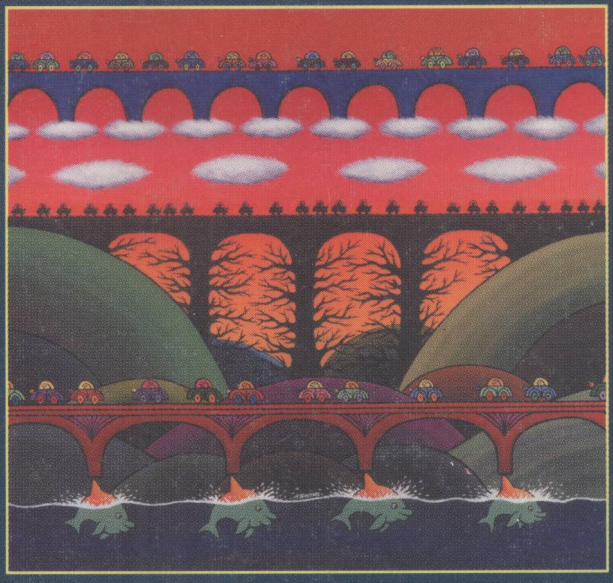
Festschrift

LNAI 2605

Dieter Hutter
Werner Stephan (Eds.)

Mechanizing Mathematical Reasoning

Essays in Honor of Jörg H. Siekmann on the Occasion of His 60th Birthday



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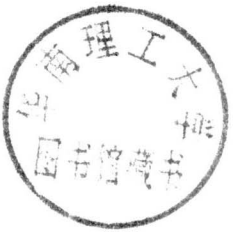

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Library of Congress Control Number: 2005921072

CR Subject Classification (1998): I.2.3, I.2, F.4.1, D.2.4

ISSN 0302-9743
ISBN 3-540-25051-4 Springer Berlin Heidelberg New York

Typesetting: Camera-ready by author, data conversion by Olgun Computergrafik
Printed on acid-free paper SPIN: 11399056 06/3142 5 4 3 2 1 0

Lecture Notes in Artificial Intelligence 2605

Edited by J. G. Carbonell and J. Siekmann

Subseries of Lecture Notes in Computer Science

Preface

These essays pay tribute to Jörg H. Siekmann on his 60th birthday, which gave reason to his friends, former and recent students, and colleagues to celebrate his career as a scientist who has contributed to many diverse fields. These are covered by the wide range of essays that make up this volume. The way the scientific contributions were grouped reflects the development of Jörg's research interests over the many years of his professional life. Moreover, many of them are directly influenced by his own work.

Part 1 starts with contributions on basic deduction techniques, from decision theories, rewriting, constraint solving and unification to entire systems for automated theorem proving. When Jörg started his academic career, the area of automated reasoning and also Jörg's early work were almost completely dominated by these disciplines. Today, after two or more decades of substantial improvements, techniques like those developed in his groups and those discussed in this volume provide the basic machinery for application-specific, more comprehensive support systems.

Shortly before and during his time in Saarbrücken Jörg became more and more involved in several forward-looking and application-driven developments that use "automated deduction inside." Part 2 focuses on various application scenarios like knowledge representation and retrieval, natural language processing and e-learning.

As opposed to applications in education and Web technology, for example, the use of deductive techniques in formal software development goes back to the 1970s. Jörg was in contact with the developers of these early approaches primarily through his collaboration with Peter Raulefs in Karlsruhe and Kaiserslautern. However, it was through the VSE project that he became active in this rapidly growing research area, which became an important role for his group at the DFKI.

Besides the more technical research issues mirrored in most of the contributions of this volume, Jörg was always concerned about the fundamental problem of explaining human intellectual behavior by means of computer models. In particular the study of emergent behavior and self-organization attracted him beyond the use of agent architectures for theorem proving or, in the other direction, the application of deductive techniques for agent planning. Part 4 presents work in the spirit of Jörg's research group on multiagent systems.

Compiling this volume has been a great pleasure. We are grateful that everyone who we asked to contribute responded positively, expressing their desire to honor Jörg H. Siekmann. We thank the authors for their patience during the long period between the first ideas on preparing this volume and its later publication. Special thanks goes to Jörg for providing us with a preliminary draft of his autobiography which illuminates various facets of his eventful life. The draft turned out to be an invaluable source when writing the appraisal of his career.

Jörg has had a major impact on our lives. I, Dieter, first met him in 1979 when I was an undergraduate student at the University of Karlsruhe, obliged to give a proseminar on Lenat's AM system. His inspiring enthusiasm and energy for this kind of AI system stirred my growing interest in automated theorem proving in general and guiding such provers in particular. Not surprisingly, after finishing my MSc thesis I registered as a PhD student of Christoph Walther and Peter Deussen, joining the development of the inductive theorem prover INKA. Years later, Jörg offered me a research position in Saarbrücken to incorporate proof guiding techniques into VSE; I accepted willingly.

At the time when Jörg moved to Karlsruhe I, Werner, was working in Wolfgang Menzel's group, which together with Deussen's group formed the institute of theoretical computer science. Despite countless controversial discussions on AI-related topics and developments in the common academic context, as well as ongoing changes in the German society of the early 1980s, we shared many basic views and soon became friends. But also, in a more restricted sense, my academic work was influenced by Jörg's often more than enthusiastic way of standing up for AI and, in particular, automated deduction. Being interested at that time in the semantics of programming languages and logics, the discussions with Jörg's group sharpened my view that computer-assisted deductive systems (together with "model based" analysis techniques) "animate" formal development techniques thereby enabling their application in software engineering.

Since then, our work at Jörg's research department at the DFKI has been guided by the search for a close integration of formal methodology and deductive support, bringing together two communities that, still today, are often far from working hand in hand. Throughout all the years, Jörg has been a constant source of inspiration, friendship and humor. In presenting Jörg with this book we hope that he will enjoy reading it, and since his work is by no means finished, we hope to return the favor by reading more of the essays he has promised to write in the coming years.

Dieter Hutter
Werner Stephan

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A Portrait of a Scientist: Logic, AI and Politics

Dieter Hutter and Werner Stephan*

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1 Bückeburg

Mitnehmen kann man das Vaterland
An den Sohlen und an den Füßen
Das halbe Fürstentum Bückeburg
Blieb mir an den Stiefeln kleben.
So lehmichte Wege habe ich wohl
Noch nie gesehen im Leben.

Heinrich Heine: Ein Wintermärchen, 1844

At the time Alan Turing was engaged in deciphering the code of the Enigma in Bletchley Park and Konrad Zuse applied his patent for the first electronic computer called "Rechenvorrichtung" in Berlin, Jörg was born into the rural capital of the smallest Fürstentum of Germany, called Schaumburg-Lippe, a name even well educated Germans have probably never heard of. Jörg grew up as the oldest son of a family whose male providers had been joiners and curlers for centuries. There has never been a question that one day he would inherit the small family owned curler and joiners workshop.

But things turned out otherwise: Schaumburg-Lippe never became an independent Land again and the once respectable Siekmann family of joiners, curlers and church leaders was on the decline: mass furniture production became a highly capital intensive, fully automated business, where a certain Swedish company set the pace. In that process, almost all of the family-owned small and medium sized woodworking companies vanished and the once proud Schaumburg Lippesche Handwerkskammer dating back far into medieval times became obsolete.

But Jörg did not quite fit particularly well anyway: when he could not decide whether he wanted to be an artist or a scientist – an idea so inconceivable that his father threatened to cut off all his family ties – he took his juvenile poems and drawings to a family friend who looked at his paintings and poems with a stern expression and suggested: "Son, you better learn the trade of your fathers!"

So, Jörg became a joiner's apprentice in the nearby village of two hundred souls called Scheie, and after three and a half years he passed the traditional examinations and practical tests with some distinction: being now a well recognized member of the German chamber of handicraft entitled to call himself a Tischlergeselle.

Two years in the army, a further apprenticeship as a metalworker and welder finally qualified him to enter the Technikum Rosenheim, an engineering school

* We like to thank Jörg for freely using his "Autobiographic Notes" from which some material and most of the personal information is drawn and quoted without explicit indication.

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for woodwork and furniture production, which bestowed the title of grad.Ing. Rosenheim on him. A small research and technology company hired him right away and they invented the "R-value", a ventilation measure, apparently still in use today, which classifies the ventilation capacity of (wooden) windows.

Being bored with the "science" of window manufacturing, still unwilling to accept the position as the head of his father's company, which did not flourish all too well anyway, he decided it was time for a fundamental change and a new start.

University life was walled up in those days by the Abitur, the German equivalent of the anglo-saxon A-levels, a watershed in the conservative Germany of Adenauer's days that divided those who have from those who have not. His first marriage (of which there were several more to come) broke up and he started again as a schoolboy in evening classes and eventually he was admitted as a student at the Braunschweig Kolleg, a prestigious German adult education centre. Three years later at the age of almost thirty all doors were finally open: he had his Abitur!

But life never seemed to evolve in a straight line with Jörg; politics dominated his life: this was the late sixties, the peak of the student revolt in Paris and Germany. Benno Ohnesorg, his fellow student from the Braunschweig Kolleg, was shot by a policeman during a student demonstration, Greece was controlled by the military dictatorship of Papadopoulos and his colonels. This is a period in Jörg's life he wisely concealed in his curriculum vitae and application letters to the university in a country that not only exported terms like Kindergarten and Eigenwert into the English language, but also the word Berufsverbote.

2 Göttingen and Essex

Zu Göttingen blüht die Wissenschaft,
Doch bringt sie keine Früchte.
Ich kam dort durch in stockfinstrer Nacht,
Sah nirgendwo ein Lichte.

Heinrich Heine: Der Tannhäuser, 1836

In nineteen seventy the dream of the "little joiner's boy" became true: he enrolled as a student in mathematics and physics at Göttingen University and he was accepted as a member and soon elected a senior tutor of the Akademische Burse.

The introduction to mathematics by Grauert and Brieskorn, Scheibe's lectures on time and relativity and the intellectual and political debates of the Akademische Burse were formative years. But it was logic and its introductory courses by Patzig and others that captured his imagination: apparently there are deeper and more eternal truths behind the appearance of everyday academic life.

The Vordiplom in mathematics and physics, evening classes in the English Language Lab, a few months at the Sound and Vibration research institute in Southhampton (where they implemented one of the fastest Fourier-Transformations of its time), and finally a one-year grant from the DAAD prepared for a master course in computer science in England at Essex University. Science and politics again: the final M.Sc. degree with distinction and the admittance

to Oxford as a PhD student of Dana Scott but also a course he taught at the student union on Rosa Luxemburg and Mandel's economic theory.

In the end the public lectures on artificial intelligence by Terry Winograd, Carl Hewitt, Roger Schank and Yorick Wilks at Essex sparked a new flame that should now last for a lifetime: if machines can think and we can talk to them – these were the years of Terry Winograd's SHRDLU and Nils Nilsson's SHAKEY – then surely this was a much greater scientific challenge than all of mathematics and physics taken together, and certainly on par with some of the grand problems in logic related to the fundamental barriers of human and machine thinking.

So when Pat Hayes joined the staff of Essex University and accepted him as his PhD student, all future plans with Oxford and Germany were abandoned. The excitement with the new subject was fuelled by the staff at Essex: Richard Bornat, Mike Brady, Jim Doran, Pat Hayes, Bernard Sufrin, Yorick Wilks and a constant stream of visiting scientists from Edinburgh, Sussex and also from America provided much of the early excitement for this new subject.

His thesis "Unification and Matching Problems" on unification theory for combinations of associativity, commutativity and idempotency introduced the notion of a unification hierarchy based on the cardinality of the set of most general unifiers. With his collaboraters Mike Livesey and Peter Szabo, Jörg elaborated a classification of this hierarchy, which now carries his name. The early work of Gordon Plotkin, the thesis of Gerard Huet, and his work with Peter Szabo and others finally established unification theory as a subject of its own, with annual workshops and subsections at AI, automated reasoning and mathematics conferences.

3 Karlsruhe

Eines Nachmittags ging Markgraf Karl Wilhelm im Hardtwald auf die Jagd, um seinen Aerger zu vergessen. Er traf einen Hirsch, verfolgte das Tier und ließ dabei sein Gefolge weit hinter sich. Vom langen Ritt ermüdet, setzte er sich schließlich auf einen Eichenstumpf mitten im Wald. Bald war er eingeschlafen. Erst nach Stunden fanden seine Jagdgenossen ihren schlafenden Herrn. Man weckte ihn, und als er sich umschaute, gefiel ihm der Ort so gut, dass er sagte: "In meinem Leben habe ich noch niemals besser geschlafen als hier. An diesem Platz möchte ich immer wohnen. 'Karls Ruhe' soll er künftig heißen. Und über diesem Baumstumpf will ich eine Kirche errichten, in der ich einstens zur ewigen Ruhe gebettet werde."

Historical saga of the foundation of Karlsruhe

In 1976 Jörg moved to Karlsruhe when AI slowly started to gain ground in Germany. The year before, the first informal German meeting on artificial intelligence was organised and a year later it was accepted formally as a working group of the GI, the German computer science society. Jörg was now an assistant and soon an associate (Hochschulassistent) in the institute of Peter Deussen at the computer science department in Karlsruhe.

His research area continued to be unification theory working in close collaboration with his friend Peter Szabo, but also and more importantly – at least in Jörg's values – the beginning of the automated theorem proving system with

the tongue-twister name Markgraph Karl Refutation Procedure (MKRP). He convinced Germany's funding agencies that he could build a theorem proving system that would not only outperform the strongest American systems by far, but establish a new paradigm of less search and more (mathematical) knowledge for theorem proving. He claimed that Deussen's book "Halbgruppen und Automaten" would be the first text book completely generated in natural language by a machine – a promise that turned out to keep him busy not only for the anticipated decade but obviously till the end of his active life.

We had the days of Carl Hewitt's PLANNER, the declarative versus procedural debate and Pat Hayes paper "An arraignment of theorem proving or a logician's folly". But the field of automated theorem proving was not particularly influenced by these debates and still dominated by Alan Robinson's resolution calculus. Its few and simple inference rules entrapped many researchers to believe that developing a successful general purpose strategy for theorem proving would be only a matter of time. Under the influence of the Essex debates and Pat Hayes' way of thinking, the new MKRP-system was supposed to be the first knowledge based theorem proving system to lead out of the trap of the merely search based approaches of the day. Bob Kowalski's connection graph seemed to be a good starting point for the new MKRP-system because of its immediate access to available resolution steps, and soon innumerable papers about connection-graph based theorem proving in general and all sorts of refinements in particular poured out of Jörg's group. The system developed well at first and soon it exhausted the computational resources of the computing faculty. Every Wednesday evening the faculties' single computer (occupying more than half of the basement of the faculties' building) was rebooted in a single-user mode for the sole reason of accommodating Germany's best theorem proving system within its four megabyte of virtual memory; and every Wednesday evening, Jörg's group reassembled in front of a VT100 terminal observing and soothsaying MKRP's behaviour on the latest examples of the deduction community.

The race was stiff with two major horses at that time: his friend Larry Wos with his much smaller team and their parsimonious but extremely well-engineered system OTTER versus the big elephant MKRP. Larry would call – usually very early in the morning – mocking a German accent: "Hey can you do zis, ve have just solved it" and then the group had a few days at most to prove a new challenge theorem from a given set of axioms. The sooner the answer "We have just done it as well, Sir" the better – so the day had twenty four hours after such a phone call to analyse the new proof and adjust the settings of the various refinement strategies such that MKRP would also find the proof[1]. The next challenge's twist was then to spot weaknesses in the opponents system, design a hard problem whose solution relied on a special technique within the weak spot of the competitor, solve it at leisure – and send it in reverse right over the Atlantic waiting for their phone call.

[1] You can always solve a difficult mathematical problem when another system has already succeeded given enough time: just analyse, set the parameters right, analyse again, add a new procedure, analyse again, etc.

While this went on for many years, the pendulum for the first prize sometimes swung to this side of the Atlantic and then back to the other. Both systems improved considerably – but none of the promised breakthroughs was forthcoming. Deussen's book was still waiting to be automatically generated.

The MKRP-effort showed that indeed you can build a knowledge based theorem proving system which prunes the search space by several orders of magnitude – but the traditional search based systems performed all in all just as well. As Larry Wos pointed out in a seminal debate at one of the CADE conferences: "We now have the ultimate system Ψ that proves a theorem without any search: it uses its efficient and knowledgeable supervisor OTTER to find a proof and then proceeds by using this knowledge to guide Ψ right through the search space". "MKRP was unfortunately still wrapped too much in the intellectual time warp of the sixties" as Jörg would comment on these developments later.

At that time, research in AI and on deduction in particular was not a mainstream business in Germany. There were yearly informal meetings on AI, until in 1981 Jörg initiated the annual German workshops on Artificial Intelligence (GWAI) with proper proceedings published by Springer. These annual meetings at the Hölterhoff Stiftung in Bad Honnef near Bonn stimulated the early excitement about AI in Germany and much of the proud and more often than not the over-important sense of self, called WIR-GEFÜHL in German, emanated from these – sometimes hilarious – meetings. In March 1982, Jörg and Wolfgang Bibel started the first German summer school on AI in Teisendorf. With more than 100 participants, it was a big success not only because Jörg became acquainted with his later wife, but also because the lecturers succeeded in transmitting their enthusiasm about AI to the convened young researchers always looking for a PhD thesis.

Politically the late 70's saw the growth of the German peace movement from a small circle of concerned scientists and peace activists into a mass movement: the planned deployment of Pershing missiles close to the eastern boarder and iron curtain reduced the effective early warning time from several hours down to a few minutes and the Soviet Union responded with the threat of an automatic launching policy – which fortunately was never fully implemented by either side. Several false alarms – some up to the highest threat level – were computed by the huge American early warning system and when these facts became public, several professors of jurisdiction and computer science, including Jörg, opened a law case against the German government at the Federal Court in Karlsruhe: some courageous American senators provided classified material for the German computer society of concerned scientists FIFF, of which Jörg was one of the founders. He made the material public, wrote several papers and a journal article with Karl Bläsius. He must have given a few hundred public talks, television interviews and speeches to the peace movement all over Germany and experienced for the first time the difference between giving a seminar talk and being a speaker in front of ten thousand people.

Politics would meet AI again when Peter Raulefs, Jörg and Graham Wrightson organized the International Joint Conference on AI (IJCAI) in 1983 at Karl-

sruhe: with more than two thousand participants it was the first major event of this size in Germany and widely covered by the media – not least because the accompanying industrial exhibition proudly displayed an empty Martin Marietta (Pershing) booth.

4 Kaiserslautern

P.T. aus Arizona
von dem Stamme der Apachen
lebte ziemlich gut in K-town, Germany.
War GI und bei der Army,
na, und Sehnsucht nach den Staaten
hatte P.T., der Apache, eigentlich nie.
Nur im Herbst, wenn Vögel schrien,
über K-town südwärts zogen,
sagte P.T. manchmal leise zu sich "Uff".
Und dann trank er sehr viel Bourbon,
stieg in seinen alten Chrysler
und fuhr rüber nach Karlsruhe in den Puff.
P.T. P.T. Das hat dem P.T. gutgetan ...

Franz-Josef Degenhardt: P.T. Arizona, 1968

In 1980 the department of computer science of the University in Kaiserslautern advertised the first professorship for AI in Germany and after the usual tiresome medival "rituals", Jörg was offered the job and in 1983 he moved from Karlsruhe to Kaiserslautern with his newly wedded wife and his coltish dog called Minsky.

To us, the next generation of scientists, who found AI already an established subject when we were students, it is probably Jörg's lecture series 'Introduction to Artificial Intelligence' that is most vivid in memory. By the mid eighties the field was thriving and banging at the doors of the scientific establishment, but it was still provocative in its general claims regarding the nature of human versus machine thinking.

The lecture at its peak drew sometimes more than five hundred students from all over Germany and many other European countries to Kaiserslautern, with students occupying the floor, the windows – wherever there was additional space – completely electrified by the subject and the atmosphere generated by this strange and witty missionary of a futuristic technology[2] with his hand-crafted slides decorated with flowers in the style of the sixties.

Jörg appeared on television, newspapers and radio shows: the AI hype had finally infected Germany as well and the bearded messiah with his dog Minsky became a familiar sight[3]. The 1984 paper on the subject of AI and its future invited by the OECD, has been printed and reprinted many times and was

[2] The lecture of the 80's was actually filmed and made publicly available as videotapes. His AI-lecture today, more mature and sober now (and available on the web), uses Stuart Russell's textbook on AI as its base.

[3] There is the funny event, when Jörg was invited for one of his well-paid AI-intros to German industrialists, in this case called "Schock der Moderne", and he hesitated to go as he had to care for his dog that day. So they sent two chauffeur driven big black Mercedes cars headed by a motorbike leading the convey to little Kaiserslautern University: one with the back seat removed for his dog and the other one for himself.