The Logic Summer School 2004

Linková, Zdeňka
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Institute of Computer Science
Academy of Sciences of the Czech Republic

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Technical report No. 925

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Abstract:

Abstract Logic is the foundational discipline of many sciences. Part mathematics, part philosophy and part computing science, logic remains a core intellectual study and is increasingly relevant to practical concerns. It spreads into planning, into program synthesis, into circuit design and into discourse analysis. It underpins the entire science of artificial intelligence. In order to increase knowledge from the field of logic, I participated in the Logic Summer School. This report covers some information.

Keywords:
Logic, Summer School

Contents

1 Introduction

Modern logic is the foundational discipline of the information sciences. It includes not only the science of reasoning but also computability theory, type theory and other tools for understanding processes, declarative programming, automatic proof generation, program verification and much more. Logic is not useful only for computer scientists, but also for mathematicians and philosophers. All professionals, teachers, students, and anyone, who finds logic enticing, could attend The Logic Summer School [1].

The Logic Summer School was hosted at The Australian National University (ANU) by the Automated Reasoning Group in the Research School of Information Sciences and Engineering. It was held from the 6th to the 17th of December 2004 in Canberra. The Summer School provided a unique, high-quality, intensive period of study.

2 The Logic Summer School

The School consisted of short courses on aspects of pure and applied logic taught by experts from Australia and overseas. The school lasted two weeks. Logic lessons were held all weekdays, for free weekends there was some social program. First week were topics like *Foundations of First Order Logic*, *Introduction to Automated Reasoning*, *Introduction to Modal and Temporal Logics*, and *Computability and Incompleteness* on program. Next week were taught *Formal Methods*, *Knowledge Representation and Reasoning*, and *Non-Classical Logic*.

There were no formal requirements for the school registration; however, participants were expected to be familiar with the concepts and notation of propositional and first order logic. It was assumed that students were at least familiar with logical notation for connectives and quantifiers, and could manipulate truth tables, some kind of proof system or semantic tableaux. Students without that much background were advised to study an introductory logic [2], [3] textbook before the start of the Summer School. Also some more knowledge, even if they were not necessary, they were useful and could help. For example, an advantage was familiarity with graph theory and algebra.

Each participant of the Summer School got lecture notes for lessons of logic. Some materials for lessons were available on the Internet. Therefore (and of course for mail checking etc.) a computer room was accessible and a personal account was found for every student.

3 Course overview

Foundations of First Order Logic

This course contained completeness theorems and model theory and proof theory topics [4], [5], [6]. The course provided an introduction to the metatheory of elementary logic. Following a refresher on the basics of notation and the use of classical logic as a representation language, it was concentrated on the twin notions of models and proof. An axiomatic system of first order logic was introduced and proved complete for the standard semantics, and then an overview of the basic concepts of proof theory and of formal set theory was given. The material in this course was presupposed by other courses in the Summer School, which is why it was presented first.
Lecturers of this course were Dr John Slaney, Convenor The Australian National University and National ICT Australia, and A/Prof. Valentin Goranko from Rand Afrikaans University. *John Slaney* [7] is the founder and convenor of the Logic Summer School. He originated in England and came to Australia in 1977. He gradually moved here, joining the Automated Reasoning Project in 1988 on a three-year contract. His research interests cover non-classical logics, automated deduction and all sorts of logic-based AI. Currently, he leads the Automated Reasoning Group at ANU and is the leader of the Logic & Computation program within in NICTA. *Valentin Goranko* [8] is an associate professor in mathematics at Rand Afrikaans University in South Africa, where he has worked since 1992. He completed his PhD and then worked at the Faculty of Mathematics and Computer Science of the University of Sofia, Bulgaria. His scientific interests include just about everything to do with logic, plus much of theoretical computer science, artificial intelligence, discrete mathematics, game theory, etc., but his active research is mainly focused on modal and temporal logics.

Introduction to Automated Reasoning

This course's topic was first order theorem proving, simple arithmetic reasoning, and satisfiability and constraints. We looked briefly at several varieties of mechanical reasoning. The first was automatic deduction, whereby conclusions are derived from assumptions purely by following an algorithm, without user intervention. We noted completeness and other results for the standard deductive procedures such as unification and resolution, and saw how they can be refined to make them more efficient. Secondly, we examined the dual problem of generating models of a given theory. This often goes under the name of constraint satisfaction. Finally, we revisited deduction, but this time in the case where a user is expected to interact with the computer.
This course was lectured by Dr Michael Norrish from National ICT Australia, Dr Toby Walsh from National ICT Australia, and Dr John Slaney, Convenor The Australian National University and National ICT Australia. *Michael Norrish* [9] is a NICTA post-doctoral research fellow. He is originally from Wellington, New Zealand. He did his PhD in Cambridge, England, and then spent three years as a research fellow at St. Catharine's College. His research interests are in interactive theorem-proving, and the application of this technology to areas of theoretical computer science, particularly the semantics of programming languages. *Toby Walsh* [10] is a Research Fellow at National ICT Australia and Professor at the Department of Computer Science and Engineering, UNSW, Sydney. He is also External Professor in the Department of Information Science at Uppsala University. Before moving to Australia, he was a Research Professor at University College Cork. He has also been an EPSRC advanced research fellow at the University of York, a Marie Curie postdoctoral fellow in Italy and France, and a postdoctoral fellow at Edinburgh University.

Introduction to Modal and Temporal Logics

Course covered the syntax, Kripke semantics, correspondence theory and tableaux-style proof theory of propositional modal and temporal logics [11]. These logics have important applications in a diverse range of fields including artificial intelligence, theoretical computer science and hybrid systems.
Course lecture was Dr Rajeev Goré from The Australian National University and National ICT Australia. *Rajeev Goré* [12] obtained his PhD from Cambridge University in 1992. He was a Research Fellow at Manchester University until 1994 when he joined the ANU's Automated Reasoning Group. From 2003 he has also been a member of the Logic and Computation Program of NICTA's Canberra Research Laboratory.

Computability and Incompleteness

This course covered computability, recursive functions, and Gödel's incompleteness theorem [13]. We looked at abstract models of computation, with a focus on what kinds of functions on the natural numbers are computable -- the primitive recursive and the recursive functions. We then used these concepts to prove Gödel's incompleteness results, providing a limit to the kinds of theories that can be completely and effectively characterized in the language of predicate logic.
Lecture was Dr Greg Restall from University of Melbourne. *Greg Restall* [14] is Associate Professor in the Department of Philosophy at the University of Melbourne. He has research interests in the proof theory and model theory of substructural logics, the philosophy of logic and the history of philosophy. He coordinates the logic group at the University of Melbourne and is currently the editor of the Australasian Journal of logic.

Formal Methods

Course contained probabilistic program logic [15], [16] and structural operational semantics topics [17]. Probabilistic program logic is a numeric logic for probabilistic programs and systems, generalizing the traditional Boolean logics for sequential programs (Hoare/Dijkstra) and for reactive systems (mu-calculus and temporal logic). Potential applications include reasoning about distributed systems (symmetry-breaking), randomized algorithms (time/space complexity improvements) and risk analysis (safety-critical systems). Structured operational semantics is a method to precisely describe the meaning of operators on labeled transition systems. These constitute a central mathematical model for the description of reactive systems. This course introduced the method, and gave special attention to the meaning of negative premises in transition system specifications, formats of structured operational rules that guarantee the compositionality of operators, and methods to derive complete axiomatizations from transition system specifications in a certain format.
Course lecturers were Professor Carroll Morgan from University of New South Wales and Dr Rob van Glabbeek from National ICT Australia. *Carroll Morgan* [18] has worked on Z, CSP, the Refinement Calculus and most recently probabilistic logic and is the author of the books "On the Refinement Calculus" (with Trevor Vickers), "Programming from Specifications" and "Abstraction, Refinement and Proof for Probabilistic Systems" (with Annabelle McIver, in press). He is currently an Australian Professorial Fellow at UNSW. *Rob van Glabbeek* [19] has 20 years of experience in investigating mathematical models and formal languages for the representation of distributed systems and the verification of statements about them. He is particularly interested in foundational questions regarding for instance the relative expressiveness of various methods.

Knowledge Representation and Reasoning

Course content was nonmonotonic reasoning, planning, reasoning about action, cognitive robotics, and epistemic logic. Knowledge representation and reasoning deal with the formal aspects of representing and modeling problem domains and then reasoning with these representations. Research in knowledge representation and reasoning is fundamental to AI and has been an active area of research since the inception of the field. In this series of lectures we looked at some of the areas of AI for which this is particularly so, namely reasoning about action, planning, cognitive robotics, nonmonotonic reasoning and belief revision, which are all of great importance to the design of intelligent agents.

It was lectured by Dr Maurice Pagnucco from University of NSW, Dr Thomas Meyer from National ICT Australia, and Professor Tony Cohn from University of Leeds. *Maurice Pagnucco* [20] is a senior lecturer in Computer Science and Engineering at the University of New South Wales. He is also a senior scientist with the Knowledge Representation and Reasoning Program in the National ICT Australia and is affiliated with the Centre for Excellence in Autonomous Systems at UNSW. His research is in logic-based artificial intelligence particularly belief change and reasoning about action. *Thomas Meyer* [21] is currently a research scientist in the Knowledge Representation and Reasoning program of National ICT Australia. His research is currently focused on the use of logic in computer science, and more specifically, in artificial intelligence. This includes belief change, belief merging, knowledge representation, nonmonotonic reasoning, logic programming, automated reasoning, model checking, and reasoning about action and knowledge. *Tony Cohn* [22] is Professor of Automated Reasoning at the University of Leeds where he leads the Knowledge Representation and Reasoning research group, which has a particular focus on qualitative spatio-temporal reasoning, and collaborates with the Computer Vision group on applying symbolic reasoning to the field of Cognitive Vision.

Non-Classical Logic

Course contained proof theory and semantics of substructural logics [23], [24]. Since important extensions of classical logic are covered by the course on modal logic, we focused on logics weaker (or at least not stronger) than classical logic. These may be identified with substructural logics, i.e., logics whose Gentzen calculi lack some (zero or more) of the three structural rules, namely: weakening, exchange or contraction. Logics that fall under this heading include Lambek calculi, relevant logics, linear logics (without exponentials) and fuzzy logics. The course was intended as an overview. We covered Gentzen systems and algebraic semantics.

Course lectures were Dr Tomasz Kowalski from The Australian National University and Professor Hiroakira Ono from Japan Advanced Institute of Science and Technology (JAIST). *Tomasz Kowalski* [25] joined the Automated Reasoning Group in April 2003. Before this he spent five years at the Japan Advanced Institute of Science and Technology in Kanazawa. Earlier he worked at the Jagiellonian University in Krakow (Poland) where he gained his PhD. His research interests concentrate on universal algebra and algebraic methods in nonclassical logics. *Hiroakiro Ono* [26] is a distinguished logician working mostly in non-classical (modal and substructural) logics. Showing a Gentzen calculus to him is believed to be one of better methods of proving (or disproving) cut elimination. Recently he has been working on algebraizing this. Hiroakira obtained his PhD from Kyoto University in 1973. From 1976 he was Professor at Hiroshima University until 1993 when he moved to Japan Advanced Institute of Science and Technology (JAIST) where he has been Professor since.

4 Evening seminars

Every day after logic lessons was held one evening seminar. They were given by the presenters on their specific research topics or related areas.

Non-clausal SAT solving

On the 6th December 2004 Professor Toby Walsh, National ICT Australia presented his work about SAT solvers. It was a joint work with Fahiem Bacchus and Christian Thiffault. State of the art SAT solvers typically solve SAT theories encoded into CNF using DPLL based algorithms. Most problems, however, are not originally expressed in CNF. The original problem must therefore be converted into CNF. However, converting to CNF loses a considerable amount of information about the problem's structure. This is information that could be used to improve the search efficiency. He discussed how a SAT solver can be implemented to reasoning efficiently with non-clausal formulae, and where computational advantages can be gained.

Models and logics for strategic abilities in multi-agent systems

Next evening presented A/Professor Valentin Goranko his joint work with Govert van Drimmelen. He considered scenarios where a set of autonomous agents takes actions, simultaneously or in turns, on a common state space, and thus collectively effect transitions between the states. In these scenarios the agents pursue their goals by adopting suitable strategies and in the pursuit of these goals can form coalitions, which are usually competing; thus, the game-theoretic aspect is common and dominant here. Furthermore, the agents have (and exchange) information about the system and about other agents' and coalitions' abilities, goals, strategies etc. and these can interact in a rather intricate ways. In his talk he discussed recently developed logical formalisms for specification and verification of such systems. In particular, he presented some recent results regarding their semantics, satisfiability and model checking, and complete axiomatizations.

The admissibility of gamma for relevant modal logics with Lemmon-Scott axioms

On the third day made his speech Professor Takahiro Seki from Kyushu University, Japan. The admissibility of Ackermann's rule gamma is one of important problems in relevant logics. The gamma-admissibility for a wider class of relevant modal logics has not been discussed fully. Lemmon-Scott axioms are known as one of generalized forms of formulas with modal operators. We discuss that gamma is admissible for relevant modal logics with Lemmon-Scott axioms in terms of the method of using metavaluation.

What is the shape of a proof?

On the 9th December 2004 Dr Greg Restall talked about proofs. Different kinds of proofs are best suited to modeling different logical systems. The idea of a proof as leading from many different premises to a single conclusion (in the shape of a tree) fits well with intuitionistic logic and related systems. It does not fit so well with classical logic - the classical rules for negation are complicated in this setting. If we allow proofs to lead from any premises to many conclusions, on the other hand, the classical rules for negation are straightforward. In his talk he talked about these results and their significance.

Definability and Arithmetic

On the seminar held on the 10th December 2004 spoke Dr Rob van Glabbeek. His speech was about definability. A set of words could be called definable if there exists a description that tells whether a given word belongs to that set or not. The class of definable sets of words would be much larger than the class of (recursive) enumerable sets of words. However, he demonstrated, better is to define definability with a particular set of tools. One such set of tools is the language of arithmetic. Arithmetic definability still yields a much larger class than (recursive) enumerability. As an exercise illustrating the power of arithmetic he showed how to define the transitive closure of binary relations arithmetically.

Towards probabilistic Communicating Sequential Processes

On the 13th December 2004, Professor Carroll Morgan presented his work about probabilistic systems [15]. A partial semantics for a probabilistic version of Hoare's Communicating Sequential processes was induced via a mapping from probabilistic (sequential) action systems constructed within the pGCL semantics. The semantics is partial in the sense that it does not contain enough information to be compositional; in spite of that, the result are of some interest, especially given the number of attempts already made to construct a successful semantics for concurrency that includes both probabilistic and demonic choice.

Modal Higher-order Logic for Agents

Next seminar was led by Professor John Lloyd from The Australian National University. His talk introduced a modal higher-order logic for representing belief states of agents. The syntax and semantics of the logic and a tableau system for proving theorems were presented and an indication given as to how the logic can be used for building multi-agent systems.

Formalizing Proof Theory in Isabella/HOL

On the 15th December 2004, Dr Rajeev Goré presented his joint work with Jeremy Dawson. He explained how the interactive theorem prove Isabelle was used to formalize a proof of cut-elimination for the display calculus of relation algebras. He explained the basics of relation algebras, display calculi and cut-elimination. Then he told how the notions of formulae, sequents, rules and derivations were embedded into Isabelle and described how Isabelle was used to reason about derivations and derivability.

From Perceptual Inputs to Logic, and Back Again

On the16th December 2004, Professor Tony Cohn presented a system built at the University of Leeds as part of an EU project on Cognitive Vision. Their goal was to build a system that could take perceptual inputs (both visual and auditory), turn them into symbols, reason about the behaviour being observed and then demonstrate the understanding by having the computer perform actions in the world. He demonstrated a system, which achieves this, in a simple game world, watching two players.

An algebraic view of cut elimination

The last evening seminar was led by Professor Hiroakira Ono. He gave a purely algebraic proof of the cut elimination theorem for various sequent systems [27]. First he introduced "Gentzen structures" for a given sequent system S without cut, and then proved the completeness of S without cut with respect to the class of algebras for S "with cut".

5 School Background

Everyone who wanted attend the Summer School had to complete the registration form and pay a registration fee. Registration could be done on the Logic Summer School website [1]. Students in full-time education were eligible for a reduced fee after faxing a copy of proof of full-time student status.

Accommodation

Summer School participants needed to book and pay for their own accommodation. However, the Summer School has reserved a limited number of rooms at Ursula Hall [28], fully catered student style accommodation. This accommodation was available to all Summer School participants (both students and scholars). The reserved rooms were held only for a limited time only, timely room bookings were needed. The Summer School has also reserve a limited number of rooms at University House [29], which offers hotel style accommodation. Ursula Hall and University House are situated on the University campus in easy walking distance of the Summer School.

Canberra

The Australian National University commands a magnificent position between lake and mountain in the centre of the nation's capital, Canberra. Canberra is the political apex of Australia, housing the Federal Parliament. It is the major city of the self-governing province, the Australian Capital Territory (ACT). It is also the cultural heart of Australia, with the Australian War Memorial, the National Gallery of Australia, the High Court of Australia and the National Museum of Australia. The University is within easy walking distance of the city center of Canberra, a short walk away from many of Canberra's attractions including Lake Burley Griffin and the Australian National Botanic Gardens.

Social program

Before the start of the school courses, a welcoming reception was organized. This was an opportunity to meet with fellow scholars and have a chat with many of the presenters. It was held on the 5th December from 7.00 pm. Unfortunately, I missed it, because my arrival was too late.
Another social event was a trip on Saturday 11th December. The Summer School's tradition is to visit the Tidbinbilla Nature Reserve and NASA's deep space tracking station. So on the Saturday we treated ourselves to an excursion out of Canberra. At first we went to the Canberra Space Centre [30] and visited an exhibition. Then we went to the Tidbinbilla Nature Reserve. During our visit to Tidbinbilla we picnicked on some delicious finger food and drinks. After it we did a tour on top of some hill, very good view-point. Tidbinbilla Nature Reserve is around a 40 minute scenic drive south of Canberra that is nestled in the surrounding mountains. It promises coming face-to-face with the natural habitat of kangaroos, wallabies, koalas and emus, which run wild. But almost two years ago, there was a very big fire, which destroyed the nature, burned trees and plants and killed many animals. Nature is still recovering, fire consequences can be seen everywhere.

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