Learning Generalized Unsolvability Heuristics for Classical Planning

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Introduction

- Recent interest in detecting unsolvable states, i.e., there is no plan to any goal state
- Some methods are unsolvability heuristics tailored to the given problem
- We approach the problem from a generalized planning perspective: problem-independent characterization of unsolvable states
- We learn formulas of Boolean features based on description logic
- The problem is cast as a self-supervised classification task
- The input is small instances that are labeled through exhaustive search

Questions

1. Can unsolvable states be characterized using only the predicates defined in the domain?
2. If so, are the characterizations concise?
3. Can they be learned efficiently?
4. Are they fast to evaluate?
5. Can they compete against existing methods?
6. Can they complement existing methods?

Methods

The pipeline for learning formulas is roughly:

1. Label states as either solvable or unsolvable
2. Enumerate concepts and evaluate them on said states
3. Derive Boolean features from concepts
4. Find a DNF formula of Boolean features that satisfies some criteria, we consider:
    - Perfect: Holds for all and only unsolvable states
    - Safe: Holds for only unsolvable states
    - DecisionTree: Maximize F1 score

These two learned formulas are perfect:

- Hiking: $|\exists at\_person.(\exists at\_car^{-1}.\top)| = 0$
- Spanner: $|loose \sqcup \exists at.\left(\exists link^{+}.(\exists at^{-1}.man)\right)| > |usable|$

Experimental Results

							k-consistency			$\mathbb{T}$-Perfect						$\mathbb{T}$-Safe						DecisionTree					
	h^{CG}	h^{CEA}	h^{SEQ}	h^1	h^2	h^3	k=1	k=2	k=3	prec	rec	C	L	k	t	prec	rec	C	L	k	t	prec	rec	C	L	k	t
Barman	0.00	0.88	0.39	0.88	1.00	1.00	0.00	0.00	0.00	–	–	–	–	–	–	0.97	0.36	11	18	9	5h	0.97	0.99	28	56	8	6s
Childsnack	0.58	0.58	0.09	0.58	0.94	1.00	0.00	0.27	0.27	–	–	–	–	–	–	1.00	1.00	7	9	11	1h	0.91	0.98	16	32	11	10s
Hiking	0.00	1.00	0.00	1.00	1.00	1.00	0.00	0.00	0.00	1.00	1.00	1	1	8	27m	1.00	1.00	1	1	8	1m	1.00	1.00	1	1	8	1s
Nomystery	0.00	0.53	0.00	0.31	0.91	1.00	0.00	0.00	0.83	–	–	–	–	–	–	0.87	0.12	22	39	17	5h	0.65	0.92	1	1	12	1s
Spanner	0.05	0.05	0.00	0.05	0.13	0.31	0.00	0.00	0.01	1.00	1.00	1	1	13	5m	1.00	1.00	1	1	13	4m	1.00	1.00	1	1	13	1s
Woodworking	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1	1	8	50s	0.98	1.00	1	1	8	2m	0.98	1.00	1	1	9	6s

Conclusions

With respect to the questions:

1. Yes, and many unsolvable states can be decided in polynomial time
2. Yes, furthermore the formulas are interpretable
3. Primary bottleneck is enumeration and evaluation of Boolean features, this prevents us from learning features of higher complexity
4. Time polynomial in the number of objects
5. Yes, the learned formulas sometimes dominate
6. This is especially clear for Spanner where existing methods struggle, and we learn an exact characterization