THE UNIVERSITY
OF BIRMINGHAM

Towards
Agent-based Proof Planning

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joint work with

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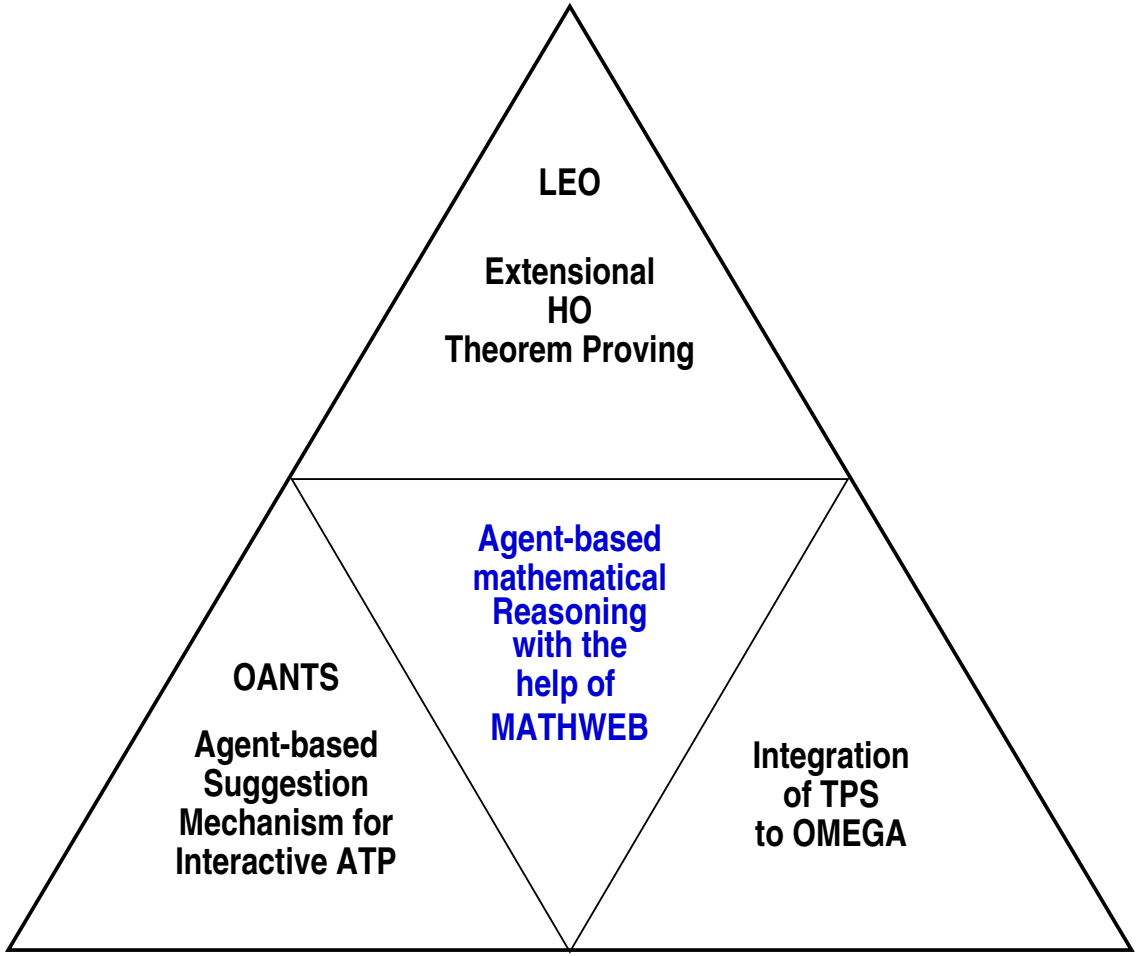
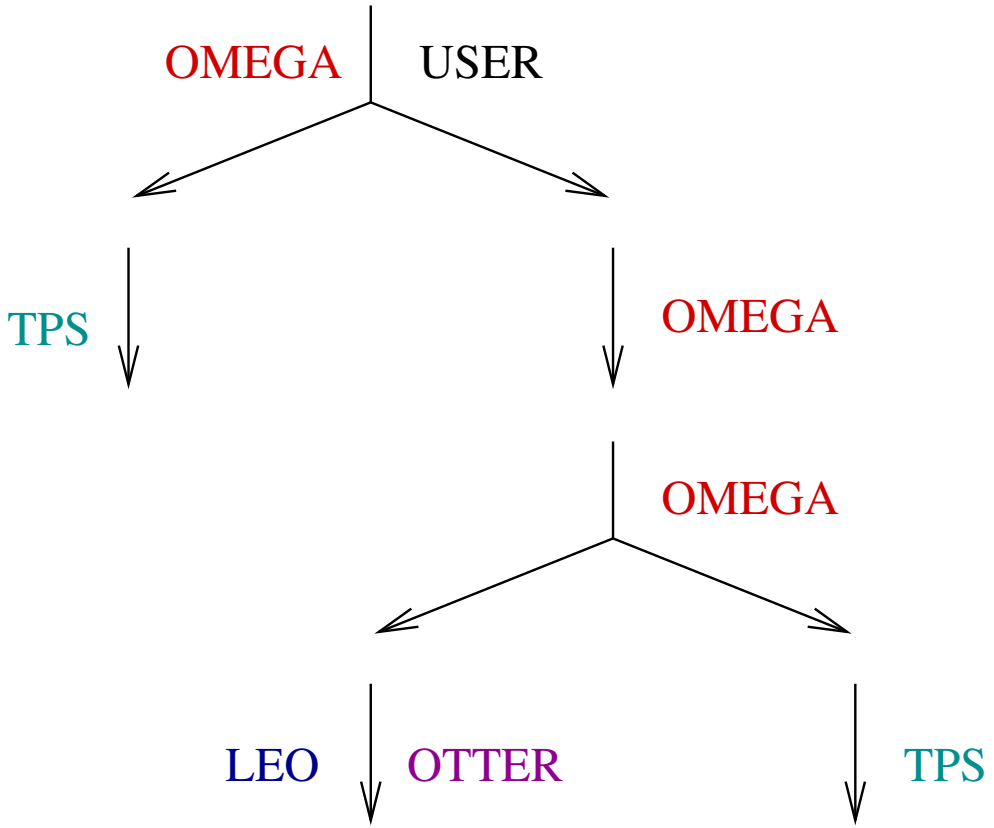
Motivation


LEO
Extensional
HO
Theorem Proving
Agent-based
mathematical
Reasoning
with the
help of
MATHWEB
OANTS
Agent-based
Suggestion
Mechanism for
Interactive ATP
Integration
of TPS
to OMEGA

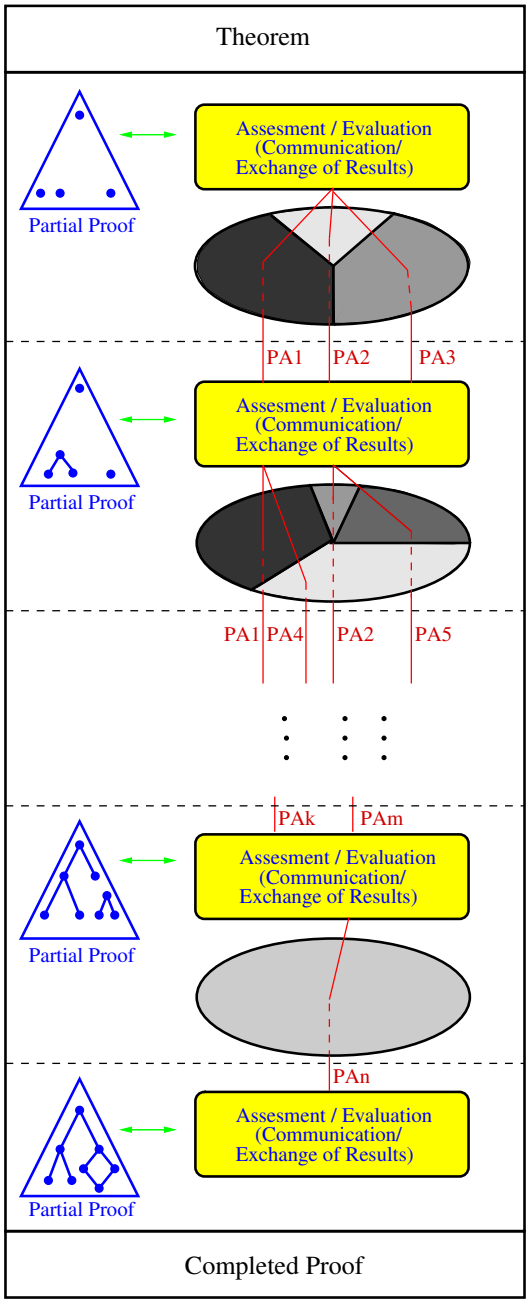
Motivating Example I

$$\forall p.\, \mathit{partition}(p) \quad \Rightarrow \quad (\exists q.\, \mathit{equivalence\text{-}rel}(q) \wedge (\mathit{equivalence\text{-}classes}(q) = p))$$



Reasoning Process

- Different proof strategies by different agents PAx
- Focus shift realised via periodic assessment and evaluation of agents
- Compute and redistribute resources
- Communication between society of agents
- Iterative construction of proof (plan) tree



Motivating Example II

$$\text{anything}(\lambda X.(p\ X) \Rightarrow (q\ X)) \Rightarrow \text{anything}(\lambda X.\neg(q\ X) \Rightarrow \neg(p\ X))$$

LEO generates the following propositional logic formulas:

$$\neg(p\ s) \vee (r\ s)$$

$$(p\ s)$$

$$\neg(r\ s)$$

$$\text{anything}(\lambda X.(p_1\ X) \Leftrightarrow \ldots \Leftrightarrow (p_n\ X)) \Rightarrow \text{anything}(\lambda X.(p_n\ X) \Leftrightarrow \ldots \Leftrightarrow (p_1\ X))$$

A loose Integration of LEO and OTTER

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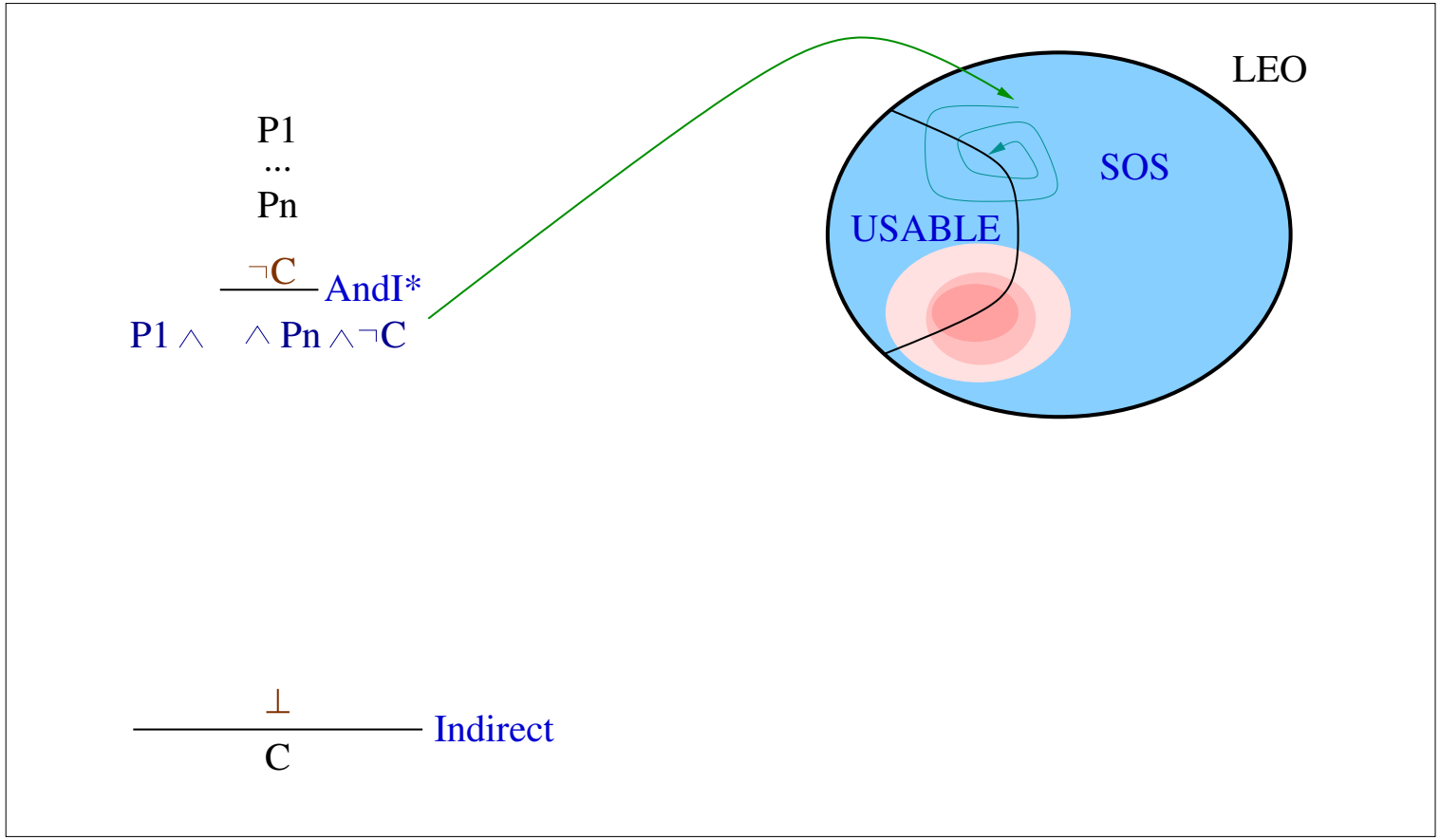
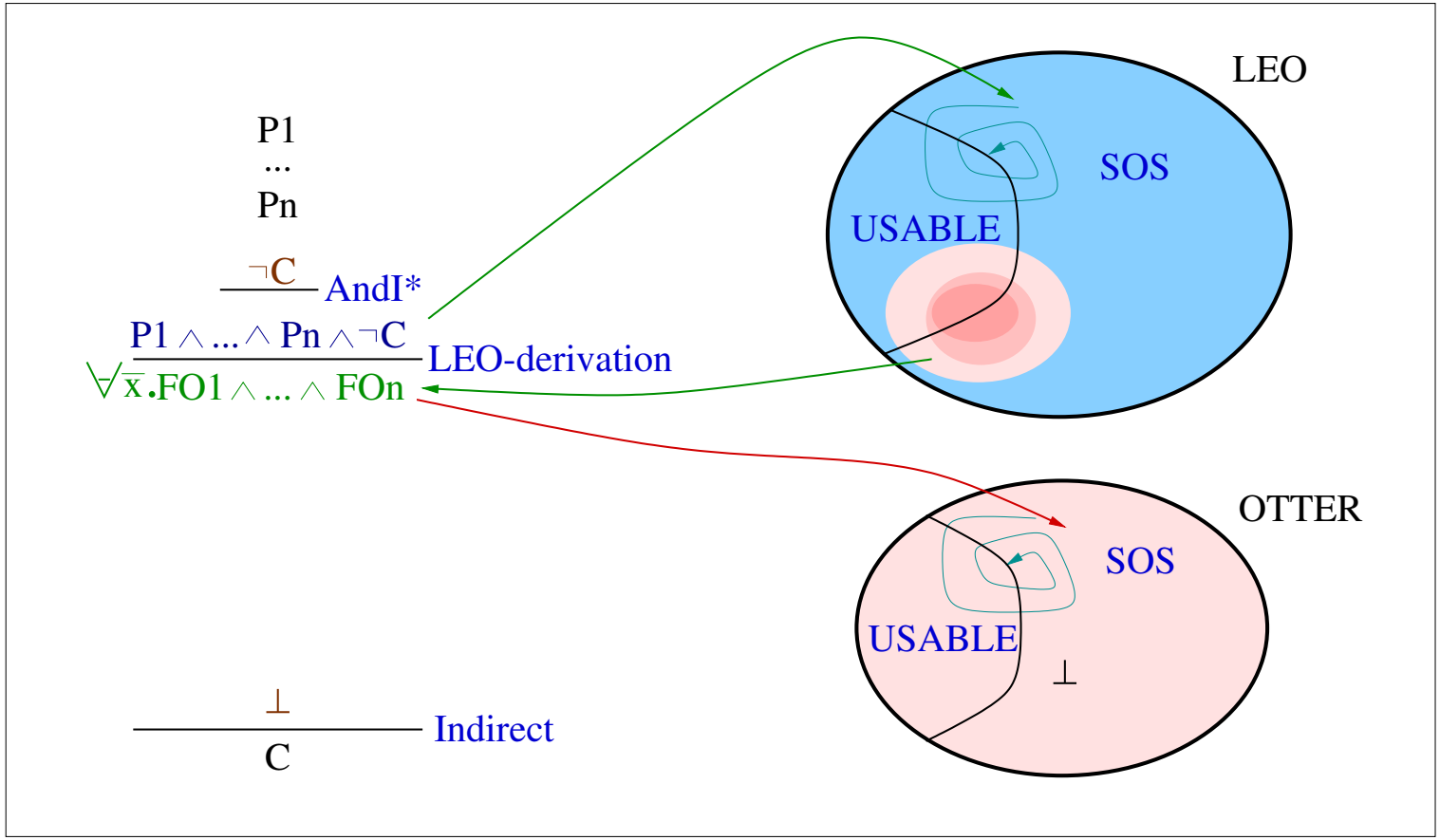
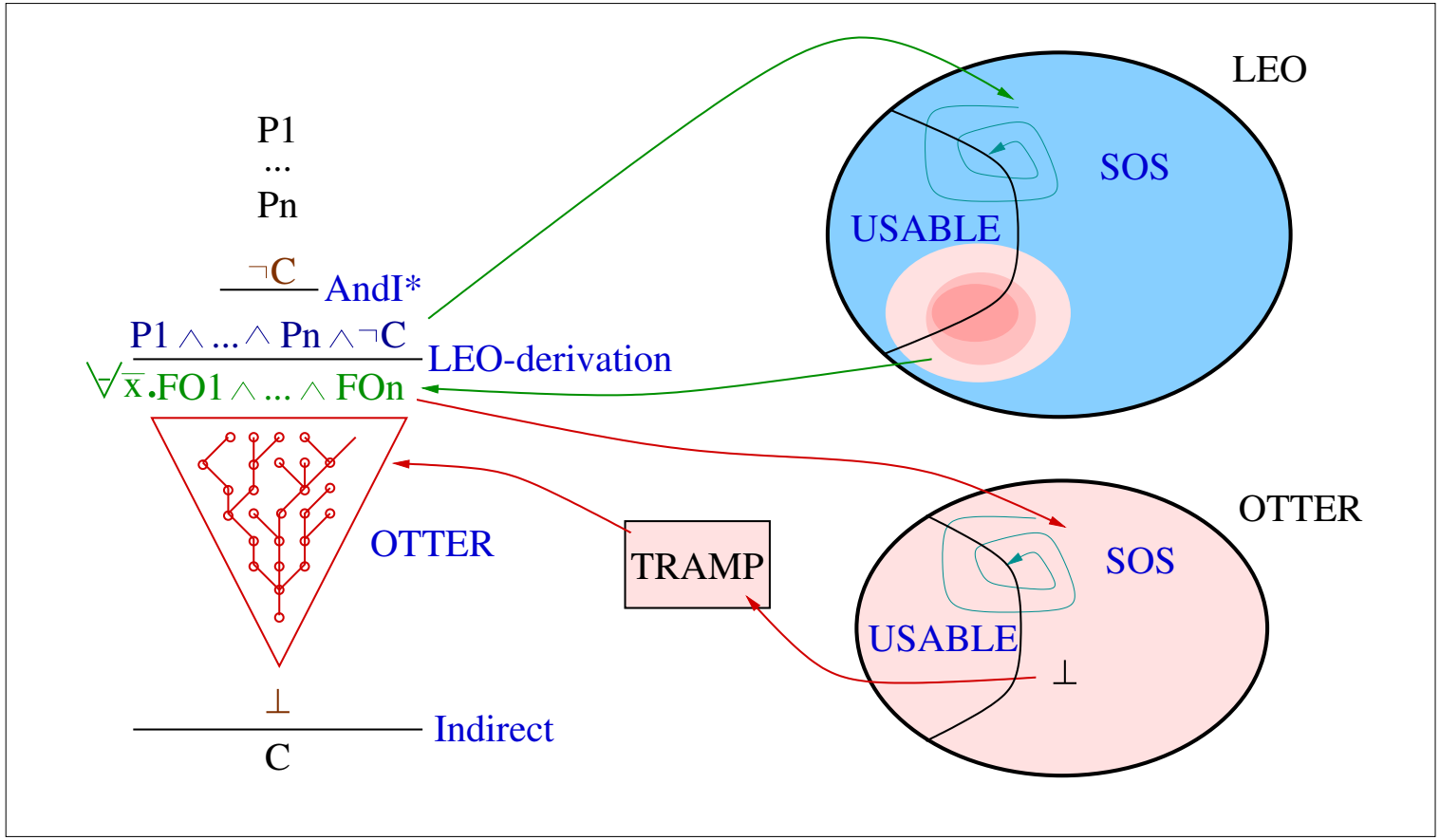


A loose Integration of LEO and OTTER



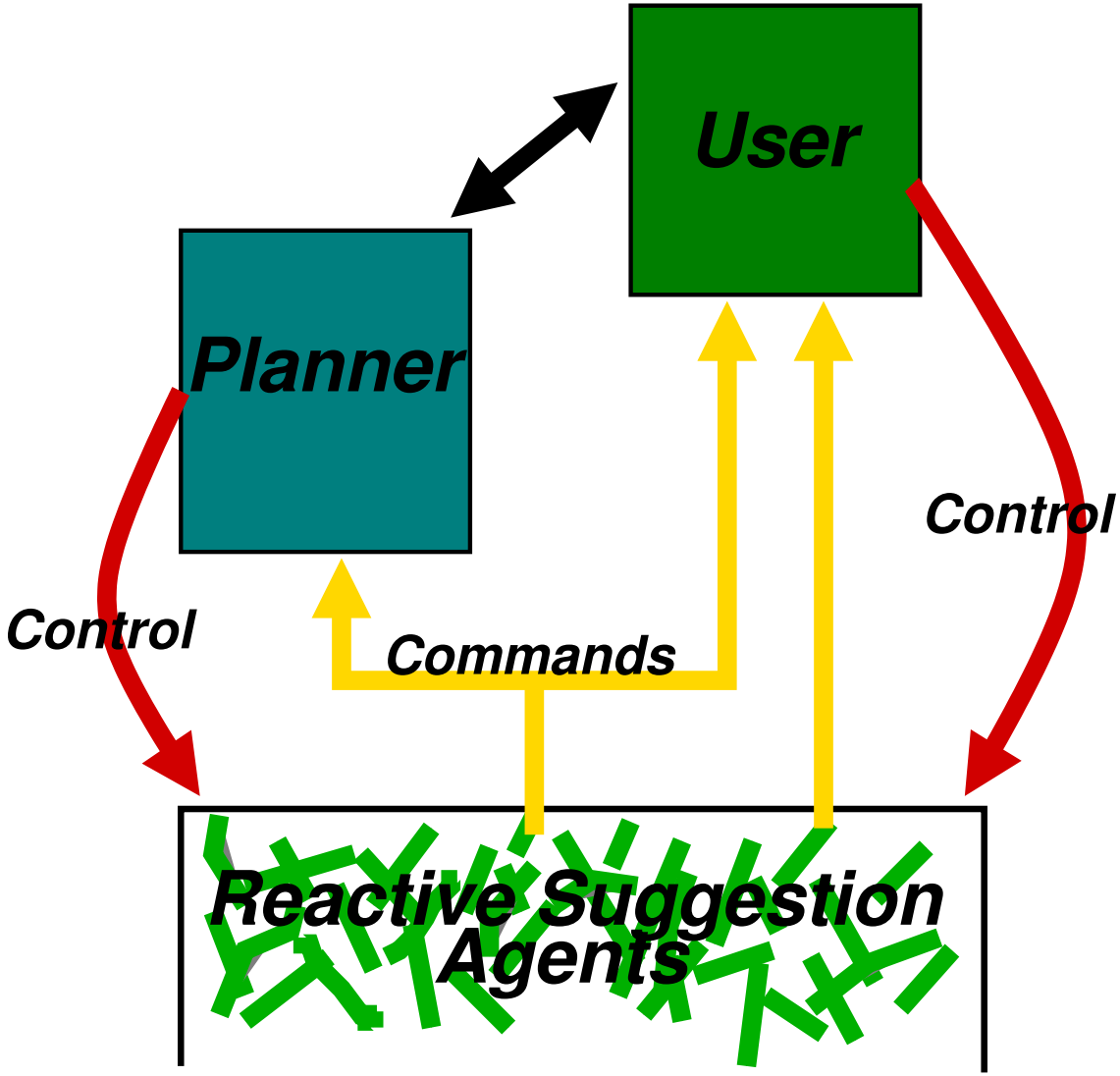
A loose Integration of LEO and OTTER



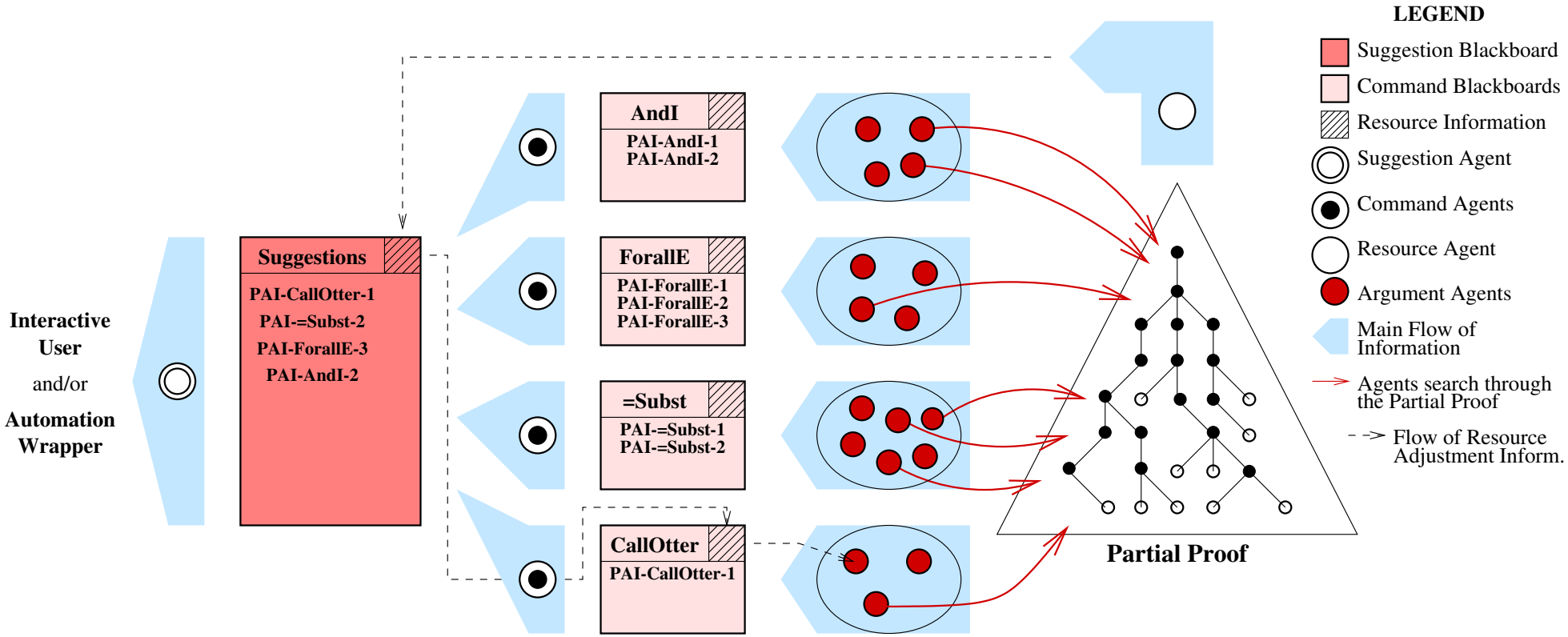
Further Examples for Integration

- specialised ATP's, or Proof Planner
- Computer-Algebra-System
- Modelgenerator (for finding Counterexamples)
- Database Agents
- Analogy Agent
- Interplay with simple ND Agents (ensuring completeness)
- . . .

Ω-ANTS as Basis



Ω-ANTS Architecture



Automation

- Choose maximum Clock Speed for automated command executions
- Simple Depth-First Search (always choose heuristically prioritised command)
- Backtracking
- Avoid recomputations by memorising blackboard entries
- Heuristics and agents can be modified at run-time
- Experiments with propositional ND calculus (NIC) and some external systems

Resource Adaptivity

When reset occurs the Agents

- gather information about their performance since last reset
- maintain average values over all runs
- Report performance information to more informed layer
- Self-evaluation of their performance $\longrightarrow$ update their resource value
- receive bonus or penalty to their resource value from more informed agents
- at a more informed layer take within their resource adjustment reasoning knowledge about performance of lower agents as well as knowledge about the proof context and/or the interactive user into account
- decide whether they thy should retire or to stay active (by comparing their resource value with a global activation/deactivation threshold)

Advantages of Blackboard Approach

- Flexibility
- Anytime Character
- User Adaptability
- Interaction
- Reasoning in Main Calculus
- Robustness
- Run-Time Extendibility
- Problem Adaptability
- Automation
- Reasoning with External Systems

Conclusion

An agent-based reactive basis in ATP or Proof Planning can fruitfully support a resource adaptive, more flexible, and less brittle proof search

- Ω-ANTS-Architecture [AIMSA'98]
- Resource and Knowledge Concept [EPIA'99]
- Automation, External Systems, Formal Semantics [Calculemus'00]
- Kognitive Motivation [AISB'00]
- Formal Investigation of Completeness & Soundness in work
- Integration of various further systems or database agents in work
- Applications of Ω-ANTS in other contexts future work

Related Work: Jörg Denzinger, Michael Fisher, Andrew Ireland, OMRS, MATHWEB, other suggestion mechanisms for interactive theorem proving

Demo

- Interaction and Automation Support
- Run-Time Extendibility
- Performance & Resource Information
- Different proof attempts depending on the chosen command execution interval
  - very few resources: failing pure ND level proof attempt
  - more resources: successful cooperative proof attempt ND, LEO, OTTER
  - lots of resources: pure LEO proof
- Lunchtime Effect