

COMP90054 — AI Planning for Autonomy

1. Plan & Goal Recognition

Contents of the Lecture

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Outline of the Lecture

- 1 Perceiving and Interpreting the Behavior of Others
- 2 Plan and Goal Recognition in AI
- 3 Plan and Goal Recognition and Classical Planning

The Heider-Simmel Experiment

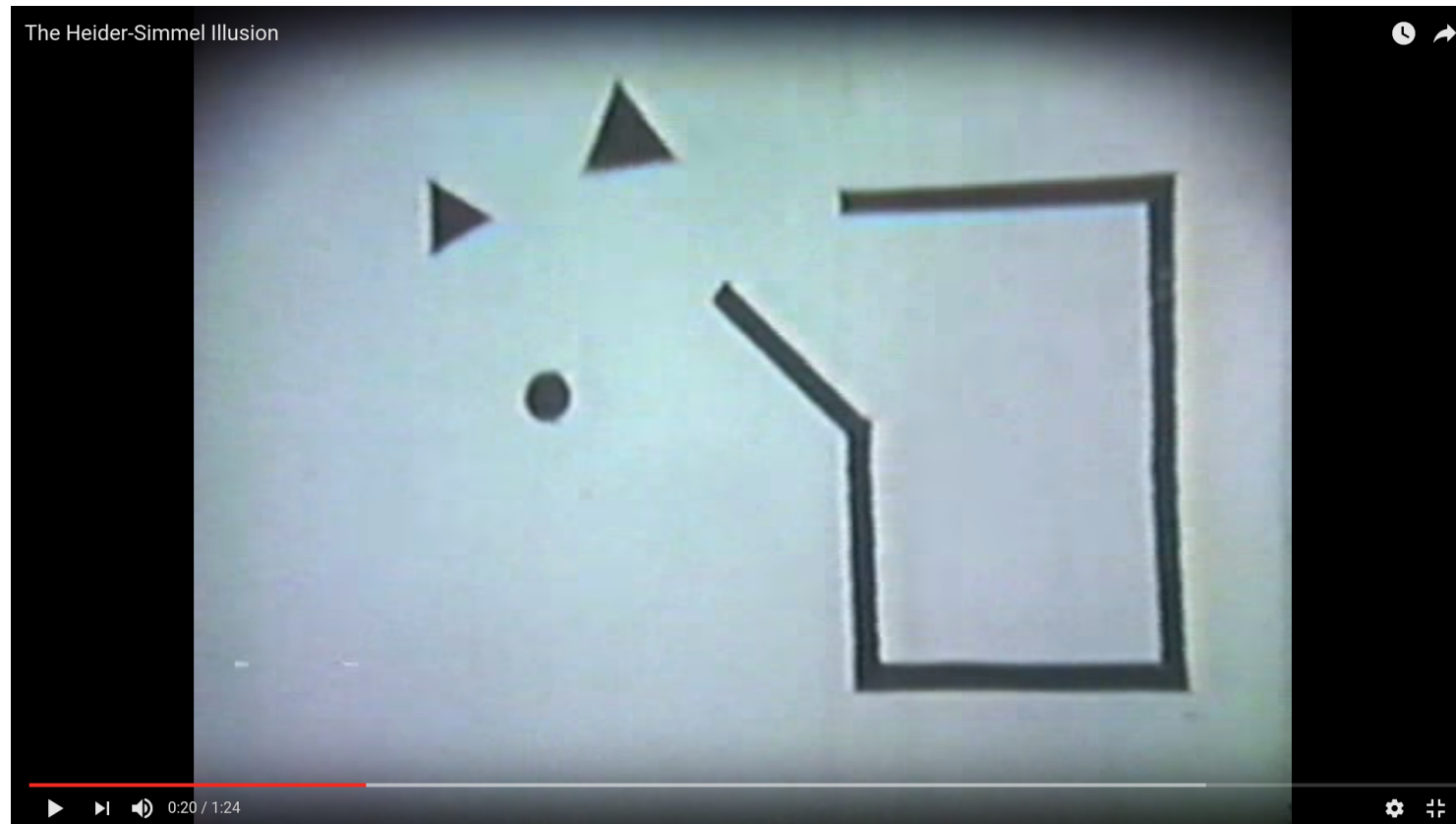


Figure: *An Experimental Study of Apparent Behavior.* F. Heider, M. Simmel. The American Journal of Psychology, Vol. 57, No. 2, April 1944

[Link to video \(YouTube\)](#)

Parsing the Big Triangle



Figure: The BIG triangle T .

PollEv.com/nirlipo

Question!

What kind of person is the Big Triangle?

(A): Aggressive, mean, angry.

(B): Strong, powerful.

(C): Dumb, stupid.

(D): Ugly, sly.

what about the Smaller one...



Figure: The small triangle t .

PollEv.com/nirlipo

Question!

What kind of person is the Small Triangle?

(A): Fearless, defiant, cocky.

(B): Passive-aggressive.

(C): Clever, weak.

(D): Protective, loyal, devoted.

and about the circle...



Figure: The circle c .

PollEv.com/nirlipo

Question!

What kind of person is the Circle?

(A): Frightened, fearful, helpless.

(C): Clever, smart.

(B): Fidgety, playful, nervous.

(D): Courageous.

Significance of Heider & Simmel Results

Leaving *aside* issues with *priming* experimental subjects...

It does seem that

- ① humans *tend* to **ascribe intentions** to *anything* that *changes* over time,
- ② this rests on *deeply rooted assumptions*.

Heider & Simmel results are the *first* *quantitative* characterization of:

Folk Psychology

Human capacity to **explain** and **predict** *behavior* and *mental state* of others

... we're *usually very good* at it, but we **fail often**!

A Theory of Common Sense

The Intentional Stance, **Daniel Dennett** (1988)

- ① **Decide** to consider the object being observed as *rational*.
- ② Work out its **beliefs** and **goals** based on its *place* and *purpose* in the world.
- ③ Use **practical reasoning** to assess what the agent *ought to do* to pursue its **goals**.

The above provides a *systematic, reason-giving explanation* for actions, based on **deeply embedded beliefs** about the agent.

Plan and Goal Recognition in Artificial Intelligence

Key Idea: use *generative* models of behavior to *predict* actions.

Plan Recognition (PR) is *Planning in reverse*.

- *Planning* – we seek *plans* π to *achieve* goals G .
- *PR*: find goals G *accounting for* partially *observed* plan π .

Formalising GR as a Multi-Agent Task

Two possible *roles* for each agent:

- **Actor** – *performs* actions to change the state of the world.
- **Observer** – *perceives* actions and updates its beliefs on the **Actor** intentions.

and *three* possible *stances* for the **Actor**:

- *Adversarial* – obfuscates deliberately its goals.
- *Cooperative* – tries to tell the **Observer** what she is up to.
- *Indifferent* – does not care about the **Observer**.

Open Challenge → Stances could be *changing over time*

Components of Goal Recognition Task

Actions describe *what* the **Actor** does

- Walking from X to Y , opening a door, using a credit card...

Goals describe *what* the **Actor** wants

- To have breakfast, Park a car, Wreck a web service...

Plans describe *how* goals can be achieved

- **Ordered** sequences of actions
- These can be **ranked** according to **cost** or **efficiency**

Sensor Model describes *what* does the **Observer** perceives

- Does it always see **every** action done by the **Actor**?
- Are actions observed **directly**? Or only their **effects** are?
- Does it know exactly **where** in the world the **Actor** is?

Goal Recognition can be modeled using STRIPS

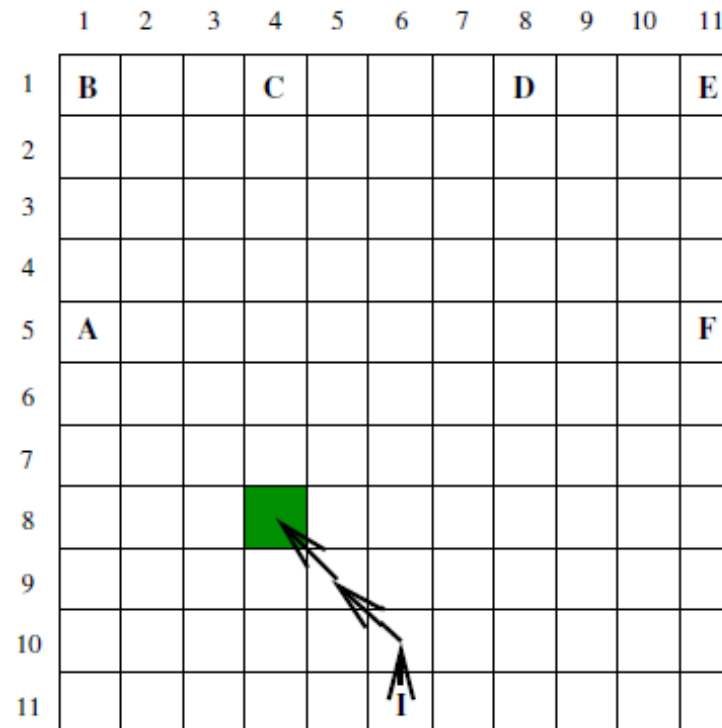
Example: Agent on a Grid World

	1	2	3	4	5	6	7	8	9	10	11
1	B			C				D			E
2											
3											
4											
5	A										F
6											
7											
8											
9											
10											
11						I					

- **starts** in “I”, *may be* heading to “A”, “B”, ..., “F”.
- **moves along compass directions** *North*, etc. with cost 1 and *North West*, etc. with cost $\sqrt{2}$.

Example

Actor now at (4, 8) after going *N* once, and twice *NW*.



Question!

Assuming the Actor prefers CHEAPEST plans which goals are most likely?

(A): *A* & *B*.

(B): *C*.

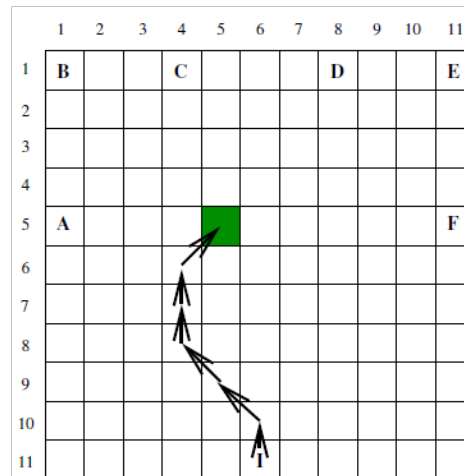
(C): *D*

(D): *E* & *F*

Example

Actor now at (5,5) after going *N* twice and once *NE*.

•



Question!

For which goal(s) observed actions are in a **CHEAPEST** plan?

(A): *A* & *B*.

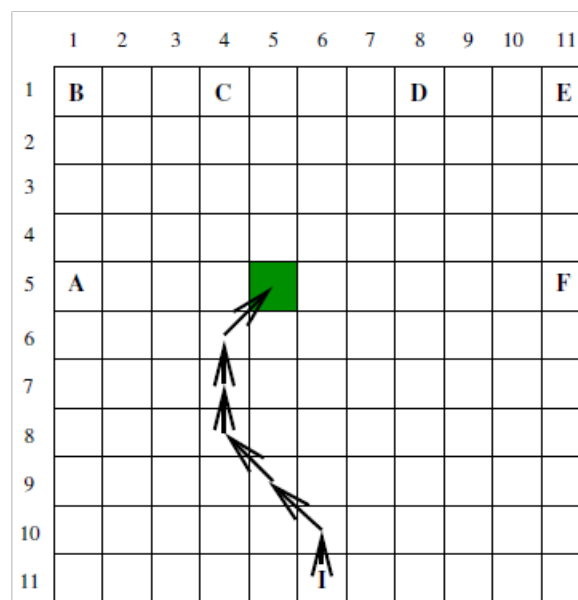
(B): *C*.

(C): *D*, *E* & *F*

(D): None

So Folk Psychology is Useless?

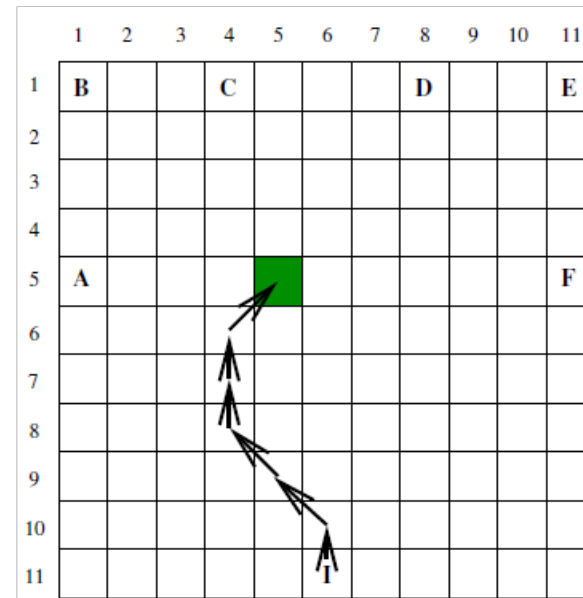
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Remarks

- Verify obs *sufficient* for G Easy
- Determine to what degree obs *necessary* for G Hard

Folk Psychology with Counterfactual Reasoning



Counterfactual Reasoning (Pearl, 2001) to Establish Necessity

Compare **cost** of **best** plans that **do not comply** with observed actions, with best plans that **do**.

→ Then it follows *B* and *C* *more likely* than *A* or *the rest*.

Key Facts of the Model-Based Approach

- ① Π given **implicitly**, requires to **solve** $|\mathcal{G}|$ planning tasks
- ② Plans “**extracted**” with **off-the-shelf** planning algorithms.
- ③ **Plausibility** of goals \mathcal{G} given as a **probability distribution**
 - Goals are *plausible* when motivate plans *consistent* with O ,
 - **and** when O is *necessary* to achieve goals *efficiently*.

Roadmap

- ① Make off-the-shelf planners compute plans **constrained** w.r.t. O ,
- ② Derive $P(G|O)$ from **best** plans that **comply with** *and* **work around** O .

PR as planning: Inferring the Goal Probabilities

Goal

Obtain **probability distribution** $P(G|O)$, $G \in \mathcal{G}$.

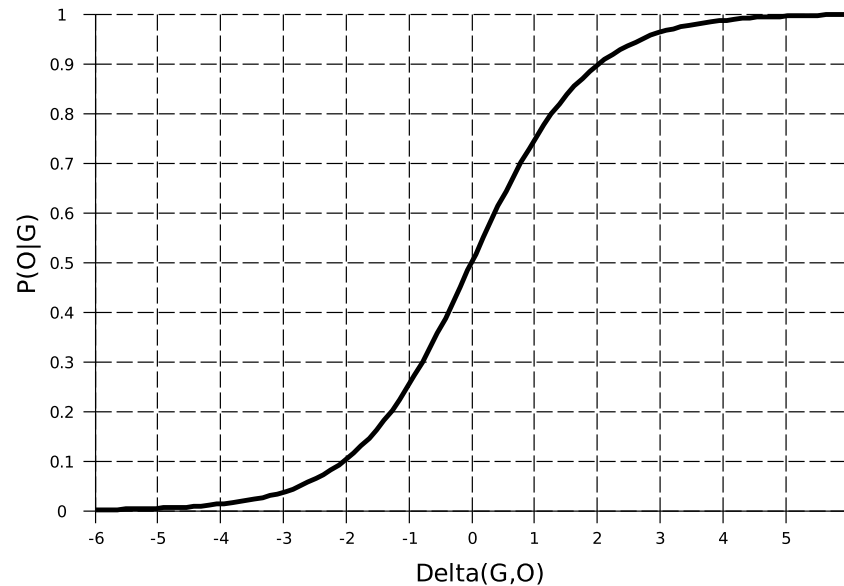
Outline of Approach

From **Bayes' Rule** $P(G|O) = \alpha P(O|G) Prob(G)$, where

- α norm. constant
- $Prob(G)$ given in problem specification
- $P(O|G)$ function of extra cost needed to not comply with O

$$P(O|G) = \text{function}(c^*(P'[G + \overline{O}])) - c^*(P'[G + O])) \quad (1)$$

Goals as Predictors for O (informally)



Properties

- 1 G predicts O **badly** when it would be **more efficient** to deviate from O .
- 2 G predicts O **perfectly** when G **unfeasible** if **not doing** O .

Demo: A Slightly More Interesting STRIPS Model



Fluents: *facts about the world*

- Locations of people
- State of appliances
- Locations of objects

Actions: *stuff people may do*

- Move across the place
- Interaction with objects & appliances

Goals: *why people do stuff*

- Cook some foodstuff
- Watch a movie
- Listen to a record
- Go to sleep
- Get ready to leave for work

Unitary action costs (to keep it simple)

GITHUB Repo PULL REQUESTS WELCOME!

Anyone looking for a Masters' project? Thor 2 has been released!

Further Reading or Watching

- Article** *An Experimental Study of Apparent Behavior*. F. Heider, M. Simmel. The American Journal of Psychology, 57(2), 1944
- A Probabilistic Plan Recognition Algorithm based on Plan Tree Grammars* C. Geib, R. Goldman, Artificial Intelligence 173(11), 2009
- Probabilistic Plan Recognition using off-the-shelf Classical Planners*. M. Ramirez and H. Geffner. Proceedings AAAI, 2010.
- Landmark-Based Heuristics for Goal Recognition*. R. Pereira, N. Oren and F. Meneguzzi. Proceedings AAAI, 2017.
- Heuristic Online Goal Recognition in Continuous Domains*, M. Vered and G. Kaminka. Proceedings IJCAI, 2017.
- Plan Recognition in Continuous Domains*, G. Kaminka and M. Vered and N. Agmon, Proceedings AAAI, 2018.
- Book** *Chapter 4, Section 4.3 A Concise Introduction to Models and Methods for Automated Planning*. B. Bonet & H. Geffner, 2013.
- Video Lecture** *Engineering & Reverse-engineering Human Common Sense*, J. Tenenbaum, Allen Institute for AI, 2015.
- Video Lecture** *Steps towards Collaborative Dialogue*, P. Cohen, Monash University, 2018.