of finite trees.

In order to establish our results we use alternating tree automata with a parity condition and games.

4 Murray Elder

University of Technology Sydney, Australia
Deciding plainness in NP

Abstract

I will describe recent work with Adam Piggott (Australian National University) on an old conjecture about rewriting systems. A group is called *plain* if it isomorphic to the free product of a finite number of finite groups and infinite cyclic groups. Madlener and Otto conjectured that a group is presented by a finite convergent length-reducing rewriting system if and only if it is plain.

We give a new geometric characterisation of groups presented by such rewriting systems, and use it prove that deciding if a group presented by an inverse-closed finite convergent length-reducing rewriting system is not plain is in NP. We also prove that the isomorphism problem for plain groups given as inverse-closed finite convergent length-reducing rewriting systems is in PSPACE.

5 Nathanaël Fijalkow

LaBRI, CNRS, France
Using probabilistic context-free grammars for program synthesis

Abstract

Program synthesis is the problem of automatically constructing a program from its specification (given for instance by a set of examples). As advocated by the Synthesis-guided synthesis framework (SyGuS), the set of programs is represented by a context-free grammar. I will discuss a solution to program synthesis which uses machine learning predictions to construct a probabilistic context-free grammar guiding the search towards a solution program. This has been successfully applied in the recent years, for instance in the tools DeepCoder, DreamCoder, and PCCoder.

In this work we show how structural results on probabilistic context-free grammars yield efficient algorithms. No knowledge of program synthesis is required.

6 Ekaterina Fokina

Technical University of Vienna, Austria
Learning structures

Abstract

Assume we have a class of structures closed under isomorphism. Assume further, we receive information about one of these structures step by step: finitely much information at each step. Our goal is to determine, after finitely many steps, which structure from the class we are observing. If we can reach the goal by identifying the structure up to isomorphism (or another suitable equivalence relation), we call the class learnable. In the talk we will formalise various aspects of this problem using ideas from computable structure theory and computational learning theory. We will give two general results about learnability of classes of structures, as well as several examples of learnable and non-learnable classes.

7 Erich Grädel

RWTH Aachen University, Germany
Automatic Structures: History and Perspectives

Abstract

Automatic structures are (in general infinite) structures that admit finite presentations by automata, which implies that their first-order theories are decidable by automata-theoretic methods. The idea of automata based decision procedures for logical theories can be traced back to the early days of automata theory and to the work of Büchi, Elgot, Trakhtenbrot and Rabin in the 1960s. The explicit notion of automatic structures has first been proposed in 1976 in the (unfortunately largely unnoticed) PhD thesis of Hodgson, and later been reinvented by Khoussainov and Nerode in 1995.

In this survey, we present an introduction into the history and basic definitions of automatic structures, and discuss the achievements in the study of different variants of automatic structures. We present their most important mathematical and algorithmic properties, their characterisations in terms of logical interpretations, and some of the mathematical techniques that are used for the analysis of automatic structures and for proving limitations of these concepts.

8 Marcin Jurdziński

University of Warwick, UK

Universal trees for parity games and automata

Abstract

The breakthrough quasi-polynomial algorithm for solving parity games by Calude, Jain, Khoussainov, Li, and Stephan (2017) has been a catalyst for the improved understanding of structural properties of parity games. Winning strategies can be decomposed recursively and the structure of such decompositions is captured by ordered trees. Daviaud, Thejaswini, and J. (2020) have proposed to measure the structural complexity of winning strategies by the Strahler number of such trees, and they have shown that it coincides with Lehtinen's (2018) register number.

Most known techniques for solving parity games (value iteration, attractor decomposition, strategy iteration, priority promotion) can be viewed as search for decompositions, in which universal trees underpin the search space. The combinatorial constructions of universal trees of quasi-polynomial size thus enable the development of quasi-polynomial algorithms using each of those techniques. Moreover, games of small register number can be solved using small Strahler-universal trees.

The improved structural understanding of winning strategies has applications to parity automata. A case in point is a quasi-polynomial translation from alternating parity automata on words to alternating weak automata that is based on universal trees. Applications to parity automata on trees deserve to be explored.

9 Bjørn Kjos-Hanssen

University of Hawaii at Mānoa, Hawaii

Automatic complexity

Abstract

The automatic complexity of finite words was introduced by Shallit and Wang in 2001. It is a finite-automata form of length-conditional Kolmogorov complexity, but is more combinatorial than information-theoretic. For instance,

the automatic complexity of any periodic word is bounded above the length of its period.

I recently answered a question of Shallit and Wang from 2001 by showing that almost all words have close to the maximal nondeterministic automatic complexity (n.a.c.), in analogy with the classical incompressibility results of Kolmogorov and Solomonoff.

In addition to finite words, one can study the automatic complexity of infinite words, via their prefixes. Hyde and I (2015) observed that the infinite Thue word has maximal n.a.c. rate. I showed (2021) that an infinite word with intermediate n.a.c. rate also exists, namely the infinite Fibonacci word. Jordon and Moser (2021) showed that a word with non-maximal automatic complexity rate can even be normal.

10 Karoliina Lehtinen

CNRS, Aix-Marseille Université, France

Good-for-games vs history-determinism in quantitative automata

Abstract

Automata models between determinism and nondeterminism can retain some of the algorithmic properties of deterministic automata while enjoying some of the expressiveness and succinctness of nondeterminism. In the setting of regular languages two such models – namely good-for-games automata and history-deterministic automata–coincide, and have known applications in reactive synthesis.

In this talk, I discuss what happens when these notions are lifted to the quantitative setting. Perhaps surprisingly, the two automata models are no longer equivalent. This talk will explore the landscape of these automata classes and their applications to different quantitative synthesis problems.

11 Luca San Mauro

Sapienza University of Rome, Italy

Learning families of algebraic structures with the help of Borel equivalence relations

Abstract

We study algorithmic learning of algebraic structures. In our framework, a learner receives larger and larger pieces of an arbitrary copy of a computable structure and, at each stage, is required to output a conjecture about the isomorphism type of such a structure. The learning is successful if the conjectures eventually stabilize to a correct guess. We prove that a family of structures is learnable if and only if its isomorphism problem is continuously reducible to the relation E_0 of eventual agreement on reals. This motivates the idea of using descriptive set theoretic tools to refine our learning paradigm. Namely, we use benchmark Borel equivalence relations (e.g., E_1, E_2, E_3, or Z_0) to calibrate the learning complexity of nonlearnable families (e.g., $\{\omega, \zeta\}$).

This is joint work with Nikolay Bazhenov and Vittorio Cipriani.

12 André Nies

The University of Auckland, New Zealand
The search for FA presentable groups

Abstract

A group G is finite automata (FA) presentable if there is a regular set representing its domain, in such a way that the group operations can also be recognized by finite automata. Examples of such groups include the integers with addition, A^ω for any finite group A, and Prüfer groups C_{p^∞}. Several results restricting the possibilities for such groups have been obtained: e.g. N. and Thomas (2008) showed that each finitely generated subgroup is virtually abelian, and Tsankov (2011) solved a long standing conjecture by showing that $(\mathbb{Q}, +)$ is not FA presentable.

In contrast, N. and Semukhin (2009) gave examples of torsion-free indecomposable Abelian groups of rank ≥ 2 that are FA presentable. Their examples involved divisibility by several primes. It is still open whether a group of this kind can be obtained as a subgroup of $(\mathbb{Z}[1/p])^n$. We will report some potential progress on this question from ongoing work with Berdinsky, and with Lupini.

Outside the abelian, N. and Stephan (Logic Blog, 2019 and 2020) have recently given examples of FA presentable groups that are central extensions of one abelian group by another; e.g. extending ${C_p}^\infty$ by C_p where C_p denotes the cyclic group of p elements. We will explain the connection between FA

presentability of a central extension of FA presentable groups and of the corresponding 2-cocycle, and also give an example, varying the one above, where the 2-cocycle is so complex that the extension is not FA presentable. All these examples are torsion groups. It is open whether every torsion-free FA presentable group is virtually abelian.

13 Pierre Ohlmann

IRIF, France
How to solve energy games by hand

Abstract

We present a (third) alternative presentation of Schewe's optimal strategy improvement algorithm [1], by means of energy games. We believe that the obtained algorithm is simple and natural, however not well known by the community. It is also very practical : the algorithm is implemented (for parity games) in the currently best LTL synthesis tool STRIX of Meyer, Sickert and Luttenberger [3], using Luttenberger's presentation of the algorithm [2], implemented over GPUs.
This is a joint work with Antonio Casares.

References

[1] S. Schewe. "An Optimal Strategy Improvement Algorithm for Solving Parity and Payoff Games". In: CSL. Vol. 5213. Lecture Notes in Computer Science. Springer, 2008, pp. 369-384

[2] M. Luttenberger. "Strategy Iteration using Non-Deterministic Strategies for Solving Parity Games". In: CoRR abs/0806.2923 (2008)

[3] P. J. Meyer, S. Sickert, and M. Luttenberger. "Strix: Explicit Reactive Synthesis Strikes Back!" In: CAV. Vol. 10981. Lecture Notes in Computer Science. Springer, 2018

14 Ammar Fathin Sabili

National University of Singapore
A computation model with automatic functions and relations on strings as

a primitive operation

Abstract

Conventional models of computation have quite basic functions as their primitive operations, such as atomic instructions in counter machines and also Turing Machine steps. Models with more sophisticated primitive operations exist. For example, addition machines that can add and compare (which then lead to a modern RAM model design) and also unlimited register machines that can copy a number from one register to another. When working with strings specifically, transducers are somewhat a popular choice to be incorporated as primitive operations by various studies.

In this survey, we present a new model of computation called an Automatic Register Machine. The model is analogous to Turing Machine but the primitive operation is a calculation of a value by automatic functions and relations. In the most general form, one can say the machine has one string as long-term memory and, in each step, it updates the string by an automatic function or relation. We discuss the reason for Automatic Register Machine being an adequate model of computation, its various extensions by allowing nondeterminisms and alternations, and also their relationships between fundamental complexity classes such as P, PSPACE, and NP.
This is a joint work with Ziyuan Gao, Sanjay Jain, Zeyong Li, and Frank Stephan.

15 Karen Seidel

Hasso Plattner Institute, Germany
Modelling binary classification with computability theory

Abstract

This talk is about learning from informant, *a formal model for binary classification*. Illustrating examples are linear separators and other uniformly decidable sets of formal languages. Due to the learning by enumeration technique by Gold the learning process can be assumed consistent when full-information is available.

The original model can be adjusted towards the setting of deep learning. We investigate the learnability of the set of half-spaces by these *incremental learners*. Moreover, they have less learning power than the full-information

variant by a fundamental proof technique due to Blum and Blum. This technique can also be used to separate consistency.

Finally, we present recent results towards a better understanding of (strong) non-U-shaped learning from binary labeled input data. To separate the syntactic variant, we employ an *infinite recursion theorem* by Case.

16 Tom van Dijk

Univeristy of Twente, Netherlands

Recursive attractor-decomposition for parity games

Abstract

We consider algorithms for parity games that use attractor-based decomposition such as Zielonka's recursive algorithm, priority promotion, and tangle learning. In earlier work, the Two Counters parity game family was identified that requires exponential time for many algorithms, including the attractor-based algorithms. We identify the main mechanism that slows down many solvers as so-called distractions. We propose an alternative method to avoid distractions by means of a recursive decomposition of open regions.