



# The CALCULEMUS Research Training Network

(HPRN-CT-2000-00102)

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# CALCULEMUS

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Interest Group  
since mid 90s

[www.calculumus.org](http://www.calculumus.org)

EU Research Training Network

09/2000 – 09/2004

[www.eurice.de/calculumus/](http://www.eurice.de/calculumus/)

Funded in EU Fifth Framework

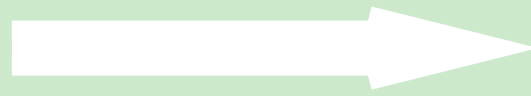
# My CALCULEMUS Motivation



Assume ...



a research freshman  
unexperienced in  
logic and TP



Wants to solve a  
hard mathematical  
problem to get a PhD  
and become a famous  
mathematician

## What options?

# My CALCULEMUS Motivation



Good old  
pen and paper  
mathematics

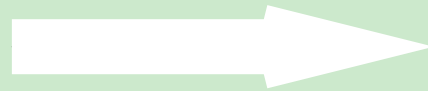


... heard about the success story of EQP in solving  
Robbins problem ... shall I try to employ such  
a push button technology for my problem?

# My CALCULEMUS Motivation



Non-Expert!



Problem formalization



Push button  
Theorem  
Prover

Is this at all  
useful?



Proof found !  
(+ probably some cryptic  
proof object)

# My CALCULEMUS Motivation



Non-Expert!



Assume  
'Proof found'

What then?  
What can I do  
with it?

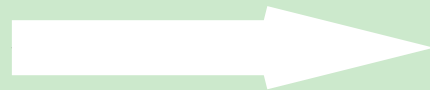
1. How can I convince myself that the answer is correct?
2. What do I learn from the proof?
3. How can I convince my colleagues that I indeed solved a big problem?
4. How can I publish my result? What do I have to publish?
5. Where can I publish the result? Who will accept my paper?
6. How can I maintain and store my proof? How can I reuse its main ideas for similar problems?
7. Will I finally be satisfied with my work?

....

# My CALCULEMUS Motivation



Non-Expert!



Problem formalization



Push button  
Theorem  
Prover

not  
useful

not  
(yet? / ever?)  
realistic

Push button theorem  
proving technology  
only useful as part  
of something bigger!

In this context:  
maths assistant environments

Proof found !  
(+ probably some cryptic  
proof object)

# Scientific Motivation

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Better (mathematical) assistant systems



# Scientific Motivation

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Better (mathematical) assistant systems

- Integration of symbolic reasoning and symbolic computation

- Applications in mathematics, maths education, formal methods

# Scientific Motivation

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## Better (mathematical) assistant systems

- Integration of symbolic reasoning and symbolic computation
- Interoperability with mathematical knowledge bases
- Integration of specialist reasoners
- Open system architectures and mathematical services
- Applications in mathematics, maths education, formal methods

# Scientific Motivation



## Better (mathematical) assistant systems

- Integration of symbolic reasoning and symbolic computation
- Interoperability with mathematical knowledge bases
- Knowledge exploration, maintenance, management of change
- Integration of specialist reasoners
- Expressive representations; human-oriented user interfaces
- Support for representation transformations
- Open system architectures and mathematical services
- Preparation and validation of mathematical texts and publications
- Applications in mathematics, maths education, formal methods

# Sociological Goal

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Early stage training of young researchers

# Sociological Goal




Early stage training of young researchers

Measures:

- The CALCULEMUS Autumn School 2002
- CALCULEMUS Symposia and Network Meetings
- Training at an Individual Level at the Network Nodes
- Local Courses, Workshops, Talks, and Seminars
- Exchange of YVRs between Network Nodes
- Industry Internships

# Network Partners





 **USAAR** Jörg Siekmann, Christoph Benzmüller, Serge Autexier


 **UED** Alan Bundy, Ewen MacLean

 **UKA** Jacques Calmet, Regine Endsuleit

 **RISC** Bruno Buchberger, Wolfgang Windsteiger, Tudor Jebelean

 **TU/e** Arjeh Cohen, Henk Barendregt, Herman Geuvers  
Freek Wiedejk

 **ITC-IRST** Fausto Giunchiglia, Roberto Sebastiani, Alessandro Cimatti,  
Marco Bozzano

 **UWB** Andrzej Trybulec, Czeslaw Bylinski, Grzegorz Bancerek

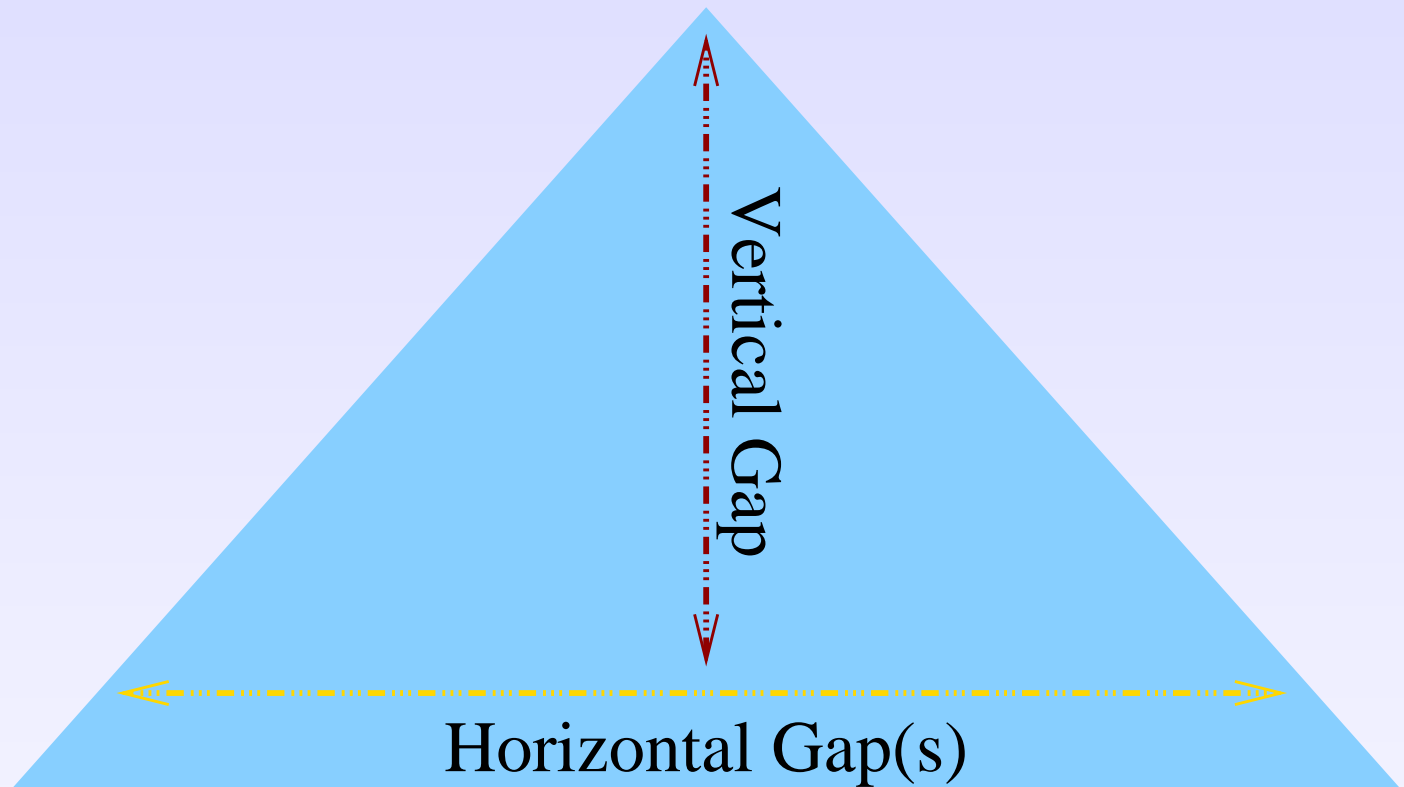
 **UGE** Alessandro Armando, Enrico Giunchiglia

 **UBIR** Manfred Kerber, Volker Sorge

# CALCULEMUS Methodology



**Vision:** powerful mathematical assistant system(s)



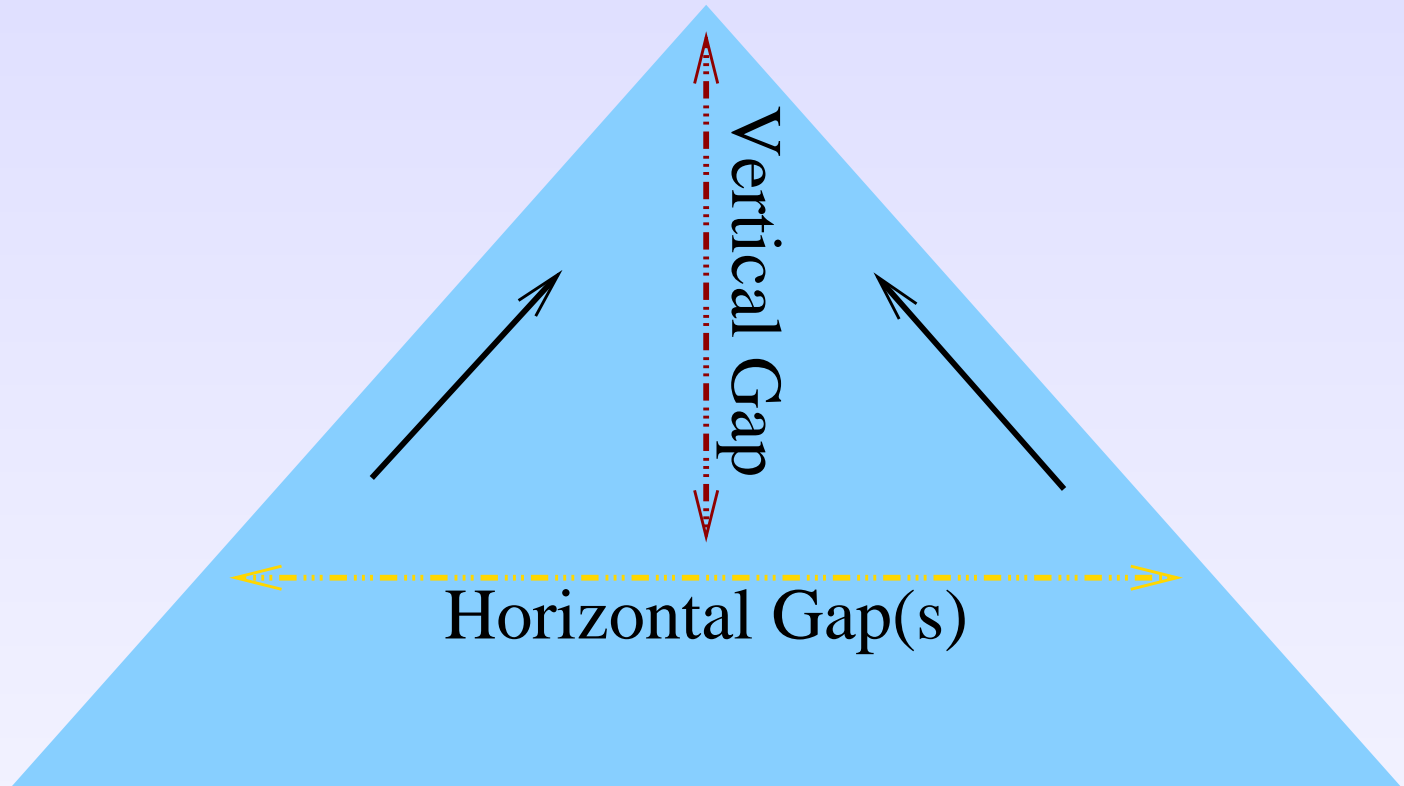
**Reality:** heterogeneous frameworks, systems, and tools  
individual strengths and weaknesses

# CALCULEMUS Methodology



Vision:

powerful mathematical assistant system(s)



Bottom-up from:

CAS DS KBs ...

When to integrate modules and when to re-implement?



# CAS & DS: The Map



DS  $\subseteq$  CAS:

- - THEOREMA  $\subseteq$  *Mathematica*
- - HR uses OTTER for MAPLE

CAS  $\subseteq$  DS:

- (tight coupling:
  - T-unification, constraint resolution, T-resolution)
- loose coupling:
  - reflection approach as used in Coq
  - proof planning ( *$\lambda$ Clam*,  $\Omega$ MEGA)

CAS  $\equiv$  DS:

- protocol, e.g. á la Calmet
- common interface:
  - top down: OMRS, MathWeb-SB, LBA, MathBroker
  - bottom up: CCR, MathSat

# Experiences

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## Bad news:

- no single predominant approach for CAS & DS

# Experiences

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## Bad news:

- no single predominant approach for CAS & DS

## Good news:

- heterogeneity is not necessarily bad
- challenge is to support heterogeneity
- new line of research: frameworks for integration at systems level ( CAS  $\equiv$  DS )

# Publications (after 08/2000)



	Joint Publications	All Publications
Refereed Papers		
- Journals	7	> 22
- Proceedings/Books	33	> 54
Technical Reports	4	> 13
PhD Thesis		> 3
Others		> 4
Total	44	> 96

Source: The CALCULEMUS Midterm Report

# Joint Systems and Applications



System, Language, Software	Developed/used at the following nodes
OMDoc	USAAR,UBIR,UED,UWB
MathWeb	USAAR,UBIR,UGE,UED
$\Omega$ MEGA	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

# Funded Young Researchers



Andrew Adams	USAAR	Pasquale De Lucia	USAAR
Gilles Audemard	ITC-IRST	Martin Pollet	UBIR
Jesus M. Aransay Azofra	UKA	Andreas Meier	UBIR
Adrian Craciun	RISC	Markus Moschner	USAAR,UWB
Simon Colton	USAAR,UKA	Julien Musset	UKA,UED
Luca Compagna	UED,UKA	Scott Murray	TUE
Hazel Duncan	UWB, USAAR	Silvio Ranise	USAAR
Armin Fiedler	UED	Markus Rosenkranz	TUE
Pierre Ganty	UGE	Stefan Schulz	RISC,UED,ITC-IRST
Mariusz Giero	TUE	Daniel Sheridan	ITC-IRST
Corrado Giromini	USAAR,UED	Sorin Stratulat	UGE
Camelia Kocsis	RISC	Dimitra Tsovaltzis	USAAR
Laura Kovacs	RISC	Josef Urban	UWB
Artur Kornilowicz	ITC-IRST	Jürgen Zimmer	UGE, UED
Vincent Lefevre	UKA	...	

# Dissemination of Results



## Proceedings of CALCULEMUS Symposia

- M. Kerber and M. Kohlhase, editors. CALCULEMUS-2000. AK Peters
- S. Linton and R. Sebastiani, editors. CALCULEMUS-2001.
- J. Calmet, et al. CALCULEMUS-2002, LNAI 2385. Springer
- O. Caprotti and V. Sorge, editors. CALCULEMUS-2002-Work-in-Progress.
- T. Hardin and R. Rioboo, editors. CALCULEMUS-2003

## Special Issues in Journal of Symbolic Logic:

- T. Recio and M. Kerber, editors. JSC 32(1/2), 2001.
- A. Armando and T. Jebelean, editors, JSC 32(4), 2001
- S. Linton and R. Sebastiani, editors. JSC 34(4), 2002.

## Proceedings of CALCULEMUS Autumn School

- C. Benz Müller and R. Endsuleit, editors. Autumn School 2002: Course Notes (Part I-III)
- J. Zimmer and C. Benz Müller, editors. Autumn School 2002: Student Poster Abstracts

## Proceedings of Workshops

- S. Colton and V. Sorge, editors. FLOC-2002 Workshop.

# Related Research Initiatives



- MONET: Mathematics on the Net  
*offering mathematical algorithms through web services*
- MOWGLI: Mathematics on the Web: Get it by Logics and Interfaces  
*from machine-readable to machine-understandable representations of mathematical information*
- OpenMath:  
*standard for representing mathematical objects with their semantics*
- MKMNet: Mathematical Knowledge Management Network  
*from paper-oriented and presentation-oriented view to a semantics-oriented view of mathematical knowledge*
- ...
- many conferences in DS and CAS



# Outlook

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Further strengthen cooperation, communication, tool exchange

- within CALCULEMUS community
- with related research projects and conferences in DS & CAS
- with QPQ project at SRI?

[www.qpq.org](http://www.qpq.org)

# Outlook

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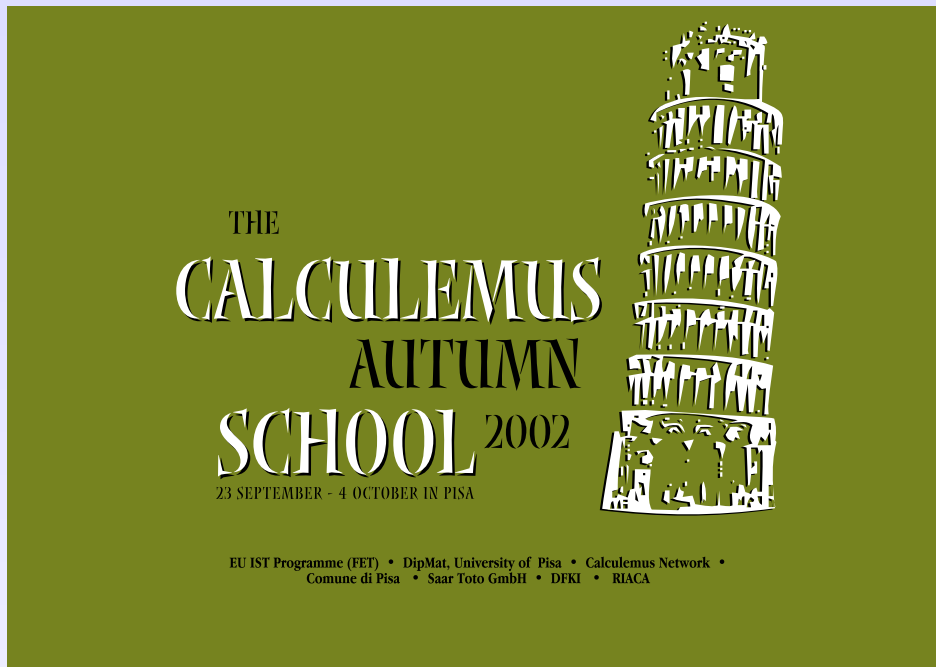
## Further strengthen cooperation, communication, tool exchange

- within CALCULEMUS community
- with related research projects and conferences in DS & CAS
- with QPQ project at SRI? [www.qpq.org](http://www.qpq.org)

## Proposal for CALCULEMUS-II in EU FP6

- strengthen the CAS side in the network
- scientific focus:
  - Integration of DS & CAS
  - New: support for theory and proof exploration
- yearly / two-yearly CALCULEMUS Autumn School?!

# The CALCULEMUS Autumn School



- Introductory and Overview Courses
- Advanced Topics
- Evening Talks
- Student Sessions
- System Demonstration
- Experimentation with Systems

The first training event with the main experts from the involved fields

- 75 participants (approx. 30 from Network): Undergrads, PreDocs, PostDocs, Researchers, Lecturers
- 26 lecturers

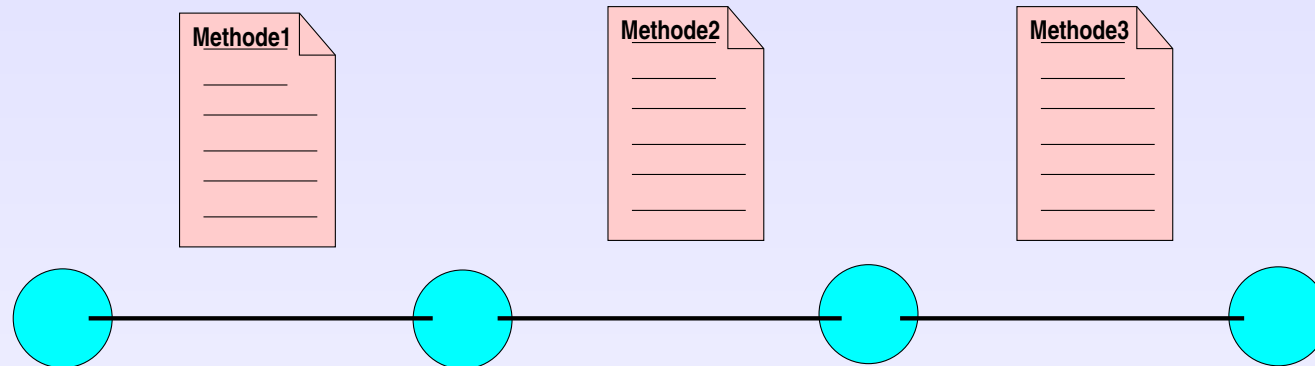


# CAS and ATP in Proof Planning



Proof Planning (as an example for  $CAS \subseteq DS$ ):

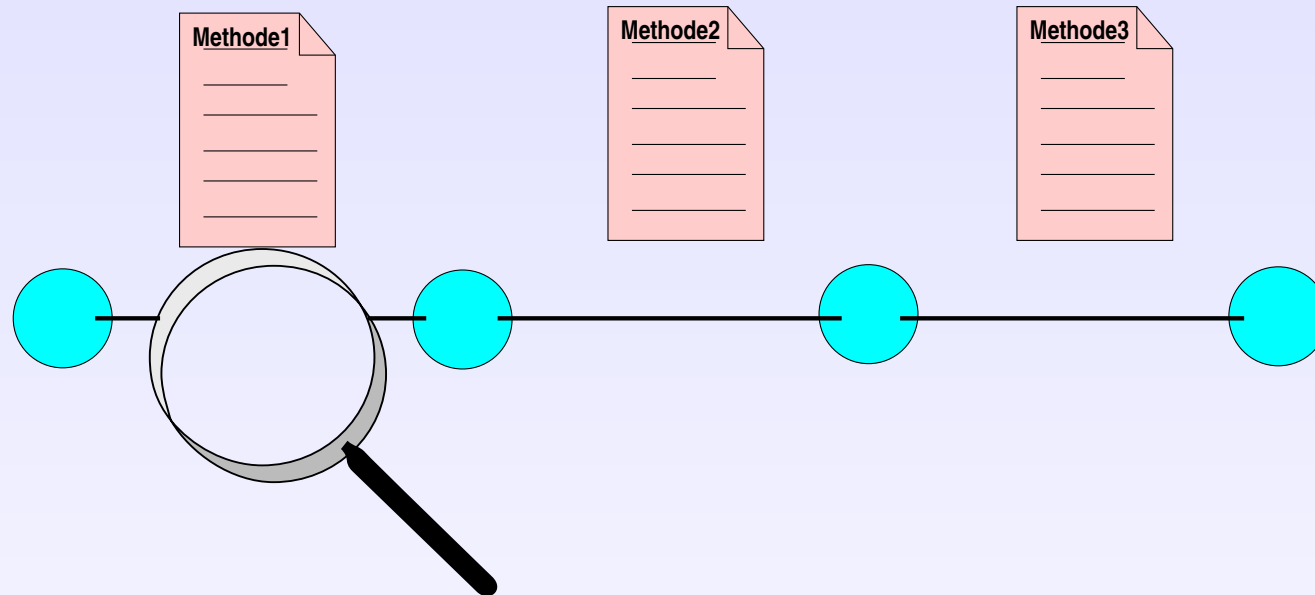
domain specific, heuristic reasoning at abstract layer



Integration of Specialist Reasoners (CASs and ATPs):

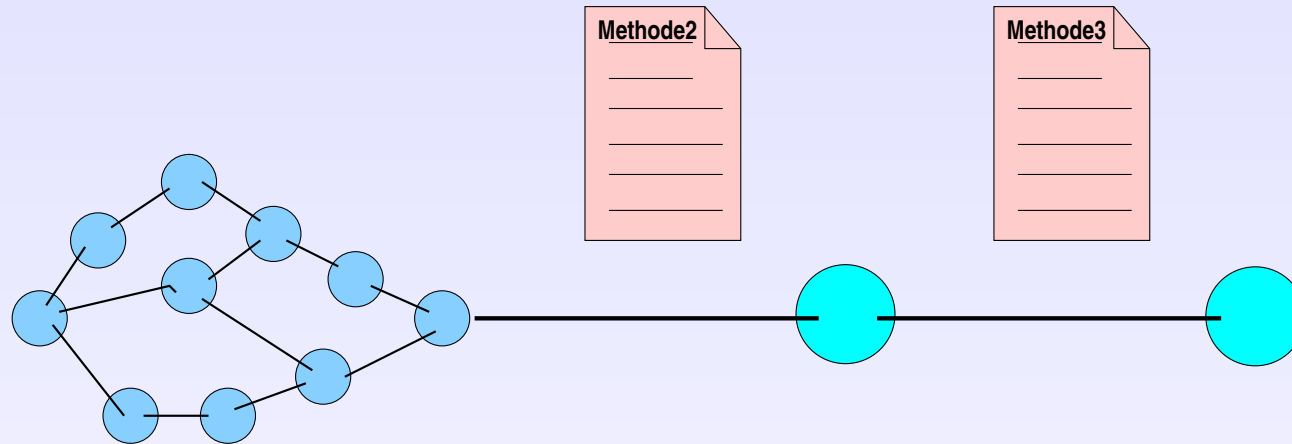
- at method layer
- at the heuristic meta-reasoning layer

# CAS and ATP in Proof Planning



soundness is evaluated by ...

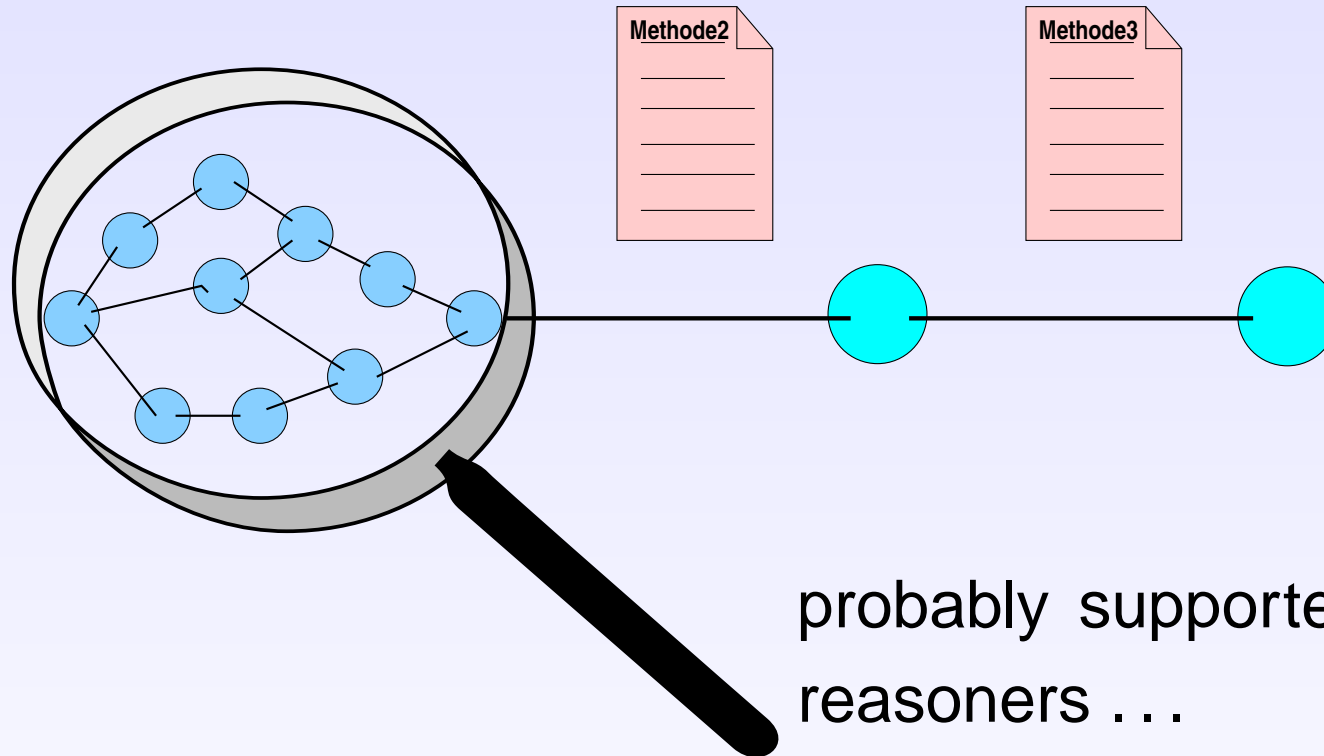
# CAS and ATP in Proof Planning



refinement (expansion)  
over several layers

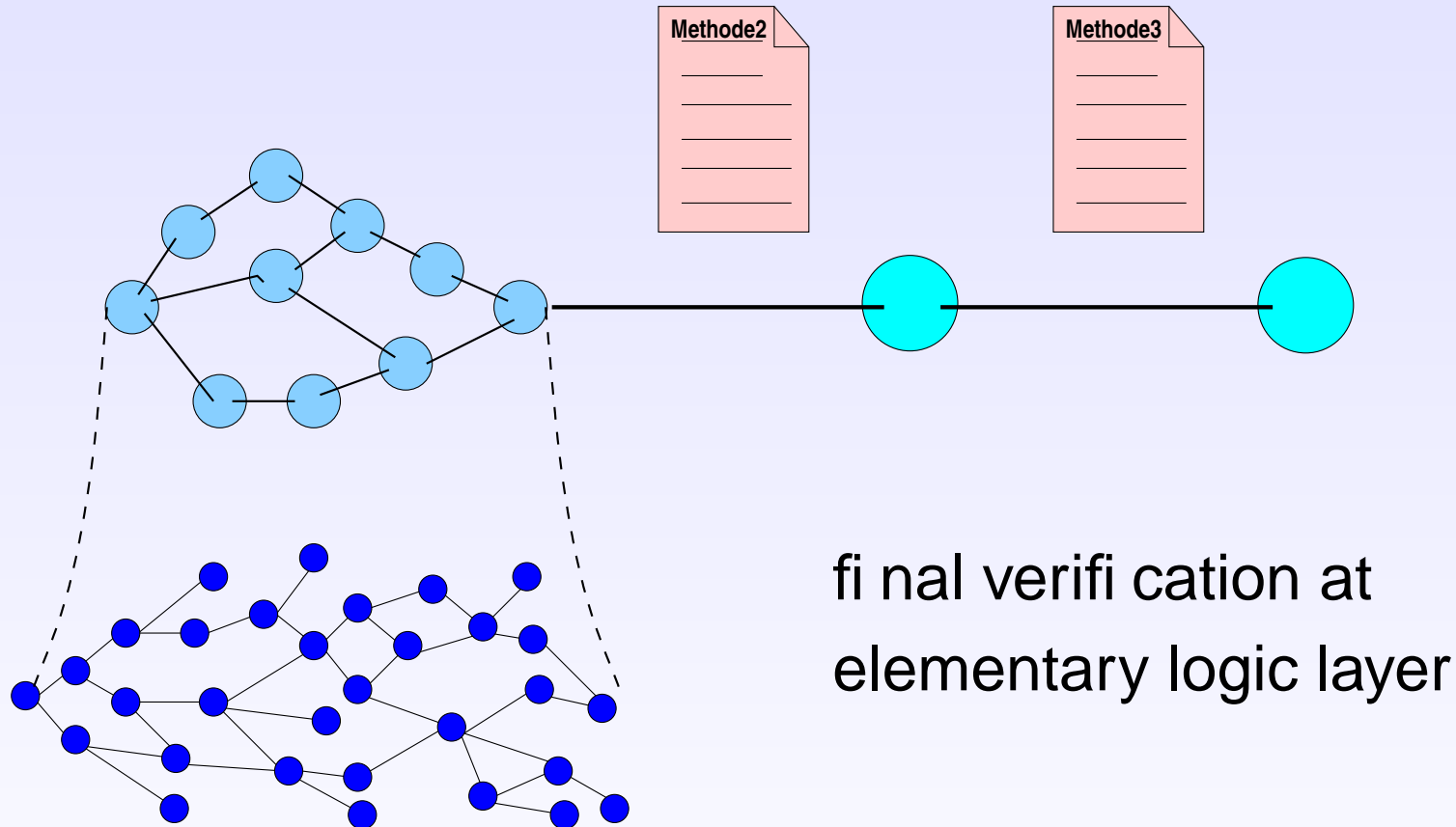
...

# CAS and ATP in Proof Planning



probably supported by external  
reasoners ...

# CAS and ATP in Proof Planning





# CAS and ATP in Proof Planning



Required/Useful for  $\text{CAS} \subseteq \text{DS}$  :

- white box integration of external specialist reasoners
- tools for extraction and transformation of results

