Curriculum Vitae

Prof. Antonino Salibra

March 30, 2017

DAIS, Università Ca' Foscari Venezia
Via Torino 155, 30172 Venezia, Italia
email: salibra@dsi.unive.it
http://www.dsi.unive.it/∼salibra

- *Academic Positions:*
  1. Full Professor of Computer Science (09/2002–to date, Università Ca' Foscari Venezia);
  2. Associate Professor of Computer Science (11/1993–08/2002, Università Ca' Foscari Venezia; 11/1992–10/1993, Università di Bari);
  3. Research Associate (10/1984–10/1992, Università di Pisa);
- *Main Responsibility Positions:*
  1. Head of PhD studies in Computer Science (06/2009 – 12/2012)
  2. Member of the Academic Senate (11/2003–10/2006).
- *Highlight 2013:*
  1. A scientific meeting in honor of Antonino Salibra, Paris, July 1-2 , 2013.
     Invited speakers:
     - Pierre-Louis Curien (CNRS and Paris 7)
     - Fer-Jan de Vries (University of Leicester)
     - Mariangiola Dezani (Università di Torino)
     - Mai Gehrke (CNRS and Paris 7)
     - Stefano Guerrini (Paris 13)
     - Martin Hyland (University of Cambridge)
     - Benedetto Intrigila (Università Roma 2)
     - Jean-Louis Krivine (Paris 7)
     - Antonio Ledda (Università di Cagliari)
     - Jean-Jacques Levy (INRIA)
     - Michele Pagani (Paris 13)
     - Francesco Paoli (Università di Cagliari)
     - Pawel Urzyczyn (University of Warsaw).

- *2011/16:*

    1. Invited talk, Université d'Aix-Marseille, 2016
    2. Invited talk, Université Paris 13, 2015
    3. Invited talk, Summer of Logic, Università di Cagliari, 2015
    4. Invited talk, at Monthly "CHoCoLa" meetings, ENS de Lyon, 2015
    5. L'anima del Gattopardo (L'âme du ghepard), film director Annarita Zambrano, Taormina Film Fest 2014
    6. A. Bucciarelli, T. Ehrhard, P.A. Melliès and A. Salibra (Guest Editors), Logical Methods in Computer Science, Special Issue on: "Scientific meeting in honor of Pierre-Louis Curien", Venice, September 2013 (to appear)
    7. Program Committee 15th Italian Conference on Theoretical Computer Science, Perugia, Italy, September 17-19th, 2014.
    8. Five Invited Talks at Computer Science Department, University of Leicester, January 26-31, 2014.
    9. Invited Speaker, Dagstuhl Seminar "Duality in Computer Science" organized by M. Gehrke, J.E. Pin, V. Selivanov, D. Spreen, Schloss Dagstuhl - Leibniz Center for Informatics, Germany, July 28-August 02, 2013
    10. Invited talk at Monthly "CHoCoLa" meetings: Curry-Howard: Logic and Computation, ENS de Lyon, February 14, 2013.
    11. Invited Speaker, 37th International Symposium on Mathematical Foundations of Computer Science (MFCS 2012), August 27–31, 2012, Bratislava, Slovakia.
    12. Mars-Avril 2012. Laboratoire PPS, Université Paris 7-Denis Diderot. Groupe de travail en "Algebras and lambda-theories", une série d'exposés d'Antonino Salibra
    13. Computability Theory, Summer School AILA (Associazione Italiana di Logica e sue Applicazioni), August 2011.

- *Sabbatical leaves:*

    1. 2016: Invited Professor, Université Paris 7 (one month)
    2. 2015: Invited Professor, Université Paris 13, Laboratoire LIPN (one month).
    3. 2014: Institute Henri Poincaré, Paris, April 22-July 11 (Trimester: Semantics of proofs and certified mathematics)
    4. 2013: Invited Professor, CNRS et Paris 7 (three months).
    5. 2012: Invited Professor, Fondation de Mathematique de Paris (two months).
    6. 2002, 2005, 2007, 2008, 2009, 2011: Invited Professor, Equipe PPS, Université Paris 7-Denis Diderot (one month, each time);
    7. 2007: Chargé de Recherche, LIX, École Polytechnique, Palaiseau (two months);
    8. 2003: Invited Professor, Hungarian Academy of Sciences, Budapest (one month);
    9. 1996-1997: Invited Professor, Mathematics Department, Victoria University of Wellington (three months);
    10. 1992: Invited Professor, Mathematics Department, Iowa State University (two months).

- *Qualifications:* Qualification aux fonctions de Professeur des Universités, Section: 27-Informatique (France), until 2017.

- *Research area:* Logic, Theoretical Computer Science and Universal Algebra. The main research subjects include Lambda Calculus; Abstract Algebras; Linear Logic; Equational Logic; Variable Binding; Abstract Model Theory and Algebraic Logic; Abstract Data Types.
- *PhD Students*: Stefania Lusin, PhD thesis, 2002. Giulio Manzonetto, PhD thesis, February 2008. Alberto Carraro, PhD thesis, Mars 2011. Giordano Favro, mars 2016.
- *Awards*:
  1. Giulio Manzonetto, Best PhD thesis of Fondation d'entreprise EADS, France, Supervisors: Chantal Berline (CNRS et Paris 7) and Antonino Salibra (Ca'Foscari).
  2. Alberto Carraro, Award Research Ca'Foscari 2012, PhD Supervisors: Antonio Bucciarelli (Paris 7) and Antonino Salibra (Ca'Foscari).
- *Teaching activity* was for the Undergraduate Courses on Computer Science Curriculum.
- *PhD Schools*:
  – Lessons at Scuola di Dottorato in Filosofia ed Epistemologia, Università di Cagliari, March 2017, February 2016, October 2014, October 2013, January 2013
  – Algebraic and topological methods in lambda calculus, Hungarian Academic of Sciences, Budapest, 2003
  – Lambda calculus, Università Ca'Foscari Venezia, 2002
  – Algebraic Semantics, Università di Bologna, 1995
- *Program committee member*:
  – 15th Italian Conference on Theoretical Computer Science, Perugia, Italy, 2014.
  – CSL'08, Computer Science Logic, Bologna, Italy, 2008.
- *Recent Research Projects*:
  – Project PRIN 2010, (2012-2014). head project DI NOLA Antonio code 2010FP79LR.
  – Control and certification of the resources, 2007-2009 (MURST; head project Simona Ronchi della Rocca, Università di Torino)
- *Recent Invited Lectures*:

  [S-6] 2015: Monthly "CHoCoLa" meetings, ENS de Lyon, May 21.

  [S-5] 2013: Invited talk at Dagstuhl Seminar "Duality in Computer Science", Germany, July 28-August 02.

  [S-4] 2013: Monthly "CHoCoLa" meetings, ENS de Lyon, February 14.

  [S-3] 2012: MFCS 2012, 37th International Symposium on Mathematical Foundations of Computer Science, August 27–31, Bratislava, Slovakia.

  [S-2] 2010: AsubL4, Algebra and Substructural Logics - take four, Ishikawa Hightech Center at Jaist. 8-10 June, Kanazawa, Japon.

  [S-1] 2009: Conference in honor of Chantal Berline, PPS et CNRS, 4-5 June, Paris, France
- Recent Invited Seminars

  [I-11] January 2014, University of Leicester

  [I-10] May 2013. Paris 13, Laboratoire LIPN.

[I-9] January 2013: Università di Cagliari.

[I-8] March-April 2012. Laboratoire PPS, Université Paris 7-Denis Diderot. Groupe de travail en Algébre et lambda-théories, une série d'exposés d'Antonino Salibra

[I-7] Laboratoire PPS, Université Paris 7-Denis Diderot, Paris (April 2010, March 2007, May 2006, June 2005 (Atelier GEOCAL), June 2004, May 2004, June 2003, May 2002).

[I-6] March 2008: Joint Queen Mary/Imperial Seminar, Queen Mary College and Imperial College, London

[I-5] February 2008: Laboratoire LIPN, Université Paris 13, Villetaneuse, France

[I-4] November 2007: LIX, Ecole Polytechnique, Palaiseau, France

1 Publications

Preprints

[1] A. Carraro, T. Ehrhard, A. Salibra. The stack calculus: equalities induced by the decomposition of Classical Logic into Linear Logic. Preprint, September 2014

[2] A. Bucciarelli, A. Ledda, F. Paoli, A. Salibra. A generalization of Boolean algebras and classical logic Submitted 2017

Editor

[3] A. Bucciarelli, T. Ehrhard, P.A. Melliès, A. Salibra (Guest Editors). Logical Methods in Computer Science, Special Issue on: "Scientific meeting in honor of Pierre-Louis Curien", Venice, September 2013; http://www.pps.univ-paris-diderot.fr/PLC-meeting (to appear)

LICS

[4] A. Salibra, G. Manzonetto, G. Favro. Factor Varieties and Symbolic Computation. Proceedings of the 31st Annual ACM-IEEE Symposium on Logic in Computer Science (LICS 2016), July 5-8, New York City, USA, pp. 739–748, 2016.

[5] A. Carraro, A. Salibra. Reflexive domains are not complete for the extensional lambda-calculus. Proceedings of the 24th Annual IEEE Symposium on Logic in Computer Science (LICS 2009), August 11-14, Los Angeles, USA, pp. 91–100, 2009.

[6] G. Manzonetto, A. Salibra. Boolean algebras for lambda calculus. Proceedings of the 21st Annual IEEE Symposium on Logic in Computer Science (LICS 2006), August 12-15, Seattle, USA, pp. 317–326, 2006.

[7] A. Bucciarelli, A. Salibra. The sensible graph theories of lambda calculus. Proceedings of 19th Annual IEEE Symposium on Logic in Computer Science (LICS 2004), July 13-18, Turku, Finland, pp. 276–285, 2004.

[8] A. Salibra. A continuum of theories of lambda calculus without semantics. Proceedings of 16th Annual IEEE Symposium on Logic in Computer Science (LICS 2001), June 16-19, Boston, USA, pp. 334–343, 2001.

Journals

[9] A. Salibra, A. Ledda, F. Paoli. Factor Varieties. *Soft Computing*, Vol. 21(6), pp 1443–1454, 2017.

[10] A. Bucciarelli, A. Carraro, G. Favro, A. Salibra. Graph easy sets of mute lambda terms. *Theoretical Computer Science*, vol. 629, pp. 51–63, 2016.

[11] K. Cvetko-Vah, A. Salibra. The connection of skew Boolean algebras and discriminator varieties to Church algebras *Algebra Universalis*, Vol. 73(3), pp. 369–390, 2015.

[12] A. Ledda, F. Paoli, A. Salibra. On Semi-Boolean-Like Algebras. *Acta Univ. Palacki. Olomuc., Fac. rer. nat., Mathematica* Vol. 52(1), pp. 101–120, 2013.

[13] A. Salibra, A. Ledda, F. Paoli and T. Kowalski. Boolean-like algebras. *Algebra Universalis*, Vol. 69(2), pp. 113–138, 2013.

[14] A. Carraro, A. Salibra. Ordered Models of the lambda calculus. *Logical Methods in Computer Science*, Vol. 9(4:21), pp. 1–29, 2013

[15] A. Carraro, A. Salibra. Easy lambda-terms are not always simple. *RAIRO - Theoretical Informatics and Applications* Vol. 46(2), pp. 291–314, 2012.

[16] G. Manzonetto, A. Salibra. Applying Universal Algebra to Lambda Calculus, *Journal of Logic and Computation* Vol. 20, pp. 877–915, 2010.

[17] C. Berline, G. Manzonetto and A. Salibra. Effective Lambda Models Versus Recursively Enumerable Lambda Theories. *Mathematical Structures in Computer Science* Vol. 19, pp. 897–942, 2009.

[18] A. Bucciarelli, A. Salibra. Graph lambda theories. *Mathematical Structures in Computer Science*, Vol. 18(5), pp. 975–1004, 2008.

[19] C. Berline, A. Salibra. Easiness in graph models. *Theoretical Computer Science* Vol. 354(1), pp. 4–23, 2006.

[20] S. Lusin, A. Salibra. The lattice of lambda theories. *Journal of Logic and Computation*, Vol. 14(3), pp. 373–394, 2004.

[21] A. Salibra. Topological incompleteness and order incompleteness of the lambda calculus. *ACM Transactions on Computational Logic* Vol. 4, pp. 379–401, 2003.

[22] S. Lusin, A. Salibra. A note on absolutely unorderable combinatory algebras. *Journal of Logic and Computation*, Vol. 13(4), pp. 481–582, 2003.

[23] A. Salibra. Nonmodularity results for lambda calculus. *Fundamenta Informaticae*, Vol. 45, pp. 379–392, 2001.

[24] A. Salibra. On the algebraic models of lambda calculus. *Theoretical Computer Science*, Vol. 249, pp. 197–240, 2000.

[25] A. Salibra, R. Goldblatt. A finite equational axiomatization of the functional algebras for the lambda calculus. *Information and Computation* Vol. 148, pp. 71–130, 1999.

[26] D. Pigozzi, A. Salibra. Lambda abstraction algebras: coordinatizing models of lambda calculus. *Fundamenta Informaticae* Vol. 33, pp. 149–200, 1998.

[27] D. Pigozzi, A. Salibra. The abstract variable-binding calculus. *Studia Logica*, vol. 55, n. 1 (1995), pp. 129–179.

[28] D. Pigozzi, A. Salibra. Lambda abstraction algebras: representation theorems. *Theoretical Computer Science*, Vol. 140, pp. 5–52, 1995.

[29] D. Pigozzi, A. Salibra. Introduction to lambda abstraction algebras. Proc. IX Latin American Symposium on Mathematical Logic, *Notas de Logica Matematica* Vol. 38, pp. 93–112, 1993.

[30] A. Salibra, G. Scollo. A reduction scheme by pre-institution transformations" (abstract), *Journal of Symbolic Logic* vol. 58, pp. 1130–1131, 1993.

[31] V. Manca, A. Salibra. Soundness and Completeness of the Birkhoff Equational Calculus for Many-sorted Algebras with Possibly Empty Carrier Sets. *Theoretical Computer Science* vol. 94, pp. 101–124, 1992.

[32] V. Manca, A. Salibra, G. Scollo. Introducing equational type logic (abstract), *Journal of Symbolic Logic* vol. 56, p. 1132, 1991.

[33] V. Manca, A. Salibra, G. Scollo. Equational Type Logic. *Theoretical Computer Science* vol. 77, pp. 131–159, 1990.

[34] V. Manca, A. Salibra. First-order Theories as Many-sorted Algebras. *Notre Dame Journal of Formal Logic* vol. 25 (1984), pp. 86–94.

Conferences and Chapters in Books

[35] A. Salibra, A. Ledda, F. Paoli. Boolean Product Representations of Algebras via Binary Polynomials. In "Don Pigozzi on Abstract Algebraic Logic and Universal Algebra" in the Springer series "Outstanding Contributions to Logic", 2016, forthcoming.

[36] A. Bucciarelli, A. Carraro, G. Favro, A. Salibra. A graph easy set of mute lambda terms. Proceedings ICTCS 2014, CEUR Workshop Proccedings, Vol. 1231, pp. 59–71, 2014.

[37] A. Ledda, T. Kowalski, F. Paoli, A. Salibra. Boolean-like algebras. N. Galatos, A. Kurz, C. Tsinakis (eds.), Proceedings TACL 2013, EPiC Series, Easychair Publisher, issn = 2040-557X, vol. 123, pp. 140–143, 2013.

[38] A. Salibra. Visser topology and other topologies from lambda calculus. Abstract in Proc. Workshop "Duality in Computer Science" (Dagstuhl Seminar 13311), M. Gehrke, J.E. Pin, V. Selivanov and D. Spreen (eds.), Dagstuhl Reports, vol. 3(7), p. 69, 2013.

[39] A. Bucciarelli, A. Carraro, A. Salibra. Minimal lambda theories by ultraproducts. In Delia Kesner and Petrucio Viana: Proc. LSFA'12, EPTCS vol. 113, pp. 61–76, 2012.

[40] A. Carraro, T. Ehrhard, A. Salibra. The stack calculus. In Delia Kesner and Petrucio Viana: Proc. LSFA'12, EPTCS vol. 113, pp. 93–108, 2012.

[41] A. Carraro, A. Salibra. On the equational consistency of order-theoretic models of the lambda calculus. CSL'12 P. Cégielski and A. Durand (Eds.), LIPICS Vol. 16, pp. 152–166, 2012.

[42] A. Salibra. Scott is always simple (Invited Lecture). Proc. MFCS'12. LNCS 7464, Springer-Verlag, pp. 31–45, 2012.

[43] A. Carraro, T. Ehrhard, A. Salibra. Resource Combinatory Algebras. MFCS'10, LNCS 6281, Springer, pp. 233–245, 2010.

[44] A. Carraro, T. Ehrhard, A. Salibra. Exponentials with infinite multiplicities. CSL'10, LNCS 6247, pp. 170–184, 2010.

[45] A. Bucciarelli, A. Carraro, T. Ehrhard, A. Salibra. On Linear Information Systems. *First International Workshop on Linearity* (Linearity'09), EPTCS vol. 22, 2010, pp. 38–48.

[46] G. Manzonetto, A. Salibra. Lattices of equational theories as Church algebras. Proc. Seventh Panhellenic Logic Symposium, July 15-19, 2009, Patras, Greece. Patras University Press, pp. 117–121, 2009.

[47] G. Manzonetto, A. Salibra. From Lambda Calculus to Universal Algebra and Back, Proc. MFCS'08. LNCS 5162, Springer-Verlag, Berlin, pp. 479–490, 2008.

[48] C. Berline, G. Manzonetto, A. Salibra. Lambda theories of effective lambda models, CSL'07, LNCS 4646, Springer-Verlag, pp. 268–282, 2007.

[49] A. Bucciarelli, A. Salibra. The minimal graph model of lambda calculus. Proc. MFCS'03, LNCS 2747, Springer-Verlag, pp. 300–307, 2003.

[50] A. Salibra. Lambda calculus: models and theories (Invited Lecture). Proc. Third AMAST Workshop on Algebraic Methods in Language Processing (AMiLP-2003), TWLT Proceedings Series n.21, University of Twente, pp. 39–54, 2003.

[51] A. Salibra. Towards lambda calculus order-incompleteness. Workshop on Böhm theorem: applications to Computer Science Theory, ENTCS Vol. 50(2), Elsevier, pp. 147–160, 2001.

[52] A. Salibra. The variety of lambda abstraction algebras does not admit n-permutable congruences for all n. Proc. 4th International Seminar RelMiCS, Ewa Orlowska and Andrzej Szalas eds., Warsaw, Poland, September 14-20, pp. 182–187, 1998.

[53] A. Salibra. On categorical frames, universal algebra and Boolean algebras with operators in a category (Invited Lecture). Proc. Workshop on Abstract Algebraic Logic, (J. Font, R. Jansana, D. Pigozzi eds.), CRM Quaderns num. 10/ gener, pp. 176–185, 1998.

[54] A. Salibra, G. Scollo. Interpolation and Compactness in categories of pre-institutions. *Mathematical Structures in Computer Science* vol. 6, pp. 261–286, 1996.

[55] D. Pigozzi, A. Salibra. Dimension-complemented lambda abstraction algebras. Proc. 3rd International Conference on Algebraic Methodology and Software Technology, (AMAST'93), Workshops in Computing, Springer, pp. 131–138, 1994.

[56] D. Pigozzi, A. Salibra. A representation theorem for lambda abstraction algebras. MFCS'93, LNCS vol. 711, Springer, pp. 629–639, 1993.

[57] D. Pigozzi, A. Salibra. Polyadic algebras over non-classical logics. *Algebraic Methods in Logic and in Computer Science*, (C. Rauszer ed.), *Banach Center Publications* vol. 28, Polish Academy of Sciences, Warszawa, pp. 51–66, 1993.

[58] A. Salibra, G. Scollo. A soft stairway to institutions. Recent Trends in Data Type Specification, (M. Bidoit, C. Choppy eds.), LNCS vol. 655, Springer-Verlag, pp. 310–329, 1993.

[59] A. Salibra, G. Scollo. Compactness and Löwenheim-Skolem properties in pre-institution categories. *Algebraic Methods in Logic and in Computer Science*, (C. Rauszer ed.), *Banach Center Publications* vol. 28, Inst. Math. Polish Acad. Sci., Warszawa, pp. 67–94, 1993.

[60] V. Manca, A. Salibra, G. Scollo. On the Expressiveness of Equational Type Logic. Proc. Conference on The Unified Computation Laboratory: Modelling, Specifications and Tools, C.M.I. Rattray, R.G. Clarke eds., Oxford University Press, pp. 85–100, 1992.

[61] A. Salibra. A General Theory of Algebras with Quantifiers. *Algebraic Logic*, (H. Andréka, J.D. Monk, I. Németi eds.), *Colloq. Math. Soc. J. Bolyai* vol. 54, North-Holland Publishing Co., Amsterdam, pp. 573–620, 1991.

[62] V. Manca, A. Salibra. On the Power of Equational Logic: Applications and Extensions. *Algebraic Logic*, H. Andréka, J.D. Monk, I. Németi eds., Colloq. Math. Soc. J. Bolyai 54, North-Holland Publishing Co., Amsterdam, pp. 393–412, 1991.

[63] V. Manca, A. Salibra. Equational Calculi for Many-sorted Algebras with Empty Carrier Sets. MFCS'90, LNCS vol. 452, Springer-Verlag, pp. 423–429, 1990.

[64] V. Manca, A. Salibra, G. Scollo. On the nature of TELLUS (a Typed Equational Logic Look over Uniform Specification). MFCS'89, LNCS vol. 379, Springer, pp. 338–349, 1989.

[65] V. Manca, A. Salibra, G. Scollo. DELTA: a Deduction system integrating Equational Logic and Type Assignment. Proc. first International Conference on Algebraic Methodology and Software Technology, AMAST'89, Iowa City, Iowa, May 23–25, pp. 137–140, 1989.

[66] A. Salibra. Universal Algebraic Semantics. *Atti degli Incontri di Logica Matematica*, Università di Siena, Siena, 1986.

[67] V. Manca, A. Salibra. Algebra Universale e Logica in Computer Science. *Atti degli Incontri di Logica Matematica*, Università di Siena, Siena, 1982.

Books

[68] S. Antonelli, V. Manca, A. Salibra. Logica del Primo Ordine. *Editrice Tecnico Scientifica*, Pisa, 1983.

[69] S. Antonelli, V. Manca, A. Salibra. Logica. *Editrice Tecnico Scientifica*, Pisa, 1981.

2 Research Activity

2.1 Lambda Calculus

Research subject: Algebraic Semantics, Model Theory of Lambda Calculus, The lattice of lambda theories.

I have launched in the nineties a research program for exploring lambda calculus using techniques of universal algebra and algebraic logic.

- *Lambda Abstraction Algebras* ([22, 18, 23, 24, 27, 54, 49, 55, 28]): The remark that the lattice of lambda theories is isomorphic to the congruence lattice of the term algebra of the least lambda theory $\lambda\beta$, is the starting point for studying the lambda calculus by universal algebraic methods. In [23] I have shown that the variety (i.e., equational class) generated by the term algebra of $\lambda\beta$ is axiomatized by the finite schema of identities characterizing λ-abstraction algebras (LAAs). The variety of λ-abstraction algebras, introduced in [55, 28] at the beginning of nineties, constitutes a purely algebraic theory of the untyped lambda calculus, which keeps the lambda notation and hence all the functional intuitions. In [23] it is shown that, for every variety of LAAs, there exists exactly one lambda theory whose term algebra generates the variety. Thus, the properties of a lambda theory can be studied by means of the variety of LAAs generated by its term algebra.

The natural LAAs are algebras of functions, which arise as "expansions" of lambda calculus models by the variables of lambda calculus. Questions on the functional representation of various subclasses of lambda abstraction algebras were investigated in a series of papers [55, 28, 54, 27]. The main result in this research was obtained in collaboration with Robert Goldblatt [24]: every lambda abstraction algebra is isomorphic to an algebra of functions arising from a model of lambda calculus.

- *The Lattice of Lambda Theories* ([15, 19, 48, 17, 23]): In [23] I have shown that the lattice of lambda theories is isomorphic to the lattice of equational theories of LAAs. Not all lattices can be lattices of equational theories because the lattices of equational theories satisfy nontrivial quasi-identities in the language of lattices. The quasi-identities which hold in the lattice of lambda theories were investigated in [19]. I have conjectured at the end of the nineties that the lattice of lambda theories does not satisfy any nontrivial lattice identity. The first result in this area was obtained in [22], where it was shown that the non-modular pentagon N_5 embeds into the lattice of lambda theories. In [18] it was shown that there exists a large and distributive interval sublattice $[\phi)$, where ϕ is a finitely axiomatizable lambda theory. In [15] it was shown that, for every natural number n, there exists a lambda theory ϕ_n such that the interval sublattice $[\phi_n)$ is isomorphic to the finite Boolean lattice with 2^n elements.
- *Boolean algebras for lambda calculus* ([5, 15]): One of the milestones of modern algebra is the Stone representation theorem for Boolean algebras, which was generalized by Pierce to commutative rings with unit and next by Comer to the class of algebras with Boolean factor congruences. In [5, 15] we have generalized the Stone representation theorem to combinatory algebras. In every combinatory algebra there is a Boolean algebra of *central elements* (playing the role of idempotent elements in rings), whose operations are defined by suitable combinators. Central elements are used to represent any combinatory algebra as a Boolean product of directly indecomposable combinatory algebras (i.e., algebras which cannot be decomposed as the Cartesian product of two other nontrivial algebras). Applications of the Stone theorem to lambda calculus were given in [5]. The indecomposable semantics (i.e., the semantics of lambda calculus given in terms of models, which are directly indecomposable as combinatory algebras) includes the continuous semantics and its refinements, and the term models of all semisensible lambda theories. The indecomposable semantics is equationally incomplete, and this incompleteness is as wide as possible: for every recursively enumerable lambda theory ϕ, there is a continuum of lambda theories including ϕ which are omitted by the indecomposable semantics.
- *The model theory of Lambda Calculus*
  - *Incompleteness* ([7, 50, 20]): A semantics of lambda calculus is equationally incomplete if there exists a lambda theory which is not induced by any model in the semantics. I have introduced a new technique to prove in a uniform way the incompleteness of all denotational semantics of lambda calculus which have been proposed so far, including the strongly stable one, whose incompleteness had been conjectured by Bastonero, Gouy and Berline. The technique is applied to prove the incompleteness of any semantics of lambda calculus given in terms of partially ordered models with a bottom element.
  - *Order-Incompleteness* ([50, 20, 14, 13]): The open problem of the order-incompleteness of lambda calculus raised by Selinger asks for the existence of a lambda theory not arising as the equational theory of a non-trivially partially ordered model. As a partial answer to the order-incompleteness problem, we have shown that there exists a lambda theory

which admits only non-trivially partially ordered models with infinitely many connected components.

- *Graph Models of Lambda Calculus* ([6, 48, 17, 47, 18, 9, 35]): An interesting question is whether, given a class of models, there exist a minimal and maximal sensible lambda-theory represented by it. We have given a positive answer to this question for the semantics of lambda calculus given in terms of graph models. The greatest sensible graph theory is characterized as the lambda-theory B generated by equating lambda terms with the same Böhm tree. This result is a consequence of the fact that all the equations between solvable lambda-terms, which have different Böhm trees, fail in every sensible graph model. Other results are: (i) the existence of a continuum of different sensible graph theories strictly included in B (this result positively answers a question by Berline); (ii) the non-existence of a graph model whose equational theory is exactly the minimal lambda theory $\lambda\beta$ (this result negatively answers a long standing open question for the class of graph models).

  Baeten and Boerboom's method of forcing is generalized to show that (i) there exists a countable infinite sequence of easy lambda terms, that can be contemporaneously equated to any other countable infinite sequence of closed lambda terms; (ii) there exists a decidable set of mute terms which are a graph easy-set.

- *Lambda theories of effective lambda models* ([47, 16]): The question of whether the equational theory of an effective model of lambda calculus can be recursively enumerable (r.e. for brevity) is investigated. The following results have been obtained: (i) The equational theory of an effective model cannot be lambda-beta, lambda-beta-eta; (ii) The order theory of an effective model cannot be r.e.; (iii) No effective model living in the stable or strongly stable semantics has an r.e. equational theory. Concerning Scott's semantics, the class of graph models has been investigated and the following results were obtained, where "graph theory" is a shortcut for "theory of a graph model": (iv) There exists a minimum order/equational graph theory; (v) The minimum equational/order graph theory is the theory of an effective graph model; (vi) No order graph theory can be r.e.

2.2 Universal Algebra

Research subject: Church Algebras, Boolean-like algebras, Skew Boolean algebras, Boolean Products

- *Church algebras* ([46, 45]) model the if-then-else instruction of programming by two constants $0, 1$ and a ternary term $q(x, y, z)$ satisfying the following identities: $q(1, x, y) = x; q(0, x, y) = y$. They include, beside combinatory algebras and lambda abstraction algebras, all Boolean algebras and all rings with unit. The interest of Church algebras is that each has a Boolean algebra of central elements, which can be used to represent the Church algebra as a weak Boolean product of algebras (i.e., algebras which cannot be decomposed as the Cartesian product of two other non-trivial algebras). We generalize the notion of an easy lambda term from lambda calculus and use central elements to prove that: (i) any Church algebra with an "easy set of cardinality κ admits a congruence ϕ such that (the lattice reduct of) the free Boolean algebra with κ-generators embeds into the lattice interval of all congruences greater than ϕ; (ii) If κ is a finite cardinal, this embedding is an isomorphism. This theorem applies directly to all Boolean algebras and rings with units. For the lattice of lambda theories it has the following consequence: for every recursively enumerable lambda theory ϕ and each natural number n, there is a lambda theory ϕ_n extending ϕ such that the lattice interval $[\phi_n) = \{\psi : \phi_n \subseteq \psi\}$ is the finite Boolean lattice with 2^n elements.

- *Boolean-like Algebras* ([11, 12, 36]): Using Vaggione's concept of central element in a double-pointed algebra, we introduce the notion of Boolean-like variety as a generalisation of Boolean algebras to an arbitrary similarity type. Appropriately relaxing the requirement that every element be central in any member of the variety, we obtain the more general class of semi-Boolean-like varieties, which still retain many of the pleasing properties of Boolean algebras. We prove that a double-pointed variety is discriminator if and only if it is semi-Boolean-like, idempotent, and 0-regular. This theorem yields a new Maltsev-style characterisation of double-pointed discriminator varieties.

- *Skew Boolean Algebras* ([10]): We establish a connection between skew Boolean algebras and Church algebras. We prove that the set of all semicentral elements in a right Church algebra forms a right-handed skew Boolean algebra for the properly defined operations. The main result of this paper states that the variety of all semicentral right Church algebras of type τ is term equivalent to the variety of right-handed skew Boolean algebras with additional regular operations. As a corollary to this result, we show that a pointed variety is a discriminator variety if and only if it is a 0-regular variety of right-handed skew Boolean algebras.

- *Boolean Products* ([34]): We mimick the construction of guard algebras and show how to extract a Church algebra out of the binary functions on an arbitrary algebra, containing a Church subalgebra of binary polynomial operations. We put to good use the weak Boolean product representations of these Church algebras to obtain weak Boolean product representations of the original algebras. Although we cannot, in general, say much about the factors in these products, we identify a number of sufficient conditions for the stalks to be directly indecomposable. As an application, we prove that every right-handed skew Boolean algebra is a weak Boolean product of directly indecomposable right-handed skew Boolean algebras.

- *Factor Varieties* ([8]): The universal algebraic literature is rife with generalisations of discriminator varieties, whereby several investigators have tried to preserve in more general settings as much as possible of their structure theory. Here, we modify the definition of discriminator algebra by having the switching function project onto its third coordinate in case the ordered pair of its first two coordinates belongs to a designated relation (not necessarily the diagonal relation). We call these algebras factor algebras and the varieties they generate factor varieties. Among other things, we provide an equational description of these varieties and match equational conditions involving the factor term with properties of the associated factor relation. Factor varieties include, apart from discriminator varieties, several varieties of algebras from quantum and fuzzy logics.

2.3 Algebraic Logic

Research subject: Variable Binding and Algebraic Logic.

I have initiated an investigation of substitution and variable-binding in the paper [60], which was presented at the Conference on "Algebraic Logic" held in Budapest in 1988. The pioneering paper [60] was developed in [56, 26], where it was introduced the abstract variable-binding calculus, which is modeled on the lambda calculus. In [26] an algebraic formulation of the variable-binding calculus is presented in which substitution is represented by an abstract operator. This gives rise to the variety (i.e., equational class) of polyadic VB-algebras. The main result of [26] is a functional representation theorem for polyadic VB-algebras which specializes to a completeness theorem for a number of familiar systems that can be formalized as variable-binding calculi. For example, the lambda calculus, the classical first-order predicate calculus, the theory of the generalized quantifier "exists uncountable many" and a fragment of Riemann integration.

The theory of polyadic VB-algebras is also designed to provide a means of algebraizing first-order extensions, with the standard quantifiers, of a wide class of nonstandard propositional logics. We have obtained some results in this direction in [56], where the polyadic algebras of standard implicational calculi (SIC) are introduced. As a special case of the representation theorem presented in [26], the main result of [56] is a functional representation theorem for polyadic S-algebras that includes many of the known representation results for polyadic algebras over nonclassical logics.

2.4 Categorical Logic

Research subject: Abstract Model Theory and Specification Formalisms.

The theory of institutions provides algebraic and logical specification with a very general framework, in fact a metatheory that proves useful to the classification and comparative analysis of several specification formalisms. Institution theory does not appear to be useful enough to formulate the expressiveness results obtained in [59]. In [53, 58, 52, 57] the concepts of pre-institution and of pre-institution transformation were introduced and the use of those concepts in the design of logical systems was analysed. A series of abstract model-theoretic results relating to pre-institution transformations were obtained. With [58], downward inheritance of model-theoretic properties along suitable pre-institution transformations turns out to be a wider phenomenon, generalizing the so-called 'reduction scheme' in model-theoretic logics. Various instances of this phenomenon are investigated in [58], where the concepts of compact transformation and of cardinal pre-institution are introduced, yielding further results on downward inheritance of compactness and of Löwenheim-Skolem properties, and on the equivalence with first-order pre-institutions. New results on interpolation and Robinson properties are included in [53].

2.5 Abstract Data Types

Research subject: Equational Logic.

We have introduced and studied ET logic [63, 64, 32, 61, 30, 59], which is an extension of conditional equational logic by a binary predicate denoting a type assignment relation. We had interest towards such an extension because of limitations which were found in practice with the use of many-sorted conditional equational logic, e.g. for the specification of abstract data types with partial functions, polymorphic types, dependent types. In comparison to other formalisms, the main advantages of ET logic are simplicity and unifying character, that is the fact that different problems find solution in a single formal system. The paper in [59] presents translation results for logics frequently found in the algebraic specification literature, thus corroborating the view of ET logic as having a unifying character. More precisely, sound and complete translations into ET logic are given for the following conditional logics: order-sorted equational logic, equational logic with partial algebras, (positive) Horn clausal logic. The translations proposed in [59] obey to a uniform scheme, which motivated the research started in [57] (see Section 2.4). ET conditional rewriting was studied in [32].

Many-sorted equational logic was used in the eighties and nineties as a formalism for specifying abstract data types, and it was shown in [33] enough powerful to represent first-order logic. Many-sorted equational logic is unsound when the possibility of having empty carrier sets is admitted. In [62, 30] a sound and complete calculus for many-sorted equational logic with possibly empty domains is provided.