

KOWALSKI, Robert, Anthony Computational logic, including knowledge representation and problem solving, in artificial intelligence and cognitive science.

Born: 15 May 1941 in Bridgeport, Connecticut, USA. *Educated:* University of Edinburgh, Ph.D. in Computer Science 1970; Stanford University and University of Warsaw, M.A. in Mathematics 1966; University of Chicago and University of Bridgeport, B.A. in Mathematics 1963. *Dissertation: Studies in the Completeness and Efficiency of Theorem-proving by Resolution. Dissertation Supervisor* Bernard Meltzer.

Regular Academic or Research Appointments: EMERITUS PROFESSOR, SENIOR RESEARCH FELLOW, SENIOR RESEARCH INVESTIGATOR, IMPERIAL COLLEGE LONDON, 1999– ; Professor of Computational Logic, Imperial College London, 1982–1999; Reader in Theory of Computing, Imperial College London, 1975–82; Research Fellow, Department of Computational Logic, University of Edinburgh, 1970–75; Research Assistant, Meta-Mathematics Unit, University of Edinburgh, 1967–1970; Assistant Professor and Acting Head, Mathematics Department, Inter-American University, San Juan, Puerto Rico, 1966–67.

Visiting Academic or Research Appointments: National Institute of Informatics, Tokyo, Spring 2006, Autumn 2002; Universidad de Los Andes, Venezuela, Spring 2005; Swiss Federal Institute of Technology at Lausanne (EPFL), Winter 2001; Meme Media Laboratory, Hokkaido University, Autumn 2001, Autumn 2000; Miegunyah Distinguished Fellow, University of Melbourne, Winter 1999; University of Syracuse, Spring 1981, Spring 1978, Spring 1972; Ricerche Istituto per le Applicazioni del Calcolo, Rome, Spring 1974; University of Marseille, Luminy, Summer 1974, Summer 1972.

Research Profile: Kowalski's PhD research was in the field of Automated Theorem Proving. His research in this field included work on semantic trees with Pat Hayes, on SL-resolution with Donald Kuehner, and on the connection-graph proof-procedure. The SL-resolution proof-procedure, with its goal-reduction proof strategy and its last-in-first-out selection of sub-goals contributed to his later work on the development of logic programming. The connection-graph proof-procedure, on the other hand, by combining selection with search, eliminates sufficiently many redundant and irrelevant steps towards a proof that its completeness is still an open research issue.

Kowalski collaborated with Alain Colmerauer on the development of logic programming (LP), the main idea of which is to apply a more flexible form of SL-resolution to execute Horn clauses as goal-reduction procedures. Kowalski contributed the theoretical insight and Colmerauer developed the programming language Prolog, based on this idea. Kowalski's book, *Logic for Problem Solving*, is often cited as an introduction to logic programming, but in fact it places logic programming in the wider context of clausal logic as a general problem solving formalism. In the late 1970s and early 1980s, he developed and led a number of projects to teach logic for problem solving to children.

Following early work on the foundations of LP, Kowalski focused on developing extensions of LP, with a view to improving its use for knowledge representation and problem solving. The earliest extension, developed with Kenneth Bowen, was an amalgamation of object-language and meta-language for such applications as the representation of knowledge and belief, as well as for implementing meta-interpreters in which one logic is simulated by another. Together with Marek Sergot, he developed the event calculus, a logic programming representation of causal reasoning, which has been used for such applications as database updates and the logical formalization of natural language.

Kowalski was one of the early developers of abductive logic programming, in which ordinary logic programs are augmented with integrity constraints and with undefined, abducible predicates. This work led to the demonstration with Phan Minh Dung and Francesca Toni that most logics for default reasoning can be regarded as special cases of assumption-based argumentation.

The two main application areas to which Kowalski has made important contributions are legal reasoning and integrity checking in deductive databases. Working with Marek Sergot, he showed how LP and its extensions can be used to formalize legal rules and regulations, distinguishing between clear concepts, which are defined by logic programs, and vague concepts, which are undefined or abducible. Working with Fariba Sadri, he developed theorem-proving techniques, which reason forward from updates, to check for violation of integrity constraints.

Recently, Kowalski's main area of research has been the development of abductive logic programming as the thinking component of an intelligent agent interacting with the changing world. Working mainly with Fariba Sadri, he has developed an agent model in which beliefs are represented by logic programs and goals are represented by integrity constraints. Integrity constraints are used to represent different kinds of goals, including maintenance goals, prohibitions, and condition-action rules. Abducible predicates are used to represent observations and actions.

The resulting agent model includes *reactive* thinking, which uses forward reasoning to derive maintenance goals and achievement goals from observations. It also includes *proactive* thinking, which uses backward reasoning to reduce achievement goals to action sub-goals.

Kowalski's current research focuses on the application of computational logic to cognitive science. This work aims to link logic's traditional role as a normative model of thinking with a more radical proposal that logic can also serve as a descriptive model of human thinking. The work extends the combination of reactive and proactive thinking to include a kind of *pre-active* thinking, which uses forward reasoning to simulate alternative candidate actions, to derive their possible consequences, to help in choosing between them.

Key Publications:

Kowalski, R. and Hayes, P. J., "Semantic Trees in Automatic Theorem-Proving", in *Machine Intelligence 4*, (eds. B. Meltzer and D. Michie), Edinburgh University Press, 1969, pp. 181–201. Reprinted in *Anthology of Automated Theorem-Proving Papers*, Vol. 2, Springer-Verlag, 1983, pp. 217–232.

Kowalski, R. and Kuehner, D., "Linear Resolution with Selection Function", in *Artificial Intelligence*, Vol. 2, 1971, pp. 227–60. Reprinted in *Anthology of Automated Theorem-Proving Papers*, Vol. 2, Springer-Verlag, 1983, pp. 542–577.

Kowalski, R., "Predicate Logic as Programming Language", in *Proceedings IFIP Congress*, Stockholm, North Holland Publishing Co., 1974, pp. 569–574. Reprinted in *Computers for Artificial Intelligence Applications*, (eds. Wah, B. and Li, G.-J.), IEEE Computer Society Press, Los Angeles, 1986, pp. 68–73.

Kowalski, R., "A Proof Procedure Using Connection Graphs", in *JACM* Vol. 22, No. 4, 1975, pp. 572–595.

van Emden, M. and Kowalski, R., "The Semantics of Predicate Logic as a Programming Language", in *JACM*, Vol. 23, No. 4, 1976, pp. 733–742.

Kowalski, R., "Logic for Problem Solving", North Holland Elsevier, 1979, 287 pages.

Bowen, K. and Kowalski, R., "Amalgamating Language and Meta-language in Logic Programming", in *Logic Programming*, (eds. K. Clark and S-A. Tarnlund), Academic Press, 1982, pp. 153–172.

Kowalski, R. and Sergot, M., "A Logic-based Calculus of Events", in *New Generation Computing*, Vol. 4, No.1, February 1986, pp. 67–95. Also in *Knowledge Base Management-Systems*, (eds. C. Thanos and J. W. Schmidt), Springer-Verlag, pp. 23–51. Also in *The Language of Time: A Reader* (eds. Inderjeet Mani, J. Pustejovsky, and R. Gaizauskas) Oxford University Press. 2005.

Sergot, M., Sadri, F., Kowalski, R., Kriwaczek, F., Hammond, P., and Cory, T., "The British Nationality Act as a Logic Program", in *CACM*, Vol. 29, No. 5, 1986, pp. 370–386.

Sadri, F. and Kowalski, R., "A Theorem-Proving approach to Database Integrity", in *Deductive Databases and Logic Programming*, (ed. J. Minker), Morgan Kaufman, Los Altos, Ca., 1988, pp. 313–362.

Eshghi, K. and Kowalski, R., "Abduction Compared with Negation by Failure", in *Sixth International Conference on Logic Programming*, (eds. G. Levi and M. Martelli) MIT Press, 1989, pp. 234–254.

Kowalski, R., "Legislation as Logic Programs", in *Logic Programming in Action* (eds. G. Comyn, N. E. Fuchs, M. J. Ratcliffe), Springer-Verlag, 1992, pp. 203–230.

Kowalski, R., "Database Updates in the Event Calculus", in *Journal of Logic Programming*, 1992, Vol. 12, No. 162, pp. 121–146.

Kowalski, R., "Using Metalogic to Reconcile Reactive with Rational Agents" In *Meta-Logics and Logic Programming* (K. Apt and F. Turini, eds,) MIT Press, 1995. (Revised version in Proc. PAAM96).

Kakas, T., Kowalski, R. and Toni, F., "The Role of Logic Programming in Abduction", *Handbook of Logic in Artificial Intelligence and Programming 5*, 1998 (eds. D. Gabbay, C.J. Hogger, J.A. Robinson) Oxford University Press, pp. 235–324.

Bondarenko, A., Dung, P. M., Kowalski, R., and Toni, F. " An Abstract Argumentation-theoretic Approach to Default Reasoning". *Journal of Artificial Intelligence* 93 (1–2), 1997, pp. 63–101.

Kowalski, R. and Sadri, F., " From Logic Programming towards Multi-agent Systems, *Annals of Mathematics and Artificial Intelligence*, Volume 25 (1999), pp. 391–419.

Kowalski, R. "Artificial intelligence and the natural world" *Cognitive Processing*, 4 (2001), pp. 547–573.

Dung, P. M., Kowalski, R., and Toni, F. "Dialectic proof procedures for assumption-based, admissible argumentation". *Journal of Artificial Intelligence* 170(2), February 2006, pp. 114-159.

Kowalski, R. "The Logical Way to be Artificially Intelligent". *Proceedings of CLIMA VI* (eds. F. Toni and P. Torroni) Springer Verlag, LNAI, to appear.

A full list of references, including links to some of these papers and to the work in progress below can be found on the author's homepage: <http://www.doc.ic.ac.uk/~rak/>

Work in Progress:

A book, "The Logical Way to be Artificially Intelligent", which presents Computational Logic informally, so that it can be used by ordinary people in everyday life.

An investigation of thinking as the activation of links in a connection graph of sentences in clausal form. The hypothesis that the mind is organized as a collection of modules is explained by the possibility that such a graph may contain implicit or explicit sub-graphs, with a high degree of connectivity within sub-graphs and a low degree between sub-graphs.

An investigation of the relationships between object-orientation (OO) and abductive logic programming multi-agent systems (ALP systems). OO is the dominant paradigm in computing today, and it challenges logic as a way of looking at the world. ALP systems arguably combine the advantages of logic with the main benefits of OO.

Service to the Profession: Editorial Advisory Board, Progress in Informatics, 2005– ; Head, Department of Computing, Imperial College, 1997–1999; Editorial Board, Theory and Practice of Logic Programming, 2001– ; Founding Co-ordinator, European Compulog Network of Excellence, 1991–1992; Editorial Board, Interest Group in Propositional and Predicate Logics, 1993– ; Editorial board, Journal of Logic and Computation, 1990– ; Editorial board, Journal of Artificial Intelligence and Law, 1990– ; Editorial Advisory Board, IEICE transactions on Information and Systems, 1990– ; Scientific Advisory Board, Deutsches Forschungszentrum für Künstliche Intelligenz, 1989–1998; Coordinator, European Community Basic Research Project, Compulog, 1989–1991; Chairman, Program Committee, International Joint Logic Programming Conference, 1988; Scientific Advisor, UNDP Knowledge-Based Computer Systems Project in India, 1987–1991; Honorary Secretary, Association for Logic Programming, 1986–1998; Editorial Board, Mind and Language, 1986– ; Head, Logic Programming Group, Department of Computing, Imperial College, 1985–87, 1990–96; Editorial Board, New Generation Computing Journal, 1983– ; Editorial Board, Logic Programming Journal, 1983–2000; Joint Chairman, Program Committee, Conference on Automated Deduction, 1980; Member of Science and Engineering Research Council Subcommittee for Computing and Communications, 1980–1983.

Teaching: Kowalski has supervised seventeen Ph.D. students at Imperial College in the field of Computational Logic, including Christopher Hogger, Keith Clark, Marek Sergot, Fariba Sadri, Kave Eshghi, Suryanarayana Sripada, Francis McCabe, Francesca Toni, Tze Ho Fung, Christopher Preist, Jacinto Davila, and Yongyuth Perpoontanalarp. He also contributed to the supervision of a number of Ph.D. students at the University of Edinburgh, including David H. Warren,

Vision Statement: Attempts to use traditional logic in artificial intelligence have led to the development of various improvements and extensions, including default reasoning, abduction and argumentation. These developments can also be applied to the original purpose of logic, to improve the quality of human thinking.

Honours and Awards: “Essays in Honour of Robert Kowalski” Computational Logic: Logic Programming and Beyond, (eds. A C Kakas and F Sadri) Springer Verlag, 2002; Special issue of ACM Transactions on Computational Logic “Dedicated to Robert Kowalski”, Vol. 2, No. 4, 2001; Fellow of the Association for Computing Machinery, 2000; Fellow of the European Coordinating Committee for Artificial Intelligence, 1999; Miegunyah Distinguished Fellow, University of Melbourne, 1999; Fellow, Deutsches Forschungszentrum für Künstliche Intelligenz, 1998; Fellow, City and Guilds of London Institute, 1997; Fellow, American Association for Artificial Intelligence, 1991; "Docente a titolo individuale" Giuridica "H Kelsen", dell'Università degli Studi di Bologna, 1990; Insight Award for Contributions to Fifth Generation Computing, 1984.