



THE UNIVERSITY
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Towards Agent-based Proof Planning

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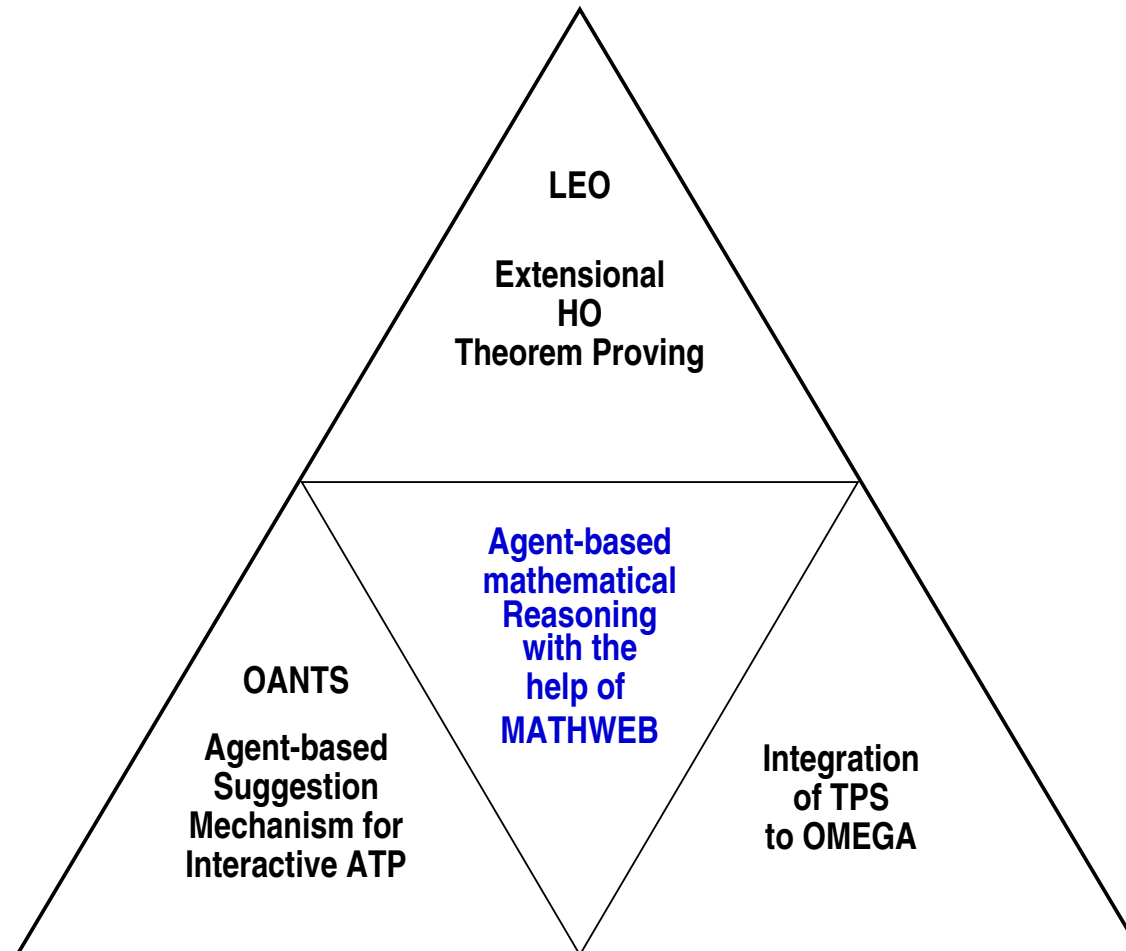
joint work with

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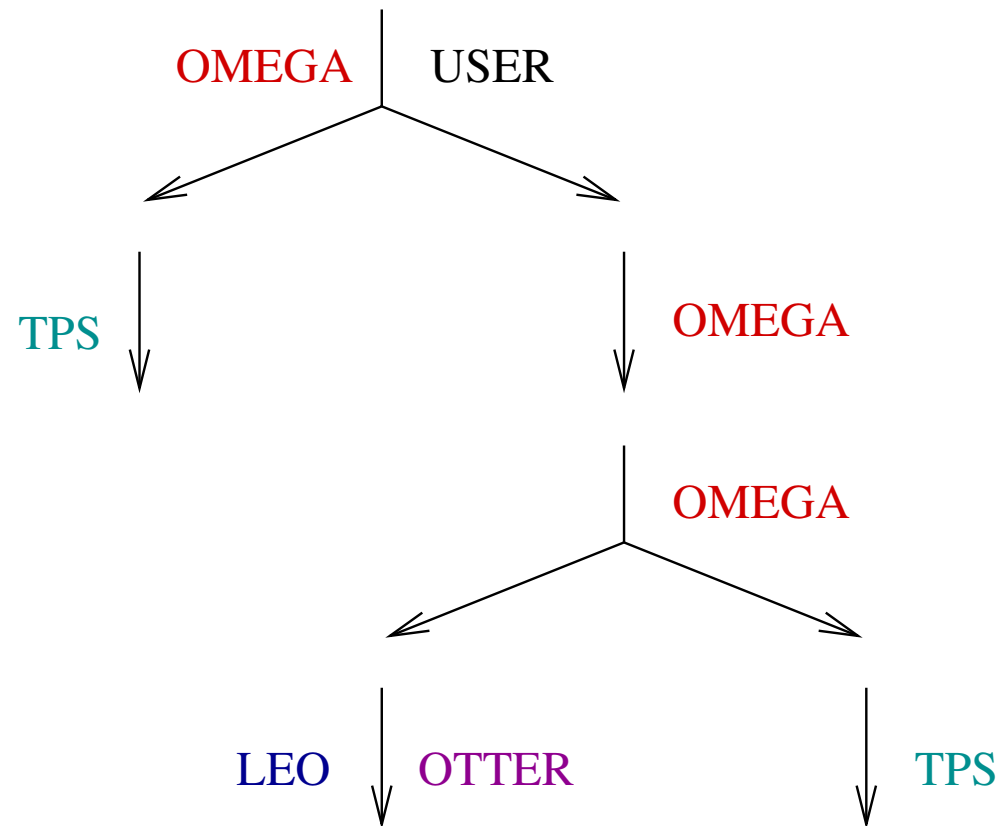
Deduktionstreffen 2000, 6./7. Oktober, Saarbrücken

Motivation



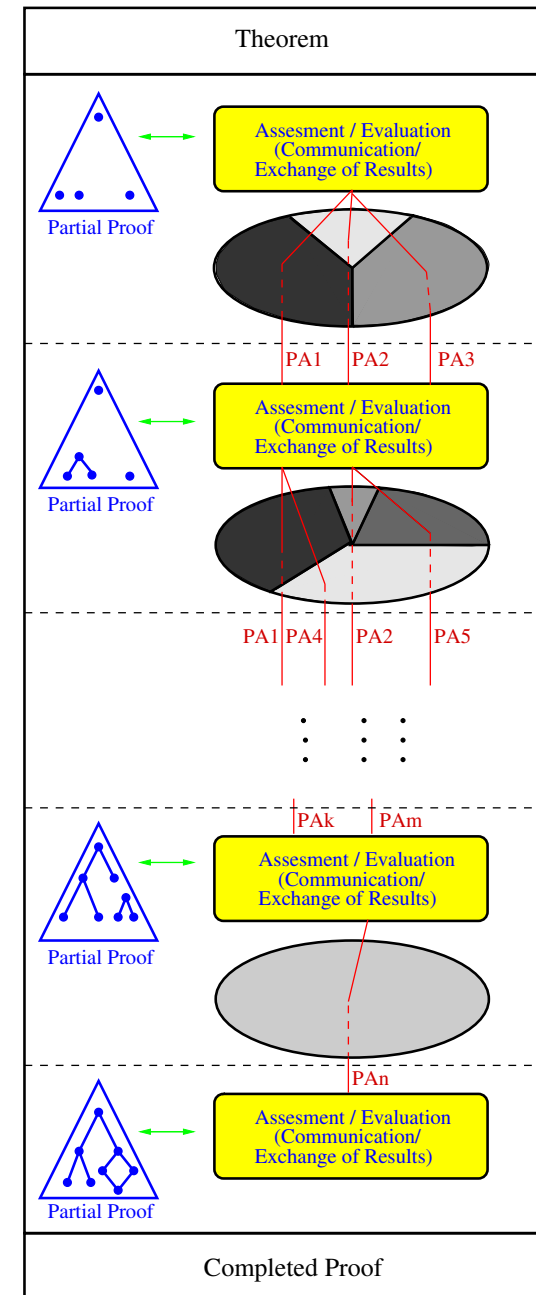
Motivating Example I

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



Reasoning Process

- Different **proof strategies** by different agents PA_x
- 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

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

LEO generates the following propositional logic formulas:

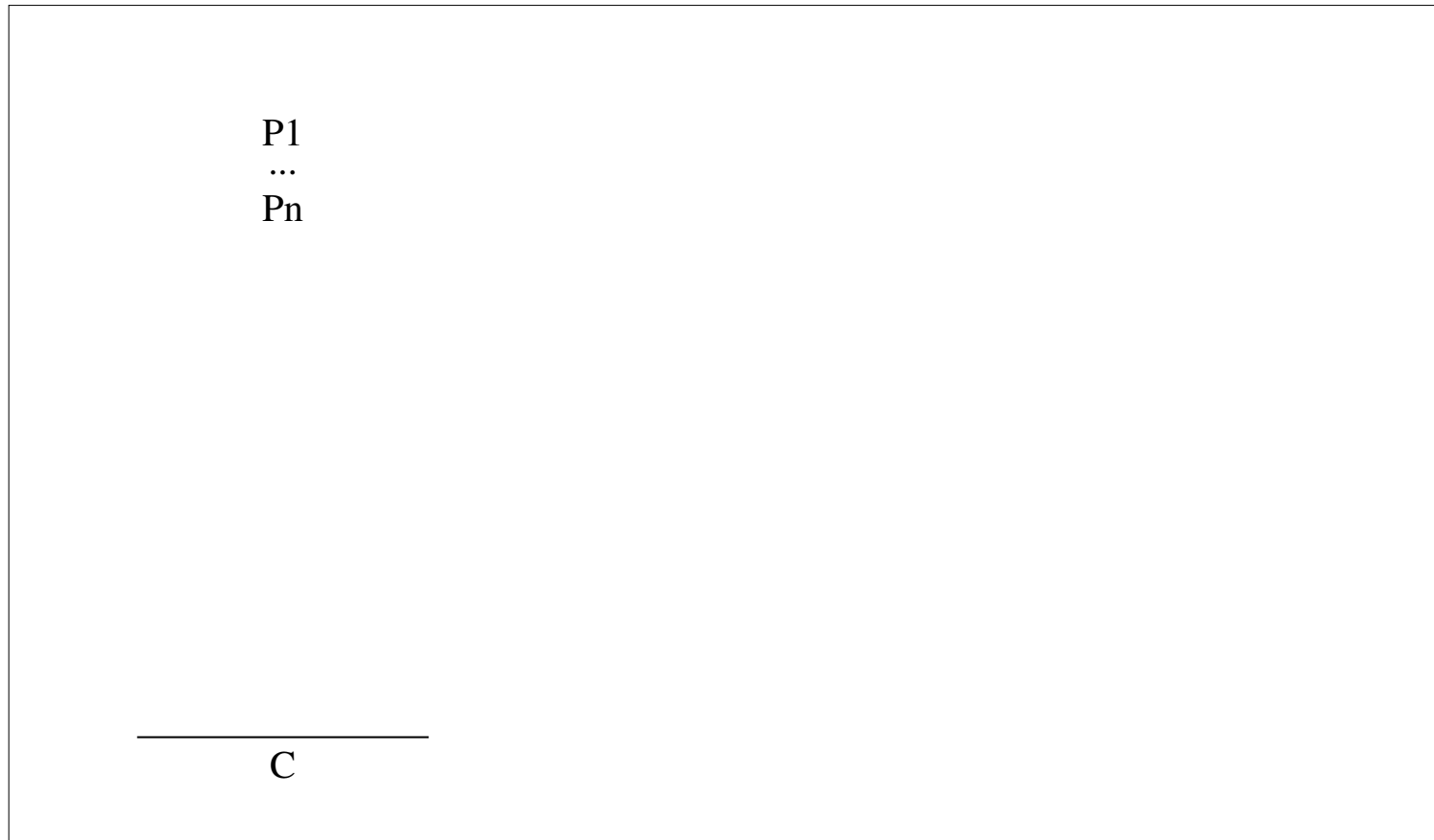
$$\neg(p s) \vee (r s)$$

$$(p s)$$

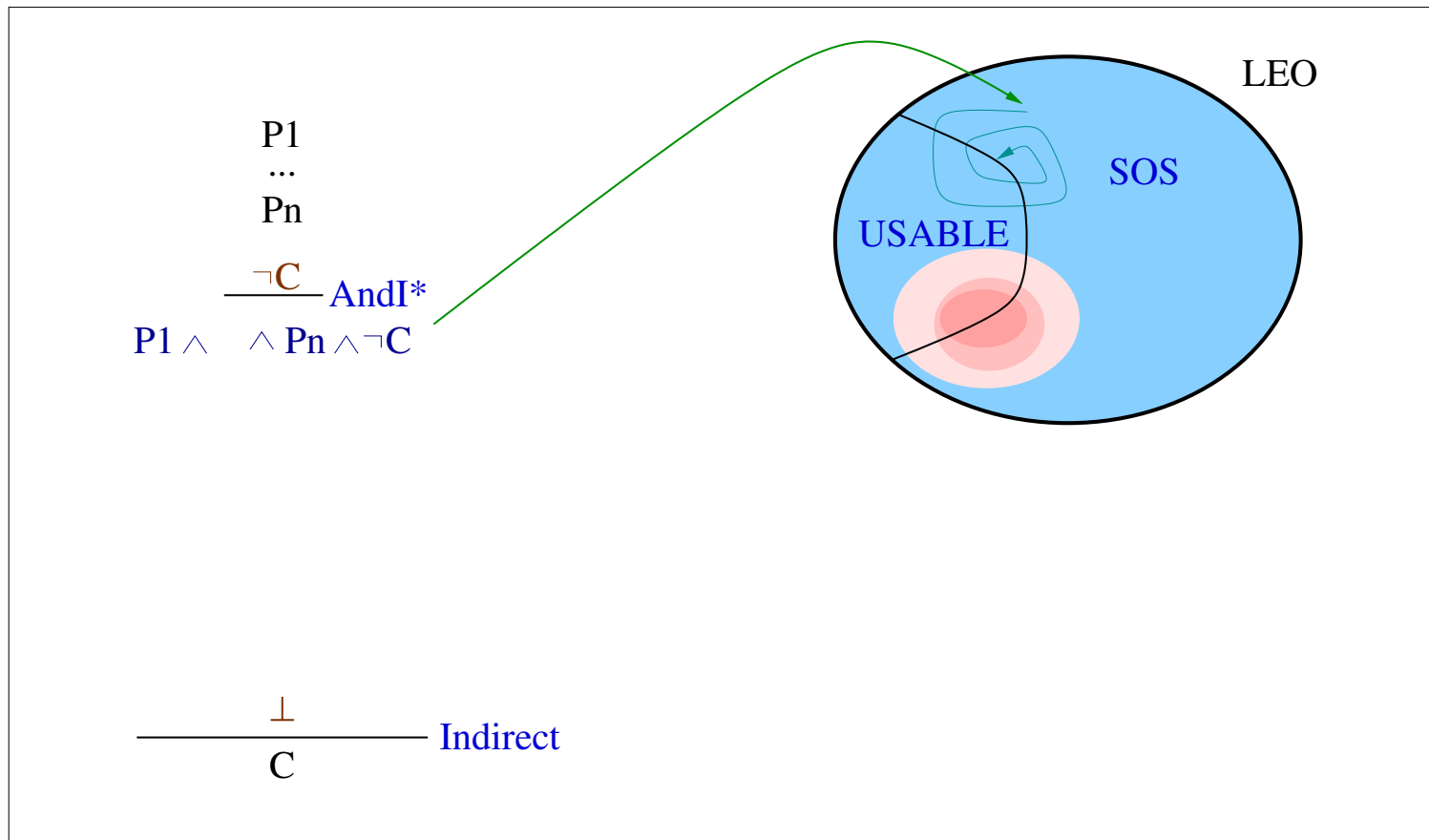
$$\neg(r s)$$

anything($\lambda X.(p_1 X) \Leftrightarrow \dots \Leftrightarrow (p_n X)$) \Rightarrow anything($\lambda X.(p_n X) \Leftrightarrow \dots \Leftrightarrow (p_1 X)$)

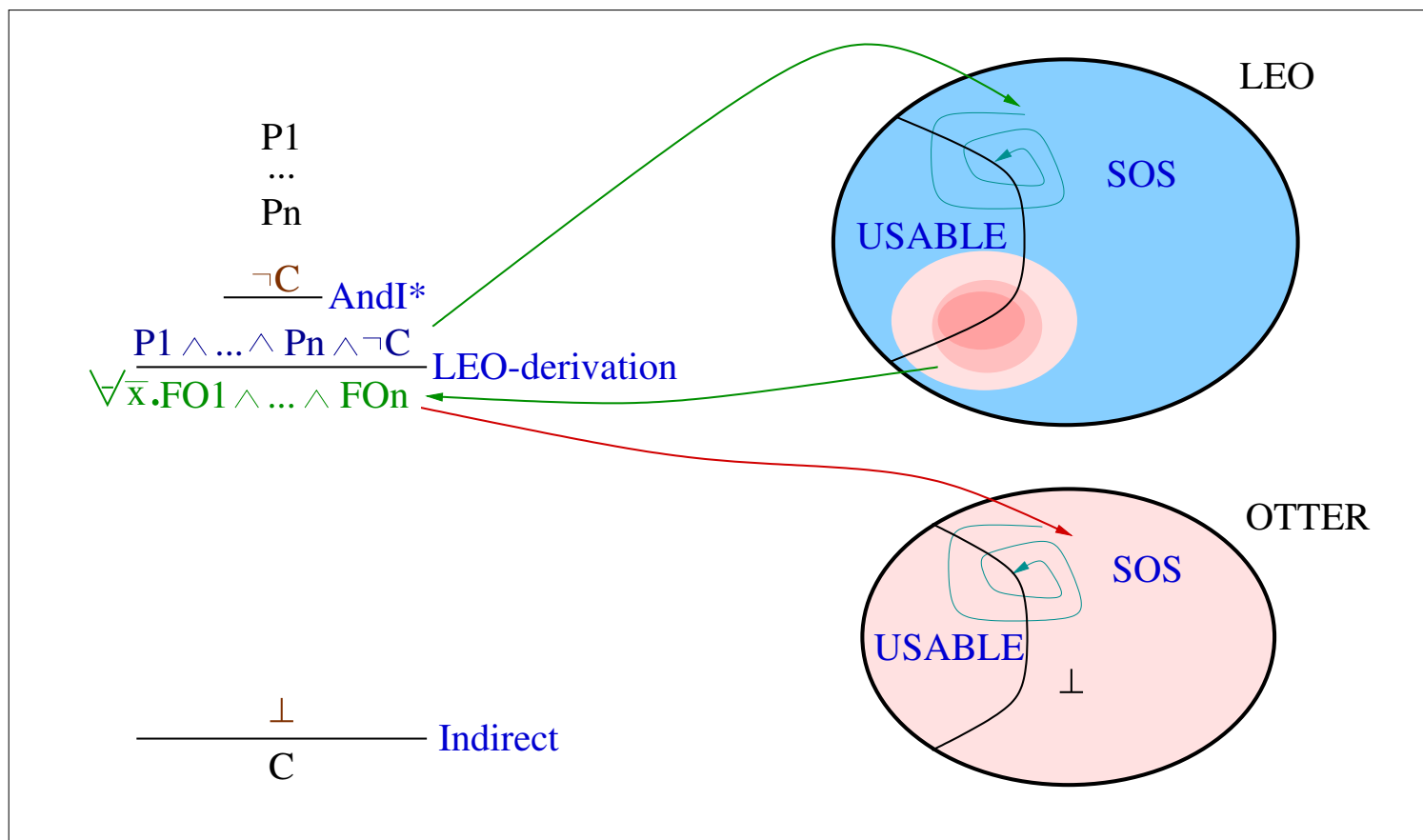
A loose Integration of LEO and OTTER



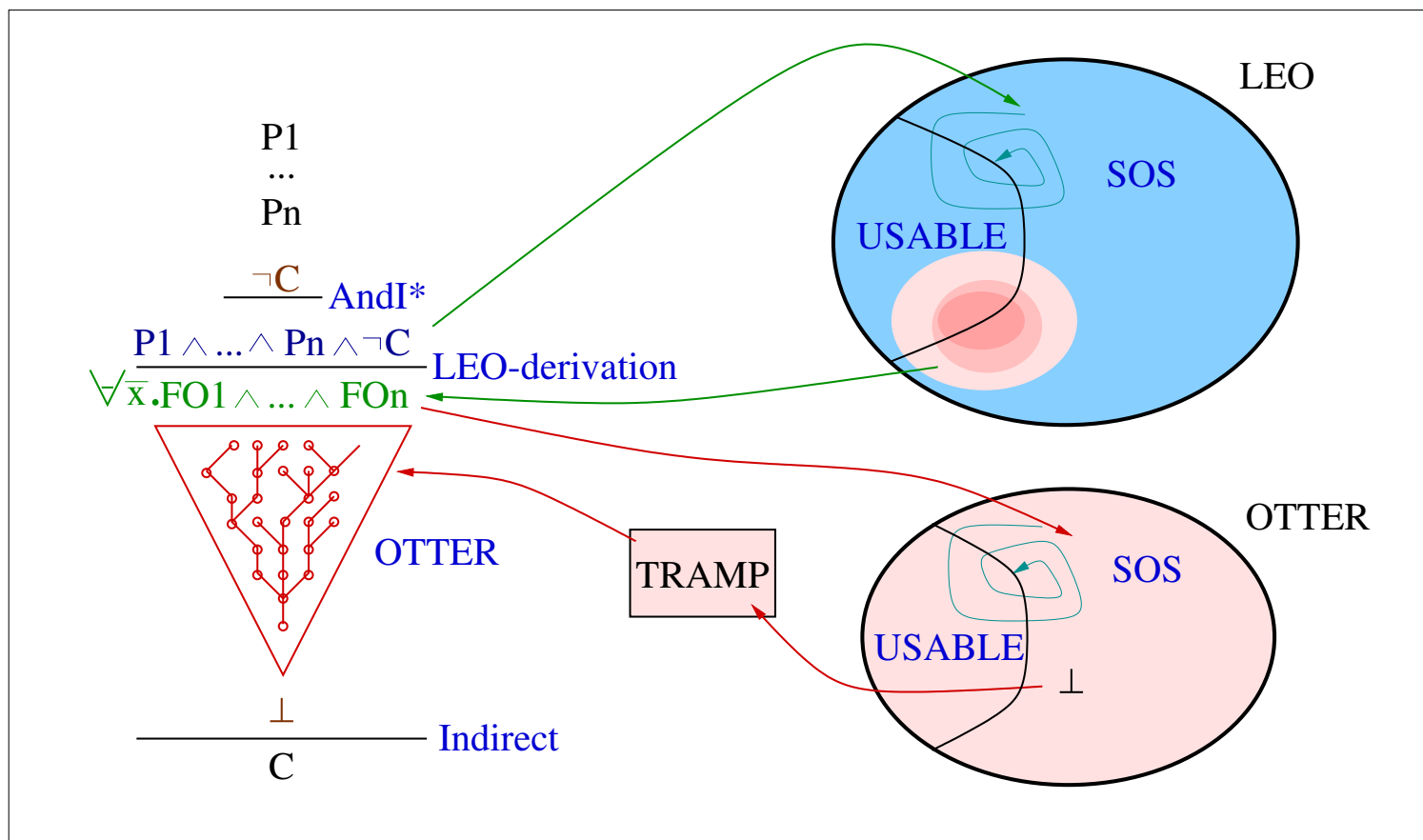
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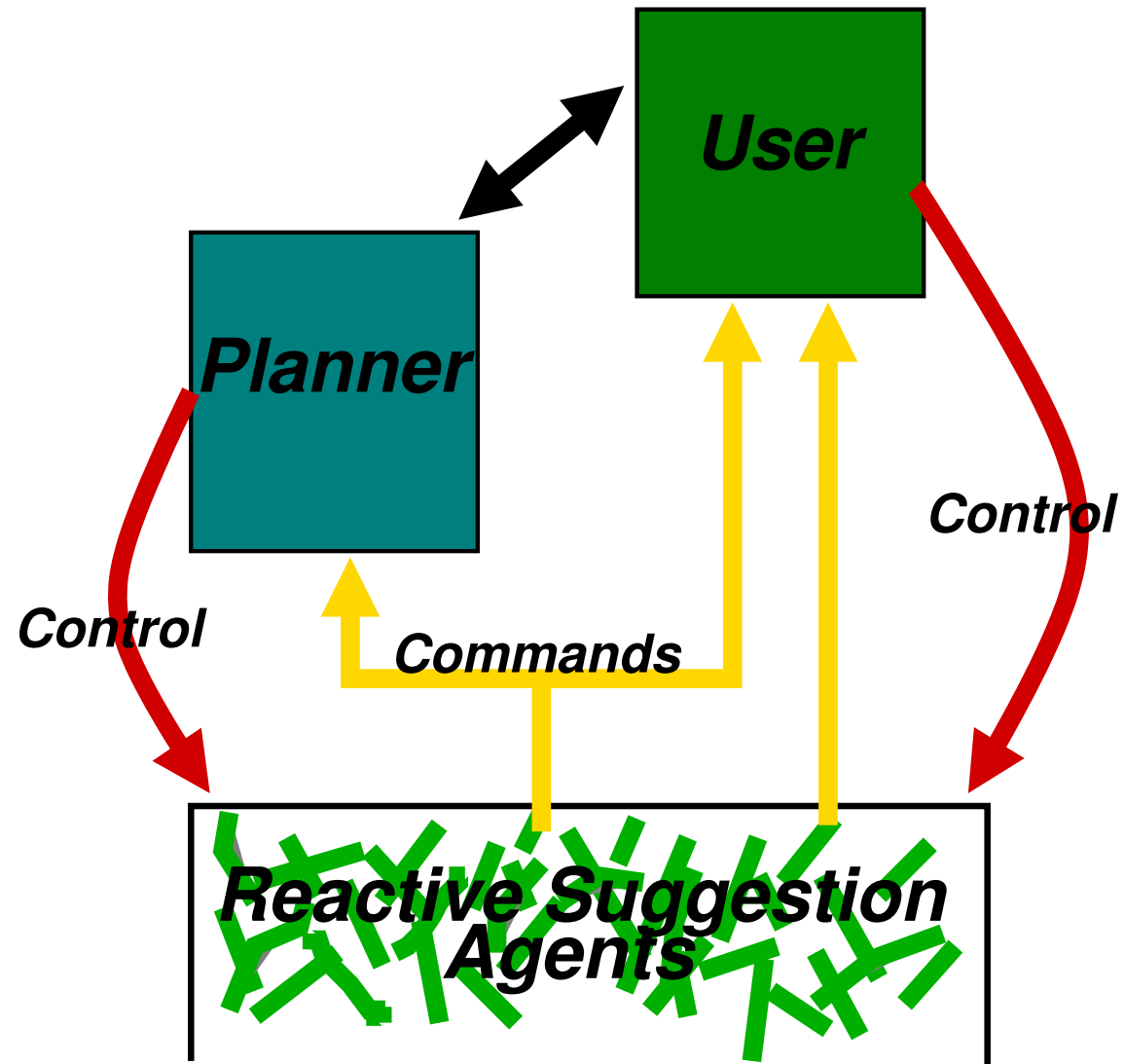
A loose Integration of LEO and OTTER



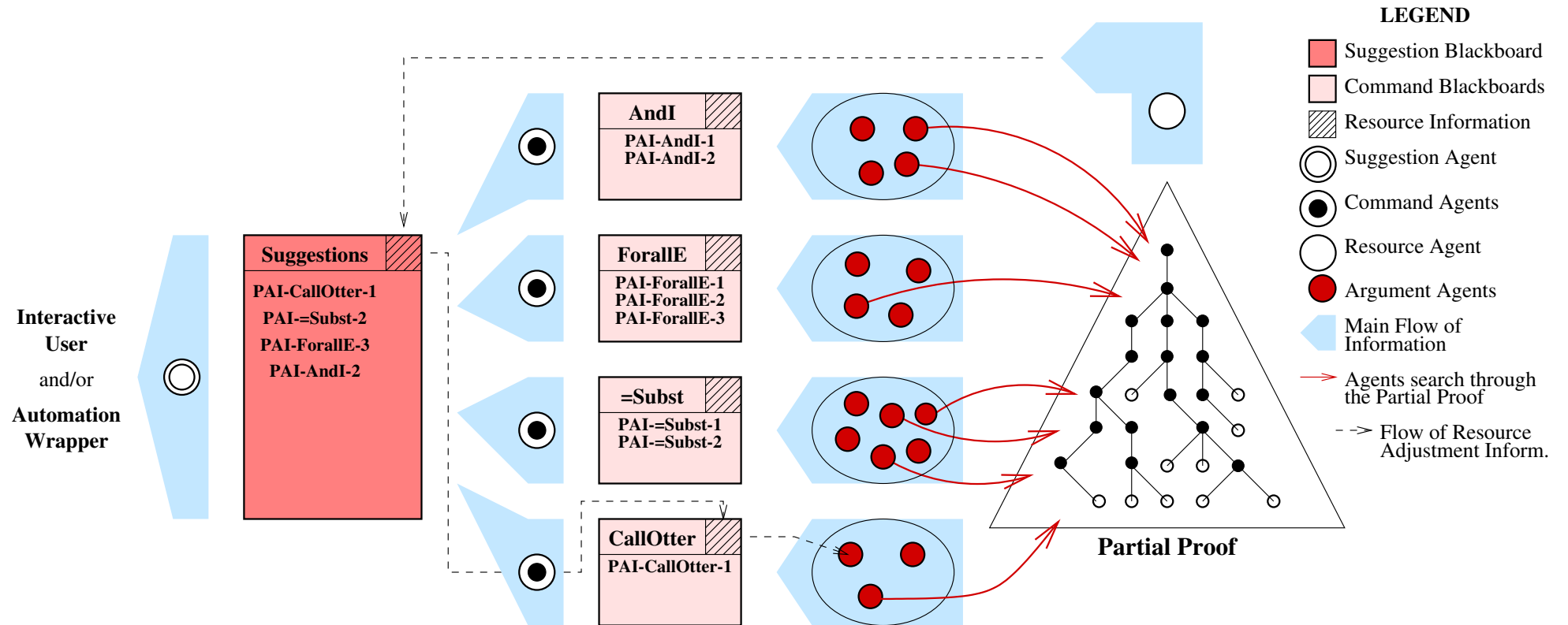
Further Examples for Integration

- 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