From LP to ASP and TN

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Pisa, October 23, 2009

Tentative goal

- Tracing some unlikely, unexpected influences
- Of the ideas floating in Giorgio's group in early 90s
- On apparently unrelated areas
  - ASP (Answer Set Programming)
  - TN (Trust Negotiation)

"after you learn LP, you can't help using it while solving new problems"
(V.S. Subrahmanian, personal communication)

Some evidence about unrelatedness

Claim 1

- Not a single joint paper since 1987

[Guinnes Book of Records, submitted]

Giorgio has been my advisor

- Master thesis (accidentally)
- PhD thesis (deliberately)

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  - **T**endentious **N**onmonotonicity ?
  - **T**erùn in **N**aples ?
- Send suggestions to bonatti@na.infn.it

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- **T**raino a **N**uoto…

This is about *energy*

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- Master thesis (unintentionally)
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  - Back from IRST with many ideas on nonmonotonic reasoning
    - Empty intersection with G.'s background and TO-DO list
  - Visit to VS Subrahmanian @ Univ. of Maryland
  - Unexpected bonus: first steps in security

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  - Unexpected bonus: first steps in security
- Exposure to the group's cultural environment
  - Constraint logic programming
  - Meta-interpreters
  - Partial evaluation
  - Static LP analysis

Now for the inspiration...

Applications to Trust Negotiation (TN)

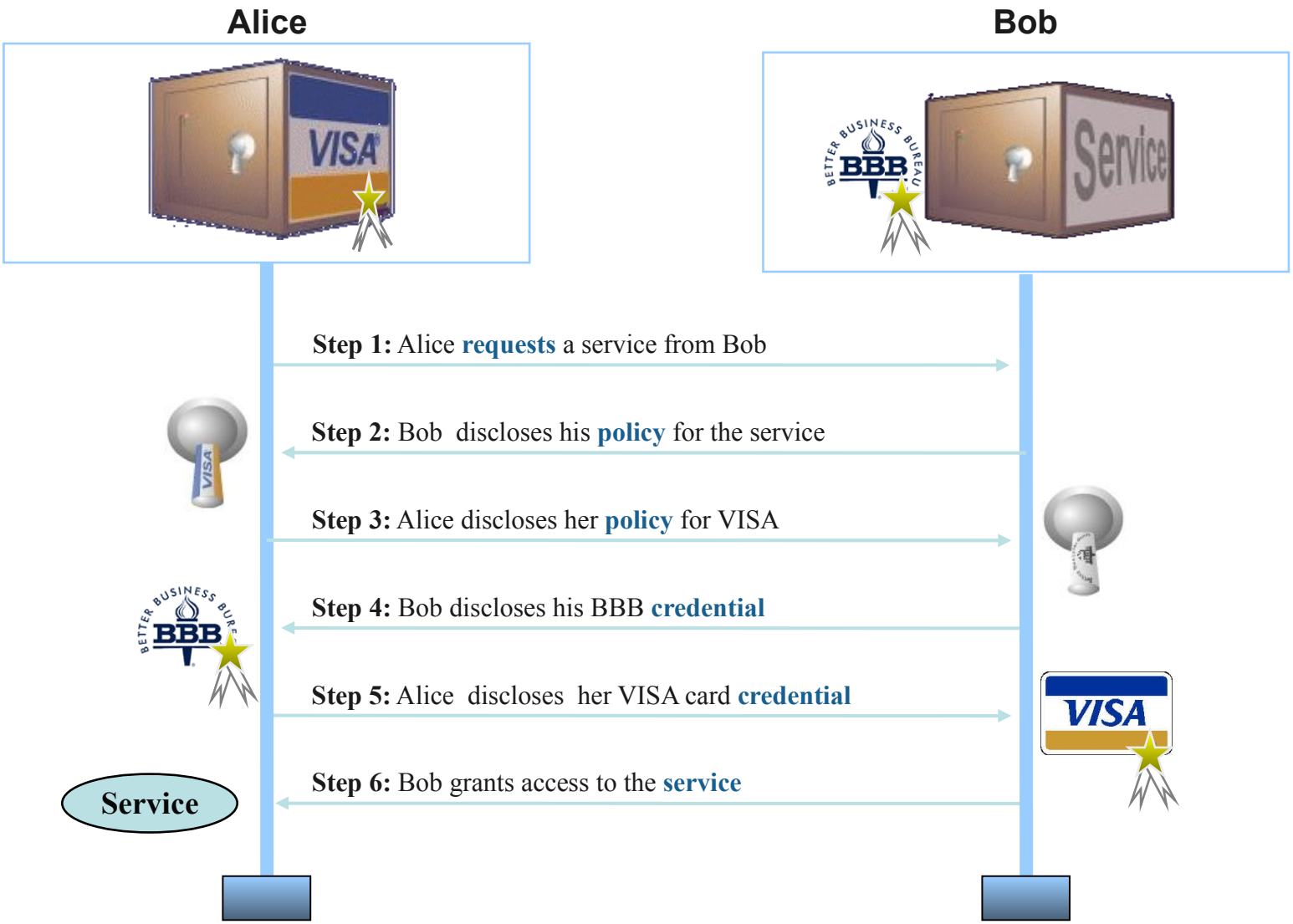
What is Trust Negotiation

- Client and server exchange pieces of information
  - Servers need to know user properties for access control
    - age, membership to companies, subscriptions, nationality
  - Clients ask servers for certifications (privacy guarantees)
    - seal programs: eTrust, BBB (Better Business Bureau)
  - Encoded as X.509 digital credentials and unsigned declarations
- Automatic negotiation
  - For usability (reduce burden on users)
  - And stronger guarantees (credential requests may be forced)

An example (I)

- Server policy
  - Public resources can be downloaded by everybody
  - **Authenticated users** can download the resources they subscribed
  - Any resource can be downloaded by providing
    - An **ID** (passport, driving licence, student ID, …)
    - An accepted **credit card** (VISA, Mastercard, American Express, …)
- Client policy
  - Credit cards are disclosed only to **members** of eTrust or BBB

An example (II)



How to request information

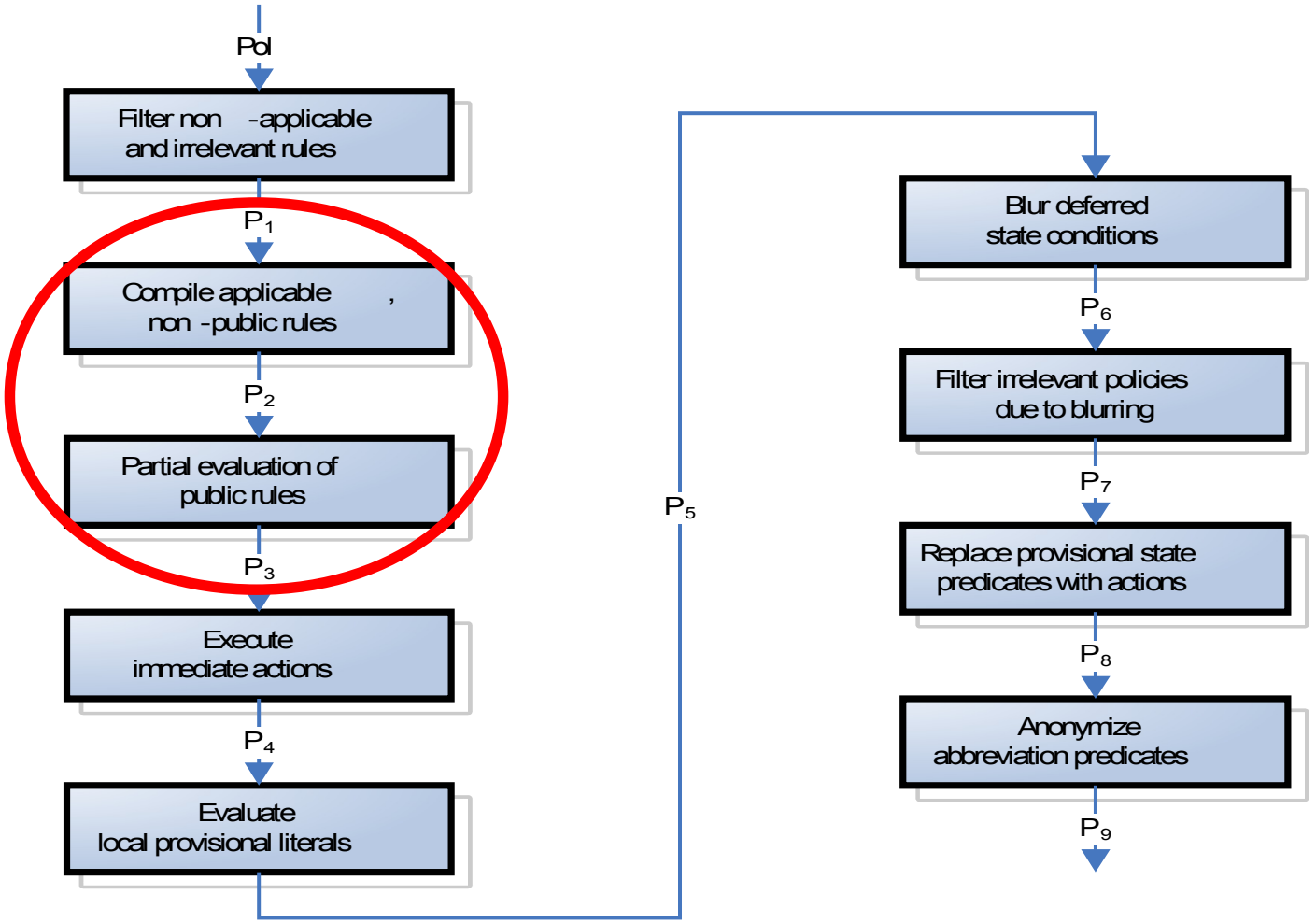
- One specific set of credentials ?
  - (among all possible alternatives)
  - Blind backtracking!
- All possible sets of credentials ?
  - Huge messages!
- The policy applying to the requested resource
  - More efficient (less and smaller messages)
  - Privacy-enhancing (users can choose the best option)

However, policies may be sensitive

- For example:
  - Only my best friends can see these pictures
  - Company X's employees can access confidential data
  - The list of accepted credit cards can be disclosed
  - The list of correct user-password pairs cannot
- How to protect the sensitive parts of a policy?

Policy filtering

- **Partial evaluation**! In PROTUNE:



Adapted results

- Equivalence of original and filtered policies w.r.t. a given goal (authorization)
  - Equivalence up to *blurring*
    - Partial or total removal of a predicate's definition
  - In general there is loss of information
  - Soundness is guaranteed
  - Completeness relative to non-blurred information

  - Not mentioned here: metainterpreters for credential selection and explanations

Now for something completely different (ASP)

What is answer set programming

- A declarative problem solving paradigm
- Syntax: Normal logic programs

$$A \leftarrow B_1, \ldots, B_m, \text{ not } B_{m+1}, \ldots, \text{ not } B_n$$

- Semantics: Stable *model* semantics
  - Gelfond-Lifschitz reduct P^M (partial evaluation again...)
    - Remove all rules with a not B such that $B \in M$
    - Remove all negative literals from the surviving rules
  - M is a *stable model* of P iff

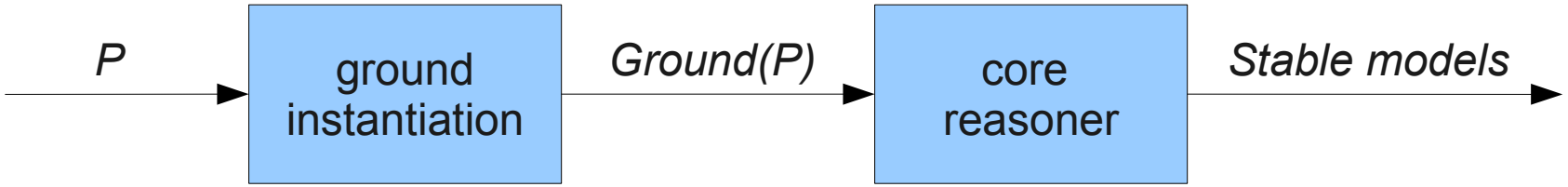
$$M = \textit{least model of } P^M$$

- Negation is an amalgamated unprovability modal operator

How to solve problems in ASP

- A normal program may have 0, 1, or multiple stable models
- Write *P* so that its stable models are in 1-1 correspondence with problem solutions
- Complete for NP (Datalog case)

How to implement ASP



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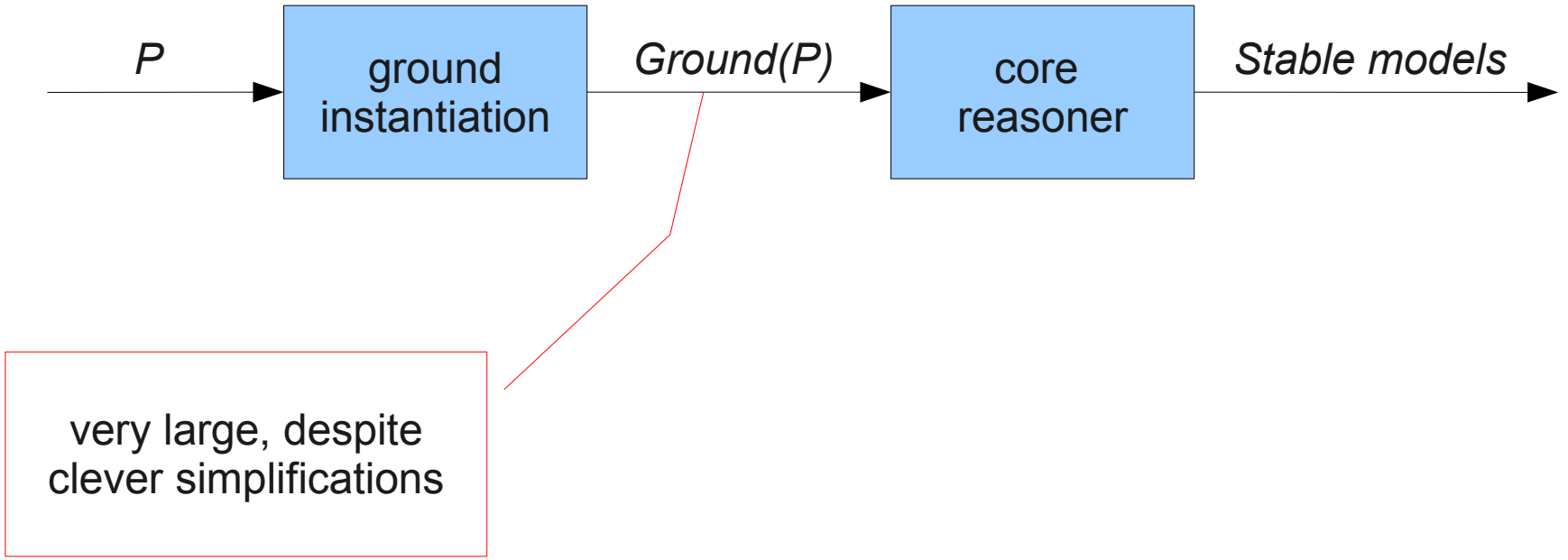

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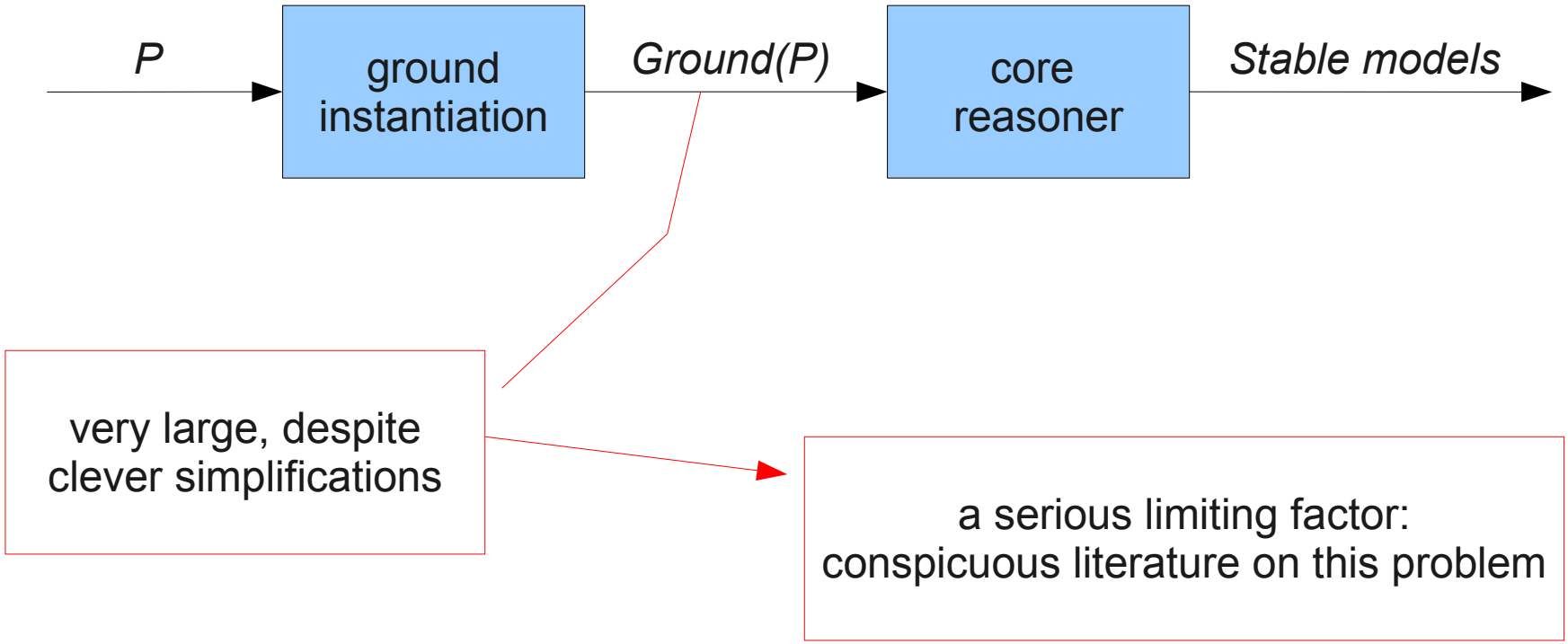

An obviously appealing solution

- **S-semantics** !
- Explored by VS Subrahmanian
- Some difficulties with disunifiers

Our approach

- ASP + **Constraint Logic Programming**
  - Joint work with S. Baselice and M. Gelfond
- Rigid partitioning of program rules
  - ASP, Constraints, Bridge
  - Strong syntactic restrictions, but
  - Amazing speedups in a planning setting
    - USAdvisor (planning operations for the Space Shuttle)
- Only ASP rules need to be grounded
  - On a small domain
  - Constraints handle time (much larger!)
  - Granularity up to minutes for weeks-long plans
  - (awarded at the ASP workshop 2005)

Infinite domains
an (almost) all italian contribution to ASP

Extending ASP

- Originally ASP was restricted to Datalog with negation
  - Reasoning with function symbols: Π^1_1-complete
- However function symbols are important for:
  - Encapsulation
  - Recursive data structures
    - Including HTML, XML
- We introduced the first computationally well-behaved ASP fragment with functions [IJCAI'01]
  - **Finitary programs**
  - Ground queries: decidable
  - Nonground queries: r.e.-complete

A very expressive class

- It contains
  - All the standard list/tree manipulation programs
  - Many planning programs
  - SAT and QBF metainterpreters
  - A simulator of Turing machines with bounded tape
- Much more expressive than Datalog ASP

Problem

- Checking whether a normal LP is finitary is **undecidable**
- Let's see why

Finitary programs: definition

- Finitary =
  1. *Finitely recursive*
  2. *Finitely many odd-cycles*
- Based on the atomic dependency graph:
  - Nodes: ground atoms
  - Edges: (A,B) such that A=head(r) and B occurs in body(r) for some r in *Ground(P)*
- Finitely recursive = each A depends on finitely many B
  - *A depends on B* iff ∃ a path from *A* to *B*
- Odd-cycle = with an odd number of negative edges
  - Negative edge: B occurs in the scope of negation

More on undecidability

- Turing machines can be simulated with binary clauses
- Computations = paths in the dependency graph
- Undecidability proof by reduction from termination

Rescued by static analysis

- First idea: use *norms* (“size” of a term)
  - $|t|$ = #simbols in t
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  - They cause infinite branching in the graph
- This requires proving that
  - For each ground instance of the head
  - The answer substitutions for the body are *finitely many*
  - By subterm analysis
    - e.g. member(X,L) where X local and L occurs in the head

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- Thorough analysis of finitely recursive programs
  - That generalize all of the above
  - Best paper at IJCAI'07

What *will* happen next

- Syntactic, decidable class based on norms
  - Without ruling out infinite models
- So far, restrictions are somewhat *ad hoc*
- Plan: use **abstract interpretations** to prove that the class is “optimal”
  - Best exploitation of the adopted approximation

That's almost all, folks

Final remarks

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- A final mention to his rich *vision* of a professor's role, beyond mere scientific influence

Thank you!