

Representing and Solving Factored Markov Decision Processes with Imprecise Probabilities

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About the authors

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 - Main interest: Artificial Intelligence Planning
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 - Main interest: Imprecise Probabilities

The main idea of the paper

Obtain a model with imprecise probabilities that can be applied to problems in Artificial Intelligence Planning.

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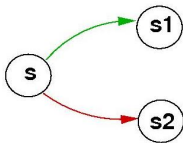
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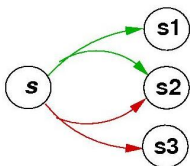
Obtain a model with imprecise probabilities that can be applied to problems in Artificial Intelligence Planning.

What is planning?

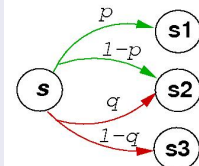
Divisions of Planning



Deterministic



Nondeterministic



Probabilistic

In probabilistic planning...

At each stage, the agent observes the current state and selects an action that maximizes the probability of reaching a goal state.

Markov Decision Process

Traditional formulation: tuple $\langle \mathcal{T}, \mathcal{S}, \mathcal{A}, P, R \rangle$

\mathcal{T} : set of stages or decision epochs

\mathcal{S} : set of possible states of the system

\mathcal{A} : set of available actions or decisions

P : conditional probability distributions

R : immediate reward function

Bellman equation

$$V(s) = \max_a \left[R(s, a) + \gamma \sum_r P(r|s, a) V(r) \right]$$

Markov Decision Process

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Explicit or *extensional* representation

Representations of states

Explicit or extensional

- States are enumerated
- Intuitive
- Most appropriate for small problems

Intensional or factored

- States or sets of states are described using sets of multi-valued *features* or *factors*
- Can be very compact (requires presence of structure)
- Allows the use of languages (STIRPS, PDDL, CTL, etc.)
- Other components can also be represented implicitly

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Factored representation

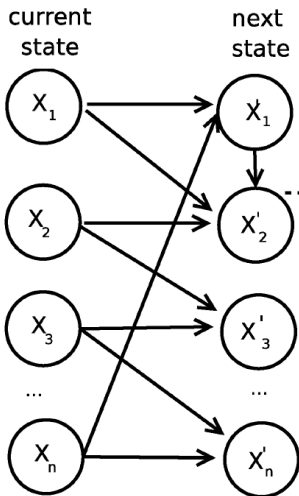
Factored representation of states

$$s_j \in \mathcal{S} \leftrightarrow \{x_1, x_2, \dots, x_n\} \in \{X_1, X_2, \dots, X_n\}$$

Factored MDP: Factorization of the probability distribution

$$P(\vec{x}' | \vec{x}, a) = \prod_{i=1}^n P(x'_i | pa(X'_i), a);$$

Dynamic Bayesian Network



b)

X_1	X_2	X'_1	$X'_2 = 1$
T	T	T	0.9
T	T	F	0.95
T	F	T	0.01
T	F	F	0.01
F	T	T	0,33
F	T	F	0,35
F	F	T	0.01
F	F	F	0.005

MDPIP

Formulation: tuple $\langle \mathcal{T}, \mathcal{S}, \mathcal{A}, K, R \rangle$

\mathcal{T} : set of stages or decision epochs

\mathcal{S} : set of possible states of the system

\mathcal{A} : set of available actions or decisions

K : sets of conditional probability distributions

R : immediate reward function

Bellman equation (Γ -Minimax)

$$V(s) = \max_a \left[R(s, a) + \gamma \min_{P \in K} \sum_r P(r|s, a) V(r) \right]$$

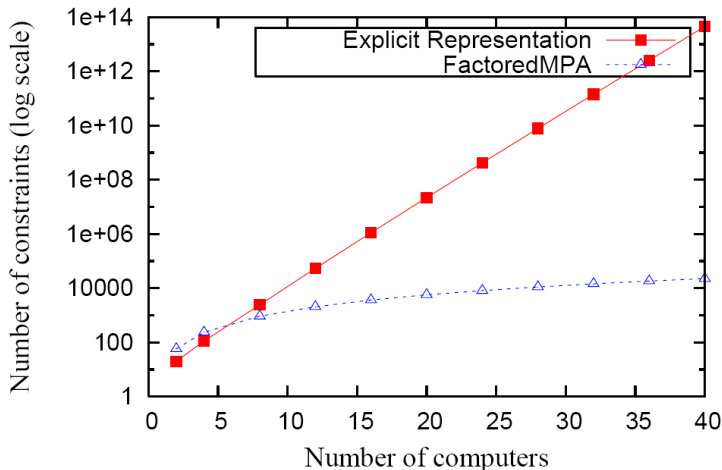
Results

- 1 Definition of Factored MDPIP (MDPIP + use of factored representation)
- 2 Multilinear program based on FactoredLPA
- 3 Extension of PPDDL to represent Factored MDPIP

Please check poster for details

Graphics

Multilinear Solution



Graphics

