Mihaiela-Ana Lupea

Andreea-Diana Mihiș

CLASSICAL LOGICS IN COMPUTER SCIENCE

reasoning

inference rule

deduction

algorithm

tautology

proof

Presa Universitară Clujeană

MIHAIELA-ANA LUPEA
ANDREEA-DIANA MIHIȘ

CLASSICAL LOGICS IN COMPUTER SCIENCE

PRESA UNIVERSITARĂ CLUJEANĂ
2014

Referenţi ştiinţifici:

Prof. univ. dr. Doina Tătar

Prof. univ. dr. Gabriela Czibula

ISBN 978-973-595-758-2

Universitatea Babeş-Bolyai
Presa Universitară Clujeană
Director: Codruţa Săcelean
Str. Hasdeu, nr. 51
400371 Cluj-Napoca, România
Tel./fax: (+40)-264-597.401
E-mail: editura@editura.ubbcluj.ro
http://www.editura.ubbcluj.ro/

PREFACE

The purpose of this book is to present fundamental concepts and results of classical logics in a formal style and in an explicitly computational way. Applications to automated theorem proving in propositional logic and first-order logic are discussed. The studied proof methods are: the resolution method, the semantic tableaux method and the sequent calculus.

The paper combines the theoretical presentation of classical logics with numerous examples explained and a rich base of proposed exercises.

Chapter 1 is dedicated to *propositional logic*.The semantic issues discussed are: truth tables, validity, consistency, inconsistency, logical equivalence, logical consequence, normal forms. From a syntactic perspective, propositional logic is introduced as an axiomatic (deductive) system, with the purpose of reasoning modeling.

First-order (*predicate*) *logic* is the topic of **chapter 2** of the paper. A Hilbert axiomatic system is used to present predicate calculus in a syntactic approach. The semantics of predicate logic is introduced in order to provide a meaning in terms of the modeled universe for each formula from the language. Normal forms, substitutions and unifiers used in predicative resolution are also discussed.

Chapter 3 treats the *semantic tableaux method*, a refutation proof method. The classic approach through graphical representation using a binary tree is very suggestive. The formulas are decomposed in order to determine their models.

Chapter 4 presents *the sequent calculus*, an improvement of the natural deduction system. As a syntactic and direct proof method, it is used to check the validity/derivability and non-validity/non-derivability in propositional logic and first-order logic.

The topic of **chapter 5** is *resolution*, a syntactic and refutation proof method, very efficient and easily to implement. Resolution is introduced as an axiomatic (formal) system and as a procedure. In order to increase the efficiency of the resolution process, the strategies (deletion, set-of-support, unit preference, level saturation, linear) and the refinements (lock, linear) of resolution are studied.

By its content, this book is usefull to all those interested in classical logics, fundamental in computer science. Professionals in computer science are offered a theoretical basis in the applicative direction of building automated proof systems used in mathematics, software engineering, intelligent agents, robotics, natural language, artificial vision.

We wish to acknowledge our deep appreciation to Prof. Dr. Doina Tătar for many valuable scientific discussions and guidance during all the years of study and research in the field of classical logics. Special thanks for all her constructive comments made during the preparation of this paper.

Cluj-Napoca
2014

Mihaiela-Ana Lupea
Andreea-Diana Mihiş

CONTENTS

INDEX

Index

BIBLIOGRAPHY

1. **Ben-Ari, M.,** *Mathematical Logic for Computer Science*, Springer, 2001.
2. **Benzaken, C.,** *Systemes Formels. Introduction a la Logique*, Masson, 1991.
3. **Bibel, W.,** *Automated Theorem Proving*, View Verlag, Braunschweig, second edition, 1987.
4. **Boian, F. M.,** *De la aritmetică la calculatoare*, Presa Universitară Clujeană, 1996.
5. **Bonatti, P., Olivetti, N.,** *Sequent Calculi for Propositional Nonmonotonic Logics*, ACM Trans. Comput. Log., 2002, pag. 226-278.
6. **Boole, G.,** 1847, *The Mathematical Analysis of Logic. Being an Essay Towards a Calculus of Deductive Reasoning*, Cambridge: Macmillan, Barclay, 1847.
7. **Boole, G.,** 1854, *An Investigation of the Laws of Thought, on which are Founded the Mathematical Theories of Logic and Probabilities*, London: Walton & Maberly, 1854.
8. **Both, N.,** *Algebra logicii cu aplicaţii*, Editura Dacia, Cluj-Napoca, 1984.
9. **Both, N.,** *Capitole Speciale de Logică Matematică*, Universitatea Babeş-Bolyai, Cluj-Napoca, 1994.
10. **Boyer, R.S.,** *Locking: A Restriction of Resolution*, Ph.D. Thesis,University of Texas at Austin, Texas, 1971.
11. **Chang, C.L.,** *The unit proof and the input proof in theorem proving*, Journal Assoc. Comput. Mach. 17, 1970, pp.698-707.
12. **Chang, C.L, Lee, R.C.,** *Symbolic Logic and Mechanical Theorem Proving*, Academic Press, 1973.
13. **Church, A.,** *An unsolvable problem of number theory*, American Journal of Mathematics, 58, pag.345-363, 1936.
14. **Cocan, M., Pop, B.,** *Bazele Matematice ale Sistemelor de Calcul*, Editura Albastră, Cluj-Napoca, 2001.
15. **Davis, M., Putnam, H.,** *A computing procedure for quantification theory*, Journal Assoc. Comput. Mach., 7, 1960, pp. 201-215.
16. **Delahaye, J.P.,** *Outils Logiques pour l'Intelligence Artificielle*, Eyrolls, 1986.
17. **Dreben, B., Goldfarb, W.,** *The Decision Problem: Solvable Classes of Quantificational Formulas*, Addison-Wesley, 1979.
18. **Duffy, D.A.,** *Principles of Automated Theorem Proving*, John Wiley & Sons, 1991.
19. **Dumitrescu, D.,** *Principiile Inteligenţei Artificiale*, Editura Albastră, Cluj-Napoca, 2002.

20. **Fitting, M.,** *First-order logic and Automated Theorem Proving*, Springer Verlag, 1990.
21. **Floarea, A., Boangiu, A.,** *Inteligenţa Artificială*, Universitatea Tehnică Bucureşti, 1994
22. **Gentzen, G.K.E,** *Untersuchungen über das logische Schließen. I*, Mathematische Zeitschrift 39 (2),1934, pp. 176–210.
23. **Genesereth, M.R., Nilsson, N.J.,** *Logical Foundations of Artificial Intelligence*, Morgan Kaufman, 1992.
24. **Hilbert, D., Ackermann, W.,** *Principles of Mathematical Logic*, Chelsea, New York, 1950.
25. **Hsu, J. Z.,** *Computer logic. Design Principles and Applications*, Springer-Verlag, New York, 2002.
26. **Kleene, S.C.,** Mathematical Logic, Wiley, New York, 1967.
27. **Lenzen, W.,** *Leibniz's Logic, in Handbook of the History of Logic*, D. M. Gabbay/J. Woods (eds.), volume 3: The Rise of Modern Logic: From Leibniz to Frege, Amsterdam et al.: Elsevier-North-Holland, pp. 1–83, 2004.
28. **Livovschi, L.,** *Circuite cu contacte de relee*, Editura Academiei Republicii Socialiste România, 1968.
29. **Littlewood, J.E.,** *Varietăţi matematice*, Bucureşti, 1969.
30. **Loveland, D.W.,** *A linear format for resolution*, Proceedings IRIA Symp. Automatic Demonstration, Versailles, France, 1968, Springer-Verlag, New York, 1970, pp. 147-162.
31. **Loveland, D.W.,** *Automated Theorem Proving: A Logical Basis*, North Holland, Amsterdam, 1978.
32. **Luckham, D.,** *Refinements in resolution theory*, Proceedings IRIA Symp. Automatic Demonstration, Versailles, France, 1968, Springer-Verlag, New York, 1970, pp. 147-162.
33. **Lupea, M.,** *Lock resolution - a refinement of resolution*, Seminar on Computer Science, Editura Universitatii Babes-Bolyai, Cluj-Napoca, 1994, pp. 57-64.
34. **Lupea, M.,** *Semantic tableaux to compute extensions for different versions of default logic*, Research Seminar on Computer Science, Editura Universitatii Babes-Bolyai, Cluj-Napoca, 2000, pp. 31-48.
35. **Lupea, M.,** *Raţionament nemonoton prin logici implicite*, Ph.D Thesis, Babeş-Bolyai University, Cluj-Napoca, 2002.
36. **Lupea, M.,** *Axiomatization of credulous reasoning in rational default logic*, Studia Universitas Babeş-Bolyai, Informatica, LII(1), pag:101-111, 2007.
37. **Lupea, M., Mihiş, A.,** *Logici clasice şi circuite logice. Teorie şi exemple*, Editura Albastra, Cluj-Napoca, first edition (2008), second edition (2009), third edition (2011).
38. **Maliţa, M., Mircea M.,** *Bazele Inteligenţei Artificiale*, Vol.I, Logici propozitionale, Editura Tehnică, Bucureşti, 1987.

39. **Mihiş, A.D., Chisăliţă-Creţu C., Mihăilă C., Şerban C.,** *BOOFS - a tool that supports simplifying conditional expressions using boolean functions simplification methods*, Proceedings of International Conference of Mathematics & Informatics, ICMI45, Bacău, Septembrie 18-20, 2006, Studii şi cercetări ştiinţifice, nr.16 – 2006 Supplement, Universitatea din Bacău, Facultatea de Stiinţe, Seria Matematica, ISN 1224-2519.
40. **Moşcenski, V.A.,** *Lecţii po matematiceskoi logike*, Minsk, 1973.
41. **Nasin, P.,** *Circuite logice şi automatizări secvenţiale*, Editura Tehnică, Bucureşti 1967.
42. **Nilsson, N.J.,** *Principles of Artificial Intelligence*, Tioga, Palo Alto, Morgan Kaufmann, 1980.
43. **Paulson, L.C.,** *Logic and Proof*, Cambridge University, 2000, www.cl.cam.ac.uk/teaching/2000/LogicProof/notes.pdf.
44. **Popa, C.,** *Logica predicatelor*, Editura Hyperion, Bucureşti, 1992.
45. **Possega, M.,** *Deduction Systems*, Institute of Informatics, 2002, on-line course.
46. **Rădulescu, V.,** *Revanşa minţii*, Editura Militară, Bucureşti, 1974.
47. **Reeves S., Clarke, M.,** *Logic for Computer Science*, Eddison-Wesley, 1990.
48. **Rich, E.,** *Artificial Inteligence*, Mac Graw-Hill, NewYork, 1983.
49. **Risch, V., Schwind, C.B.,** *Tableau-Based Characterization and Theorem Proving for Default Logic*, Journal of Automated Reasoning, Vol 13, Nr. 2, 1994, pag. 223-242.
50. **Robinson, J.A.,** *A machine oriented logic based on resolution principle*, Journal Assoc. Comput. Mach, 12, 1965, pp. 23-41.
51. **Robinson, J.A.,** *Automatic deduction with hyper-resolution*, International Journal Computation Math, 1, 1965, pp. 227-234.
52. **Robinson, J.A.,** *Logic, Form and Function. The Mechanization of Deductive Reasoning*, University Press, Edinburg, 1979.
53. **Roul de Palma,** *Algebra binară a lui Boole şi aplicaţiile ei în informatică*, Editura Tehnică, Bucureşti, 1976.
54. **Russel, S., Norwig, P.,** *Artificial Intelligence*, Prentice Hall, 1995.
55. **Rusu, E.,** *Cum gândim şi rezolvăm 200 de probleme*, Editura Albastros, Bucureşti, 1972.
56. **Schwind, C.B.,** *A tableaux-based theorem prover for a decidable subset of default logic*. 10-th International Conference on Automated Deduction. Lecture Notes in A.I. 449, 1990.
57. **Slagle, J.R.,** *Automatic theorem proving with renamable and semantic resolution*, Journal Assoc. Comput. Mach, 12, 1965, pp. 536-541.
58. **Smullyan, R.M.,** *First-Order Logic*, Springer Verlag, Berlin, 1968. Revised Edition, Dover Press, New York, 1996.
59. **State, L.,** *Elemente de Logică Matematică şi Demonstrarea Automată a Teoremelor*, Universitatea Bucureşti, 1989.

60. **Tarski, A.,** *Introduction to Logic*, Oxford University Press, 1976.
61. **Thayse, A.,** editor: *From Standard Logic to Logic Programming*, John Wiley & Sons, vol1 (1989), vol2 (1989), vol3 (1990).
62. **Tătar, D.,** *Bazele Matematice ale Calculatoarelor*, Lito, Babeş-Bolyai University, Cluj-Napoca, 1999.
63. **Tătar, D.,** Inteligenţa Artificială: Demonstrare Automată de Teoreme şi NLP, Editura Microinformatica, Cluj-Napoca, 2001.
64. **Tîrnoveanu, M.,** *Elemente de logică matematică, vol.1, Logica propoziţiilor bivalente*, Editura didactică şi pedagogică, Bucureşti, 1964.
65. **Wos, L., Robinson J.A., Carson, D.F.,** *Efficiency and completeness of the set of support strategy in theorem proving*, Journal Assoc. Comput. Mach, 12, 1965, pp. 536-541.

modus ponens

axiom

disjunction

syllogism

theorem

proof

modus tollens

ISBN: 978-973-595-758-2