Robust probabilistic inference engines for autonomous agents

Stefano Ermon
Stanford University
Problem Solving in AI

**What** to compute?

**How** to compute?

**Problem instance** → **Model Generator (Encoder)** → **General Reasoning Engine** → **Solution**

Domain-specific instances → General modeling language and algorithms

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Problem solving in AI:

Separate modeling from algorithms
Safety and reliability require:

1. precise models
2. accurate reasoning techniques
Challenges in reasoning about complex systems

Preferences and Utilities

Optimization

Combinatorial Optimization

Stochastic Optimization

Decision-making

Probabilistic Reasoning

Statistics

Combinatorial Reasoning

High-dimensional Spaces

Lack of information/Uncertainty
Challenges in reasoning about complex systems

- Theorem provers, logical reasoning, SAT solvers, soundness, certificates of optimality, ...
- Preferences and Utilities
- Optimization
  - Combinatorial Optimization
  - High-dimensional Spaces
  - Lack of information/Uncertainty
- Decision-making
  - Probabilistic Reasoning
  - Statistics
- Hardware verification
- Program synthesis

The image contains a Venn diagram illustrating the relationships between challenges in reasoning about complex systems, including:

- Optimization
- Combinatorial Optimization
- High-dimensional Spaces
- Lack of information/Uncertainty
- Preferences and Utilities
- Decision-making
  - Probabilistic Reasoning
- Statistics

The diagram highlights intersections and overlaps among these categories, indicating how different challenges intersect and influence each other in the context of reasoning about complex systems.
Proposal and recent results

**Proposal**: use *combinatorial reasoning/optimization* techniques (logic, verification, synthesis) for *probabilistic reasoning* tasks (machine learning)

- Algorithms that can provide **certificates/proofs of accuracy**
- Handle **extreme (unsafe) events**
- Can support deterministic + probabilistic dependencies

• Some recent results:
  - Satisfiability Modulo Theory solvers for statistical hypothesis testing (Zhao et al., AAAI-2016)
  - Integer Linear Programming for sampling (Kim et al., AAAI-2016)
  - Integer Linear Programming and SAT for decision making under uncertainty (Xue et al., NIPS-2016)
  - Variational methods with guarantees (Achim et al., AISTATS-2016)
Thanks!