

# Epistemic Plan Recognition

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LAMAS 2020



# Plan Recognition



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# Motivation

Why epistemics?

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- | Incorporating a notion of **epistemics** into the recognition process enables the observer to:
  1. Assume the actor's perspective when recognizing her plan.
  2. Recognize the actor's epistemic goals.

# Our Contributions

- | A specification of epistemic plan recognition (EPR).
- | A computational realization of EPR as **epistemic planning**.
- | An evaluation of our approach on a set of EPR problems.

## Building on Broad Shoulders

(Schmidt et al., 1978)  
(Cohen, Perrault, & Allen, 1981),  
(Kautz & Allen, 1986),  
(Pollack, 1986),  
(Levesque, 1988),  
(Liu et al., 2004),  
(Avrahami-Zilberbrand et al., 2005),  
(Sindlar et al., 2008),  
(Ramírez & Geffner, 2009),  
(Baker et al, 2011),  
(Bolander et al., 2011),  
(Talamadupula et al., 2014),  
(Kominis & Geffner, 2015),  
(Muisse et al., 2015),  
(Huang et al., 2017) ,  
(Engesser et al., 2017),  
(Le et al., 2018)

# Background

- | Multi-agent epistemic logic framework
- | KD45 axioms (Fagin et al., 1995)
  - | For example, *positive introspection* –  $B_i \rightarrow B_i B_i$
- |  $B_i$  which should be interpreted as "*Agent i believes*"



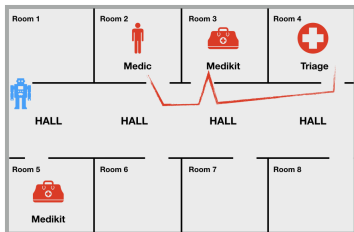
## Example - Search & Rescue (Talamadupula et al., 2014)

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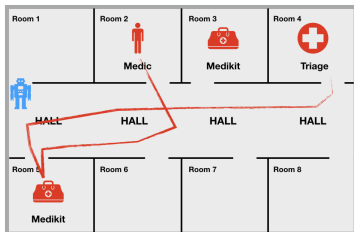
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$$B_{Robot}(at(\text{Medikit1}, \text{Room3}) \wedge at(\text{Medikit2}, \text{Room5})) \wedge \\ B_{Robot} B_{Medic}(: at(\text{Medikit1}, \text{Room3}) \wedge at(\text{Medikit2}, \text{Room5}))$$

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# Epistemic Plan Recognition

An **Epistemic Plan Recognition problem** is a tuple  $\langle hP; A; D; Ag; I; G; Oi \rangle$ , where:

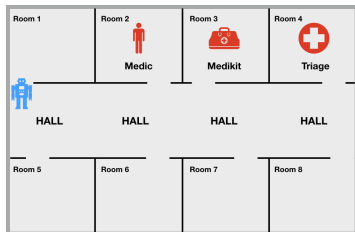
- | The set of agents  $Ag$  includes the **observer** and the **actor**.
- |  $I$  captures the observer's beliefs about the actor's beliefs about the state of the world.
- |  $D$  captures the observer's beliefs about the actor's beliefs about the actions in  $A$ .

## Epistemic Plan Recognition

Given an EPR problem,  $\langle P; A; D; Ag; I; G; O \rangle$ , a **solution** is a pair  $(\pi, G)$ , where  $G \in G$  is a goal and  $\pi$  is a sequence of actions – a plan – that satisfies  $O$ .



## Example - Search & Rescue (Talamadupula et al., 2014)



$$I \not\models B_{Robot} : at(\text{Medikit1}, \text{Room5}) \wedge B_{Robot} B_{Medic} at(\text{Medikit1}, \text{Room5})$$

## Example - Search & Rescue (Talamadupula et al., 2014)

$$I \not\models B_{Robot} : at(\text{Medikit1}, \text{Room5}) \wedge \\ B_{Robot} B_{Medic} at(\text{Medikit1}, \text{Room5})$$

## Example - Search & Rescue (Talamadupula et al., 2014)

$KW(at(Medikit, Room8))$

# Epistemic Plan Recognition as Epistemic Planning

- | Plan recognition as planning approach  
(Ramírez & Geffner, 2009)
- | EPR problem is transformed to an epistemic planning problem

# Empirical Evaluation

- | Applicability of existing epistemic planners
  - | RP-MEP (Muisse et al., 2015)
  - | MEPK (Huang et al., 2017)
  - | EFP (Le et al., 2018)
  
- | Comparison between epistemic planners
  
- | Inadequacy of the observer's beliefs

# Summary

- | Why epistemics?
  - | The observer can assume the actor's perspective.
  - | The observer can recognize the actor's epistemic goals.

## **Epistemic Plan Recognition**

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