Report from Dagstuhl Seminar 19031

Logics for Dependence and Independence

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Abstract

This report documents the programme and outcomes of Dagstuhl Seminar 19031 "Logics for Dependence and Independence". This seminar served as a follow-up seminar to the highly successful seminars "Dependence Logic: Theory and Applications" (13071) and "Logics for Dependence and Independence" (15261). A key objective of the seminar was to bring together researchers working in dependence logic and in the application areas so that they can communicate state-of-the-art advances and embark on a systematic interaction. The goal was especially to reach those researchers who have recently started working in this thriving area as well as researchers working on several aspects of database theory, separation logic, and logics of uncertainty.

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1 Executive Summary

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Brief Introduction to the Topic

Dependence and independence are interdisciplinary notions that are pervasive in many areas of science. They appear in domains such as mathematics, computer science, statistics, quantum physics, and game theory. The development of logical and semantical structures for these notions provides an opportunity for a systematic approach, which can expose surprising connections between different areas, and may lead to useful general results.

Dependence Logic is a tool for modeling dependencies and interaction in dynamical scenarios. Reflecting this, it has higher expressive power and complexity than classical logics used for these purposes previously. Algorithmically, first-order dependence logic corresponds exactly to the complexity class NP and to the so-called existential fragment of second-order logic. Since the introduction of dependence logic in 2007, the framework has been generalized, e. g., to the contexts of modal, intuitionistic, and probabilistic logic. Moreover, interesting connections have been found to complexity theory, database theory, statistics, and dependence logic has been applied in areas such as linguistics, social choice theory, and physics. Although significant progress has been made in understanding the computational side of these formalisms, still many central questions remain unsolved so far. In addition to addressing the open questions, the seminar also aimed at boosting the exchange of ideas and techniques between dependence logic and its application areas.

Organization of the Seminar and Activities

The workshop brought together 40 researchers from mathematics, database theory, natural language semantics, and theoretical computer science. The participants consisted of both senior and junior researchers, including a number of postdocs and advanced graduate students.

Participants were invited to present their work and to communicate state-of-the-art advances. Over the five days of the workshop, 27 talks of various lengths took place. Introductory and tutorial talks of 90-60 minutes were scheduled prior to the workshop. Most of the remaining slots were filled, mostly with shorter talks, as the workshop commenced. The seminar ended with an open problems and perspectives session. The organizers considered it important to leave ample free time for discussion.

The tutorial talks were scheduled during the beginning of the week in order to establish a common background for the different communities that came together for the workshop. The presenters and topics were:

- Miika Hannula: Team semantics
- Val Tannen: Provenance
- Dan Suciu: Probabilistic databases
- Meghyn Bienvenu: Constraints in ontology based databases
- David Pym: Resource semantics
- Magdalena Ortiz: Complete and incomplete information in knowledge-enriched databases
- Jef Wijsen: Database repairs

In addition, the seminar consisted of 20 shorter contributed talks, addressing various topics concerning expressibility, axiomatizability, complexity and applications of team-based logics.

The last session of the workshop was devoted to open problems and consisted of contributions by Phokion Kolaitis, Jouko Väänänen and Juha Kontinen presenting questions about decidability and axiomatizability of the implication problem of various fragments of dependence and independence logic, Joachim Biskup addressing decidable first-order prefix classes in the database context, Heribert Vollmer presenting open relationships among various counting classes related to team-based logics, Lauri Hella talking about union-closed properties in Σ^1_1, and finally Raine Rönnholm addressing relationships between fragments of inclusion logic and greatest fixed-point logic.

The workshop ended with a discussion of future perspectives of the study of logics for dependence and independence.

The workshop achieved its aim of bringing together researchers from various related communities to share state-of-the-art research. The organizers left ample time outside of this schedule of talks and many fruitful discussions between participants took place throughout the afternoons and evenings.

Concluding Remarks and Future Plans

The organizers regard the workshop as a great success. Bringing together researchers from different areas fostered valuable interactions and led to fruitful discussions. Feedback from the participants was very positive as well.

Finally, the organizers wish to express their gratitude toward the Scientific Directorate of the Center for its support of this workshop.

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3 Overview of Talks

3.1 Team semantics

Miika Hannula (University of Helsinki, FI)

Team semantics provides a framework for modern logics of dependence and independence. In this tutorial talk we cover the basic theory for logics in team semantics. We also give a quick survey to some of the recent trends and developments in the field.

3.2 The Semiring Framework for Provenance

Val Tannen (University of Pennsylvania – Philadelphia, US)

Data provenance: Imagine a computational process that uses a complex input consisting of multiple items. The granularity and nature of "input item" can vary significantly. It can be a single tuple, a database table, or a whole database. It can be a spreadsheet describing an experiment, a laboratory notebook entry, or another form of capturing annotation by humans in software. It can also be a file, or a storage system component. It can be a parameter used by a module in a scientific workflow. It can also be a configuration rule used in software-defined routing or in a complex network protocol. Or it can be a configuration decision made by a distributed computation scheduler (think map-reduce). Provenance analysis allows us to understand how these different input items affect the output of the computation. When done appropriately, such analysis can be further used, for example,

A1: to figure out how much to trust the output, assuming that we may trust some input items more than others;
A2: to minimize the cost of obtaining the output, assuming that one has to pay for the input items;
A3: to figure out the clearance level required for accessing the output, assuming that we know the clearance levels for the input items;
A4: to compute the probabilistic distribution of the output, assuming that we know the distributions of the input items;
A5: to figure out if the output might change (and therefore whether output maintenance is necessary) when certain input items change; or
A6: to track back and find the input items at fault, assuming the output is somehow wrong.

We shall have occasion below to refer to the applications A1-A6 just listed. In practice, a computational process will produce a collection of output items and the applications above become more interesting when we realize that we may get different analyses for each output item.

Now, observe that these applications should not rely on just a trace, or a log, of a specific execution of the computational process itself. Some approach to applications A3 and A5 could probably be devised using just execution traces, but we should still worry whether repeating the execution with the same input items but with a differently optimized execution platform will produce the same provenance. At the same time, we cannot simply peg provenance as a kind of static analysis of the underlying program since it will also depend on the input items themselves. This dual static-dynamic nature makes provenance analysis particularly interesting, especially so for database computations.

Provenance of FOL model-checking: Given a first-order sentence, a model-checking computation tests whether the sentence holds true in a given finite structure. Data provenance extracts from this computation an abstraction of the manner in which its result depends on the data items that describe the model. Previous work on provenance was, to a large extent, restricted to the negation-free fragment of first-order logic and showed how provenance abstractions can be usefully described as elements of commutative semirings — most generally as multivariate polynomials with positive integer coefficients. We introduce a novel approach to dealing with negation and a corresponding commutative semiring of polynomials with dual indeterminates. These polynomials are used to perform reverse provenance analysis, i.e., finding models that satisfy various properties under given provenance tracking assumptions.

3.3 Probabilistic databases

Dan Suciu (University of Washington – Seattle, US)

We examine the implication problem between soft constraints in two settings. The first uses a probability distribution on models, and is based on the work done in probabilistic databases and in Markov Logic Networks (MLN). The second is based on using information theoretic measures to quantify the degree of a constraint.

3.4 A brief introduction to ontology-mediated query answering

Meghyn Bienvenu (University of Bordeaux, FR)

Recent years have seen an increasing interest in ontology-mediated query answering (OMQA), in which the semantic knowledge provided by an ontology is exploited when querying data. In this talk, I will give a short introduction to this area, focusing on ontologies formulated using description logics. After introducing description logics and the OMQA problem, I will provide a brief overview of the main algorithmic techniques and the complexity landscape.

3.5 Logic as a modelling technology: resource semantics, systems modelling, and security

David J. Pym (University College London, GB)

The development of BI, the logic of bunched implications, together with its resource semantics, led to the formulation of Separation Logic, which forms the basis of the Infer program analyser deployed in Facebook's code production. However, this rather successful story sits within a broader, quite systematic logical context. I will review the (family of) logics – including modal logics, logics for layered graphs, and process logics – that are supported by resource semantics, explaining their more-or-less uniform meta-theoretic basis and illustrating their uses in a range of modelling applications, including access control, systems security, and workflow simulation. Many references are available at: http://www.cs.ucl.ac.uk/staff/D.Pym/.

3.6 Complete and incomplete information in knowledge-enriched databases

Magdalena Ortiz (TU Wien, AT)

Joint work of Shqiponja Ahmetaj, Labinot Bajraktari, Nhung Ngo, Magdalena Ortiz, Mantas Simkus
Main reference Labinot Bajraktari, Magdalena Ortiz, Mantas Simkus: "Combining Rules and Ontologies into Clopen Knowledge Bases", in Proc. of the Thirty-Second AAAI Conference on Artificial Intelligence, (AAAI-18), the 30th innovative Applications of Artificial Intelligence (IAAI-18), and the 8th AAAI Symposium on Educational Advances in Artificial Intelligence (EAAI-18), New Orleans, Louisiana, USA, February 2-7, 2018, pp. 1728–1735, AAAI Press, 2018.
URL https://www.aaai.org/ocs/index.php/AAAI/AAAI18/paper/view/16991

Ontologies are background theories expressing domain knowledge written in a logical formalism that supports automated inference (i.e., logics with a decidable entailment problem, such as description logics). Ontologies have been successfully used for inferring better answers from incomplete data, but the usual first-order semantics used in this setting, which assumes that all data is incomplete, can sometimes be too weak and not give all expected answers. To overcome this problem, closed predicates have been considered in the description logics literature. In a nutshell, closed predicates enhance an ontology with a list of predicates that are assumed complete, analogously to master tables in databases. This talk summarizes some of the challenges that closed predicates pose, including non-monotonicity of the consequence relation and increased computational complexity of reasoning [3]. We discuss some rewritings of ontology-mediated queries with closed predicates into Datalog extensions [1], and briefly describe a very rich knowledge representation language that supports closed predicates and extends some classic hybrid languages combining Datalog and description logics [2].

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3.7 Database Repairs

Jef Wijsen (University of Mons, BE)

Research in database repairing and consistent query answering started with the seminal paper [Arenas, Bertossi, and Chomicki, PODS 1999]. In this talk, we survey twenty years of research in this field, with a particular focus on the following topics:

- database dependencies that have appeared in logics for dependence and independence;
- a generic definition of the notion of database repair;
- the computational complexity of the problem known as symmetric-difference repair checking, for different classes of database dependencies;
- the computational complexity of symmetric-difference consistent query answering with respect to conjunctive queries and different classes of database dependencies;
- a fine-grained complexity classification for consistent query answering to self-join-free conjunctive queries with respect to key dependencies.

3.8 Complexity Classifications of Functional Dependencies in Database Repairing

Benny Kimelfeld (Technion – Haifa, IL)

The talk describes our research on the computational complexity of problems that arise in reasoning about the inconsistency of databases. To that extent, an inconsistent database is a database that violates a set of integrity constraints, and a repair is a consistent database that is obtained from the inconsistent one via a legitimate sequence of repairing operations. Focusing on functional dependencies as constraints and tuple deletions as repairing operations, I discuss several related computational problems. One problem is that of repairing through a minimal number of deletions. Another problem is that of finding a most probable repair when tuples are associated with probabilities. Other problems involve counting and enumerating set-minimal repairs, possibly in the presence of preferences among tuples. In each problem, the talk focuses on the classification of the constraint sets into ones that admit a tractable solution, and ones that are provably hard.

3.9 Semiring Provenance for Logics with Team Semantics

Erich Grädel (RWTH Aachen, DE)

Joint work of Erich Grädel, Lukas Huwald

We extend the approach of provenance analysis by interpretations in commutative semirings to logics of dependence and independence. We investigate issues such as locality, closure properties, game based analysis, and expressive power in this wider context. It turns out that for a smooth theory the cases of idempotent or absorptive semirings seem particularly adequate.

3.10 An atom's worth of anonymity

Jouko Väänänen (University of Helsinki, FI)

I observe that team semantics is very suitable for the study of k-anonymity and other concepts motivated by privacy concerns. To this end I introduce what I call k-anonymity atoms. The 2-anonymity atom has been already introduced by Galliani under the name of non-dependence atom. k-anonymity atoms and even stronger related atoms have been introduced by Grädel and Hegselmann under the name of forking atom. I give a complete axiomatization of 2-anonymity atoms and suggest an axiomatization of k-anonymity atoms. I also conjecture that there is a complete axiomatization of the anonymity atom together with the dependence atom. By results of Galliani, anonymity logic, i.e. the extension of first order logic by anonymity atoms, is equivalent to inclusion logic.

3.11 On the expressive power of anonymity atoms

Raine Rönnholm (Tampere University, FI)

Anonymity atoms (originally called non-dependence atoms) were introduced by Pietro Galliani in 2012. Galliani has shown that when anonymity atoms are added to first order logic with team semantics, we obtain an equivalent logic with inclusion logic. The truth condition of the anonymity atom $\mathrm{an}(x, y)$ intuitively states that the truth of the corresponding dependence atom $=(x, y)$ is "violated" for each value of x in the team. That is, for each value of x, there exist assignments s and s' which agree on x but have a different value for y. These atoms can be further generalized to so-called m-anonymity atoms which state that for each value of x there are at least m different values for y in the team. We obtain k-ary (m)-anonymity atoms by allowing $(k-1)$-tuples of variables in the place of the variable x in the atom $\mathrm{an}(x, y)$. We study how the expressive power of (m)-anonymity atoms is affected by making these restrictions on the arity. We present some new results which are obtained by making comparisons with the arity fragments of inclusion logic and the relational arity fragments of existential second order logic.

3.12 Various forms of independence in possibility theory: An overview

Henri Prade (University of Toulouse, FR)

The idea of independence has been mainly discussed in two settings: probability and logic. In probability, the independence between events is a symmetrical notion, since saying that B is independent of A reads Prob(B|A) = P(B) which is equivalent to P(A&B) = P(A)P(B) (& stands for conjunction). Moreover we can simplify probabilistic calculations by knowing or assuming that variables are (conditionally) independent. Logical independence differs from stochastic independence, and the situation is not the same, since it is rather dependencies that are asserted in logic. In this presentation, we provide an overview of various notions of independence that have been defined in possibilty theory, a setting appropriate for modelling epistemic uncertainty, and which also remains close to logic. First, independence between events is no longer necessarily symmetrical in possibility theory, and is useful for introducing independence information in nonmonotonic reasoning. Independence between variables is of a different nature: it may be symmetrical and generalize logical independence. The relation with possibilistic functional dependencies that have been recently introduced and shown useful in database design will be also discussed.

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3.13 Initial Steps into Parametrised Complexity of Dependence Logic

Yasir Mahmood (Leibniz Universität Hannover, DE)

In this talk, we present work in progress. We introduce parametrised complexity for team-based logic and start with the propositional dependence logic.

- Questions addressed are: Satisfiability, Model-checking & Validity of a PDL-formula.
- Potential parameters are: Team-size, number of splits, tree-width, tree-depth and number of variables.

We present some initial results: for (MC)

1. An application of Courcelle's theorem to model checking (for both, lax and strict semantics)
2. An FPT-algorithm when the parameter is team-size + tree-depth and team-size + #splits
3. (For SAT) when parameter is #variables.

Furthermore, we present some observations regarding the satisfiability problem and close with some questions that will be addressed in the future.

3.14 Dependency Concepts up to Equivalence

Matthias Hoelzel (RWTH Aachen, DE)

Joint work of Matthias Hoelzel, Erich Grädel
Main reference Erich Grädel, Matthias Hoelzel: "Dependency Concepts up to Equivalence", in Proc. of the 27th EACSL Annual Conference on Computer Science Logic, CSL 2018, September 4-7, 2018, Birmingham, UK, LIPIcs, Vol. 119, pp. 25:1–25:21, Schloss Dagstuhl – Leibniz-Zentrum fuer Informatik, 2018.
URL http://dx.doi.org/10.4230/LIPIcs.CSL.2018.25

We study logics with dependency statements that cannot distinguish elements up to equality, but only up to a given equivalence relation. We analyse the power of such logics, by identifying equally expressive fragments of existential second-order logic or greatest fixed-point logic, with relations that are closed under a given equivalence.

3.15 Variations on a Causality Theme in Data Management

Leopoldo Bertossi (Carleton University – Ottawa, CA & RelationalAI Inc., CA)

Joint work of Leopoldo Bertossi, Babak Salimi

The presentation reviews several problems and results in relation to the specification and computation of causes for query answers in data management. In particular, the problems of computing causes, their responsibilities, and maximum-responsibility causes are considered, and results for them are obtained by exploiting a connection between DB causality and repairs of databases that violate integrity constraints (ICs). Also answer-set programs (ASPs) are proposed for the specification of causes and their responsibilities. They are based on ASPs that specify database repairs. The problems of specifying and computing causes under ICs are introduced and some results are presented. Finally, a formalization of causes for query answers at the attribute level is proposed.

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3.16 Logics with Multiteam Semantics

Richard Wilke (RWTH Aachen, DE)

Joint work of Erich Grädel, Richard Wilke

Team semantics is the mathematical basis of modern logics of dependence and independence. In contrast to classical Tarski semantics, a formula is evaluated not for a single assignment of values to the free variables, but on a set of such assignments, called a team. Team semantics is appropriate for a purely logical understanding of dependency notions, where only the presence or absence of data matters, but based on sets, it does not take into account multiple occurrences of data values. It is therefore insufficient in scenarios where such multiplicities matter, in particular for reasoning about probabilities and statistical independencies. Therefore, an extension from teams to multiteams (i.e. multisets of assignments) has been proposed by several authors.

We aim at a systematic development of logics of dependence and independence based on multiteam semantics. We study atomic dependency properties of finite multiteams and discuss the appropriate meaning of logical operators for multiteam semantics, so as to extend the atomic dependencies to full-fledged logics for reasoning about dependence and independence in a multiteam setting. We compare the properties and expressive power of a number of different logics with team and multiteam semantics. It turns out that the relationship between multiteam semantics, team semantics, and classical Tarski semantics, and the study of the expressive power of logics with multiteam semantics are more delicate and more interesting than one might expect. In particular, with multiteam semantics, inclusion and exclusion logic does not correspond to independence logic.

3.17 Probabilistic team semantics

Jonni Virtema (Hasselt University, BE)

Joint work of Arnaud Durand, Miika Hannula, Åsa Hirvonen, Juha Kontinen, Vadim Kulikov, Arne Meier and Jonni Virtema
Main reference Arnaud Durand, Miika Hannula, Juha Kontinen, Arne Meier, Jonni Virtema: "Probabilistic Team Semantics", in Proc. of the Foundations of Information and Knowledge Systems – 10th International Symposium, FoIKS 2018, Budapest, Hungary, May 14-18, 2018, Proceedings, Lecture Notes in Computer Science, Vol. 10833, pp. 186–206, Springer, 2018.
URL https://doi.org/10.1007/978-3-319-90050-6_11

We review recent work on probabilistic team semantics [1, 2]. Probabilistic team semantics is built compositionally upon the notion of a probabilistic team, that is, a probability distribution over variable assignments. This framework allows the study of logical and probabilistic dependencies simultaneously. Adapting probabilistic team semantics recovers some desired properties of the so-called strict team semantics. Probabilistic team semantics has also a close connection to the area of meta finite model theory; the expressive powers of related logics are captured by variants of two-sorted logics with arithmetic operations on the second numeric sort.

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3.18 Propositional Union Closed Team Logics

Fan Yang (University of Helsinki, FI)

Logics based on team semantics (also called team logics) often have interesting closure properties. For example, dependence logic is closed downwards, meaning that the truth of a formula on a team is preserved under taking subteams. In this talk, we discuss propositional team logics that are closed under unions, meaning that if two teams both satisfy a formula, then their union also satisfies the formula. Inclusion logic [1] is closed under unions. Other known union closed logics are classical logic extended with anonymity atoms (introduced very recently by Väänänen to characterize anonymity in the context of privacy), or with the relevant disjunction (introduced by Rönnholm [3], and also named nonempty disjunction by some other authors [2, 5]).

While propositional downwards closed team logics are well studied (e.g., [4]), propositional union closed team logics are not understood very well yet. It follows from [2] that propositional inclusion logic (PInc) with extended inclusion atoms is expressively complete, and PInc is thus expressively equivalent to classical logic extended with relevant disjunction (PU), which is shown to be also expressively complete in [5]. We show in this talk that classical logic extended with anonymity atoms (PAm) is also expressively complete, and PInc with slightly less general inclusion atoms is already expressively complete. From the expressive completeness, we will derive the interpolation theorem for these logics. We also provide axiomatizations for these logics, which are lacking in the literature.

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3.19 Set-valued Dependence versus Value Independence and Inferences in Pure Flat Attribute Universes for Relational Database Schema Design

Joachim Biskup (TU Dortmund, DE)

Joint work of Joachim Biskup, Sebastian Link
Main reference Joachim Biskup: "Inferences of Multivalued Dependencies in Fixed and Undetermined Universes", Theor. Comput. Sci., Vol. 10, pp. 93–105, 1980.
URL https://doi.org/10.1016/0304-3975(80)90075-4

Dependence and independence are crucial notions for layered relational database schema design, which includes decisions on data formats and their consequences for storing data either together or separately. The design process considers at least two layers, first conceptual modeling with pure flat attributes and then relational formalization with flat predicates of fixed arity (a variant of FOL formatting). Reviewing the expressive means of the layers and how constraints are first specified and later converted, we observe that a set-valued dependence constraint between pure flat attributes might become closely related to a value independence constraint for a fixed predicate. Originally studied for relational database schema design guided by multivalued dependencies and later on also exploited for other intensional data formatting tasks, such relationships have to be reflected by "appropriate inference", distinguishing between application-driven reasoning on the layer of pure flat attributes and formatting-driven reasoning on the layer of fixed flat predicates.

3.20 Separation Logic and Team Semantics

Erich Grädel (RWTH Aachen, DE)

In this short talk, I discussed how (a particular variant of) separation logic can be understood in terms of team semantics. I hope that this may lead to a deeper study of connections between separation logic (and its cousins) with logics of dependence and independence.

3.21 Temporal Logics for Hyperproperties

Bernd Finkbeiner (Universität des Saarlandes, DE)

A hyperproperty is a set of sets of traces. Hyperproperties are commonly used in information flow security to express requirements of the type "the public output of a system must not depend on its secret inputs" such as noninterference, noninference, or observational determinism. In this talk, I will give an overview on HyperLTL, the extension of linear-time temporal logic (LTL) to hyperproperties, and related logics such as LTL with team semantics and first-order logic over sets of traces.

3.22 Holistic treatment of syntax and semantics

Bernhard Thalheim (CAU Kiel, DE)

Database research as well as Computer Science research separate syntax and semantics in a two-step definition mould. Syntax is considered to be a "firstness" property and semantics some kind of "secondness" (in the sense of Peirce).

We propose a holistic treatment of syntax and semantics similar to the one that natural languages use.

The holistic treatment is necessary for model development and utilisation.

It can be considered as an specific form of team semantics that is extended by context.

3.23 Reasoning about dependence and independence in aggregation problems

Eric J. Pacuit (University of Maryland – College Park, US)

Joint work of Eric J. Pacuit, Fan Yang

Notions of dependence and independence are central to many key results in preference aggregation and opinion pooling (aggregating probabilistic judgements). In this talk, I will briefly discuss joint work with Fan Yang on the formalization of Arrow's Theorem in an independence logic. My goal in this talk is to examine other results in the preference and judgement aggregation literature that are amenable to formalization in dependence and/or independence logic. I will focus on capturing notions of domain restrictions from the social choice literature and impossibility results about the preservation of independence when aggregating probabilistic judgements.

3.24 On matrices and K-relations

Jan Van den Bussche (Hasselt University, BE)

Joint work of Jan Van den Bussche, Robert Brijder, Marc Gyssens

MATLANG, proposed by Brijder, Geerts, Van den Bussche and Weerwag at ICDT 2018, is an algebra for querying matrix databases. K-relations can represent matrices as well, and a semantics for the positive relational algebra on K-relations was defined by Green, Karvounarakis and Tannen at PODS 2007. We refer to this algebra as ARA. One can easily translate MATLANG into ARA, and only relations with at most three attributes are needed for this translation; we denote this by ARA(3). We prove a converse result: every binary ARA(3) query over binary relations can be expressed in MATLANG.

3.25 Approximate dependency atoms

Åsa Hirvonen (University of Helsinki, FI)

Joint work of Åsa Hirvonen, Juha Kontinen, Arno Pauly

We give a brief overview of approximate dependency atoms in infinite teams over metric spaces. The motivation is, on one hand, to get better behaved notions of dependency when one looks at infinite metric teams from a computational point of view, on the other, to develop notions of approximate dependencies tied to "almost correct" data.

3.26 Counting of Teams in First-Order Team Logics

Juha Kontinen (University of Helsinki, FI)

Joint work of Juha Kontinen, Anselm Haak, Fabian Müller, Heribert Vollmer, Fan Yang

We study descriptive complexity of counting complexity classes in the range from #P to #·NP. A corollary of Fagin's characterization of NP by existential second-order logic is that #P can be logically described as the class of functions counting satisfying assignments to free relation variables in first-order formulae. In this talk we extend this study to classes beyond #P and extensions of first-order logic with team semantics. Our results show that the class #·NP can be logically characterized by independence logic and existential second-order logic, whereas dependence logic and inclusion logic give rise to subclasses of #·NP and #P, respectively. Our main technical result shows that the problem of counting satisfying assignments for monotone Boolean Σ_1-formulae is #·NP-complete as well as complete for the function class generated by dependence logic.

3.27 Finite-State Dependence

Dietmar Berwanger (CNRS, ENS Paris-Saclay, FR)

The use of information in games hinges on the notion of dependence. On the one hand, the actions of a player are constrained to depend on the information to which he has access. In turn, the consequence of an action can convey information to another player and thus loosen her respective information constraints.

Scenarios that involve successive (communication) actions tend to be difficult to analyse. Dependence logic appears as a suitable formalism to address such intricacies, at least in the specific case of coordination problems, which ask whether there exists a joint strategy that is successful.

If the information states are elements of a finite structure, and the objective function is first-order definable, the formulation of coordination problems in dependence logic is straightforward. However, in the more challenging settings of iterated games, information states correspond to sequences of observations, so we need to reason about infinite domains.

In the talk, we outline an interpretation of dependence logic in automatic structures with teams that admit finite-state representations. Essentially, the second-order objects involved in existential quantification and disjunction range over regular sets, and dependency relations are restricted to finite-state functions. We suggest a parametrisation of the semantics to ensure decidability via interpretation into the existential monadic theory of trees.

The perspective of this project is twofold: (1) to develop a suitable formalism for reasoning about information and coordination on the basis of dependence logic, and (2) to identify fragments of the logic that are decidable on automatic structures by retro-engineering positive results from automata theory and games with imperfect information.

3.28 The exact status of database semantics?

Joachim Biskup (TU Dortmund, DE)

Joint work of Joachim Biskup, Piero A. Bonatti
Main reference Joachim Biskup, Piero A. Bonatti: "Controlled query evaluation with open queries for a decidable relational submodel", Ann. Math. Artif. Intell., Vol. 50(1-2), pp. 39–77, 2007.
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Standard textbooks on relational database theory, as many original publications, usually assume that first-order logic can be employed for defining formal semantics for query answering, data dependencies and similar concepts. Regarding models, the authors of such work sometimes specify more precisely whether they have finite model theory or general model theory (allowing models of any cardinality) in mind. Accordingly, they consider either finite entailment or general entailment.

However, many works about relational database theory actually employ implicitly (or sometimes also explicitly) what we call database model theory

- on the syntactic layer, there is an infinite supply of constant symbols (0-ary function symbols);
- on the semantic layer, only Herbrand models with the fixed *infinite* universe consisting of the supplied constants on the one hand and only *finitely* many positively interpreted atomic sentences on the other hand, together with the pertinent unique names axioms for the constants, are considered.

The open problem then is the following: What is the exact status of the resulting database model semantics, in comparison to finite model semantics and general model semantics?

In many contexts the problem might be irrelevant, for example when studying safe and domain-independent queries. In some other contexts, however, distinguishing between the three types of semantics might be crucial, in particular when dealing with inference control where pure finite models could enable combinatorial reasoning. Moreover, database model semantics generate unusual tautologies. For example, for an open formula $f(x)$ – with x denoting the free variables – that is safe and domain-independent when seen as a query, the sentence $(\exists x)\neg f$ is true in all database models!

In our own work on inference control for open relational queries, see Section 2 of the main reference, we have exhibited a sufficient condition for the three kinds of semantics coinciding, introducing out-of-active-domain axioms besides the well-known unique names axioms. Though this condition has been helpful for a specific task, the exact relationship between the three semantics remains open.

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