EFP 2.0: A MULTI-AGENT EPISTEMIC SOLVER WITH MULTIPLE E-STATE REPRESENTATIONS

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Overview

1. Multi-Agent Epistemic Planning

2. A New Epistemic State Representation

3. Contribution

4. Conclusions & Future Works
Chapter 1

Multi-Agent Epistemic Planning
Introduction

Epistemic Reasoning

Reasoning not only about agents’ perception of the world but also about agents’ knowledge and/or beliefs of her and others’ beliefs.
Multi-Agent Epistemic Planning

Introduction

Epistemic Reasoning
Reasoning not only about agents’ perception of the world but also about agents’ knowledge and/or beliefs of her and others’ beliefs.

Multi-agent Epistemic Planning Problem [BA11]
Finding plans where the goals can refer to:
- the state of the world
- the knowledge and/or the beliefs of the agents
Chapter 2

A New Epistemic State Representation
A New Epistemic State Representation

**Possibilities Overview**

- Introduced by Gerbrandy and Groeneveld [GG97]
- Used to represent multi-agent information change
- Based on *non-well-founded sets*
- Corresponds with a class of *bisimilar Kripke structures* [Ger99]

A possibility

<table>
<thead>
<tr>
<th>A possibility</th>
<th>Its system of equation</th>
<th>Corresponding K-Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p )</td>
<td>( {A} )</td>
<td></td>
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<tr>
<td>( {A} )</td>
<td>( w(p) = 1 )</td>
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<tr>
<td>( {B} )</td>
<td>( v(p) = 1 )</td>
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<tr>
<td>( u(p) = 0 )</td>
<td>( w(A) = {v} )</td>
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<td>( v(A) = {v} )</td>
<td>( w(B) = {\emptyset} )</td>
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<td>( u(A) = {\emptyset} )</td>
<td>( v(B) = {u} )</td>
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<tr>
<td>( {B} )</td>
<td>( u(B) = {\emptyset} )</td>
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<tr>
<td>p,q</td>
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Possibility [GG97]

Let $\mathcal{AG}$ be a set of agents and $\mathcal{F}$ a set of propositional variables:

- A possibility $u$ is a function that assigns to each propositional variable $\ell \in \mathcal{F}$ a truth value $u(\ell) \in \{0, 1\}$ and to each agent $ag \in \mathcal{AG}$ a set of possibilities $u(ag) = \sigma$ (information state).

**Intuitively:**

- The possibility $u$ is a possible interpretation of the world and of the agents’ beliefs
- $u(\ell)$ specifies the truth value of the literal $\ell$
- $u(ag)$ is the set of all the interpretations the agent $ag$ considers possible in $u$
A New Epistemic State Representation

The action language $mA^o$

- Introduced in [Fab+19] as modification of $mA^*$ [Bar+15]
A New Epistemic State Representation

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- Able to comprehensively reason on:
  - unlimited *nested belief*/knowledge; and
  - *common belief*/knowledge

Models three types of actions:
- **ontic**: modifies the world;
- **sensing**: refines the knowledge;
- **announcement**: shares information with others.

Agents with degrees of awareness w.r.t. actions execution
- Fully observant
- Partial observant
- Oblivious
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Chapter 3

Contribution
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$mA^\rho$ updated Semantics

Provided an updated formalization for $mA^\rho$ transition function:

- Redesigned semantics of $mA^\rho$ (w.r.t. [Fab+19])
  - More compact and clean
  - More efficient implementation
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- Redesigned semantics of $mA^\rho$ (w.r.t. [Fab+19])
  - More compact and clean
  - More efficient implementation

- Demonstrated that $mA^\rho$ respects fundamental properties of multi-agent epistemic reasoning
Contribution

The Planner EFP 2.0

- Comprehensive Epistemic Forward Planner
Contribution

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- Complete code rework w.r.t. EFP 1.0 [Le+18]
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  - Kripke structures: follows the semantics of $mA^*$
  - Possibilities: follows the new semantics of $mA^\rho$
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- Kripke structures size reduction based on Paige and Tarjan’s algorithm [PT87]
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  ◦ Kripke structures: follows the semantics of $mA^*$
  ◦ Possibilities: follows the new semantics of $mA^p$
• Kripke structures size reduction based on Paige and Tarjan’s algorithm [PT87]
• Mechanism for already visited e-states verification
Contribution

Experimental Evaluation I

EFP 1.0 = planner of [Le+18]

K-OPT = K-MAL + e-state reduction

P-MAR = EFP 2.0 + possibilities

TO = Time Out (25 minutes)

WP = Wrong Plan

| CB with |AG| = 3, |F| = 8, |A| = 21 |
|---|---|---|---|---|
| L | EFP 1.0 | K-MAL | K-OPT | P-MAR |
| 2 | .003 | .003 | .006 | .001 |
| 3 | .048 | .077 | .097 | .016 |
| 5 | WP | 5.546 | 1.438 | .367 |
| 6 | WP | 108.080 | 14.625 | 2.932 |
| 7 | WP | 317.077 | 38.265 | 6.996 |

| AL with |AG| = 2, |F| = 4, |A| = 6 |
|---|---|---|---|---|
| d | EFP 1.0 | K-MAL | K-OPT | P-MAR |
| 2 | .43 | .32 | .42 | .07 |
| 4 | .96 | .75 | .64 | .11 |
| 6 | 26.20 | 27.85 | 13.51 | 2.44 |
| 8 | TO | TO | 883.87 | 150.92 |
| C | .44 | .32 | .43 | .08 |

Coin in the Box domain. Assembly Line.
Contribution
Experimental Evaluation II

K-MAL = EFP 2.0 + K. structures
K-OPT = K-MAL + e-state reduction
P-MAR = EFP 2.0 + possibilities
-NV = config w/o visited check

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Runtimes for the Grapevine domain. We compare the configurations with and without (-NV) the visited e-states check.
Contribution

Experimental Evaluation III

**EFP 1.0** = planner of [Le+18]  
**P-MAR** = EFP 2.0 + possibilities

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**Figure:** Comparison between EFP 1.0 and EFP 2.0 on SC.
Chapter 4

Conclusions & Future Works
Conclusions

EFP 2.0 provided significantly **better results** w.r.t. the previous state-of-the-art

- **Possibilities** as e-state
- **Dynamic programming** paradigm
- **Reduced size** of e-states
- **Complete refactoring** of EFP 1.0:
  - Corrections
  - Optimizations
Conclusions & Future Works

Future Works

- E-state *symbolic representations*
- Concept of *non-consistent belief*
- Formalization of novel concepts such as *trust, lies* and *misconception*
- Consider heuristics as in [Le+18]
Thank You for the attention


