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COMPUTABILITY AND COMPUTER SCIENCE

Invited talks

Contributed talks

INVITED TALKS

▸ RAIMUNDO BRICEÑO, *Dismantlability, connectedness, and mixing in relational structures.*
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The Constraint Satisfaction Problem (CSP) and its counting counterpart appears under different guises in many areas of mathematics, computer science, and elsewhere. Its structural and algorithmic properties have demonstrated to play a crucial role in many of those applications. For instance, in the decision CSPs, structural properties of the relational structures involved—like, for example, dismantlability—and their logical characterizations have been instrumental for determining the complexity and other properties of the problem. Topological properties of the solution set such as connectedness are related to the hardness of CSPs over random structures. Additionally, in approximate counting and statistical physics, where CSPs emerge in the form of spin systems, mixing properties and the uniqueness of Gibbs measures have been heavily exploited for approximating partition functions and free energy.

In spite of the great diversity of those features, there are some eerie similarities between them. These were observed and made more precise in the case of graph homomorphisms by Brightwell and Winkler, who showed that dismantlability of the target graph, connectedness of the set of homomorphisms, and good mixing properties of the corresponding spin system are all equivalent. In this paper we go a step further and demonstrate similar connections for arbitrary CSPs. This requires much deeper understanding of dismantling and the structure of the solution space in the case of relational structures, and new refined concepts of mixing introduced by Briceño. In addition, we develop properties related to the study of valid extensions of a given partially defined homomorphism, an approach that turns out to be novel even in the graph case. We also add to the mix the combinatorial property of finite duality and its logic counterpart, FO-definability, studied by Larose, Loten, and Tardif.

This is joint work with Andrei Bulatov, Víctor Dalmau, and Benoît Larose.

▶ ANUJ DAWAR, *Definability and symmetric computation.*
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A high-level description of a decision problem, given in a formal language such as that of first-order logic, can be automatically translated to an algorithm for deciding the problem. The algorithms so obtained have certain natural symmetry properties. Indeed, definability in the logic of fixed-points with counting (FPC) yields a natural notion of ”symmetric computation”. This enables us to translate methods for proving logical undefinability into complexity lower bounds for a natural and powerful class of algorithms, including symmetric linear programs. In this talk, I will give an overview of these methods.

▶ RUSSELL MILLER, *Essential lowness of algebraic properties.*
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For a presentation F of an algebraic field extension of the rational numbers, the *root set* of F is the set R_F of polynomials in $F[X]$ with roots in F, and the *splitting set* is the set S_F of polynomials in $F[X]$ that are reducible there. These are known to be Turing-equivalent to each other (relative to F itself). We show that in almost all cases, they are both of low Turing degree relative to the degree of F, although in general not computable from F itself.

Of course we need to specify what is meant by "almost all cases." A fair portion of the talk with be spent describing how the isomorphism types of such fields form a topological space homeomorphic to Cantor space, and which measures on this space are most reasonable to use. In the end, we will see that for every $\varepsilon > 0$, there is a Turing functional Φ that, for every presentation F of each isomorphism type outside a set of measure $< \varepsilon$, computes the jump of R_F from the jump of F itself, justifying the lowness claim above. A stronger statement holds for Baire category on the space: a single functional computes $(R_F)'$ from F' for all presentations F of every K outside a meager class in the space. Finally, we will discuss the extent to which a similar analysis can be applied to Hilbert's Tenth Problem for subrings of the rational numbers, as these subrings also form a homeomorphic copy of Cantor space.

▶ JUAN REUTTER, *SHACL (Shapes Constraint Language)*.
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SHACL (Shapes Constraint Language) is a W3C recommendation for validating graph-based data against a set of conditions. Among the interesting features of SHACL is the ability to define recursive shapes, to state, for example, that children of persons in a social graph must be persons themselves. Although the recommendation left open the semantics of recursive shapes, there has already been proposals to extend the official semantics for the case of recursion. In this talk I will review the different options for semantics, providing a unifying framework to specify all of them, and their implications in terms of computational complexity. We will also talk about the options for implementing these semantics, either using SAT solvers of Answer Set Programming reasoners.

▸ DAN TURETSKY, *Coding in the automorphism group of a structure*.
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In this talk I will discuss a new technique for coding a closed set into the automorphism group of a structure. This technique has applications to problems in Scott rank, effective dimension, and degrees of categoricity. For instance, I will explain how it can be used to construct a computably categorical structure with noncomputable Scott rank. This is partly joint work with Johanna Franklin.

CONTRIBUTED TALKS

▶ SERGIO ABRIOLA[1], DIEGO FIGUEIRA[2], SANTIAGO FIGUEIRA[3], *Branching counter systems and logics of repeating values on data trees.*
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We study connections between Branching Vector Addition Systems (BVAS) and the satisfiability problem for data-aware logics on data trees. We consider a natural temporal logic of "repeating values" (LRV) which, in addition to having navigational CTL-like modalities, can also test whether a data value in the current node is repeated in some descendant node.

We show that the satisfiability of a restricted version of LRV on ranked data trees can be reduced to the control-state reachability problem for Branching Vector Addition Systems. This reduction produces elementary upper bounds for its satisfiability problem, showing that this restriction of LRV behaves much better than other data-aware logic over data trees, downward-XPath, which has a non-primitive-recursive satisfiability problem.

On the other hand, satisfiability for LRV is shown to be reducible to control-state reachability for a novel branching model we introduce, called Merging VASS (MVASS). MVASS is an extension of Branching Vector Addition Systems with States (BVASS), allowing richer merging operations of the vectors. We show that the control-state reachability for MVASS, as well as its bottom-up coverability, are in 3ExpTime.

These results can be seen as a natural continuation of the work initiated by Demri, D'Souza and Gascon for the case of data words, but this time considering *branching* structures and counter systems. However, in the case of data trees we need more powerful models in order to encode satisfiability.

[1] Stéphane Demri, Deepak D'Souza, and Régis Gascon, *Temporal logics of repeating values*, ***Journal of Logic and Computation***, vol. 22 (issue 5), 2012, pp. 1059–1096.

[2] Stéphane Demri, Diego Figueira, and M. Praveen, *Reasoning about data repetitions with counter systems*, ***Logic in Computer Science***, IEEE, 2013, pp. 33–42.

[3] Abriola Sergio, Diego Figueira, and Santiago Figueira, *Logics of repeating values on data trees and branching counter systems*, ***Lecture Notes in Computer Science*** vol. 10203, Springer, 2017, pp. 196–212.

▸ MARCELO ARENAS, MARTIN MUÑOZ, CRISTIAN RIVEROS, *Descriptive complexity for counting complexity classes.*
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Descriptive Complexity has been very successful in characterizing complexity classes of decision problems in terms of the properties definable in some logics. However, descriptive complexity for counting complexity classes, such as FP and #P, has not been systematically studied, and it is not as developed as its decision counterpart. In this work, we propose a framework based on Weighted Logics to address this issue. Specifically, by focusing on the natural numbers we obtain a logic called Quantitative Second Order Logics (QSO), and show how some of its fragments can be used to capture fundamental counting complexity classes such as FP, #P and FPSPACE, among others. We also use QSO to define a hierarchy inside #P, identifying counting complexity classes with good closure and approximation properties, and which admit natural complete problems. Finally, we add recursion to QSO, and show how this extension naturally captures lower counting complexity classes such as #L.

▸ RODRIGO TORRES-AVILÉS, *Mixing notions on SMART*.
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Turing machines have traditionally been studied as computational models, but we center our line of research on the dynamical properties of Turing machines, thus focusing on their behavior rather than the final results. This approach, in the context of Turing machines, has been fruitful since its inception by Kůrka in 1997 [2], with studies on immortality [4, 5], entropy, equicontinuity, periodicity and, recently, transitivity and minimality [1, 3].

The existence of a Topological Transitive and Topological Minimal Turing machine was presented recently [1], concepts ligated to reaching finite configurations in the orbits of the Turing machine. Nevertheless, *Mixing* notions have not been studied in this field. *Total Transitivity, Weak Mixing* and *Topological Mixing* endorse time restriction to reaching finite configurations inside the orbits of the machine, therefore requiring a deeper understanding on the dynamics of the studied machines. Although, known Turing machines with all the previous properties have very simple dynamics.

In this presentation, we prove that the complex machine SMART [1] presents the properties Total Transitivity and Weak Mixing.

[1] J. Cassaigne, N. Ollinger and R. Torres-Avilés. *A Small Minimal Aperiodic Reversible Turing Machine.* ***Journal of Computer and System Science****, 84C:288-301, 2017.*

[2] P. Kůrka. *On topological dynamics of Turing machines.* ***Theoretical Computer Science****, 174(1-2):203-216, 1997.*

[3] A. Gajardo, N. Ollinger and R. Torres-Avilés. *The Transitivity Problem of Turing Machines.* ***Mathematical Foundation of Computer Science 2015*** *(Milano, Italy) Lecture Notes of Computer Science, 9234:231-242, 2015.*

[4] J. Kari and N. Ollinger. *Periodicity and Immortality in Reversible Computing.* ***Mathematical Foundation of Computer Science 2008*** *(Roun, Poland) Lecture Notes of Computer Science, 5162:419-430, 2008.*

[5] E. Jeandel. *On immortal configurations in Turing machines.* ***Conference on Computability in Europe 2012*** *(Cambrige, UK) Lecture Notes of Computer Science, 7318:334-343, 2012.*