## Lecture Notes

## NORMALIZATION, CUT-ELIMINATION AND THE THEORY OF PROOFS

A. M. Ungar



### **Normalization Cutelimination And The Theory Of Proofs**

**Helmut Alt, Afonso Ferreira** 

#### **Normalization Cutelimination And The Theory Of Proofs:**

An Introduction to Proof Theory Paolo Mancosu, Sergio Galvan, Richard Zach, 2021 Proof theory is a central area of mathematical logic of special interest to philosophy It has its roots in the foundational debate of the 1920s in particular in Hilbert's program in the philosophy of mathematics which called for a formalization of mathematics as well as for a proof using philosophically unproblematic finitary means that these systems are free from contradiction Structural proof theory investigates the structure and properties of proofs in different formal deductive systems including axiomatic derivations natural deduction and the sequent calculus Central results in structural proof theory are the normalization theorem for natural deduction proved here for both intuitionistic and classical logic and the cut elimination theorem for the sequent calculus In formal systems of number theory formulated in the sequent calculus the induction rule plays a central role It can be eliminated from proofs of sequents of a certain elementary form every proof of an atomic sequent can be transformed into a simple proof This is Hilbert's central idea for giving finitary consistency proofs. The proof requires a measure of proof complexity called an ordinal notation The branch of proof theory dealing with mathematical systems such as arithmetic thus has come to be called ordinal proof theory. The theory of ordinal notations is developed here in purely combinatorial terms and the consistency proof for arithmetic presented in detail Normalization, Cut-elimination, and the Theory of **Proofs** Anthony M. Ungar, 2000 Normalization, Cut-Elimination, and the Theory of Proofs A. M. Ungar, 1992-06-01 Gentzen's cut elimination theorem is widely used as a tool for meta mathematical investigations. It is sometimes claimed however that the theorem and its proof have interest which is independent of these applications and derives from the information they supply about the structure of proofs in general Ungar investigates this claim in the context of first order logic Ungar gives an account of Gentzen's theorem for various formalisms and discusses the difficulties involved in treating these different versions uniformly as instances of a single theorem which is not tied to a particular system of rules By extending the theorem to a natural deduction calculus whose derivations are allowed to have more than one conclusion Ungar argues that the different versions of the theorem are more or less natural specializations of a single result whose significance can be understood in terms of the proofs represented by formal derivations A concluding discussion focuses on the relationship between proofs and formal derivations and the role proofs may play as part of a general theory of evidence

Types for Proofs and Programs Thorsten Altenkirch, Conor McBride, 2007-09-13 The refereed post proceedings of the International Workshop of the Types Working Group are presented in this volume The 17 papers address all current issues in formal reasoning and computer programming based on type theory including languages and computerized tools for reasoning applications in several domains such as analysis of programming languages certified software formalization of mathematics and mathematics education 

Dag Prawitz on Proofs and Meaning Heinrich Wansing, 2014-11-27 This volume is dedicated to Prof Dag Prawitz and his outstanding contributions to philosophical and mathematical logic Prawitz s eminent

contributions to structural proof theory or general proof theory as he calls it and inference based meaning theories have been extremely influential in the development of modern proof theory and anti-realistic semantics. In particular Prawitz is the main author on natural deduction in addition to Gerhard Gentzen who defined natural deduction in his PhD thesis published in 1934 The book opens with an introductory paper that surveys Prawitz's numerous contributions to proof theory and proof theoretic semantics and puts his work into a somewhat broader perspective both historically and systematically Chapters include either in depth studies of certain aspects of Dag Prawitz's work or address open research problems that are concerned with core issues in structural proof theory and range from philosophical essays to papers of a mathematical nature Investigations into the necessity of thought and the theory of grounds and computational justifications as well as an examination of Prawitz's conception of the validity of inferences in the light of three dogmas of proof theoretic semantics are included More formal papers deal with the constructive behaviour of fragments of classical logic and fragments of the modal logic S4 among other topics In addition there are chapters about inversion principles normalization of p roofs and the notion of proof theoretic harmony and other areas of a more mathematical persuasion Dag Prawitz also writes a chapter in which he explains his current views on the epistemic dimension of proofs and addresses the question why some inferences succeed in conferring evidence on their conclusions when applied to premises for which one already possesses evidence the Curry-Howard Isomorphism Morten Heine Sørensen, Pawel Urzyczyn, 2006-07-04 The Curry Howard isomorphism states an amazing correspondence between systems of formal logic as encountered in proof theory and computational calculi as found in type theory For instance minimal propositional logic corresponds to simply typed lambda calculus first order logic corresponds to dependent types second order logic corresponds to polymorphic types sequent calculus is related to explicit substitution etc The isomorphism has many aspects even at the syntactic level formulas correspond to types proofs correspond to terms provability corresponds to inhabitation proof normalization corresponds to term reduction etc But there is more to the isomorphism than this For instance it is an old idea due to Brouwer Kolmogorov and Heyting that a constructive proof of an implication is a procedure that transformsproofs of the antecedent into proofs of the succedent the Curry Howard isomorphism gives syntactic representations of such procedures The Curry Howard isomorphism also provides theoretical foundations for many modern proof assistant systems e g Coq This book give an introduction to parts of proof theory and related aspects of type theory relevant for the Curry Howard isomorphism It can serve as an introduction to any or both of typed lambda calculus and intuitionistic logic Key features The Curry Howard Isomorphism treated as common theme Reader friendly introduction to two complementary subjects Lambda calculus and constructive logics Thorough study of the connection between calculi and logics Elaborate study of classical logics and control operators Account of dialogue games for classical and intuitionistic logic Theoretical foundations of computer assisted reasoning The Curry Howard Isomorphism treated as the common theme Reader friendly introduction to two complementary subjects lambda calculus and

constructive logics Thorough study of the connection between calculi and logics Elaborate study of classical logics and control operators Account of dialogue games for classical and intuitionistic logic Theoretical foundations of computer Normalization and Cut-elimination in First-order Logic Anthony M. Ungar, 1986 **Introduction to Intuitionistic Logic** Grigori Mints, 2005-12-20 Intuitionistic logic is presented here as part of familiar classical logic which allows mechanical extraction of programs from proofs to make the material more accessible basic techniques are presented first for propositional logic Part II contains extensions to predicate logic This material provides an introduction and a safe background for reading research literature in logic and computer science as well as advanced monographs Readers are assumed to be familiar with basic notions of first order logic One device for making this book short was inventing new proofs of several theorems. The presentation is based on natural deduction. The topics include programming interpretation of intuitionistic logic by simply typed lambda calculus Curry Howard isomorphism negative translation of classical into intuitionistic logic normalization of natural deductions applications to category theory Kripke models algebraic and topological semantics proof search methods interpolation theorem. The text developed from materal for several courses taught at Stanford University in 1992 1999 Logic, Language, Information, and Computation Leonid Libkin, Ulrich Kohlenbach, Ruy de Queiroz, 2013-08-15 Edited in collaboration with FoLLI the Association of Logic Language and Information this book constitutes the refereed proceedings of the 20th Workshop on Logic Language Information and Communication WoLLIC 2013 held in Darmstadt Germany in August 2013 The 17 contributed papers presented together with 6 invited lectures were carefully reviewed and selected from 30 submissions. The scope of the workshop spans the theoretical and practical aspects of formal logic computing and programming theory and natural language and reasoning

Advances in Natural Deduction Luiz Carlos Pereira, Edward Haeusler, Valeria de Paiva, 2014-07-08 This collection of papers celebrating the contributions of Swedish logician Dag Prawitz to Proof Theory has been assembled from those presented at the Natural Deduction conference organized in Rio de Janeiro to honour his seminal research Dag Prawitz s work forms the basis of intuitionistic type theory and his inversion principle constitutes the foundation of most modern accounts of proof theoretic semantics in Logic Linguistics and Theoretical Computer Science The range of contributions includes material on the extension of natural deduction with higher order rules as opposed to higher order connectives and a paper discussing the application of natural deduction rules to dealing with equality in predicate calculus The volume continues with a key chapter summarizing work on the extension of the Curry Howard isomorphism itself a by product of the work on natural deduction via methods of category theory that have been successfully applied to linear logic as well as many other contributions from highly regarded authorities With an illustrious group of contributors addressing a wealth of topics and applications this volume is a valuable addition to the libraries of academics in the multiple disciplines whose development has been given added scope by the methodologies supplied by natural deduction The volume is representative

of the rich and varied directions that Prawitz work has inspired in the area of natural deduction Introduction to Incompleteness Serafim Batzoglou, 2024-08-30 Incompleteness is a fascinating phenomenon at the intersection of mathematical foundations computer science and epistemology that places a limit on what is provable However despite its importance it is often overlooked in the mathematics curricula because it is difficult to teach This book aims to help bridge this pedagogical gap by providing a complete and accessible technical exposition of incompleteness for a wide audience The author accomplishes this by making conceptually difficult proofs more approachable by providing intuitive explanations of the main ideas Care is taken to emphasize the different layers of the mathematical argument the layer within and the metalayer about an axiomatic system Structurally the book efficiently examines key results and arrives at some of the most interesting concepts as quickly as possible It begins with G del s incompleteness theorems before continuing on to challenging concepts in the arithmetized completeness theorem the Paris Harrington theorem and the independence of the continuum hypothesis Other topics covered include the Lucas Penrose arguments ordinals and cardinals and axiomatic set theory Additionally the author's coverage of forcing is a notable addition to the existing literature Introduction to Incompleteness will be of interest to researchers students and instructors looking for a resource to teach this topic It may also be suitable for self study Knowledge of undergraduate level theoretical mathematics or computer science is required as Mathematical Logic and Computation Jeremy Avigad, 2022-11-24 A thorough well as a familiarity with abstract proofs introduction to the fundamental methods and results in mathematical logic and its foundational role in computer science

Handbook of Proof Theory S.R. Buss,1998-07-09 This volume contains articles covering a broad spectrum of proof theory with an emphasis on its mathematical aspects The articles should not only be interesting to specialists of proof theory but should also be accessible to a diverse audience including logicians mathematicians computer scientists and philosophers Many of the central topics of proof theory have been included in a self contained expository of articles covered in great detail and depth The chapters are arranged so that the two introductory articles come first these are then followed by articles from core classical areas of proof theory the handbook concludes with articles that deal with topics closely related to computer science Basic Proof Theory A. S. Troelstra, H. Schwichtenberg, 2000-07-27 This introduction to the basic ideas of structural proof theory contains a thorough discussion and comparison of various types of formalization of first order logic Examples are given of several areas of application namely the metamathematics of pure first order logic intuitionistic as well as classical the theory of logic programming category theory modal logic linear logic first order arithmetic and second order logic In each case the aim is to illustrate the methods in relatively simple situations and then apply them elsewhere in much more complex settings There are numerous exercises throughout the text In general the only prerequisite is a standard course in first order logic making the book ideal for graduate students and beginning researchers in mathematical logic theoretical computer science and artificial intelligence For the new edition many sections have been rewritten to improve

clarity new sections have been added on cut elimination and solutions to selected exercises have been included **Proof Theory and Automated Deduction** Jean Goubault-Larrecq,I. Mackie,2001-11-30 Interest in computer applications has led to a new attitude to applied logic in which researchers tailor a logic in the same way they define a computer language In response to this attitude this text for undergraduate and graduate students discusses major algorithmic methodologies and tableaux and resolution methods The authors focus on first order logic the use of proof theory and the computer application of automated searches for proofs of mathematical propositions Annotation copyrighted by Book News Inc Portland OR

Logic and Scientific Methods Maria Luisa Dalla Chiara, Kees Doets, Daniele Mundici, Johan van Benthem, 2013-06-29 This is the first of two volumes comprising the papers submitted for publication by the invited participants to the Tenth International Congress of Logic Methodology and Philosophy of Science held in Florence August 1995 The Congress was held under the auspices of the International Union of History and Philosophy of Science Division of Logic Methodology and Philosophy of Science The invited lectures published in the two volumes demonstrate much of what goes on in the fields of the Congress and give the state of the art of current research The two volumes cover the traditional subdisciplines of mathematical logic and philosophical logic as well as their interfaces with computer science linguistics and philosophy Philosophy of science is broadly represented too including general issues of natural sciences social sciences and humanities The papers in Volume One are concerned with logic mathematical logic the philosophy of logic and mathematics and Proof and System-Reliability Helmut Schwichtenberg, Ralf Steinbrüggen, 2012-12-06 As society comes computer science to rely increasingly on software for its welfare and prosperity there is an urgent need to create systems in which it can trust Experience has shown that confidence can only come from a more profound understanding of the issues which in turn can come only if it is based on logically sound foundations This volume contains contributions from leading researchers in the critical disciplines of computing and information science mathematics logic and complexity All contributions are self contained aiming at comprehensibility as well as comprehensiveness The volume also contains introductory hints to technical issues concise surveys introductions and various fresh results and new perspectives STACS 2002 Helmut Alt, Afonso Ferreira, 2003-08-03 This book constitutes the refereed proceedings of the 19th Annual Symposium on Theoretical Aspects of Computer Science STACS 2002 held in Antibes Juan les Pins France in March 2002 The 50 revised full papers presented together with three invited papers were carefully reviewed and selected from a total of 209 submissions The book offers topical sections on algorithms current challenges computational and structural complexity automata and formal languages and logic in computer science Computer Science Logic Michael Kaminski, Simone Martini, 2008-09-10 This book constitutes the refereed proceedings of the 22nd International Workshop on Computer Science Logic CSL 2008 held as the 17th Annual Conference of the EACSL in Bertinoro Italy in September 2008 The 31 revised full papers presented together with 4 invited lectures were carefully reviewed and selected from 102 submissions All current aspects of logic in computer

science are addressed ranging from foundational and methodological issues to application issues of practical relevance The book concludes with a presentation of this year's Ackermann award **Extensions of Logic Programming** Evelina Lamma, Paola Mello, 1993-02-12 This book contains papers which investigate how to extend logic programming toward the artificial intelligence and software engineering areas covering both theoretical and practical aspects Some papers investigate topics such as abductive reasoning and negation Some works discuss how to enhance the expressive power of logic programming by introducing constraints sets and integration with functional programming Other papers deal with the structuring of knowledge into modules taxonomies and objects withthe aim of extending logic programming toward software engineering applications A section is devoted to papers concentrating on proof theory and inspired by Gentzen style sequent or natural deduction systems Topics such as concurrency are considered to enhance the expressive power of logic languages Finally some papers mainly concernimplementation techniques for some of these logic programming extensions

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