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Preface

This volume contains the papers presented at the 21st Workshop on Logic, Language, Information and Computation (WoLLIC 2014) held during September 1–4, 2014, at the Department of Informatics, Universidad Técnica Federico Santa Maria in Valparaiso, Chile.

The WoLLIC series of workshops started in 1994 with the aim of fostering interdisciplinary research in pure and applied logic. The idea is to have a forum that is large enough for the number of possible interactions between logic and the sciences related to information and computation, and yet is small enough to allow for concrete and useful interaction among participants.

There were 34 submissions of which five were withdrawn. Each of the remaining 29 submissions was reviewed by at least three Program Committee (PC) members who were assisted by 25 external reviewers. The committee decided to accept 15 papers. We very much like to thank all PC members and external reviewers for the work they put into reviewing the submissions. The help provided by the EasyChair system created by Andrei Vorokonkov is hardly to be overestimated.

The program also included six invited lectures by Verónica Becher (Universidad de Buenos Aires), Juha Kontinen (University of Helsinki), Aarne Ranta (University of Gothenburg), Kazushige Terui (Kyoto University), Luca Vigano (King's College London), and Thomas Wilke (Christian-Albrechts-Universität zu Kiel).

We would like to thank the entire Organizing Committee (Anjolina G. de Oliveira, Juan Reutter, and Cristian Riveros) for making WoLLIC 2014 a success. Finally, we would like to acknowledge the generous financial support provided by NIC (Chile) and the Pontificia Universidad Católica de Chile as well as the scientific sponsorship of the following organizations: Interest Group in Pure and Applied Logics (IGPL), The Association for Logic, Language and Information (FoLLI), Association for Symbolic Logic (ASL), European Association for Theoretical Computer Science (EATCS), European Association for Computer Science Logic (EACSL), Sociedade Brasileira de Computação (SBC), and Sociedade Brasileira de Lógica (SBL).

By the time this volume was to be delivered to the publishers, we heard the sad news of the passing away of Prof Grigory Mints (Stanford University). Grisha, as he was usually known by colleagues and students alike, was an enthusiastic and very active member of WoLLIC community, having also acted in past instances of the meeting as an invited speaker, member of steering committee, member of Programme Committee, chair of Programme Committee, guest editor of proceedings as well as of a special issue, and chair of the organizing committee. Grisha will be missed for all his intellectual and personal leadership qualities. This volume is dedicated to his memory.

May 2014

Ulrich Kohlenbach
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Invited Talks
(Abstracts)

On Normal Numbers

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Normality is a basic form of randomness. A real number is *simply normal* to a given base if each digit occurs in the expansion with the same limit frequency. A real number is *normal* to a given base if each *block* of digits of equal length occurs in the expansion with the same limit frequency. And a real is *absolutely normal* if it is normal to all bases. This definition was introduced by Émile Borel more than one hundred years ago, but still not much is known about normal numbers. One of the famous open problems is whether the usual mathematical constants, as π, e and $\sqrt{2}$, are simply normal to any base.

In this talk I will summarize some recent results on normal numbers that answer the following questions:

- How does simple normality (respectively normality) to one base relates to simple normality (respectively normality) to other bases?
- How does normality relates to compressibility on different automata?
- How can we efficiently compute the expansion of absolutely normal numbers?
- How can we construct absolutely normal Liouville numbers?

The proofs integrate logical, combinatorial and number-theoretic tools.

This research has been done partly with Yann Bugeaud, Olivier Carton, Pablo Heiber and Theodore Slaman.

Dependence Logic

Juha Kontinen

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Abstract. Dependence logic, introduced by Jouko Väänänen in 2007, is a new logic incorporating the concept of dependence into first-order logic. In the past few years, the team semantics of dependence logic has grown into a new framework in which various notions of dependence and independence can be formalized and studied. We review recent results on dependence logic and its applications.

Syntax and Semantics for Translation

Aarne Ranta

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Abstract. Translation is expected to preserve the semantics of the source text and produce correct syntax in the target language. Obvious as this is for human translators, machine translation usually involves shortcuts that compromise both of these requirements. In this talk, we will take a look at what is needed to fulfil them. In particular, we will see how formal grammars should be written in order to help translation preserve semantics. The syntax and semantics that result are in many ways different from grammars that are written in a monolingual perspective. The question has its roots in the old ideas of a Universal Grammar, and has in modern times been suggested by Curry. Translation-oriented grammars were put to use in the Rosetta system at Philips in the 1980's, and are used today in the Grammatical Framework (GF). This talk will start from the basic concepts of syntax, semantics, and translation, and end up discussing some recent developments in GF.

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Intersection Types for Normalization and Verification

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One of the basic principles in typed lambda calculi is that typable lambda terms are normalizable. Since the converse direction does not hold for simply typed lambda calculus, people have been studying its extensions. This gave birth to the *intersection type systems*, that exactly characterize various classes of lambda terms, such as strongly/weakly normalizable terms and solvable ones (see e.g. [6] for a survey).

There is another, more recent trend: intersection types are not only useful for extending simple types but also for *refining* them [4]. One thus obtains finer information on simply typed terms by assigning intersection types. This in particular leads to the concept of *normalization by typing*, that turns out to be quite efficient in some situations [5]. Moreover, intersection types are invariant under $\beta\eta$-equivalence (when assigned to simply typed terms), so that they constitute a denotational semantics (the *Scott model of linear logic* [1]), that provides a seemingly more direct interpretation of lambda terms than the traditional filter model. Finally, intersection types also work in an infinitary setting, where terms may represent infinite trees and types play the role of automata. This leads to a model checking framework for higher order recursion schemes via intersection types [2, 3].

The purpose of this talk is to outline the recent development of intersection types described above. In particular, we explain how an efficient evaluation algorithm is obtained by combining normalization by typing, β-reduction and Krivine's abstract machine, to result in the following complexity characterization. Consider simply typed lambda terms of boolean type $o \to o \to o$ and of order r. Then the problem of deciding whether a given term evaluates to "true" is complete for n-EXPTIME if $r = 2n + 2$, and complete for n-EXPSPACE if $r = 2n + 3$ [5].

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Backward Deterministic Büchi Automata

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Finite words are symmetric: they have a first and a last letter. Opposed to this, ω-words are not symmetric: they have a first letter, but no last letter. This is why forward and backward deterministic finite-state ω-automata are fundamentally different. For instance, a theorem by Olivier Carton and Max Michel [1] states that for every regular ω-language there exists a reverse deterministic Büchi automaton recognizing this language, whereas this is not true for ordinary forward deterministic Büchi automata. The talk gives an overview of the theory of backward deterministic ω-automata, focusing on Büchi automata.

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Quantum State Transformations and Branching Distributed Temporal Logic*

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Abstract. The Distributed Temporal Logic DTL allows one to reason about temporal properties of a distributed system from the local point of view of the system's agents, which are assumed to execute independently and to interact by means of event sharing. In this paper, we introduce the Quantum Branching Distributed Temporal Logic QBDTL, a variant of DTL able to represent quantum state transformations in an abstract, qualitative way. In QBDTL, each agent represents a distinct quantum bit (the unit of quantum information theory), which evolves by means of quantum transformations and possibly interacts with other agents, and n-ary quantum operators act as communication/synchronization points between agents. We endow QBDTL with a DTL-style semantics, which fits the intrinsically distributed nature of quantum computing, we formalize a labeled deduction system for QBDTL, and we prove the soundness of this deduction system with respect to the given semantics. Finally, we discuss possible extensions of our system in order to reason about entanglement phenomena.

* The work presented in this paper was partially supported by the EU FP7 Marie Curie PIRSES-GA-2012-318986 project "GeTFun: Generalizing Truth-Functionality". Part of this work was carried out while Luca Viganò was at the Dipartimento di Informatica, Università di Verona, Italy.

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