Dynamic Epistemic Logic

1. Introduction

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What is Dynamic Epistemic Logic?

What is Dynamic Epistemic Logic?

And Why Should I Care?

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What is DEL?

Example: Hanabi

DEL within AI

Remark:

- Ultimately, we are interested in planning with dynamic epistemic logic.

Objective:

- Social robots should have a theory of mind.
- $\rightsquigarrow$ ability to take perspective of humans they interact with.
- Example for how easily this perspective-taking comes to humans and how it leads to smooth interaction:

  `https://www.youtube.com/watch?v=RK8rKKp-vP0&t=1m1s`

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Theory of mind and developmental psychology:

False beliefs, Sally-Anne test (Wimmer and Perner, 1983)

- Sally takes a marble and hides it in her basket.
- Sally then leaves the room and goes for a walk.
- While Sally is away, Anne takes the marble out of Sally's basket and puts it in her own box.
- Sally comes back to the room.
- Question: Where will Sally look for the marble? In the basket or in the box?

$\rightsquigarrow$ correct answer requires reasoning about others' (possibly false) beliefs, i. e., a theory of mind.

Question: Can we make machines pass the Sally-Anne test? Can something like Dynamic Epistemic Logic help?

Planning with Dynamic Epistemic Logic

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Planning with Dynamic Epistemic Logic

Formal language
+ inference rules
+ semantics

What is Dynamic Epistemic Logic?

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Planning with
Dynamic Epistemic Logic

"Relating to knowledge"; a logic that can talk about knowledge

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What is Dynamic Epistemic Logic?

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Planning with
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"Relating to change"; (facts and) knowledge of facts can change

"Relating to knowledge"; a logic that can talk about knowledge

Formal language
+ inference rules
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What is Dynamic Epistemic Logic?

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How to find a course of actions that changes (facts and) knowledge about facts in a desired way?

Planning with Dynamic Epistemic Logic

"Relating to change"; (facts and) knowledge of facts can change

"Relating to knowledge"; a logic that can talk about knowledge

Formal language
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Remarks:

- From now on, we often abbreviate Dynamic Epistemic Logic as DEL.
- DEL mostly interesting in a multi-agent setting where knowledge can change, e. g., through announcements/communication.
- DEL can be seen as a modal logic.

Remarks (ctd.):

- We will look at different dynamic epistemic logics:
  - In simpler ones, actions can only change knowledge (epistemic actions).
  - In advanced ones, actions can also change facts (ontic actions).

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- We will look at different dynamic epistemic logics:
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  - In advanced ones, actions can also change facts (ontic actions).
- Remark: Don't confuse epistemic and ontic actions.

  Otherwise, this can happen:

  > *Two hunters are out in the woods when one of them collapses. He doesn't seem to be breathing and his eyes are glazed. The other guy whips out his phone and calls the emergency services. He gasps, "My friend is dead! What can I do?" The operator says, "Calm down. I can help. First, let's make sure he's really dead." There is a silence; then a gun shot is heard. Back on the phone, the guy says, "OK, now what?"*

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Example: Hanabi

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Concrete example: Hanabi

(the “Hello world!” of DEL-based planning?)

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Hanabi

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Rules:

- Cooperative card game
- Five suits (red, yellow, green, blue, white)
- Per suit: three 1's, two 2's, 3's, and 4's each, and one 5
- Three fuse tokens, five information tokens
- Players (between two and five) are dealt cards (five per player for two to three players, four cards for four or five players).
- Each player holds the cards so that only the other players can see them, but he himself cannot.

Hanabi

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Rules (ctd.):

- Play proceeds around the table. Three options:
  - Give information: The player points out for one other player either color or face of the cards. Give up one information token.
  - Discard a card: Putting one card on the discard pile face-up. Get back one information token. Replenish your hand.
  - Play a card: If it fits, okay; otherwise, a fuse token is taken away. Replenish your hand.
- After the third fuse token is gone, the game is over/lost.
- Winning means:
  - All five piles completed
  - No more cards on the replenishment pile

Hanabi

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- Successful play requires reasoning about others' knowledge.
- We will later model simplified versions of Hanabi (with fewer cards) in DEL and plan for the individual agents to achieve successful cooperative play.
- Questions when building a Hanabi bot:
  - How to represent the knowledge states of the agents?
  - How to change the representation when (epistemic) actions are executed?
- See also: Bard et al., The Hanabi Challenge: A New Frontier for AI Research, 2019. (https://arxiv.org/abs/1902.00506)

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DEL in the AI landscape

DEL in the AI landscape

(hugely simplified . . .)

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Symbolic AI, e. g. . . .

Knowledge representation and reasoning

Logic

AI planning, search

- Knowledge and symbols
- Often model-based
- Explainability: ✔

Sub-symbolic AI, e. g. . . .

Perception (vision, . . .)

Pattern Recognition

(Deep) Learning

- Data, no symbols
- Often model-free
- Explainability: ✗

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