The CALCULEMUS Midterm Report

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Project Data

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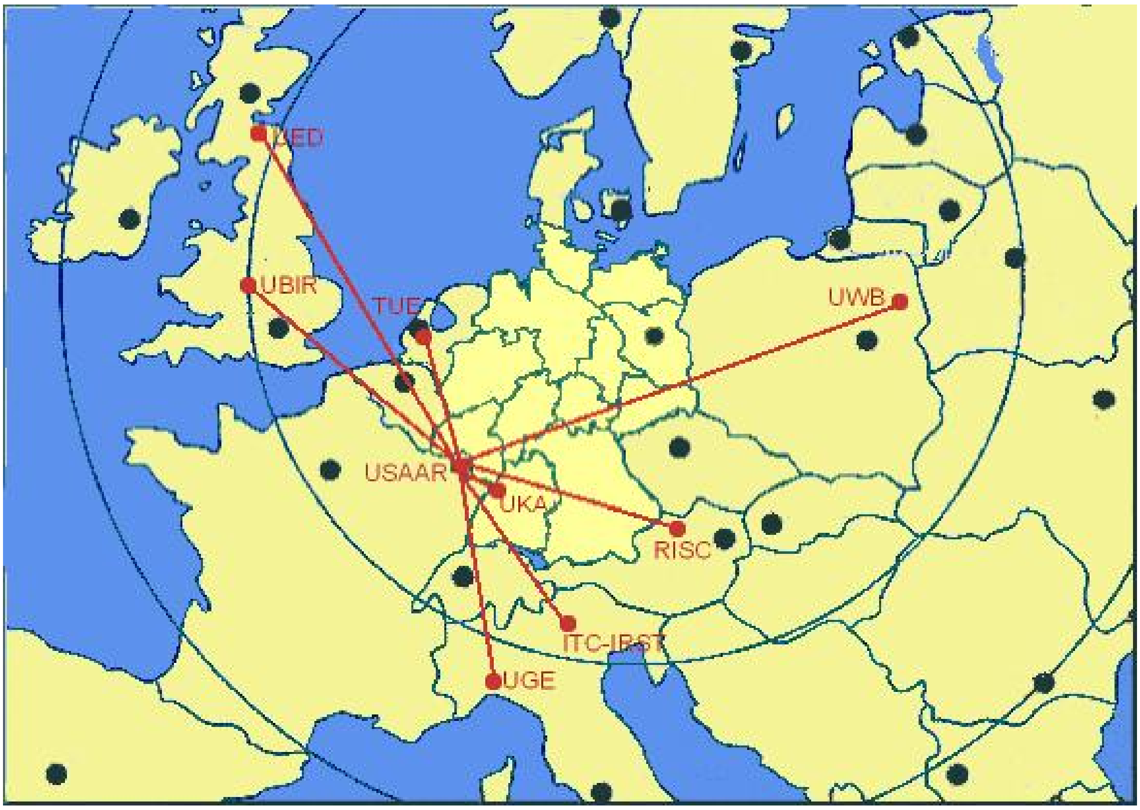
The CALCULEMUS Midterm Review Meeting is held on Monday, 31st of March in Saarbrücken, Germany. Meeting Venue is the Department of Computer Science at Saarland University and the German Research Centre for Artificial Intelligence (DFKI).

The Network Partners



USAAR	Saarland University, DFKI, and EURICE GmbH
UED	The University of Edinburgh
UKA	Karlsruhe University
RISC	Research Institute for Symbolic Computation, Linz
TUE	Eindhoven University of Technology and University of Nijmegen
ITC-IRST	Instituto per la Ricerca Scientifica e Tecnologica, Trento
UWB	University of Bialystok
UGE	Unversità degli Studi di Genova
UBIR	The University of Birmingham

Contents

Research Results

A.1 Scientific Highlights

The main research objective of the CALCULEMUS Network is to foster the integration of deduction systems (DS) and computer algebra systems (CAS) both at a conceptual and at a practical level. The point of origin for this kind of research is a landscape of heterogeneous approaches and systems on both sides of the spectrum, where the diversity on the DSs side is probably greater than on the side of CASs.

Since its start in September 2000 the CALCULEMUS Network has contributed to the convergence of DSs and CASs through its research on unifying frameworks for encoding and combining computation and deduction, the identification of the architectural requirements for a new generation of reasoning systems with combined reasoning and computational power, and the prototypical implementation and application of the improved systems. However, a single predominant theoretical framework is currently not possible. Such an approach would particularly involve predominant solutions to the still rather diverging systems at both sides of the spectrum between DSs and CASs.[1] Therefore a strong line of research in the Network focuses on the modelling and integration of CASs and DSs at the systems layer. In this research direction, significant progress has been made and several systems of project partners and other research institutes have been connected in order to form networks of cooperating mathematical service systems. The benefits and impacts of such integrations have been investigated in prototypical case studies.

The researchers of the CALCULEMUS Network also fostered the Mathematical Knowledge Management (MKM, EU MKMNET IST-2001-37057) research initiative; see [39, 8]. This relatively young line of research adopts a broader perspective on the future of mathematics (research and publication practice, education, and knowledge maintenance) in the 21st century. A significant amount of CALCULEMUS research is MKM relevant and is currently being taken up in this community in order to adopt and integrate it into the broader MKM perspective.

The extensive research activities of the CALCULEMUS Network are furthermore shown inter alia by three special issues of the Journal of Symbolic Computation [85, 4, 71] and the following international events: CALCULEMUS Symposium 2000 in St. Andrews, Scotland [64, 85], CALCULEMUS Symposium 2001 in Siena, Italy [71], CALCULEMUS Symposium 2002 in Marseilles, France [44, 48], CALCULEMUS Autumn School 2002 in Pisa, Italy [22, 23, 24, 104]

In the following paragraphs we sketch the highlights of our research in the different work tasks; for more detailed reports to all tasks we refer to [21].

Task 1.1: Mathematical Frameworks TUE and Nijmegen University investigated type theory for the purpose of formalising mathematics: Barendregt and Geuvers [20] give an overview of type theory, how it is used to represent logic and mathematics and what issues and choices come up. Type theory (encoded in OPENMATH) as a way for communicating mathematics is proposed in [19] and in [47] it is shown how a proof presentation can be generated from a formalised proof

[1] The Network is therefore also striving towards the definition of a uniform theoretical framework for DSs; see, for instance, [13] for some preliminary work.

in type theory. This paper argues that 'formal contexts' in Coq can be used as a basis for interactive mathematical documents. This topic is also treated in [83]. An in-depth discussion of the various ways to treat computations in theorem provers is given in [18] and further related work is presented in [35].

The Network has also studied other approaches to theorem proving and their capacities to integrate computations (see also [98]). This includes proof planning, as developed and employed by the nodes USAAR and UED. In the ΩMEGA system [87], at USAAR, symbolic calculations can be integrated into proof planning in two ways: (i) to guide the proof planner and to prune the search space by computing hints with control rules and (ii) to shorten and simplify the proofs by calling a CAS within the application of a method to solve equations. As a side-effect both cases can restrict possible instantiations of meta-variables. These approaches are discussed in [51, 90, 77, 88].

An investigation into the use of deduction for the implementation of correct computations within computer algebra system was considered at UGE and is presented in [1].

The THEOREMA system, developed at RISC, aims at providing one mathematical framework encompassing all aspects of algorithmic mathematics, notably the aspects of *proving*, *computing*, and *solving*; see [38, 36, 37].

In [65, 66] it is critically argued by UBIR that aspects of mathematical concepts, including procedural knowledge, are hard to reconstruct from the formalisation in deduction systems. This work points to limitations of the flexibility of mathematical representations which apply to all our current approaches.

Task 1.2: Definition of Mathematical Service The primary goal of this Task is the enhancement of existing computer algebra systems and deductive systems by turning them into *open* systems capable of using and/or providing mathematical services. After a preliminary analysis of the state-of-the-art of reasoning systems, it was decided to tackle the problem, in parallel, by a top-down and a bottom-up approach.

In the top-down approach, new infrastructures (both at the conceptual, specification, and architectural level) for the seamless integration of mathematical services have been investigated. This was intended not only for current systems, but also and in particular for future implementations. To this extent particular emphasis was on the definition of frameworks (languages, protocols, semantic specifications, architectural schemata) suitable for making mathematical services accessible over the web. The relevant top-down approaches are: OMRS (Open Mechanised Reasoning Systems) developed by UGE and ITC-IRST [2], LBA (Logic Broker Architecture) developed by UGE [6, 7], MathWeb-SB (MathWeb Software Bus) developed by USAAR [105], MathBroker developed by RISC [74]. These networks can themselves be coupled again as, for instance, exemplarily investigated in [103].

In the bottom-up approach, we have investigated how complex mathematical services can be built out of simpler ones. A particular emphasis has been devoted to decision procedures, and in particular to the integration of procedures specific for solving mathematical problems with deductive procedures. Examples for bottom up approaches are CCR (Constraint Contextual Rewriting) developed by UGE and MathSat [59, 11, 10, 9, 12], developed by ITC-IRST.

In Task 1.2 the CALCULEMUS network also closely cooperates with the EU project MONET (project number IST-2001-34145) and a joint workshop[2] has been organised by O. Caprotti in November 2002 at RISC. In MONET special ontologies comprising mathematical problems, queries and services have been defined and investigated.

Task 2.1: Integration of CASs and DSs via Protocols Cooperation among several software systems can be achieved with indirect, unidirectional and bidirectional communication. The goal of this task is to investigate how protocols can be defined to provide a semantics as well as soundness results for systems exchanging mathematical information. This definition hints at several other tasks in the Network dealing with very similar problems. This is for example true when defining a context for a computation and is partly covered in Task 1. Unidirectional and bidirectional

[2] See `www.esblurock.com/~ocaprott/mathbrokerWS.html`.

communication protocols are designed when coupling directly different modules. Although there are no direct links between the services with indirect communication, interaction is possible when systems can communicate with a common user interface, central unit, mediator or evaluator. This approach, which is partly based on a joint work with ITC-IRST on OMSCS (Open Mechanised Symbolic Computation Systems), has been investigated within the KOMET system at UKA see [43, 69, 54, 45].

A semantics can be provided by at least three approaches: (a) define a mathematical software bus, (b) define a context from which a semantic can be derived, (c) formulate the problem as a knowledge representation paradigm.

These approaches are shared by several of the partners. Indeed, they lead to introduce multi-agent systems, contexts, and ontologies to just quote a few features (see for instance the LBA and the MathWeb-SB).

Task 2.2: Enhancing the Reasoning Power of Computer Algebra Systems Enhancement of CAS with reasoning power can be attempted at different levels: (a) enhancement of CAS on the System Level, (b) enhancement of CAS on the Theory Level, and (c) enhancement of CAS on the User Level.

Direction (a) can be achieved by adding additional reasoning capabilities, i.e., logical inference systems, to algorithms built into the CAS. The Constraint Contextual Rewriting (CCR) framework developed by UGE can be used in order to integrate the evaluation mechanism of the CAS MAPLE with an appropriate decision procedure for checking side-conditions, see [1] and [5].

Direction (b) can be achieved by adding proven knowledge about CAS functions to the CAS knowledge base. The HR system, developed at UED, has been used to conjecture properties of functions available in the MAPLE algorithm library from empirical patterns detected in computational data produced by the CAS [52].

Direction (c) can be achieved by giving the CAS user the possibility to prove mathematical statements using proof techniques from logic within the CAS in addition to the computing facilities that each CAS offers. In the framework of the CALCULEMUS Network, the work of RISC represents this aspect of CAS enhancement: The THEOREMA system, see [40], is an add-on package for the widespread and popular CAS *Mathematica* where the user formulates mathematical theorems and proves them entirely within the *Mathematica* environment.

Task 2.3: Enhancing the Computation Power of Deductions Systems UED investigated the combination of the proof-planner $\lambda Clam$ [86] with other systems for computationally costly tasks. This includes (a) an implementation of the GS flexible decision procedure system framework in (Teyjus) LambdaProlog and within the $\lambda Clam$ proof planning system [41] and (b) the integration of the $\lambda Clam$ proof-planner into the MathWeb-SB system [53].

UED also investigated the combination of systems to discover attacks to security protocols [91, 92]. This work makes use of computational power in that it generates a large number of clauses in its processing.

Further relevant work has been done in the $\lambda Clam$ proof-planner to construct very large and modular proof-plans for complicated real analysis theorems [60, 72, 73].

The ΩMEGA proof planner at USAAR has been coupled with different CASs via MathWeb-SB, see [90, 77, 88]. The ΩANTS approach to integrate CASs into mathematical assistant systems is sketched in [28, 27, 33, 34]. This work proposes an agent-based modelling of inference rules and external systems at a very basic level within theorem provers.

Finally, work done at UBIR and UGE which render techniques from automated reasoning highly efficient by using enhanced computational power are presented in [61, 62, 63] and [9, 12, 3]. Further relevant work is given in [84].

Task 3.1: Automated Support to Writing Mathematical Publications Typically, a mathematical publication contains the following ingredients: natural language text, mathematical formulae, formal text (i.e. definitions and theorems), proofs, examples (typically with computations), and graphics (tables, drawings, sketches, etc.). In the optimal case, a software system for supporting mathematical publications would support all these facets of mathematical publications. Several systems and languages have been used for case studies in this area:

(a) The MIZAR approach (at UWB) is based on two kinds of software which automate the process of writing formal mathematical papers: (i) software used to prepare an article as a formal text whose correctness is computer verified and (ii) the software for automatic (or semi-automatic) translation into natural language (particularly English); this includes also the software for translation into XML-based formats. The cooperation with other CALCULEMUS sites includes development of the MIZAR Mathematical Library (MML) and also the above mentioned translation into XML formats. Relevant publications are [81, 58, 15, 16, 17].

(b) THEOREMA is a prototypical software system designed to give computer-support to the working mathematician during all phases of mathematical activity. Several features qualify THEOREMA as a powerful system for creating mathematical publications entirely inside the system. “Classical” mathematical documents can be written that are intended mainly for printout, as for instance the thesis [101] or the conference papers [99], [100], and [102]. In the case studies, however, emphasis has been put on using the THEOREMA system for developing interactive lecture notes for university mathematics courses. Mostly since the THEOREMA language is very similar to the language used in “ordinary mathematics” the system is highly suitable for this approach, both in illustrating computation-based courses as well as in supporting proof-oriented courses.

(c) The OMDOC [67] content markup scheme which has been developed at USAAR, supports authors with writing formal mathematical documents including articles, textbooks, interactive books and courses. OMDOC allows to capture the semantics and structure of these documents. Various tools are available to transform OMDOC documents into other formats for presentation purposes (using, e.g., MathML) or to support inter-system communication (e.g., by transformation into the logic of a theorem prover).

(d) TUE has developed the MATHDOX tool supporting interactive mathematical documents. MATHDOX is based on DOCBOOK but also has similarities to OMDOC.

Task 3.2: Support to the Development of an Industrial-Strength Application of Formal Methods to Program Verification In addition to formal methods, which is undoubtedly the most important application area for our research, we have identified the education sector as another interesting application for DSs and CASs. Actually the systems THEOREMA (RISC) and ACTIVEMATH [80] (USAAR), which make use of tools and approaches developed in the CALCULEMUS Network, are already employed in education practice. Another example is the MATHDOX tool developed at TUE since the next version of the interactive textbook *Algebra Interactive!* [50] will appear in this format.

Formal method applications currently pursued in the Network include (a) an approach to support the verification of hybrid systems with the help of mathematical services in MathWeb-SB [26, 25] — cooperation of UGE, USAAR, UED, (b) the investigation whether specialised reasoning tools within the MathWeb-SB can fruitfully support the formal verification of information flow properties and error detection in security protocols [12] — cooperation of UGE, USAAR, UED, ITC-IRST, and (c) the application of proof planning in first-order linear temporal logic (FOLTL) to feature interactions as they arise in large telephone networks [49] — at UED.

Task 3.3: Support to the Solution of Undergraduate Exam in Calculus and Economics In this Task we focus on simple, mathematics education oriented problems with a strong emphasis on the particular way the problems are solved, how interaction with the user is supported and how the solution is presented. We analyse whether our systems can be employed in a user friendly and adequate way and whether the interaction and maths presentation capabilities of the systems are appropriate.

A task relevant case pursued at Nijmegen University compares how the problem of proving the irrationality of $\sqrt{2}$, which involves computations, can be proved in fifteen different theorem proving environments (including systems of the CALCULEMUS Network) [98, 97, 89, 32, 88].

Among the case studies that are currently being started at USAAR are exercises from the German *Bundeswettbewerb Mathematik* and Calculus exercises being encoded and investigated in the ACTIVEMATH project. Empirical studies at USAAR investigates the phenomena of natural language dialog with mathematical assistant systems on proof exercises in naive set theory.

Task 3.4: Modelling of Existing Systems as Mathematical Services The work in this Task so far has concentrated both on developing the required infrastructure (languages, protocols, semantic specifications, architectural schemata) for making existing systems inter-operate, and on studying extensions and enhancements of the reasoning capabilities of some existing tools. The relevant contributions are: (i) MathSat framework developed at ITC-IRST [11, 10], (ii) the RDL (Rewrite and Decision procedure Laboratory), (iii) the LBA [6, 7, 103] developed by UGE, (iv) the modelling of existing systems, for instance, $\lambda Clam$ developed at UED [86], as mathematical services in MathWeb-SB developed at USAAR [53].

Further work at USAAR concentrates on the mediation of mathematical knowledge between the mathematical knowledge base MBASE, which has been integrated to the MathWeb-SB, and mathematical assistant systems such as ΩMEGA [55, 32, 31].

Task 3.5: Challenge Mathematical Problems During the work on the above tasks some challenging mathematical problems had to be tackled already, in order to have non-trivial working examples. Some of the examples were done either by single partner nodes or in collaboration between some of the nodes. The examples include: (i) Fundamental Theorem of Algebra [57, 56], (ii) Involutive Bases [46, 42], (iii) Exploration in Finite Algebra, (iv) The Residue Class Domain [75, 78, 76, 77], (v) Proving with Invariants [79], (vi) The Jordan curve theorem for special polygons, (vii) Continuous lattices [68], (viii) Order sorted algebras [95, 93, 94], (ix) Proofs in Homological Algebra, (x) Proofs in Graph Theory, (xi) Exploration in Zariski Spaces. Further related work is given in [29, 30].

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A.2 Joint Publications and Patents

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[PISA-II] C. Benzmüller and R. Endsuleit, editors. *CALCULEMUS Autumn School 2002: Course Notes (Part II)*, number SR-02-08 in SEKI Technical Report, 2002.

[PISA-III] C. Benzmüller and R. Endsuleit, editors. *CALCULEMUS Autumn School 2002: Course Notes (Part III)*, number SR-02-09 in SEKI Technical Report, 2002.

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Comparison with the Joint Programme of Work

B.1 Project Objectives

The project objectives as laid down in the work programme are still urgent and achievable; they are

1. *outline the design of a new generation of mathematical software systems and computer-aided verification tools;*
2. *the training of young researchers in the broad field of mechanical reasoning and formal methods;*
3. *the dissemination of the results both in industry and in academia; and*
4. *the cross-fertilisation and amalgamation of the automated theorem proving (ATP/DS), computer algebra (CAS), term rewriting systems (TRS), interactive proof development systems (ITP) and software engineering (SE) research communities.*

B.2 Research Method and Work Plan

The methodological approach and the break down of the work programme into single tasks have turned out to be reasonably defined and are still valid.

Except for a slight delay at the beginning of the Network, due to several reasons, most notably to attract and hire YVRs at a time e-commerce was still considered a gold mine, there are no significant differences for the work plan as envisaged in the contract.

However, for some work packages we propose a slight adaptation/broadening of the research tasks:

3.2 (Industrial-strength Applications) There are two main application areas for the systems and approaches developed in the Network: (i) Formal Methods and (ii) Mathematics Education. While the original work plan mainly focused on (i) the proposal is to additionally investigate (ii). At RISC the THEOREMA system is, for instance, already employed in practice to teach students in courses and similarly the ΩMEGA system is used within the mathematical tutor system ACTIVEMATH.

3.3 (Exams in Calculus and Economics – Harvard) We propose to allow more flexibility with respect to the concrete mathematical domain to be chosen for the comparative analysis of the experimental results on using the prototype systems. Related work has already been completed on comparing solutions of different systems for the problem of proving the irrationality of $\sqrt{2}$.

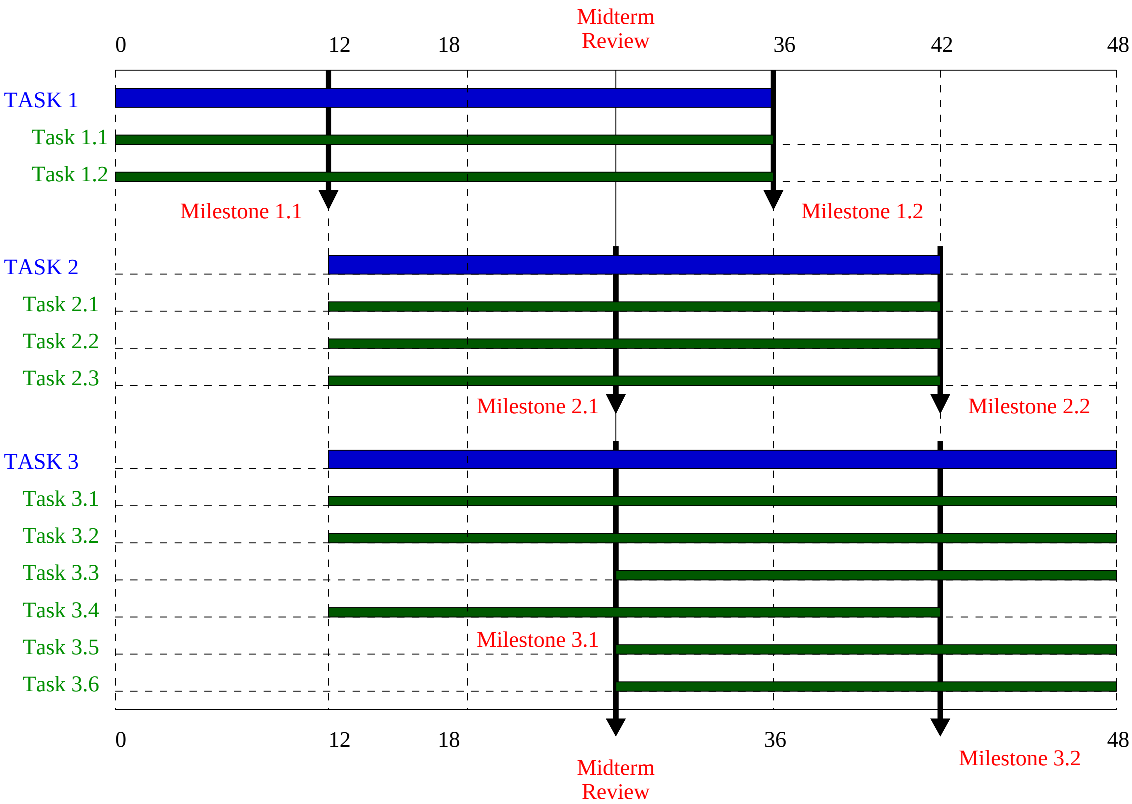

Figure B.1: Scheduling of the tasks

3.5 (Challenge Mathematical Problems) The formalisation and (semi-)automation of some challenging mathematical problems with our approaches and systems is possible but typically requires special techniques and very experienced users. Therefore, we propose to additionally investigate to what extent our systems also support non-expert and novice users in doing normal and every day mathematics with a computer.

B.3 Schedule and Milestones (where relevant)

According to the agreed work programme the midterm assessment criteria are:

Milestone 1.1 Basic Research (after 12 months) *Deliverable: Mathematical Frameworks for (i) incorporating symbolic computation in type theory, (ii) extending symbolic computation with deduction. Definition of Mathematical Service.*

Milestone 2.1 Systems Enhancement (after 24 months) *Deliverable: Design and demo of a prototype implementation of a protocol for coarse grained interaction between CASs and DSs. Design and demo of prototype implementation of a CAS enhanced with deductive power. Design and demo of a prototype implementation of a DS enhanced with symbolic computation.*

Milestone 3.1 Case Studies (after 24 months) *Deliverable: Report on experiments on using the prototype systems as support for writing a mathematical subject. At the corresponding Network workshop the partners will determine the systems (i.e., the approaches) most suited to* *tackling Task 3.1 and Task 3.2.*

The Networks' detailed joint report [21] provides an in-depth overview on the progress made in *all work packages* and subsumes single milestones reports. Demonstrations of prototype implementations as required in Milestone 2.1 will be offered at the Midterm Review Meeting. See also `www.risc.uni-linz.ac.at/people/wwindste/Research/Calculemus/Task2.2.html` and `www.risc.uni-linz.ac.at/people/wwindste/Research/Calculemus/Task3.1.html` for further information.

Taking the few months overall delay of the Network into account the schedule given in Figure B.1 is still valid.

B.4 Research Effort of the Participants

The research effort of the participants is illustrated by the following table:

No.	**Site**	Young researchers financed by the contract (person-months)	Researchers financed from other sources (person-months)	Researchers who contributed to the project (number of individuals)
1	USAAR	*27*	30	8
2	UED	*19*	29	7
3	UKA	*9*	20	3
4	RISC	*17*	30	7
5	EUT	*14*	30	4
6	ITC-IRST	*21.5*	31	7
7	UWB	*11*	14	5
8	UNIGE	*17*	13	3
9	UBIR	*8*	14	4
	Total	*143.5*	211	47

B.5 Networking Activities

Conferences, Workshops, and Network Meetings In 2002 the Calculemus Network organised or participated in the scientific events listed below. These events were particularly used for frequent scientific discussions and the training of young researchers.

- Calculemus **Symposium in St. Andrews**, Scotland, August 6th-7th, 200. The Calculemus Symposium 2001 was collocated with the International Symposium on Symbolic and Algebraic Computation, ISSAC 2000.

  Highlight of the event was the invited talk by Gaston Gonnet Institute for Scientific Computation, ETH Zürich, Switzerland, and the joint invited talk by Prof. Henk Barendregt, Nijmegen University and Prof. Arjeh Cohen, TUE.

  Contributions of the event were published as a book by A.K.Peters [64] and selected papers did appear in a Special issue of the Journal of Symbolic Computation [85].

- CALCULEMUS **Symposium in Siena**, Italy, June 21st-22nd, 2001. The CALCULEMUS Symposium 2001 was held in conjunction with the International Joint Conference on Automated Reasoning (IJCAI). This event particularly fostered the interaction of the CALCULEMUS community with the deduction systems community. A result of this ongoing interaction is that CALCULEMUS is becoming a full member of the next IJCAR conference to be held in 2004 in Cork, Ireland.

  Highlight of the CALCULEMUS Symposium 2001 was the invited talk of Prof. Doron Zeilberger, Department of Mathematics, Temple University , Philadelphia, USA.

  Selected papers of the proceedings were published in a special issue of the Journal of Symbolic Computation [71].

  Participants: approx. 70

- CALCULEMUS **Network Meeting in Genova**, Italy, February 14th-15th, 2002:
  This internal meeting was used to identify and discuss the Networks' main bottlenecks. The two days meeting was split into a scientific part and an organisational part. The scientific part was used to discuss the current state of all work packages. The emphasis, however, was on the work packages 1 and 2. In the organisational part measures were discussed and decided to improve the internal communication strategy and to force better YVR hiring strategies; see also Section B.6. Furthermore, the organisation of the CALCULEMUS Autumn School was addressed.

  Participants: approx. 31 **Network Participants: approx. 31**

- CALCULEMUS **Symposium in Marseilles**, France, July 3rd-5th, 2002: The CALCULEMUS Symposium 2002 (`www.ags.uni-sb.de/~calculemus2002`) was held in conjunction with the AISC 2002 Conference: Artificial Intelligence and Symbolic Computation – Theory, Implementations, and Applications. The joint event (with joint proceedings in the Springer LNAI series; see [44] in publication list) fostered the interaction of the CALCULEMUS interest group and the symbolic computation community. Highlights of the event were the invited talks of Prof. Claude Kirchner, INRIA Paris, France, and Prof. Thomas Sturm, University Regensburg, Germany, and the CologNet Panel Discussion on *Challenge Mathematical Problems* chaired by Prof. Jacques Calmet with Prof. Alain Colmerauer, Prof. James Davenport, Prof. Claude Kirchner, Prof. Jörg Siekmann, and Prof. Thomas Sturm as panelists.

  The proceedings of the Symposium, appeared in the Springer LNAI series [44] and selected papers will be published in a special issue of the Journal of Symbolic Computation. Work in progress papers, including contributions of YVRs from the CALCULEMUS Network, are published in [48].

  Participants: approx. 45 **Network Participants: approx. 18**

- CALCULEMUS **Autumn School**, Pisa, Italy, September 23th - October 4th, 2002. More details on this central training event of the Network will be given in Section C.2.

  The course notes of the event are published in [22, 23, 24] and the student poster abstracts in [104].

  Participants: $\geq$ 75 **Network Participants: approx. 30**

- **Several Task Force Meetings**. Special task force meetings were held in conjunction with CALCULEMUS Network meetings in

  - CALCULEMUS Network Meeting in Siena, Italy, 2001
  - CALCULEMUS Network Meeting in Genova, Italy, 2002
  - CALCULEMUS Symposium in Marseilles, France, 2002
  - CALCULEMUS Autumn School in Pisa, Italy 2002

Participants: approx. 5-10 **Network Participants: approx. 5-10**

- **Topic related Workshops and Tutorials** Members and YVRs of the Network did organise or participate in several topic related smaller workshops and tutorials. Among them are:
  - The yearly Clam-INKA-OMRS Workshops (CIAO) with participants from USAAR, UED, UGE, and UBIR; see `http://www.dfki.de/CIAO-2003/`
  - A joint Workshop of the CALCULEMUS and the MONET project (IST-2001-34145) organised in November 2002 at RISC with participants from RISC, USAAR, ITC-IRST, and TUE; see `http://www.esblurock.com/~ocaprott/mathbrokerWS.html`
  - An ΩMEGA Tutorial at UBIR with participants from USAAR and UBIR
  - A THEOREMA-ΩMEGA Meeting to be held at RISC in May 2003

Joint System Development and Joint Applications The following figures illustrate the joint system developments and the joint application scenarios of the CALCULEMUS partners.

System, Language, Software	Developed/Employed by the following nodes
OMDOC	USAAR,UBIR,UED,UWB
MathWeb	USAAR,UBIR,UGE,UED
ΩMEGA	USAAR,UBIR
MIZAR	UWB,TUE
MathSat	ITC-IRST,UWB

Application	performed by the following nodes
Irrationality of $\sqrt{2}$	TUE,USAAR,UWB,RISC
Exploration of Residue Classes	USAAR,UBIR,UED
Permutation Groups	USAAR,UBIR,TUE
Zariski Spaces	UBIR,UED
Hybrid Systems	USAAR,UGE,UED
Correct Functions in MAPLE	UKA,UED,UGE
Security Protocols	UED,UGE,ITC-IRST
Model Checking for Real-Time Systems	ITC-IRST,UWB

B.6 Network Organisation and Management

End of 2001 Christoph Benzmüller from USAAR has taken over the scientific coordination of the CALCULEMUS Network. A first action together with Corinna Hahn from Eurice GmbH was to encourage the partners to spend more effort in the hiring of young researchers in order to reach the dominant training goals. The situation before the meeting in Genova in February was unsatisfactory since most nodes were still far behind the proposed employment figures while few nodes had already successfully hired YVRs. The scientific results were in most cases also slightly behind the proposed work plan. A main measure to improve the situation was the proposal to initiate a respective redistribution of YVR person months from underspending nodes to nodes with overspending capacities in case the situation would not have been improved by July at the CALCULEMUS Symposium in Marseilles. As a consequence the employment situation improved since the beginning of 2002. The employment figures in total are no longer behind the proposed figures. The individual figures differ slightly; this is also because the work plan is not balanced with respect to the YVR employment figures for each partner.

A major idea of the CALCULEMUS Network was to organise industry internships for the YVRs. The coordinator strongly encourages YVRs and host nodes to organise such internships and was involved in the initiation of the ongoing or agreed industry internships of the Network so far.

However, for several reasons (which we will discuss in more detail in Section B.8) the network is still behind the possible figures of actual internships.

The main communication means of the CALCULEMUS Network are presented in Figure B.2. Particularly the CVS repository at USAAR turns out as a very useful tool. CVS supports the *direct* joint development of documents such as the CALCULEMUS Network Report [21]; for this purpose it has proved far more flexible and useful than information exchange solely via e-mail or web-pages.

B.7 Cohesion with Less Favoured Regions and Associated States

The MIZAR group from Bialystok (UWB), Poland, is fully integrated in the project and is the Networks' leading figure in the development of large bodies of formalised mathematics. In order to get access to the rich content of the MIZAR mathematical library developed at UWB the Network (involving YVRs) is currently developing tools that translate from MIZAR to other formats, such as OMDOC or first-order logic, which support the exchange of information with other systems of the Network.

UWB is also integrated in the exchange of YVRs between nodes (see, for instance, M. Moschner) and UWBs YVR employment figures are very good. Actually UWB meanwhile has a need for further YVR person months.

Another aspect that illustrates how well UWB is integrated into the CALCULEMUS and the broader MKM community is that UWB will host the next MKM Conference to be held in 2004.

B.8 Connections to Industry

It was foreseen that the networks training programme comprises industry internships of YVRs in affiliated companies. The completed, ongoing, agreed or planned internships include:

- Corrado Giromini: at a telecommunication company near Edinburgh
- Jürgen Zimmer: at the same company
- Andreas Meier: at a car component supplier, Germany
- Luca Compagna: at an electronic group, Germany
- further internships are planned at RISC and ITC-IRST

The internship figures at present are still behind the proposed/expected figures. There are several reasons for this:

- Some YVRs agreed only to very short stays; there was not sufficient time for an additional industry internship. Example: Simon Colton's stay at UKA and Silvio Ranise's stay at USAAR.
- Some YVRs work on topics that are thematically not compatible with an industry internship. Example: Martin Pollet's work at UBIR.
- The individual nodes interests in spending their YVRs person months in industry internships is subdominant to their interest in spending them in their CALCULEMUS research interests.

The network currently works hard to improve the industry internships figures. However, since they clearly make no sense for *all* YVRs of the network, we will propose a slight adaptation of the industry intership clause of the Networks training programme; see Section F.

e-mail	calculemus-ihp@ags.uni-sb.de	Network Researchers and YVRs
	calculemus-ihp-steering@ags.uni-sb.de	Network Steering Committee
	calculemus-autumn-school@eurice.de	Autumn School Organisation Team
	calculemus2002school@ags.uni-sb.de	Autumn School Participants
Web	www.eurice.de/calculemus/	Network Homepage
	www.eurice.de/calculemus/autumn-school/	Autumn School Homepage
Web	www.win.tue.nl/~smurray/calculemus/eut.html	Partner Nodes CALCULEMUS Web-sites
	www.ags.uni-sb.de/~chris/calculemus/SB-reports/report.html	
	www.risc.uni-linz.ac.at/people/wwindste/Research/Calculemus/RISC.html	
	www.cs.bham.ac.uk/~mmk/projects/CALCULEMUS/	
	mizar.uwb.edu.pl/calculemus/	
	www.mrg.dist.unige.it/~armando/calculemus/genova.html	
	www.uni-karlsruhe.de/Uni/	
	dream.dai.ed.ac.uk/calculemus/	
	sra.itc.it/projects/calculemus/node_report.html	
	...	...
	Further Task Report Web-sites	
	...	...
CVS	Concurrent Version Control System maintained at USAAR	Joint Document Development
	(contact pollet@ags.uni-sb.de for access)	
	(see also www.ags.uni-sb.de/~chris/calculemus-cvs/)	

Figure B.2: Communication infrastructure of the CALCULEMUS Network.

Training

C.1 Appointment of Young Researchers

The following table illustrates the latest employment figures of the Network:

Participant	Contract deliverable of Young Researchers to be financed by the contract (person- months)			Young Researchers financed by the contract so far (person-months)		
	PreDoc (a)	PostDoc (b)	Total (a+b)	PreDoc (c)	PostDoc (d)	Total (c+d)
USAAR	18	15	33	22	5	27
UEDIN	26	16	42	19	0	19
UKA	24	15	39	6	3	9
RISC	18	13	31	17	0	17
EUT	24	14	38	2	12	14
ITC-IRST	26	17	43	0	21.5	21.5
UWB	12	3	15	8	3	11
UNIGE	11	8	19	12	5	17
UBIR	8	8	16	8	0	8
TOTAL	167	109	276	94	49.5	143.5

C.2 Training Programme

The training measures of the Network include:

1. Training at an Individual Level at the Network Nodes,

2. Local Courses, Workshops, Talks, and Seminars,
3. Exchange of YVRs between Network Nodes,
4. Industry Internships,
5. Participation in Network Meetings and Joint Training Measures.

In many cases the work of YVRs in the CALCULEMUS Network either lead to a PhD project (an example is C. Giromini) or was already a priori thematically related to their PhD project (examples are J. Zimmer and M. Pollet).

Training at an Individual Level The training measures at the individual level comprises supervision of YVRs by the Network's senior researchers, the introduction to the approaches, systems, languages and tools employed and developed at the individual partner nodes, and the YVRs social integration to the respective research groups, which typically stimulates intellectual exchange with the other group members.

An example for training at an individual level is the introduction of YVRs to the tools and systems at USAAR. These introductions are typically given by other young researchers of USAAR (including other YVRs of the Network) supervised and coordinated by the senior researchers. For instance Jürgen Zimmer introduces YVRs to MathWeb-SB, Andreas Franke to MBASE, Andreas Meier and Martin Pollet to ΩMEGA. This immediate contact between young researchers has a positive effect on networking aspects and may even lead to joint publications amongst them; see [55].

Training by Local Courses, Workshops, Talks, and Seminars In their role as university professors or lecturers the senior researchers of the CALCULEMUS give courses at their host institutes. Often these courses are directly related to the research interests and tasks of the CALCULEMUS network. For instance, Bruno Buchberger and Wolfgang Windsteiger at RISC already actively employ the THEOREMA system for mathematics education in university courses.

In addition to the university courses the YVRs are trained by their participation in local talks, seminars, and group meetings. There are also frequent visits and invited talks of CALCULEMUS senior researchers at partner nodes which contribute to the local training of YVRs. In 2002, for instance, J. Siekmann visited UGE, UBIR, and RISC, A. Bundy visited UGE, and C. Benzmüller visited UBIR, to name just a few of these visits.

Exchange of YVRs between Network Nodes If possible the YVRs of the Network visit more than just one of the Network nodes. Examples are:

- J. Zimmer from USAAR visited UGE and UED, and participated in a tutorial/workshop at RISC.
- M. Moschner visited USAAR and UWB.
- C. Giromini from UGE visited USAAR and UED, and did give an invited presentation at UBIR.
- S. Colton from UED visited UKA and as part of this stay also USAAR.

Training by Industry Internships The industry internship aspect has already been addressed in Section B.8 and examples for completed, ongoing or agreed internships were given. We emphasise here again, that we want to concentrate on such industry internships which are thematically compatible with the work and research program of the YVRs in the Network in order to guarantee a maximum benefit for both sides.

Training by Participation in Network Meetings and Joint Training Measures The Networks YVRs usually attend all the Conferences, Workshops and Meetings that take place during their employment period. The respective events organised so far have been listed in Section B.5. Amongst those events the main joint training measure was the CALCULEMUS Autumn School 2002 in Pisa.

The CALCULEMUS Autumn School 2002 (see `www.eurice.de/calculemus/autumn-school/`) was held September 23rd — October 4th in Pisa. It was organised in a cooperation between USAAR (Christoph Benzmüller and Jörg Siekmann), UKA (Regine Endsuleit and Jacques Calmet), Eurice GmbH (Corinna Hahn), and University of Pisa (Carlo Traverso).

Two further events were co-located with the event: (i) an OPENMATH workshop and (ii) an MKM Network kick off meeting.

CALCULEMUS Autumn School had more than 75 participants (including the lecturers; some of them did attend all courses as well). The participants split into undergraduates, postgraduates, postdocs, and experienced researches. All current Young Visiting Researchers of the Network were present. In order to support participation of students from outside the Network 26 student grants were available in the EU IST programme. Due to these grants several students, for instance, from eastern European countries were able to attend the school which could not have attended without support. Since all participants, including the lecturers, were accommodated at the former monestary Santa Croce in Fossabanda, many discussions and interactions were fostered aside from the main programme.

The participants were trained both theoretically and experimentally on selected topics and tools. They were given the opportunity to experiment with the main tools of this area and to interact with the researchers developing them.

In addition to representatives from all CALCULEMUS Network nodes further experts from the field were invited, such as Prof. James Davenport (University of Bath, England), Prof. Tobias Nipkow (TU Munich, Germany) and Prof. Christoph Kreitz (Cornell University, Ithaca, USA). The other lecturers were: Alessandro Armando (UGE), Christoph Benzmüller (USAAR), Bruno Buchberger (RISC), Alan Bundy (UED), Jacques Calmet (UKA), Arjeh Cohen (TUE), Herman Geuvers (Nijmegen University, Netherlands), Fausto Giunchiglia (ITC-IRST), Dieter Hutter (DFKI, Germany), Manfred Kerber (UBIR), Michael Kohlhase (Carnegie Mellon University, USA), Ursula Martin (University of St. Andrews, Scotland), Andreas Meier (USAAR), Erica Melis (DFKI, Germany), Marco Pistore (ITC-IRST), Marco Roveri (ITC-IRST), Jörg Siekmann (USAAR), Volker Sorge (UBIR), Werner Stephan (DFKI, Germany), Czeslaw Bylinski (UWB), Wolfgang Windsteiger (RISC), Tom Kelsey (University of St.Andrews, Scotland), Olga Caprotti (RISC)

We briefly discuss the impact and success of the Autumn School which was in fact the first major international display of *all* major system developers in this interdisciplinary area.

1. Training: The success of the CALCULEMUS Autumn School as a training measure for students has been evaluated by a questionnaire. The evaluation of this questionnaire shows that the overall concept of the school which had many short lectures of max. 3 hours was highly appreciated by the participants. The idea of the school was to provide a complete overview of CALCULEMUS relevant topics instead of picking out just a few single aspects and presenting them in full detail; see also the Course Notes of the Autumn School published in [22, 23, 24].

   This way the participants particularly had the opportunity to get into contact with the research topics and senior researchers from all partner nodes of the CALCULEMUS Network. The questionnaire also shows that Autumn School indeed optimally targeted students at the postgraduate level, since their overall ratings of the School were the best; but also the ratings given by undergraduates and postdocs are highly satisfying.

2. Student Posters: The students (including YVRs from the Network) were asked to give poster presentations on their current research projects; see also the student poster abstracts in [104]. This particularly supported an important flow of information from Network and non-Network

students to the lecturers and the senior scientists of the Network. Many discussion and new research ideas were fostered.

3. Networking and External Research Contacts: Networking was strongly supported by the Autumn School at various levels (i) amongst young visiting researchers, (ii) between students and lecturers, (iii) between lecturers, and (iv) between the CALCULEMUS Network and related interest groups due to the co-located OPENMATH workshop and MKM kick off meeting. The informal atmosphere particularly fostered new social contacts.

4. Dissemination of Results: Due to the high number of participants and the wide announcement of the school, the event web-site, the preparation of notes, etc., the event strongly contributed to a dissemination of the Networks' research results.

5. Recruitment of YVRs: The event provided an excellent opportunity for the recruitment of new YVRs. From the recruitment perspective it seems to be a valuable suggestion for research training Networks' to organise such an event approximately at the beginning of the second year; i.e. several months earlier as we did in the CALCULEMUS Network.

C.3 Factual Information on the Young Researchers

Name	National.	Age at App.	Start of Appointm.	End of Appointm.	Categ.	Speciality	Place of Work	Country of Work	Prev. Exper. in Netw.
Adams, Andrew	British	31	01.07.01	30.09.01	PostDoc	Theorem proving with the real numbers: PVS system	USAAR	D	
Audemard, Gilles	French	29	01.11.01	31.08.02	PostDoc		ITC-IRST	IT	
Aransay Azofra, Jesus Maria	Spanish	24	01.06.01	30.11.01	PreDoc; PhD student	Verification of computer algebra systems with theorem powers	UKA	D	
Colton, Simon	British	29	01.10.01	31.12.01	PostDoc	Integration of HR in MathWeb-sb, Soundness of Maple Functions	UKA	D	
Compagna Luca	Italian	27	01.08.02	30.11.02	PreDoc; PhD student	Verification of security protocols	UED	UK	UED, 10.07.01–10.10.01
Craciun, Adrian	Romanian	24	01.09.01	30.06.03	PreDoc; PhD student	Automatic Reasoning	RISC	A	
De Lucia, Pasquale	Italian	25	01.07.02	30.08.02	PreDoc	Integration of Decision Procedures in MathWeb-sb	USAAR	D	
Duncan, Hazel	British	21	21.10.02	21.12.02	PreDoc; PhD Student	Automatic Theorem Proving	UWB	PL	
Ganty, Pierre	Belgian	22	01.09.02	01.04.03	PreDoc	Verification of security protocols	UGE	IT	
Giero, Mariusz	Polish		01.01.03	31.12.03	PreDoc	Formalization of the Jordan Curve Theorem in Mizar	TUE	NL	
Giromini, Corrado	Italian	25	01.03.02	30.05.03	PreDoc	Formal methods and knowledge management	USAAR	D	UED, 01.12.02–28.02.03
Kornilowicz, Artur	Polish	32	16.07.01	30.06.02	PostDoc	Computer Science	ITC-IRST	IT	
Moschner, Markus	Austrian	35	01.10.02	31.12.02	PostDoc	Mathematical knowledge bases; protocols for the exchange of mathematical knowledge	UWB	PL	USAAR, 01.06.01–31.05.02
Murray, Scott	British	30	01.08.01	31.07.02	PostDoc	Mathematics and Deduction Systems	TUE	NL	
Musset, Julien	French	26	21.09.02	20.12.02	PreDoc; PhD student	Verification of infinite states system	UED	UK	
Pollet, Martin	German	30	01.06.02	31.08.02	PreDoc; PhD student	Knowledge representation, proof planning	UBIR	UK	UBIR, 01.10.01–28.02.02
Ranise, Silvio	Italian	30	01.10.01	30.11.01	PostDoc	Integration of Decision Procedures, Rewriting and Theorem Proving	USAAR	D	
Rosenkranz, Markus									
Stratulat, Sorin	Romanian	29	01.05.01	30.09.01	PostDoc	Automated reasoning	UGE	IT	
Urban, Josef	Czech	28	15.02.02	15.08.02	PreDoc; PhD student	Mathematics, computer science	UWB	PL	
Zimmer, Jürgen	German	29	01.10.01	31.03.02	PreDoc; PhD student	Networks of reasoning services, inductive proof planning and computer algebra computations	UED	UK	UNIGE, 01.01.01–07.07.01

Sketches of the Young Researchers

Sketches of YVRs are appended to this document (see the Appendix). Some of the YVRs did not send back their sketch sheets in time; we will add this information and forward it to the EU as soon as we receive it.

Network Financing

Partcipant	Cost Categories (spent to date, €)				Estimated Eligible Costs (foreseen in the contract, €)			
	Personnel	Networking	Overheads	Total	Personnel	Networking	Overheads	Total
USAAR	91651.74	54158.30	29162.00	174972,04	92750.00	56772.00	29904.40	179426.40
UEDIN	39545.08	8577.88	9624.60	57747.56	73510.00	20449.00	18791.80	112750.80
UKA	31012.50	12648.35	8732.17	52393.02	97250.00	23117.00	24073.40	144440.40
RISC	28177.52	24886.20	10612.74	63676.46	77380.00	20600.00	19596.00	117576.00
EUT	48253.42	4847.70	10620.22	63721.34	86437.50	20900.00	21467.50	128805.00
ITC-IRST	70391.36	6223.53	15322.97	91937.86	92333.00	22045.00	22875.60	137253.60
UWB	11594.00	15422.70	5403.34	32420.04	14068.00	22330.00	7279.60	43677.60
UNIGE	42465.00	18562.52	12205.50	73233.02	42782.00	11125.00	10781.40	64688.40
UBIR	39473.78	11439.91	10182.73	61096.42	31590.00	10723.50	8462.70	50776.20
Totals	402564.40	156767.09	111866.27	671197.76	608100.50	208061.50	163232.40	979394.40

Proposed Revision of the Contract

1. We propose to slightly adapt/broaden the research tasks 3.2, 3.3, and 3.5 as already mentioned in Section B.2.

2. As discussed in Section B.8 it is not reasonable and realistic that *all* YVRs go for an industry internship; we therefore propose to modify the industrial internship clause in the training programme as follows: *The YVRs should accomplish an industry internship if this internship (a) is reconsilible with the duration of their employement as YVR in the* CALCULEMUS *Network and (b) does at least loosely fit their own research interests or the work programme of the host node.*

   If an internship is however directly beneficial to the YVR we propose that the stay in industry may be extended in time.

3. We propose that the Network should be allowed to more flexibly redistribute YVRs person months from underspending nodes to nodes with additional YVR capacity. A requirement, however, is that this redistribution of YVR person months is also reflected in a respective redistribution of the work load of the involved parties.

4. Because of the slight delay at the beginning of the Network we propose to adjust the duration of the contract respectively.

5. For further Training Networks we suggest that a small central budget is maintained for the organisation of joint training measures such as the CALCULEMUS Autumn School. The reason for this suggestion is the avoidable hassle and work load the solution in our Network causes for the coordinator and event organisers (in the CALCULEMUS Network this budget was distributed over the partner nodes).

Sketches of Young Researchers

Andrew Adams

1. Networking activities:

   Activity type: Workshop MKM '01
   Duration: 4 days
   Name of partner institution: RISC Hagenberg/SCCS/University of Linz
   Funding (CALCULEMUS RTN or other): CALCULEMUS

2. Background and experiences in the network:
   My visit to USAAR took place at the end of my first year of appointment as a probationary lecturer at the University of Reading, UK. It was invaluable as a way to kick-start my personal research agenda. I was welcomed and supported well during my stay in Saarbrucken, which was only three months due to my career developments in the UK. I have remained an active research in Calculemus, submitting a joint research paper to a workshop in 2002 with Jurgen Zimmer and Andreas Franke of USAAR. A further paper on ongoing work deriving from my post at USAAR will be submitted to the Calculemus Workshop this year. I am also in receipt of an overseas travel grant from the UK's EPSRC to continue this collaboration with USAAR and with SRI International in California, USA.

Gilles Audemard

1. Networking activities:

   Activity type: CALCULEMUS Network Task Forces Meeting, Genova
   Duration: 14-15 February 2002
   Name of Partner Institution: ITC-IRST
   Funding (CALCULEMUS RTN or other): CALCULEMUS RTN

   Activity type: MRG-SRA 2K2 Symposium, Levanto
   Duration: 05-07 June 2002
   Name of Partner Institution: ITC-IRST
   Funding (CALCULEMUS RTN or other): other

   Activity type: CALCULEMUS-2002 Symposium, Marseille
   Duration: 01-05 July 02
   Name of Partner Institution: ITC-IRST
   Funding (CALCULEMUS RTN or other): CALCULEMUS RTN

   Activity type: CALCULEMUS Interest Group Meeting, Marseille
   Duration: 05 July 2002

Name of Partner Institution: ITC-IRST
Funding (CALCULEMUS RTN or other): CALCULEMUS RTN

2. Background and experiences in the network:
My work at ITC-IRST focused on the analysis, design and implementation of efficient algorithms that combine algebraic decision procedures (mathematical solving and computing services) and logical reasoning capabilities (proving services), with the main goal of automatically verifying timed systems. In particular, I took part to the requirement analysis, design and implementation of MathSAT, a system combining the (high-performances) boolean reasoning capabilities of the SAT procedure SIM with the mathematical solving capability of a home-made decision procedure for linear arithmetic formulas over the reals. I have taken in charge the development of the resulting system. I contributed to the development of the general framework (logical foundations and basic algorithms) for combining boolean decision procedures and mathematical solvers, and to the definition of the main requirements that boolean and mathematical solvers must fulfill in order to achieve the maximum benefits from their integration. To this extent, my contribution focused mainly on the requirements for boolean decision procedures. I also contributed to the development of the encoder able to convert a Bounded Model Checking problem for timed systems into the satisfiability of math-formulas. During my stay at ITC-IRST I was trained in formal methods, model checking, techniques for integrating SAT with domain-specific procedures and techniques for mathematical solving. I presented part of my work during the CALCULEMUS Network Task Forces Meeting (Genova, 14-15 February 2002).

Jesus Maria Aransay Azofra

1. Networking activities:

Activity type: study visit
Duration: 6 months
Name of partner institution: Universität Karlsruhe
Funding (CALCULEMUS RTN or other): Calculemus RTN

Activity type: CALCULEMUS Autumn School, Pisa
Duration: 23.9 - 4.10.2002
Name of partner institution:
Funding (CALCULEMUS RTN or other):

2. Background and experiences in the network:

Since our work was focused on the study of the Computer Algebra System (CAS) Kenzo, which is a CAS written on Common Lisp and with a high performance of functional programming for computations in Algebraic Topology, our first idea was to study the interoperability of the system with other programming languages

We tried to solve the problem of implementation and definition of algebraic structures in Magma and Maple. There was not much to say about Magma, where the problem's solution is very similar to our starting point in Common Lisp. There, functions are first-order objects and lexical closures are well implemented. But in Maple, with the version V Release 4, some problems were found: although functions are first-order objects, the lexical closures are not well implemented; both features are necessary to get to work nicely, otherwise results are wrong. The point was that there are only two contexts, the global one and the one for the working function, and, of course, lot of problems arise if one tries to work with nested functions. In the newer versions of Maple (after Maple V Release 5) this bug was fixed and everything worked like in Magma (and in Common Lisp). The same work was also made in Java and C++, and it was presented as a join work with Julio Rubio and Juan Jose Olarte at the meeting EACA'2001 with funding from the Calculemus network.

During the stay in Karlsruhe the question of giving a certified version of the BPL (one of the most important parts of the Kenzo system) was detected as a challenging problem. This work is being carried out in collaboration with Julio Rubio and Clemens Ballarin. Some preliminary results in this area have been presented, first in the EACA'2002, where some equational reasoning about Algebraic Topology was made, then in the IDEIA'2002, with some work focused on the implementation of structures, and also as a poster in the Calculemus Autumn School 2002.

Simon Colton

1. Networking activities:

   Activity type: CALCULEMUS Network Task Forces Meeting, Genova
   Duration: 2 days (14-15 February 2002)
   Name of partner institution: UNIGE
   Funding (CALCULEMUS RTN or other): CALCULEMUS RTN

   Activity type: CALCULEMUS-2002 Symposion, Marseille
   Duration: 1-5.7.2002
   Name of partner institution:
   Funding (CALCULEMUS RTN or other): CALCULEMUS RTN

2. Background and experiences in the network:
   I have been developing the area of automated theory formation in mathematics. This involves starting with a limited amount of information such as the axioms of a finite algebra, and generating a theory containing examples, concepts, conjectures, theorems and proofs. My particular application within the Calculemus framework has been to be use my HR system and the Otter theorem prover to make conjectures about Maple functions. This fits into section 2.2 of the Calculemus proposal, because we have enhanced the reasoning power of CAS systems using inductive reasoning (to produce conjectures) and deductive reasoning (to prove and discard conjectures which can be proved from first principles).

   Responsibilities in the network For the last three years I have been the Edinburgh representative for the Calculemus project. This has involved attending meetings, writing reports and, to some extent, organising the visits of YVRs to Edinburgh. This role has now been taken over by Ewen Maclean.

   Evaluation I was made to feel very welcome by the host institution, both at Karlsruhe, which was employing me, and at Saarbrucken, which I visited for one of the three months I was working in Germany. The host institutions sorted out many practical matters including accomodation, payment and travel. My one complaint is that it has taken a very long time to sort out my tax refund (if I get one). This has been very difficult to work out, and is still not resolved. It would have been much simpler for me if the (non-academic) adminstrators of Calculemus had sorted this out for me, or if there was some system in place for dealing with tax claims. It all seems very ad-hoc.

   In terms of the teaching aspect of the network, my application to Maple functions was only made possible through discussions and demonstrations about Maple with Jacques Calmet and members of his research group (Clemens Ballarin in particular). While at Saarbrucken, I had much training in the use of the MathWeb software bus, which I could pass on to the other research group members in Edinburgh, in addition to using it for my own work.

This collaboration led to two publications with Jurgen Zimmer, from the Saarbrucken node of the network. Also, while in Saarbrucken, I had discussions about the application of automated theory formation and proof planning to some specific problems involving residue classes. This collaboration has led to a publication with Andreas Meier from Saarbrucken and Volker Sorge from the Birmingham node of the network.

Luca Compagna

1. Networking activities:

   Activity type: CALCULEMUS Network Task Forces Meeting, Genova
   Duration: 2 days (14-15 February 2002)
   Name of partner institution: UNIGE
   Funding (CALCULEMUS RTN or other):

2. Background and experiences in the network:

   I took my master degree in 2000 at University of Genova. It concerned "Integration of decision procedures with conditional rewriting".

   Currently, I am doing a PhD in a co-operation programme between University of Genova (A. Armando) and U.of Edinburgh (A. Smaill) working on "Verification of Security Protocols". In this context the Calculemus research network has contributed refunding travel and accomodation costs and, therefore, making the co-operation programme feasible in practice.

Adrian Craciun

1. Networking activities:

   Activity type: Meeting: Calculemus Network Task Force Meeting 14-15 February 2002 Duration: 2 days Name of partner institution: Funding (CALCULEMUS RTN or other): Calculemus

   Activity Type: Workshop:
   April 25 - 27, 2002 SFB-Statusseminar, Strobl, Austria
   Duration: 3 days
   Name of partner institution:
   Funding (CALCULEMUS RTN or other): SFB

   Activity type: Conference: Calculemus/AISC 2002, July 1st-5th, 2002
   Duration: 3 days (the Calculemus days at the conference)
   Name of partner institution:
   Funding (CALCULEMUS RTN or other): Calculemus

   Activity type: Autumn School: Calculemus, Sept 23-Oct 4, 2002
   Duration: 14 days
   Name of partner institution:
   Funding (CALCULEMUS RTN or other): Calculemus

   Activity type: Conference: SYNASC02 Oct 9-12, 2002, Timisoara, Romania
   Duration: 3 days

Name of partner institution:
Funding (CALCULEMUS RTN or other): Calculemus

Activity type: Workshop: CaVIS 2003 (Computer Aided Verification of Information Systems),Feb. 12 2003, Timisoara, Romania
Duration: 1 day
Name of partner institution: Institute e-Austria Timisoara
Funding (CALCULEMUS RTN or other): e-Austria

2. Background and experiences in the network:

   Scientific Background
   1995-1999 Studies of Computer Science at the University of Timisoara, Romania
   1999-2000 Advanced Studies (MSC) in Computer Science at the University of Timisoara, Romania
   2000 - ? PhD student at RISC Linz
   sept 2001 - june 2003 YVR@RISC Linz
   Responsabilities in the network: Member in the research group Theorema at RISC Linz

   People at the institute have been very helpful. The scientific and human environment is very good.

Pasquale de Lucia

1. Networking activities:
   Activity type: CALCULEMUS Network Task Forces Meeting, Genova
   Duration: 14-15 February 2002
   Name of partner institution: UNIGE
   Funding (CALCULEMUS RTN or other):

   Activity type: CALCULEMUS Autumn School, Pisa
   Duration: 23.9 - 4.10.2002
   Name of partner institution:
   Funding (CALCULEMUS RTN or other): grant

2. Background and experiences in the CALCULEMUS RTN:
   He did research on Model Checking on Linear Programs in infinite domains. He particularly investigated how his practical approach could be supported by cooperating reasoning tools such as constraint solvers, Computer Algebra Systems, and Theorem provers.

Hazel Duncan

1. Networking activities:

   Activity type: CALCULEMUS Autumn School, Pisa
   Duration: 23.9 - 4.10.2002
   Name of partner institution:
   Funding (CALCULEMUS RTN or other): grant

2. Background and experiences in the network:
   I completed my Bachelor defree in June 2002 at Edinburgh University. I am currently undertaking a PhD also at Edinburgh in Automatic Theorem Proving, particularly involving proof planning. My current work involves data-mining proof transcripts from existing systems and to this end I travelled to the University of Bialystock, Poland in October to learn about Mizar. I spent two months there learning the system so I can use it for my research, this involved writing a Mizar article.

Pierre Ganty

1. Networking activities:

2. Background and experiences in the CALCULEMUS RTN:
   I took my master degree in September 2002 at the Free University of Brussels, Belgium. It concerned "Efficient data structures and algorithms for handling interval constraints".
   I am mainly interested at the model-checking of infinite state space systems, specially Petri-Nets and their extensions. Currently my research concentrates on the formal methods aiming at the verification of security protocols. In this context, I made a six months visit at UNIGE in Genova where I developed a tool to discover logical flaws in security protocols.

Mariusz Giero

1. Networking activities:

2. Background and experiences in the CALCULEMUS RTN:
   I am involved in Mizar (proof-checker system) Project and working on formalization of mathematics using Mizar system. I have master degree in mathematics. The thesis concerned "Properties of products of many sorted algebras". In the context of Calculemus I am taking part in formalization of the Jordan Curve Theorem in Mizar. Currently, I am on a one year visit to Nijmegen where I am working on providing a mathematical (Mizar style) proof language for Coq (proof-assistant system).

Corrado Giromini

1. Networking activities:

   Activity type: CALCULEMUS Network Task Forces Meeting, Genova
   Duration: 14-15 February 2002
   Name of partner institution: UNIGE
   Funding (CALCULEMUS RTN or other):

   Activity type: MRG-SRA 2K2 Symposium, Levanto
   Duration: 2-8.6.2002
   Name of partner institution:
   Funding (CALCULEMUS RTN or other): CALCULEMUS RTN

   Activity type: CALCULEMUS-2002 Symposion, Marseille
   Duration: 1-5.7.2002
   Name of partner institution:
   Funding (CALCULEMUS RTN or other): CALCULEMUS RTN

Activity type: CALCULEMUS Autumn School, Pisa
Duration: 23.9 - 4.10.2002
Name of partner institution:
Funding (CALCULEMUS RTN or other): CALCULEMUS RTN

Activity type: Project Meeting
Duration: July - September 2002
Name of partner institution: INRIA - Nancy
Funding (CALCULEMUS RTN or other): CALCULEMUS RTN

Activity type: Study visit
Duration: 17th - 23th November 2002
Name of partner institution: RIACA - University of Eindhoven
Funding (CALCULEMUS RTN or other): other

Activity type: Theory Seminar
Duration: 7th February 2003
Name of partner institution: School of Computer Science - University of Birmingham
Funding (CALCULEMUS RTN or other): other

I achived my Master degree in Computer Science Engineering in 2001 at the University of Genoa, Italy. My master thesis was concerned "Logic Broker Architecture: an Interconnection for Distributed Automated Reasoning Systems". This one was granted by the Calculemus Network. In the context of Calculemus I was Involved in different projects under supervision of the University of Saarland, University of Edinburgh, University of Genoa. These projects involve different aspects of Artificial Intelligence and are closely related with industries. Due to one of them, I had a stage in the Motorola GSG labs to apply formal methods in their context. Currently my research fields are: Formal Methods, Mathematical Knowledge Management, and Distributed Systems.

Artur Kornilowicz

1. Networking activities:

   Activity type: CALCULEMUS Network Task Forces Meeting, Genova
   Duration: 14-15 February 2002
   Name of Partner Institution: ITC-IRST
   Funding (CALCULEMUS RTN or other): CALCULEMUS RTN

   Activity type: MRG-SRA 2K2 Symposium, Levanto
   Duration: 05-07 June 2002
   Name of Partner Institution: ITC-IRST
   Funding (CALCULEMUS RTN or other): other

2. Background and experiences in the network:
   I am mainly interested in formalization (encoding) of mathematics. My master thesis consists of a formal proof of Birkhoff Theorem for many sorted algebras. During my PhD investigations I developed a theory of random access Turing machines. I formalized a theory of generic computers - computers parameterized by an algebraic structure.

   My work at ITC-IRST focused on the design and implementation of efficient algorithms that automatically establish the satisfiability of a specific class of mathematical formulae, which can be used to model timed systems. The algorithms are designed in order to closely integrate as a Math-Solver module of a system called MathSAT. I have taken in charge the development of the Math-Solver module. I also contributed to the development of the general framework for combining boolean decision procedures and mathematical solvers, and to the definition of the main requirements that boolean and mathematical solvers must fulfill in order to achieve the maximum benefits from their integration. To this extent, my contribution focused mainly on the requirements for mathematical solvers. I contributed to the conception of the logical encoding for converting a Bounded Model Checking problem for timed systems into the satisfiability of math-formulas. During my stay at ITC-IRST I was trained in SAT, formal methods, model checking, techniques for integrating SAT with domain-specific procedures, and algorithms for mathematical solving. During the CALCULEMUS Network Task Forces Meeting in Genova I gave a presentation on "Model Checking Timed Systems by an Integrated SAT+Math Procedure", and at the MRG-SRA 2K2 Symposium in Levanto I gave a presentation on "Bounded Model Checking for Timed Systems".

In my opinion ITC-IRST (SRA) is a strong scientific institution where people do investigations in many areas, especially in many branches of artificial intelligence. A large number of publications and international conferences organized by IRST prove the power of IRST. During my stay in Trento I attended many lectures given by famous scientists invited to IRST. IRST (or its divisions) has an intensive cooperation with industry (e.g., railway and avionics companies). Because of all these points I would strongly recommend visiting ITC-IRST to other YVRs.

Presently I have a position at University of Bialystok. I work in Mizar group, where we develop Mizar system itself, and Mizar Mathematical Library - the body of formal mathematical texts verified by Mizar.

Markus Moschner

1. Networking activities:

   Activity type: CALCULEMUS Network Task Forces Meeting, Genova
   Duration: 14.–15. February 2002
   Name of partner institution: UNIGE
   Funding (CALCULEMUS RTN or other):

   Activity type: CALCULEMUS Autumn School, Pisa
   Duration: 23.9 – 4.10.2002
   Name of partner institution:
   Funding (CALCULEMUS RTN or other): grant

2. Background and experiences in the CALCULEMUS RTN:

   I finished my mathematics dissertation thesis (in the field of automated model building and nonclassical logics) during a CALCULEMUS grant in Saarbrücken. Since my stay at Saarbrücken I am working on mathematical knowledge management.
   This includes joint work (with Franke and Kohlhase) on the system *MBase* with the first release and connectivity supplements for the ActiveMath system developed in Saarbrücken. Together with Franke and Pollet some experimental work on the use of *MBase* as a tool for the proof planer Ωmega was done.
   Furthermore I learned Mizar during a further CALCULEMUS grant in Biał ystok. As a result Mizar articles and work on translation of representation between OMDoc and Mizar followed. This corresponds to CALCULEMUS task 3, because Mizar gives an advanced form of checking encoded mathematical knowledge and OMDoc together with MBAse gives

a promise for handling such knowledge.
My future plans are to advance on this research direction especially exploring for bridges between Mizar style and automated reasoning.

Scott Murray

1. Networking activities:
   Activity type: CALCULEMUS Network Task Forces Meeting, Genova
   Duration: 14-15 February 2002
   Name of partner institution: TUE
   Funding (CALCULEMUS RTN or other): CALCULEMUS RTN

2. Background and experiences in the CALCULEMUS RTN:
   Scott Murray has a background in computational group theory. Thanks to Calculemus he enriched his knowledge and skills with proof theory and computer aided reasoning.

   Together with his host, he worked on algorithms providing certificates for correctness proofs of result of permutation group algorithms. In subsequent joint work with Martin Pollet and Volker Sorge, the certificates could be used to obtain full formal proofs for results of eight permutation group algorithms.

   Scott Murray will no doubt benefit from the newly acquired proof theoretic skills in other circumstances in his future career.

Julien Musset

1. Networking activities:

   Activity Type: Meeting:
   December 2, 2002, Verification of Infinite State Systems, Glascow, United Kingdom
   Duration: 1 day
   Name of partner institution:
   Funding (CALCULEMUS RTN or other): CALCULEMUS RTN

2. Background and experiences in the CALCULEMUS RTN: I am interested in the verification of systems with an infinite number of states. My researches in France are based on model-checking and reachability algorithms that are a generalisation of the techniques apply to systems with a finite number of states. People in Edinburgh use inductive tools to study this kind of problem. The aim of my visit of the Mathematical Reasoning Group was to compare the two different approaches.

   The conclusion was that it should be possible to mix both techniques to handle more complex systems, improving existing tools. I only regret that the length of the visit was too short to lead to a complete research work.

   I have been very well welcomed in this dynamic research group. They help me all along my visit (administrative troubles, research works). In conclusion, it was a great experience that has improved my research skills and has opened my mind.

Martin Pollet

1. Networking activities:

   Activity type: CALCULEMUS Network Task Forces Meeting, Genova
   Duration: 14-15 February 2002

Name of partner institution: UNIGE
Funding (CALCULEMUS RTN or other): CALCULEMUS RTN

Activity type: CALCULEMUS-2002 Symposion, Marseille
Duration: 1-5.7.2002
Name of partner institution:
Funding (CALCULEMUS RTN or other): CALCULEMUS RTN

Activity type: CALCULEMUS Autumn School, Pisa
Duration: 23.9 - 4.10.2002
Name of partner institution:
Funding (CALCULEMUS RTN or other): grant

Activity type: Meeting with Volker Sorge (UBIR) and Arjeh Cohen (EUT) in Eindhoven
Duration: 10. - 13.12.2002
Name of partner institution: UBIR/EUT
Funding (CALCULEMUS RTN or other): CALCULEMUS RTN

2. Background and experiences in the CALCULEMUS RTN:

   Scientific background: I have a diploma (master) in mathematics. I am member of the Omega group and I am working in proof planning, interactive proof planning and knowledge representation. I was involved in the development of a prototypical tutor system within the ActiveMath project. My PhD thesis, I am currently working on, is on representation of mathematical knowledge. During my visit at the University of Birmingham I was educated in learning techniques of artificial intelligence and worked together with Manfred Kerber on an analysis of current representation formalisms.

   Responsibilities in the network: task 2.3: Application of learning (as a computational algorithm) in deduction, namely in the proof planning system Omega. task 1.1: The work on mathematical representations will hopefully give insights how to add computational knowledge, and how to detect situations that are relevant for computations in a suitable representation formalism.

   I had the opportunity to meet researchers at the host institute, I visited the talks of the research seminar, and also gave a talk. My host and the host university were very helpful with all practical matters.

Silvio Ranise

1. Networking activities:

   Activity type: Study visit
   Duration: 01.10–30.11.2001
   Name of partner institution: USAAR
   Funding (CALCULEMUS RTN or other): CALCULEMUS RTN

   Activity type: CALCULEMUS-2002 Symposium, Marseille
   Duration: 1-5.7.2002
   Name of partner institution:
   Funding (CALCULEMUS RTN or other): CALCULEMUS RTN

   Activity type: Project Meeting
   Duration: July - September 2002

Name of partner institution: INRIA - Nancy
Funding (CALCULEMUS RTN or other): other

I got my Ph.D. degree in the context of a joint Ph.D. program between Università degli Studi di Genova (Genova, Italy) and Université Henri Poincaré–Nancy I (Nancy, France) at the beginning of 2002. The topic of the thesis was the integration and the extension of reasoning specialists (e.g., decision procedures for Presburger arithmetic) in more general reasoning activities such as rewriting or resolution-based calculi. The part of my thesis concerning a schema combining rewriting[1] and decision procedures providing certain interface functionalities (called Constraint Contextual Rewriting, CCR) is of particular interest to Calculemus. In fact, Armando and Ballarin in [1] show how MAPLE's evaluation process can be modelled as an instance of CCR. More in general, CCR can be seen as a reference architecture to build modules of computer algebra systems implementing symbolic manipulations which can be safely applied only if certain conditions are satisfied,[2] such rules are called conditional simplification rules. This is an important example of the benefits which can be obtained by using automated theorem proving techniques in the context of computer algebra systems. While visiting USAAR, in the same line of research, I have proposed a technique to build rich contexts of facts which can be assumed true while performing symbolic manipulations so that the largest possible number of conditional simplification rules can be applied (if the case). As said above, a simplification rule can be applied only if its conditions are satisfied. To perform this check, we preliminary need to gather the set of facts which can be assumed to hold while simplifying a given expression. My technique permits to find a large such set (which is frequently sufficient for many practical applications) by exploiting a technique called Window Inference and then using CCR to perform the suitable simplifications.

Daniel Sheridan

1. Networking activities:

2. Background and experiences in the network:
   I am a research student at the University of Edinburgh, and previously at the University of York, working on encodings for bounded model checking problems into Boolean satisfiability problems.

   I have been appointed by ITC-IRST as YVR in the CALCULEMUS network on February 13th, 2003. My interests are in improved bounded model checking encodings by reasoning about temporal logic as well as the problem domain in general, in particular the use of techniques from temporal logic theorem proving; and generally increasing the applicability of bounded model checking. My work at ITC-IRST is concerned with both the symbolic and bounded model checking aspects of NuSMV: improving the behaviour of the system on non-Boolean data types and integrating the improved encoding routines that are the results of my research.

Sorin Stratulat

1. Networking activities:

   Activity type: task forces meeting
   Duration: 14.2.2002 - 15.2.2002
   Name of partner institution: UNIGE

[1] Notice that substantial part of the activities of a computer algebra system can be seen as a sophisticated form of rewriting

[2] In fact, it is well-known that commercial computer algebra systems perform simplification eagerly without paying attention whether such manipulations are sound.

Funding (CALCULEMUS RTN or other): Calculemus

2. Background and experiences in the network:

   I am mainly interested in automated reasoning, more exactly in theorem proving by implicit induction. My scientific contribution to the Calculemus community is our proposal of an approach to integrating reasoning specialists into Cover Set Induction based on Constraint Contextual Rewriting. The approach has been successfully used to incorporate decision procedures into the SPIKE prover. The generality of the approach allows for the integration of Computer Algebra algorithms and techniques into induction theorem provers, like the integration of Buchberger algorithm into our framework.

   DIST was a wonderful host institute and I strongly recommend future researchers to join their research teams. The scientific work during the period of staying in Genova was rich and has been published in an article of Journal of Symbolic Computation.

Josef Urban

1. Networking activities:
   Activity type: MKM 2003 Conference, Bertinoro, Italy
   Duration: 16.02.2003 - 19.02.2003
   Funding (CALCULEMUS RTN or other): other

2. Background and experiences in the network:
   I studied mathematics at the Faculty of Mathematics and Physics of the Charles University in Prague from 1992 to 1998 and got Master degree in Mathematics, specialisation Set Theory and Mathematical Logic. I am interested in automated theorem proving, proof checking and formalisation of mathematics and machine learning, and especially in combining these fields - e.g. using machine learning together with databases of formalized mathematics to optimize and train theorem provers, and using theorem provers to help formalisation efforts or theorem discovery. My diplomma work "Experimenting with Machine Learning in Automated Theorem Proving" already tried this, usig Progol to learn mathematical heuristics on a part of the Mizar Mathematical Library. In my PhD, I further work in this field with the Mizar Mathematical Library, and have already written and published several tools interfacing MML and theorem proving systems.

   My work in Bialystok involved mainly further exploration of the Mizar system, specifically its type system, whose study is very important part when trying to build interfaces between Mizar and theorem proving systems. This part of my work resulted in five formal Mizar articles on Order Sorted Algebras, starting with basic definitions and facts in the first article, studying the lattice of subalgebras in the second and homomorphisms of Order Sorted Algebras in the third article, then developing the theory of quotient algebras over locally directed signatures in the fourth article, and finally using all this in the fifth article in defining free Order Sorted Algebras over a set of variables (i.e. Oder Sorted Term Algebra), algebra of parsed terms, and many related useful notions. A substantial part of my time in Bialystok went into direct programming of the Mizar system. I implemented an expat-based XML interface to Mizar and defined a XML format of the internal Mizar database, also rewriting some old pieces of Mizar code (transferer) using new interfaces on the way. While working on these two main projects, I also implemented several smaller systems. I have set up a CVS repository of the MML, imported nearly one hundred MML versions into it, made it www-accessible via CVSWeb, and wrote a CVSWeb enscript plugin for better web presentation of the articles in the CVS. I have set up the Mizar Twiki webspace, to improve the Mizar documentation and user interaction, and wrote a substantial part of its content and customization. Finally, I have been constantly improving the Mizar mode for Emacs, by providing better browsing and searching functions, implementing functions for viewing internal content of Mizar articles and linking it to search functions in the MML Query, or providing interface to Mizar TWiki.

Jürgen Zimmer:

1. Networking activities:

   Activity type: task forces meeting
   Duration: 14.2.2002 - 15.2.2002
   Name of partner institution: UNIGE
   Funding (CALCULEMUS RTN or other): Calculemus

   Activity type: Calculemus symposium
   Duration: 2.7.2002 - 7.7.2002
   Name of partner institution: Marseille
   Funding (CALCULEMUS RTN or other):

   Activity type: meeting
   Duration: 16.7.2002
   Name of partner institution: Alan Bundy, UED
   Funding (CALCULEMUS RTN or other): personal

   Activity type: CADE Conference, on FloC'02
   Duration: 26.7.2002 - 1.8.2002
   Name of partner institution: Copenhagen
   Funding (CALCULEMUS RTN or other): Calculemus

   Activity type: meeting
   Duration: 13.7.2002
   Name of partner institution: Alan Bundy, UED
   Funding (CALCULEMUS RTN or other): personal

   Activity type: meeting
   Duration: 14.8.2002
   Name of partner institution: Alan Bundy, UED, UK Grid Support Centre, Edinburgh
   Funding (CALCULEMUS RTN or other): personal

   Activity type: Calculemus Autumn School
   Duration: 23.09.2002 - 7.10.2002
   Name of partner institution: Pisa
   Funding (CALCULEMUS RTN or other): Calculemus

   Activity type: Web Services Workshop
   Duration: 10.11.2002 - 13.11.2002
   Name of partner institution: Linz
   Funding (CALCULEMUS RTN or other):

2. Background and experiences in the network:

   Scientific background and Responsibilities:

For my master's thesis at the Saarland University, I've already worked on the integration of constraint solving techniques and Computer Algebra Systems into proof planning. In November 2000, I started my PhD and I'm currently working on the development of the MathWeb Software Bus (short MathWeb-SB) which enables the integration of heterogeneous reasoning systems into a single proof development environment. Using the MathWeb-SB, reasoning systems, such as Computer Algebra Systems and Deduction Systems, can communicate with each other and exchange proof- or computation-problems, and results. The communication in the MathWeb-SB is based on the OpenMath standard for the representation of mathematical objects. Therefore, different systems can easily communicate mathematical knowledge using OpenMath phrasebooks. Since the main goal of the CALCULEMUS network is the integration of computation and deduction systems, my work plays a key role in the whole network. Reasoning systems can be easily plugged into MathWeb and use the mathematical services offered. Among others, my main responsibility in the network is the integration of various deduction and computation systems into the MathWeb-SB and to develop a communication language suited for all these systems.

Work during stay as YVR in Genova, UNIGE:

The LBA is another architecture for the integration of reasoning systems. During my stay at the University of Genoa, we combined the MathWeb-SB and the LBA. It turned out, that, although both architectures are based on different middle-ware and different models of distribution, we could find a common abstract level of communication. We applied the agent-oriented programming approach to both architectures and built a network of mathematical agents that perform cooperative problem solving.

Our work showed that it is possible to unify at least two independent approaches to the integration of reasoning systems and to find an abstract level of communication that is suitable for cooperative problem solving between heterogenous reasoning systems. This gives hope for the development of a single network of reasoning systems including all members of the CALCULEMUS network.

Work during stay as YVR in Edinburgh, UED

During my stay at the University of Edinburgh, I integrated the Lambda-Clam proof planner for inductive theorem proving into the MathWeb Software Bus (MathWeb-SB). Due to this integration, the Lambda-Clam system can now offer its inductive theorem proving expertise to other reasoning systems such as Computer Algebra or Deduction Systems. On the other hand, the Lambda-Clam proof planner can now access all reasoning systems already available in the MathWeb-SB. In my work, I focused on the use of Computer Algebra Systems in inductive proof planning, in particular, the use of Computer Algebra simplification to support induction proofs. Together with Louise Dennis, I compared my work with similar work based on a re-implementation of deduction systems on top of Computer Algebra Systems. We found out that, in general, it is better to combine existing systems via a common interface, as it is, for instance, offered by the MathWeb-SB, instead of re-implementing one of the systems on top of the other. I presented our work on the CALCULEMUS Symposium 2002 in Marseille (see publication list).

Together with Prof. Alan Bundy, I also started to work in the field of service descriptions and wrote a first informal note in which I try to apply service description languages developed in the field of Multi-Agent Systems to the definition of mathematical services. Some first ideas have been presented on the CALCULEMUS Task Forces Meeting in Genoa, Italy, 14.-15. Feb. 2002.

Together with Simon Colton, I integrated the HR system for automated theory formation into the MathWeb-SB. HR is a machine creativity program which automatically forms new mathematical concepts and conjectures. Using the MathWeb-SB, the HR system can now send conjectures to the automated theorem provers already available in the MathWeb-SB.

On the other hand, HR offers its service to the MathWeb and can now, for instance, support the proof planner of the mathematical assistant OMEGA in finding non-isomorphism proofs for residue-classes.

During my stay in the group of Prof. Alan Bundy, I had the possibility to obtain profound knowledge about inductive theorem proving in general and, in particular, about proof planning for inductive proofs in the Lambda-Clam system. I also gained knowledge about the technical realisation of proof planning in Lambda-Clam and could provide significant contributions to the development of the system also on the development level.

The interesting contributions of our work to the CALCULEMUS network are twofold: 1) the integration of Computer Algebra in an inductive theorem prover via protocols and 2) first steps towards a language for the definition of mathematical services.