Report on a Visit to ICOT (Feb 1987)

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Introduction

By a generous invitation by Dr. Fuchi of ICOT I was able to spend one month at ICOT (Feb 2 to Feb 28, 1987).

The objectives of my stay were:

-- To get an overview on current Japanese research in symbolic computation (automated theorem proving, computer algebra, automatic programming), in particular on the role symbolic computation plays in the ICOT project.

-- To get an overview on current Japanese research in parallel computation, in particular on the current state of the ICOT project for a universal parallel computer system for knowledge information processing.

-- To relate my own research and the research of the Research Institute of Symbolic Computation in Linz (RISC-LINZ) to current Japanese research in symbolic and parallel computation.

-- To promote the presence of Japanese symbolic computation research in the Journal of Symbolic Computation.

-- To promote future cooperation between ICOT and RISC-LINZ.

-- To learn some Japanese.

Seminar Lectures at ICOT

During my stay at ICOT I gave the following seminar lectures:

Feb 3, 10 - 12 am
Feb 5, 10 - 12 am
Feb 9, 10 - 12 am:

"Introduction to the Groebner Bases Method"
(for the TRS Working Group)

Feb 19, 15 -17 pm:

"The Parallel L-Language and L-Machine"
(for the KBM Working Group)

Feb 20, 14 -16 pm:

"Teaching and Research at RISC-LINZ,
the Research Institute for Symbolic Computation in Linz"
(for the CAP Working Group)

Feb 27, in the frame of the 1987 Japanese Conference on Functional Programming:

"The Parallelization of Critical-Pair/Completion Procedures on the L-Machine".

In the "Introduction to the Groebner Bases Method" I provided several details of proof techniques in this area and an overview on applications. The Groebner bases method was introduced in my ph. d. thesis and meanwhile has been successfully applied to numerous problems in algebraic and geometrical computation including inverse robot kinematic, solid modeling and geometrical theorem proving by computer. RISC-LINZ has its strongest research tradition in this area. At the end of my lecture I formulated some research problems that in my judgement are promising for future research. These are:

1) Derive algorithms for solving systems of equations defined by general first order terms by using similar techniques as used for the solutions of algebraic systems based on Groebner bases (see my recent survey on the GB method).

2) Give an axiomatic frame for critical-pair/completion algorithms based on the notion of replacement and substitution and their properties known from the Groebner bases context and the Knuth-Bendix context (see my recent survey on critical-pair/completion algorithms). The notion of a "Least Common Reducible" from my reduction ring paper could provide the key technique for this objective.

The level of detail I gave in this series of lectures paid off because three concrete research and software projects by Sakai-san, Aiba-san and Takayama-san were motivated by these lectures and could be successfully completed during my stay (see below).

In the lecture on the "Parallel L-Language and the Parallel L-Machine" I gave an overview on a research project that is pursued under my direction at RISC-LINZ since 1977. It has reached an intermediate state by the successful realization of a pilot parallel machine for symbolic computation in 1984 and the implementation of our parallel high-level L-language on this machine in 1985. At present, plans with industrial partners for the realization of the next version of the L-machine and the L-language based on the transputer are developed. The L-language is the first language that allows the description of logical interconnection topologies between processes (including the use of recursion on size parameters) and seems to be an alternative to the Guarded Horn Clause language of ICOT.

The working group on symbolic computation at the University Linz has been founded in 1974 under my direction under the name CAMP-LINZ ("Computer-Aided Mathematical Problem Solving"). After steady growth over the years the Austrian Government has transformed the working group 1986 into the "Research Institute for Symbolic Computation at the University of Linz" (RISC-LINZ). In the lecture "Teaching and Research at RISC-LINZ" I first gave an overview on the two teaching projects pursued at RISC-LINZ. One is a special graduate curriculum both for math and computer science students (master's and ph.d.) who want to specialize in symbolic computation. The core of this curriculum are 30 courses that are offered by 8 faculty belonging to RISC-LINZ. The 30 courses are grouped into courses on logic, algorithm theory, semantics of programming languages, automated theorem proving, computer algebra, automatic programming, computational geometry, symbolic computation languages and symbolic computation software systems. The second teaching project is "Math for Computer Science Undergraduates" and introduces math in a radical way by spending the first semester exclusively to the training of predicate logic as a working language for specification, knowledge derivation and algorithmic solution of problems. By these two teaching projects a steady stream of highly trained students for symbolic computation is produced. The curriculum is open to foreign students. Research at RISC-LINZ is possible in all fields of symbolic computation and its applications. At present it concentrates on Groebner bases, geo theorem proving, decision algorithms for real algebraic geometry, computer support for Gentzen type proving, term rewriting, parallel symbolic computation, a new computer algebra software system, collision detection and inverse kinematics in robot programming, molecule synthesis software. The RISC-LINZ research facilities are open for foreign researchers and industrial partners.

Software Demonstrations by ICOT researchers

During my stay at ICOT I had the pleasure to have life demonstrations of various ICOT software systems by the respective ICOT researchers who work on the development of these systems. Roughly, I think I had a chance to see all the software systems running that pertain to the area of term rewriting and automated theorem proving. In more detail, the demos were:

Constraint Logic Programming: by Aiba-san.

Metis (SW system for operations on term rewriting systems): by Sakai-san and Ousuga-san.

CAP Linear Algebra: by Kokubo-san and Fujita-san.

Logic and Functional Programming System: by Ida-san.

Computer-Algebra System using partial evaluation: by Takewaki-san.

CAD support system for hardware design: by Ichiko-san.

Discussions and Joint Research with ICOT Researchers

The discussions with ICOT researchers were the main activity during my stay. From the discussions about various technical aspects and subproblems of the ICOT project I think I was finally able to compose a picture about the overall structure and state of the project and of its future possible impacts. Thus, these discussions are of the deepest value for me and I am very grateful to the ICOT researchers who spent their time for these discussions. On the other hand, I hope that by some of these discussions I could contribute to some of the more technical subproblems of the project. In fact, a number of concrete working projects could be completed during my stay. Here are the details:

Discussions with Sakai-san on a Groebner bases implementation in PROLOG:

Immediately after my Groebner bases lectures, Sakai-san started to implement my Groebner bases algorithm in the Edinburgh PROLOG system on the DEC 2060. I was very impressed by the short time in which this implementation was working in PROLOG. Also it was interesting for me to see the Knuth-Bendix type strategy of pair selection implemented in my algorithm whereas I so far considered other types of strategies. I intend to conduct comparative research on this question in the future. I hope that my advice on how to organize the reduction process in the algorithm and on the use of criteria for ommitting certain critical pairs where of some help for improving the efficiency of the implementation. I hope that the availability of my algorithm in an ICOT software system will open various applications in the future. One of them was already started during my stay:

Discussions with Aiba-san on Extending the Constraint Logic Programming System:

Aiba-san is currently working on an implementation of a constraint logic programming system. For the implementation of linear constraints over the reals, Gauss' algorithm and the simplex algorithms are used. It is natural to attempt to use my Groebner bases algorithm for covering a much broader class of constraints, namely non-linear algebraic equations. For these systems my algorithm allows not only to determine all solutions if there are finitely many ones but also to decide solvability and to compute the dimension of the solution space. Sakai-sans implementation of my algorithm was linked to Aiba-sans Constraint Logic Programming Implementation and successfully applied to a number of intuitively appealing examples. The extension to non-linear systems is not yet available in other constraint logic programming systems. I adviced the authors how their system could be further extended by introducing

> Collins' cylindrical algebraic decomposition algorithm for the first order theory of real closed fields and
>
> by extending the Groebner bases method to more general systems of first-order equations.

Discussions with Takayama-san on a proof of the main theorem of the Groebner bases theory in a constructive mathematics system:

After my Groebner bases lectures I suggested to try a computer-aided proof of the main theorem of Groebner bases theory in the CAP system, in particular the linear algebra subsystem for testing out the practical power of the system. This seemed to be a reasonable goal since I have given several formally very detailed proofs of the theorem in the lectures and in the papers. Instead Takayama-san preferred to try the proof in the constructive QJ proof system which is not yet implemented. The proof could give valuable insights for the future system implementation. I carefully looked through various versions of the proof and sketched some important proof structures for the critical parts of the proof where the constructivistic nature of the proof becomes particularly important. I found the cooperation particularly enjoyable and hope that my comments could help to achieve the desired goal in shorter time.

Discussion with Furukawa-san on Guarded Horn-Clause Programming:

Furukawa-san spent some time for explaining to me the basic idea of GHC programming. I found this personal introduction particularly helpful. It saved me a lot of time in becoming acquainted with this important concept. I learned that the idea of GHC seems to be of central importance for making logic programming practically amenable to parallel execution. After having understood the basic idea of GHC programming I am now eager to make a comparative investigation on the power of GHC formulation of parallel interconnection topologies (which are oly implicit in GHC) and the explicit formulation of interconnection topologies in my own high-level parallel L-language.

Discussions with Ichiko-san on Formal Description of Parallel Computational Structures for Hardware Realization:

Ichiko-san was familiar with my L-language and L-machine papers and was interested in investigating the potential use of the L-language formalism for the flexible high-level description of parallel algorithms and their compilation into parallel hardware structure. This has been one of Ichiko-san's main research topics over the years. We spent relatively much time for going into the details of the problem and trying out some examples and made some tentative plans for cooperation on this important problem.

Discussion with Goto-san, Chikayama-san and Mr.Tick on the Future Structure of the PIM

This discussion was of particular importance for me because it gave me - hopefully - a very clear picture of one of the central issues of the ICOT project: the intended parallel hardware. I understood from the discussion that ICOT at the moment does not want to make any commitments regarding the final interconnection topology of the parallel inference machine. Rather, research at ICOT - at least for a while - will still continue to emphasize the study of parallel algorithms, in particular their locality and the language constructs necessary for describing algorithmic ideas in a high-level language. The high-level language on which research is concentrating at ICOT is GHC. I also learned from the discussion that one sees at ICOT that the expressive power of GHC is not sufficient for describing efficient embeddings of GHC generated processes into the processor landscape of a concrete machine. Thus, part of the research is also devoted to studying possible extensions of the GHC language for describing embeddings. Of course, a main research topic is execution strategies for high-level language parallel programs on a variety of machine models. In comparison, Goto-san was particularly interested in the paralllel language and hardware structures we realized in the L-project at RISC-LINZ and I explained the relevant features of our approach in great detail including some new features about the next version of the L-language which are not yet published.

Discussion with Yokoi-san on the Overall Structure of ICOT Automatic Programming Tools:

This discussion at the very end of my stay was very important for me because it showed me that the various automatic programming tools I had seen in the 1st Lab indeed meet some common objective and are not a mere juxtaposition of experiments with known methods. I learned that methods are chosen from the point of view whether or not they can contribute to transforming problem specifications into GHC logic programs.

Discussion with Morita-san on Unification Based Knowledge Base Machines

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Since my own research had never touched the area of data and knowledge base computation the presentation of Morita-san added a truely new facette to my understanding of the ICOT project. I really was impressed by seeing how sytematically the devotion to logic as a computer language is also realized in the knowledge processing branch of the project. Particularly, I of course am very sympathetic with the idea of using unification as the basic operation in knowledge retrieval and the realization by a dedicated parallel hardware.

Japans Presence in the Journal of Symbolic Computation

The Journal of Symbolic Computation was founded in 1985 by Academic Press and I was asked to act as its first Editor-in-Chief. Dr. Fuchi of ICOT and Prof. Goto of RIKEN agreed to represent Japan on the editorial board of the journal. It was one of the intentions of my stay in Japan to promote the presence of Japanese research in the Journal of Symbolic Computation. I learned that some Japanese researchers were not sure about the scope of the journal and I think I have been able to clarify matters on the basis of the editorial of our journal (see Vol. 1/1 of the Journal of Symbolic Computation). The main point is that, while it is true that the journal covers

algorithms,
software systems and
applications

of symbolic computation, its e m p h a s i s i s o n a l g o r i t h m s and software systems that have reached already a certain degree of maturity. Applications are only treated in the form of short "application letters" with reference to long papers in application journals (for example, physics journals or artificial intelligence journals). Thus, the core of the Journal of Symbolic Computation is the description, verification, mathematical foundation and analysis of a l g ó r i t h m s in the various subareas of symbolic computation, mainly in

automated theorem proving,
computer algebra,
automatic programming and
computational geometry.

I gave short overviews on the scope of the joural at all institutions I visited in Japan, see below. Furthermore, I came up with the idea of having a special issue of the journal exclusively devoted to "Symbolic Computation in Japan". I discussed this idea with Dr. Fuchi and Prof. Goto and a number of other Japanese researchers on occasion of my visits to various Japanese research institutions. The idea found emphatic support. Thus we decided to launch such an issue and I am happy to announce that the following Japanese researchers agreed to serve as guest-editors for this special issue:

Dr. T. Ida (ICOT TRS working group)
Dr. T. Sasaki (RIKEN)
Prof. R. Nakajima (U of Kyoto)
Dr. Y. Futamura (Hitachi).

The projected appearance date of the special issue is the end of 1988.

Furthermore, during my stay in Japan, I managed to work on the final versions of two papers by Japanese authors that will soon appear in the Journal of Symbolic Computation:

S. Sakata.
Finding a Minimal Set of Linear Recurring Relations Capable of Generation a Given Finite Two-dimensional Array.

Kobayashi.
The Solution of Algebraic Systems of Equations Using Factorization of U-Resultants.

Both papers are intimately connected with Groebner bases.

Visits to Other Japanese Research Institutions

During my stay at ICOT in February 1987 I also visited some other Japanese research institutions or had meeting with researchers from other institutions:

Feb 4, Nihon University:

I gave a three hours introductory seminar on Groebner bases and discussed various research topics in computer algebra with Prof. Kobayashi and his group, in particular the application of Groebner bases to the solution of algebraic systems of equations.

Feb 4, meeting with Prof. Katsura of Tohoku University:

Prof. Katsura met with me at Nihon U in order to discuss the application of Groebner bases to some special systems of equations occurring in theoretical physics.

Feb 6, Hokkaido University:

I was invited to meet with Prof. Yamamoto and Prof. Toshima. Prof. Yamamoto showed me his new implementation of REDUCE on microcomputers, which is significantly faster than A. Hearn's original implementation. Prof. Toshima wanted to discuss with me some applications of computer algebra in the education of math students. During my stay I was also introduced to the director of the BUG software company, Murata-san, who specializes in the production of commercial computer algebra systems on micros. Prof. Yamamoto showed me also his CAD system and wanted to learn about the use of Groebner bases for parameter representations of intersection curves.

Feb 26, participation in the 1987 Japanese Computer Algebra Meeting at RIKEN:

This one-day meeting was organized by T. Sasaki. By the lectures presented, it gave me a good insight into present research themes and working groups in computer algebra in Japan. The meeting also gave an opportunity to announce the special issue on "Symbolic Computation in Japan" of the JSC.

Feb 27, participation in the 1987 Japanese Meeting on Functional Programming at RIKEN:

This one-day meeting was organized by T. Ida. I gave a lecture on "The paralellization of Critical-Pair/Completion Procedures on the L-Machine." The corresponding paper will appear in the proceedings. It was possible during this meeting to see many of the researchers on TRS and to announce the special issue of the JSC on "Symbolic Computation in Japan" and to sollicitate papers.

Conclusions and Outlook

The objectives of my stay as outlined in the itroduction have been achieved to different extent:

ICOT and Japanese research in symbolic and parallel computation and relation to RISC-LINZ research:

By the many discussions and interactions with researchers from very different working groups I think I was able to acquire a relatively well structured picture about the present state of the ICOT project, in particular the ICOT research in symbolic computation and in parallel language and hardware. In addition, I think I now have also an overview on Japanese working groups in computer algebra and theorem proving all over the country, which will be particularly useful for the further development of interactions between Japanese research community and the Journal of Symbolic computation.

Comments on M a n a g e m e n t and S t r a t e g i e s:

The ICOT project is surely unique in the world. The kind of coordination for the scientific work of such a large group of top experts towards achieving a common goal is truely remarkable. It was particularly interesting for me to compare - during the same sabbatical - the American and the Japanese strategy promoting scientific execellence.

Roughly, I have the impression that America's strategy - implicitly, i. e. without being ever formulated as a program - is as follows: The country is extremely open for integrating foreigners. During my sabbatical I learned that, for example, in American computer science departments 60 % of the faculty are foreigners. Researchers are granted an extreme amount of freedom in choosing research goals, normally work in very small groups and thus the intellectual potential of the whole world is made working to produce new ideas. The best 10 % of these ideas are taken by private companies and are marketed as products.

ICOT's strategy is very different. There is the concentration of a big group and a predefined common goal, also a great extent of identification with Japan as a nation and also a certain extent of commitment to one basic idea (predicate logic on a prallel machine). The project exclusively relies on Japanese researchers. It is very hard to predict which of the strategies will be more successful.

For the time being, I drew the following personal conclusions:

a. In any case, the completion of the ICOT project will make the Japanese absolute leaders in research on the special topic of parallel implementation of logic programming languages.

b. The effect the project has as a positive impulse for Japanese computer industry is surely dramatic not regarding wether or not the predefined goal of the project can be achieved or not and whether or not a parallel logic machine will be drastically superior to any of the alternative architectures.

c. I found the integration of researchers from Japanese industrial research labs into the ICOT project an extremely good idea. Not only can the experience of these researchers be used as an input for the project but also, conversely, a steady stream of high-quality education by research takes place at ICOT and will fertilize Japanese computer industry.

d. Both America's strategy of "a t t r a c t i o n" and Japan's strategy of "c o n c e n t r a t i o n" is in sharp contrast to Austria's "strategy", which roughly is a strategy of "d i f f u s i o n": by tradition, Austria steadily produces highly-trained specialists in Austrian universities, then we let the alumnis go to other countries for work and, finally, Austria is proud that Austrians successfully work abroad. It is clear that this "strategy" can not work for long time and I will devote more effort than so far to make this vicious circle clear to the Austrian government.

e. I think, in the long run, Japan would be well advised to integrate more foreign researchers into its high-tech projects (not only as visitors but, in the "American" style, as employees). I guess the ERATO project is a step into the right direction.

Comments on P a r a l l e l Language and Parallel Hardware:

I looked to the present state of ICOT's research in parallel language and parallel hardware from the point of view of comparison with other parallel computation projects I have seen in the last year (there is a parallel computation project in nearly every American CS department!) and from the point of view of my own project on the parallel L-language and parallel L-machine.

In the area of languages I was very impressed by the elegance provided by GHC for implicitly expressing parallelism in algorithms, in particular, the dynamic spawning of subprocesses. Roughly, I think that parallel languages, in addition to language constructs for

communication and synchronization,

in the future must provide language constructs

for describing logical interconnection topologies between subprocesses and
for describing the embedding of the logical interconnection topologies into concrete machine topologies (e.g. meshes of clusters).

The L-language has

language constructs for the explicit (recursive and iterative) description of logical interconnection topologies and
language constructs for describing embeddings.

The GHC language has

no language constructs for topology descriptions and
language constructs for embedding are now designed.

Thus, the main difference between GHC and L-language is whether topologies are described implicitly or explicitly. At the moment, I am not sure which one is more desirable:

implicit description may be more elegant,
explicit description is often more natural.

I intend to study this question in more detail in the near future.

On the parallel hardware side I learned that ICOT does not intend to make a commitment to a particular architecture. ICOT concentrates on two-level clustered mesh structures and wants to study execution strategies for parallel GHC programs in such structures in the next future. This corresponds very much with the present situation of the L-project. We already tried out one particular very densely interconnected structure in the last years (the "L-machine") and now are planning to study L-language implementations on not so dense structures using commercially available components like the transputer, which was not possible some years ago. I have the feelig that in the area of hardware topologies and corresponding execution strategies the various research groups are all in a very similar state of seeing the problems but not having a really attractive solution that could be considered as a breakthrough. Maybe, this area will not provide a "breakthrough" but, hopefully, some good compromises.

Comments on S y m b o l i c C o m p u t a t i o n:

The symbolic computation projects (term rewriting, proof checking, synthesis from constructive proofs, constraint computation, simplification by partial evaluation, inductionless induction) at ICOT are closest to my main research area. The main ideas of these projects were known to me from the literature. I enjoyed the interactions with ICOT researchers on technical questions of these projects. I was first confused about how these subprojects fit into the overall ICOT project goal of autmatic programming because, at first sight, the selection of the concrete symbolic computation projects seems to be quite random. The discussion with Yokoi-san was central for my understanding of how the subprojects fit into the overall goal. Still, I guess that for making automatic programming a practically attractive tool (or set of tools) in the final pilot ICOT system, research in this area should be significantly expanded in two directions:

I think that in the current international literature many more promising methods are available than the few pursued at present at ICOT (e.g. Manna's approach, Collins' algorithm, Boyer-Moore approach, Bibel's approach);

original research on the transformation of predicate logic specification into logic programs by computer-aided proofs of algorithmically useful theorems would be necessary.

Worldwide, I think, very few creative ideas have been produced in the latter area and I could imagine that a research concentration of some formally well trained young researchers in an exploratory research effort should be able to produce some significant progress.

Seeing the ICOT research in symbolic computation also gave me a lot of insight for assessing RISC-LINZ research and teaching in symbolic computation. I started this teaching effort in 1974. Now 8 faculty are exclusively devoted to this graduate curriculum comprising about 30 special courses in symbolic computation with an emphasis on formal and creative research training. ICOT research orientation showed and encouraged me that we are on the "right track" and I will emphatically continue to expand RISC-LINZ as a research and teaching center in symbolic computation.

Promotion of Japanese Research Presence in the Journal of Symbolic Computation

I think that this objective of my stay has been fully achieved by the design of the special issue "Symbolic Computation in Japan" planned for 1988. I am really excited about this prospect and I could imagine that this project has various extremely positive effects for all partners cooperating in this endeavor. By the purely Japanese editorship of this special issue it should truly reflect Japan's important contribution to the field and stimulate a lot of scientific interaction with the international research community in particular also in the algorithmic foundations of the field. It also should have the effect of establishing the JSC as a publication forum for Japanese research in symbolic computation.

Future Cooperation between ICOT and RISC-LINZ

I hope of course that research contacts can be expanded in the future and I am grateful for the possibilities Mr. Kusama announced for sending faculty and ph.d. students from RISC-LINZ to ICOT for short term visits. However, I think that the exhange should be two-way and I will do everything I can to make visits of ICOT researchers possible at RISC-LINZ.

Acknowledgement

I was just overwhelmed by the hospitality and thoughtfulness of my Japanese colleagues at ICOT and it is hardly possible to individually acknowledge all the support, kind words, friendly invitations, arrangements and patient explanations about Japanese science, culture and daily life they provided. I am particularly grateful to Dr. Fuchi for having made this exciting stay possible, to Mr. Kusama for his experienced management and advice in every respect - personal and scientific -, to Drs. Yokoi, Furukawa and Ito for integrating me into the ICOT research community and to Drs. Sakai, Aiba, Takayama, Ida, Yokoi, Furukawa, Goto, Chikayama, and Ichiko for extensive scientific discussions and for organizing interesting and delightful experiences in Japanese restaurants and cultural institutions. I hope to see many of my Japanese friends some day at RISC-LINZ in Austria.

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Brief Scientific Curriculum Vitae

1974 -	full professor for mathematics at the Johannes Kepler University in Linz (Austria) special field: symbolic computation
1984	offer for a full professorship (computer science) by University of Karlsruhe (FRG)
1984, September	visiting professor Research Center for Natural Sciences University of Leipzig (DDR)
1984, April	visiting professor Mathematical Research Institute ETH Zürich
1983, July	visiting professor Università di Genova (Italy) Istituto di Matematica
1982 August/ September	visiting professor University of Wisconsin - Madison, Department of Computer Science
1982 Jannuary- June	visiting professor University of Delaware Department of Computer Science
1979 - 1981	Dean of the School of Technical Sciences Johannes Kepler University, Linz
1973	offer for an associate professorship by the University of Dortmund (FRG)
1973	habilitation in mathematics University of Innsbruck (Austria)
1966 - 1974	assistent professor University of Innsbruck Computer Science Institute
1970/71	research fellow Joint Institute for Nuclear Research in Dubna (Moscow) Department for Scientific Computation

1964 - 1968	programmer, systems programmer, mathematical consultant University of Innsbruck Computer Center
1960 - 1966	student in mathematics and experimental physics ph.d. 1966 (average grade 1.0) University of Innsbruck
1960	matura examination (average grade 1.0) Realgymnasium in Innsbruck

born 1942 in Innsbruck, Austrian citizen, married (1967), 3 children (1968, 1970, 1972).

Prof. Bruno Buchberger

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