Notions of Safety with Uncertain Specifications

RSS 2019 Workshop on Combining Learning with Reasoning

Ankit Shah, Julie Shah
{ajshah, arnoldj}@mit.edu

Motivation

- Linear temporal logic (LTL) formulas are an expressive means for specifying non-Markovian tasks.
- Prior research relies on LTL to automaton compilation for planning. However this is restricted to a single LTL formula.
- In many application there is an inherent uncertainty in specifications.[1],[2]
- In general specifications are expressed as a belief $P(\varphi)$ over support $\{\varphi\}$.

Question 1: What does satisfying a belief $P(\varphi)$ mean?

Question 2: What are the implications of the answer to Q1?

Evaluation Criteria

Most Likely

$$\mathbb{1}([\alpha] \vDash \varphi^*)$$
$$\varphi^* = argmax_{\varphi \in \{\varphi\}} P(\varphi)$$

Satisfy only the most likely formula.

Maximum Coverage

$$\frac{1}{|\{\varphi\}|} \sum_{\varphi \in \{\varphi\}} \mathbb{1}([\alpha] \vDash \varphi^*)$$

Satisfy the largest set of unique formulas.

Minimum Regret

$$\sum_{\varphi \in \{\varphi\}} P(\varphi)\mathbb{1}([\alpha] \vDash \varphi^*)$$

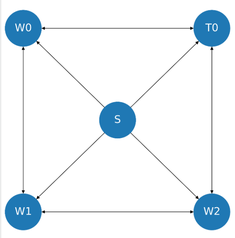
Maximize satisfaction weighted by probability.

Chance Constrained

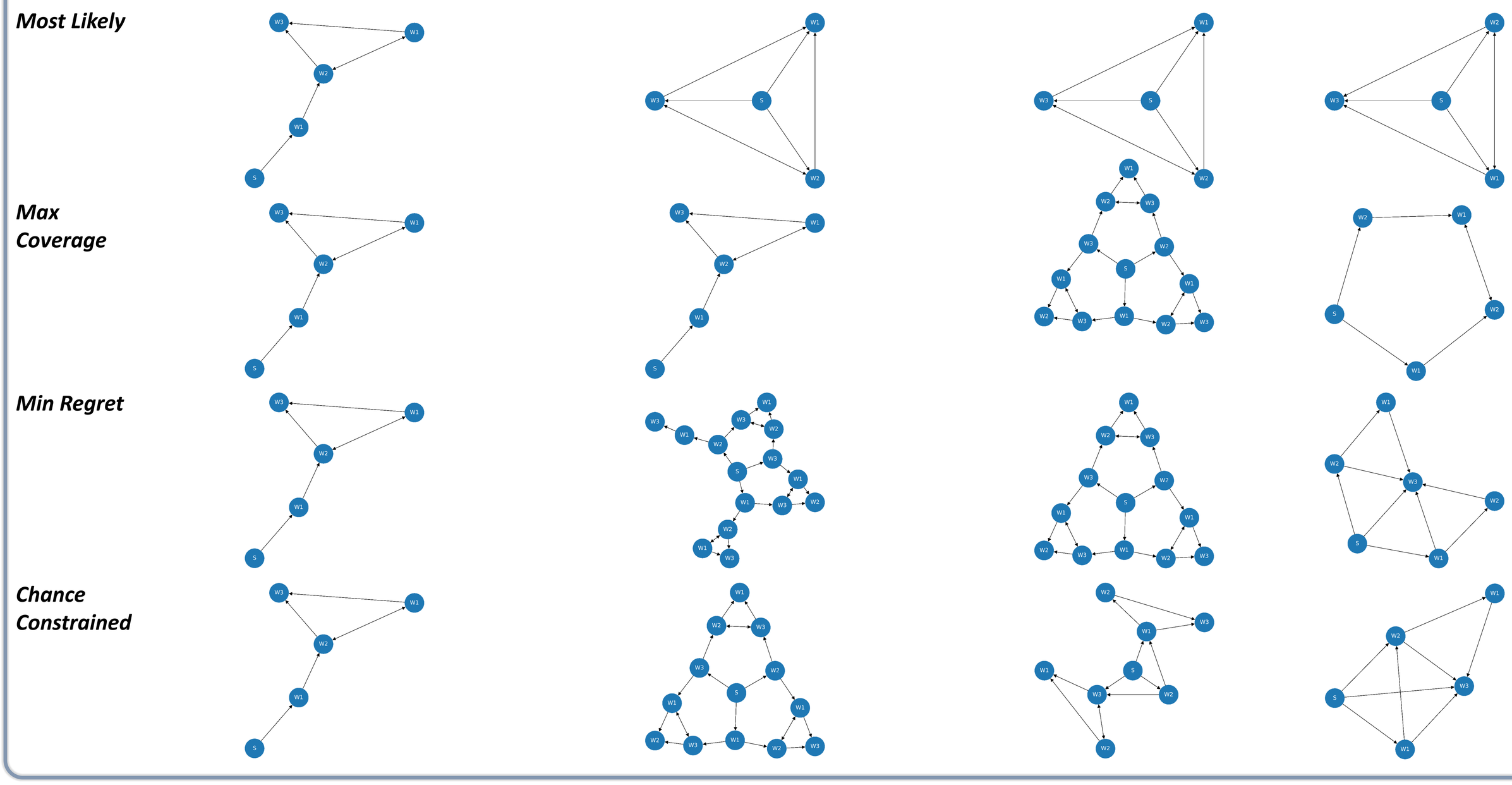
$$\sum_{\varphi \in \varphi^\delta} P(\varphi)\mathbb{1}([\alpha] \vDash \varphi^*)$$

δ is the maximum failure probability.

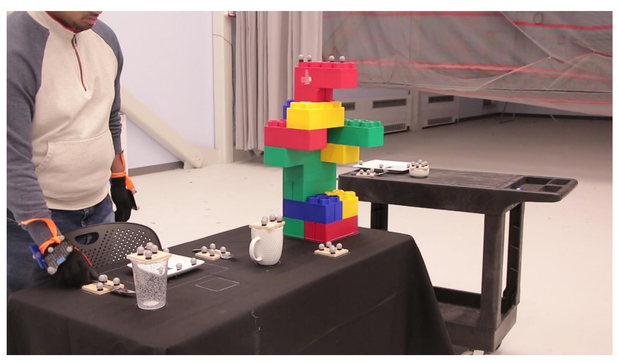
Implications Of Criterion Selection

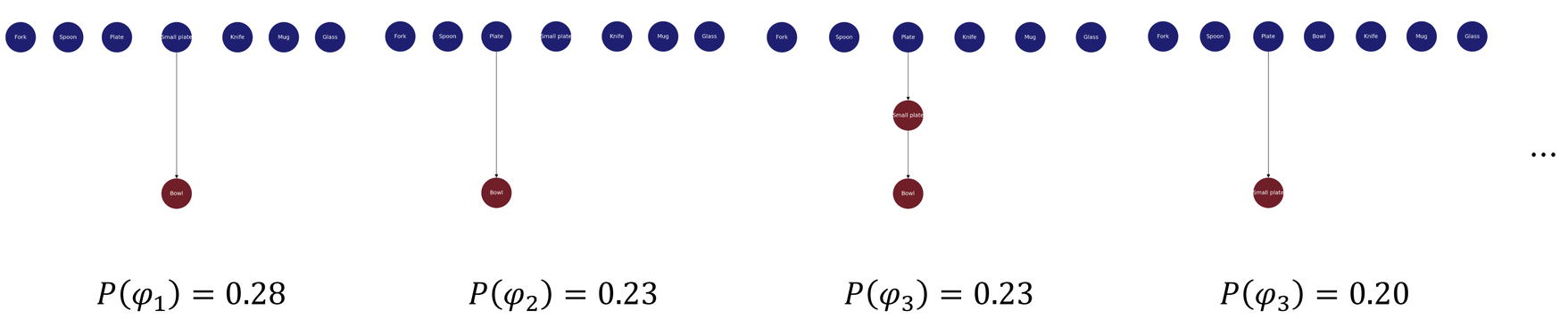


$P(\boldsymbol{F}W3 \wedge \neg W3 \boldsymbol{U} W2 \wedge \neg W2 \boldsymbol{U} W1) = 0.8$	$P(\boldsymbol{F}W3 \wedge \neg W3 \boldsymbol{U} W2 \wedge \neg W2 \boldsymbol{U} W1) = 0.8$	$P(\boldsymbol{F}W1) = 0.4$	$P(\boldsymbol{F}W1 \wedge \boldsymbol{G}\neg W3) = 0.15$
$P(\boldsymbol{F}W1 \wedge \boldsymbol{F}W2 \wedge \boldsymbol{F}W3) = 0.15$	$P(\boldsymbol{F}W1 \wedge \boldsymbol{F}W2 \wedge \boldsymbol{F}W3) = 0.15$	$P(\boldsymbol{F}W2) = 0.25$	$P(\boldsymbol{F}W2 \wedge \boldsymbol{G}\neg W3) = 0.05$
$P(\boldsymbol{F}W1) = 0.05$	$P(\boldsymbol{F}W1) = 0.05$	$P(\boldsymbol{F}W3) = 0.35$	$P(\boldsymbol{F}W3) = 0.8$



Dinner Table Setting: A LfD Case Study





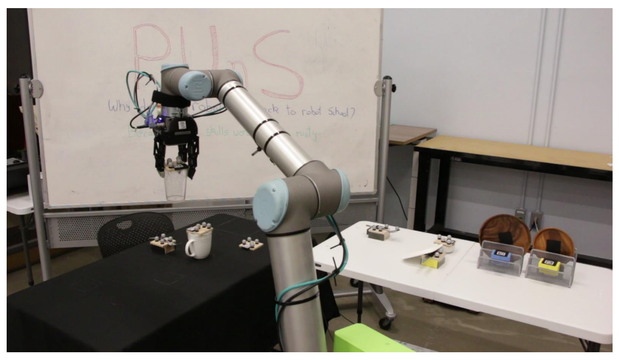
$P(\varphi_1) = 0.28$ $P(\varphi_2) = 0.23$ $P(\varphi_3) = 0.23$ $P(\varphi_3) = 0.20$

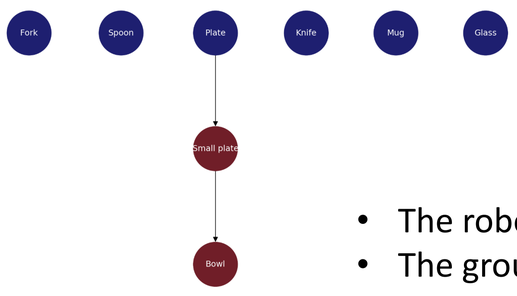
- 30 demonstrations
- 25 unique formulas in the posterior distribution

- Compiled using *minimum regret* criterion

Available action

Invalid action





- The robot honors the most restrictive task specification
- The ground-truth constraints are only 3rd most likely specification

[1] Shah, A., Kamath, P., Shah, J. A., & Li, S. (2018). Bayesian inference of temporal task specifications from demonstrations. In *Advances in Neural Information Processing Systems* (pp. 3804-3813).
[2] Kim, J., Banks, C. J., & Shah, J. A. (2017, February). Collaborative planning with encoding of users' high-level strategies. In *Thirty-First AAAI Conference on Artificial Intelligence*.

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