CS 295A/395D: Artificial Intelligence

Intro to Planning and Search

Prof. Emma Tosch

7 February 2022

The University of Vermont

Lecture agenda

- Announcements
  - This week: change of student hours for the exam
    - No Wed student hours
    - Student hours today (2:30-4pm, Innovation E456)
- Exam format
- Introduction to planning, search via topics and vocabulary for the rest of the semester

Exam format

- 5 questions + 1 extra credit
    - 1 True/False question
    - Finding and explaining an inference errors
    - Finding and explaining a resolution errors
    - Scenario-based design question: searching for satisfying assignments
    - More open-ended ontology question
    - Extra credit: surprise!
- Will give you a cheatsheet of rewrite rules and inference *schemata*
    - *No examples!*

Planning

Logic and ***ontologies*** gave us the foundations for the rest of the semester.

Planning is the selection of ***actions*** to achieve a ***goal*** without interacting with an ***environment***.

An ***action*** is an ***intervention*** in an environment that may change its ***state***.

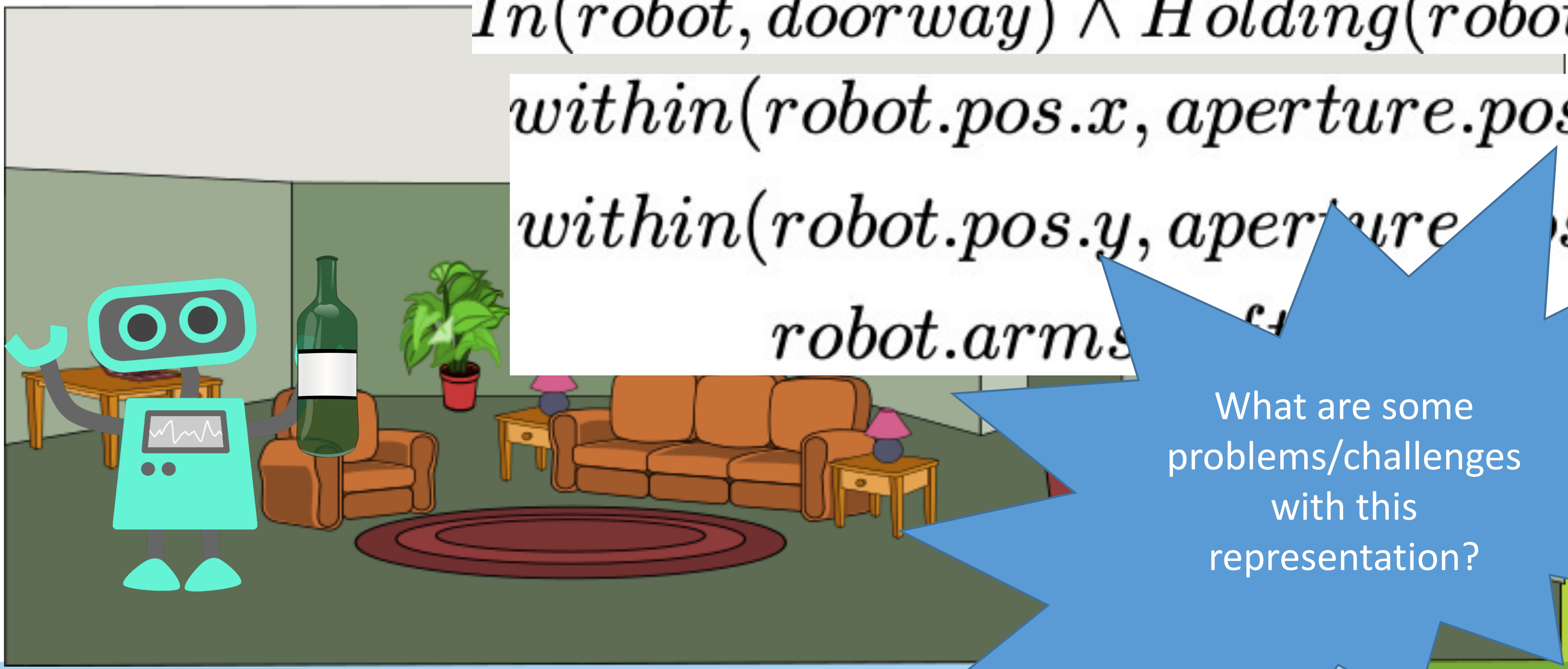
An ***intervention*** is a procedure for manipulating state.

The ***state*** of an environment is the current set of categories in our knowledge base…

(think: snapshot of the database that holds this information and the elements of the relations)

A ***goal*** is a function of a state.

Expressing Goals



$$In(robot, doorway) \wedge Holding(robot, bottle)$$

$$within(robot.pos.x, aperture.pos.x, 5) \wedge$$

$$within(robot.pos.y, aper\ldots ure\ldots s.y, 5) \wedge$$

$$robot.arms\ldots ft\ldots e > 2$$

What are some problems/challenges with this representation?

Goal: get to the door without dropping t… bottle.

Expressing invariants

$$S_0 A_0 S_1 A_1 \ldots S_{T-1} A_{T-1} S_T A_T$$

$$\forall S_i \, (Holding(S_i.robot, S_i.bottle))$$

$$\forall S_i \, (S_i.robot.arms.left.resistance > 2)$$

Can use predicate logic to encode ***goals*** and ***invariants.***

Goal: get to the door **without** dropping t

Actions as interventions on state

An ***action*** is an ***intervention*** in an environment that may change its ***state***.

Actions as interventions on state

What state is being changed?

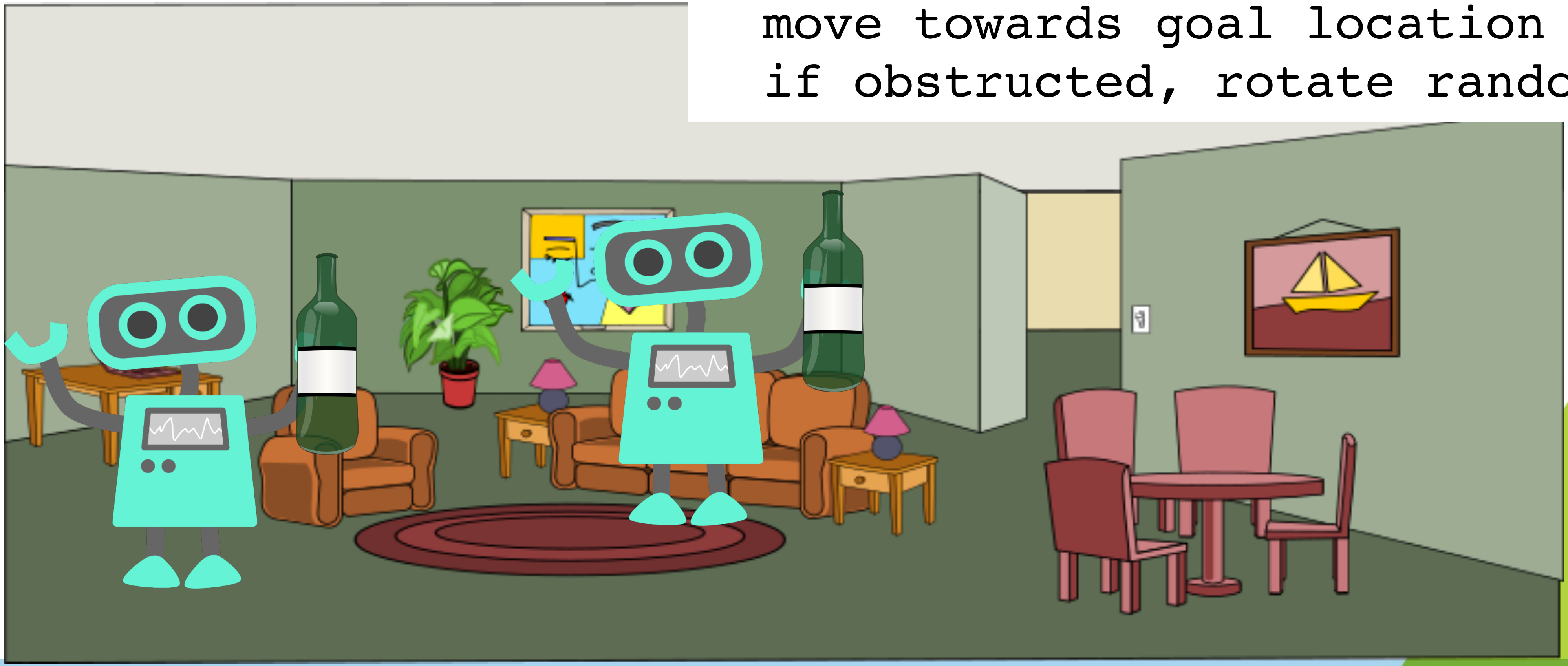
$$S_i.robot.pos.x$$

Robot is part of the state!

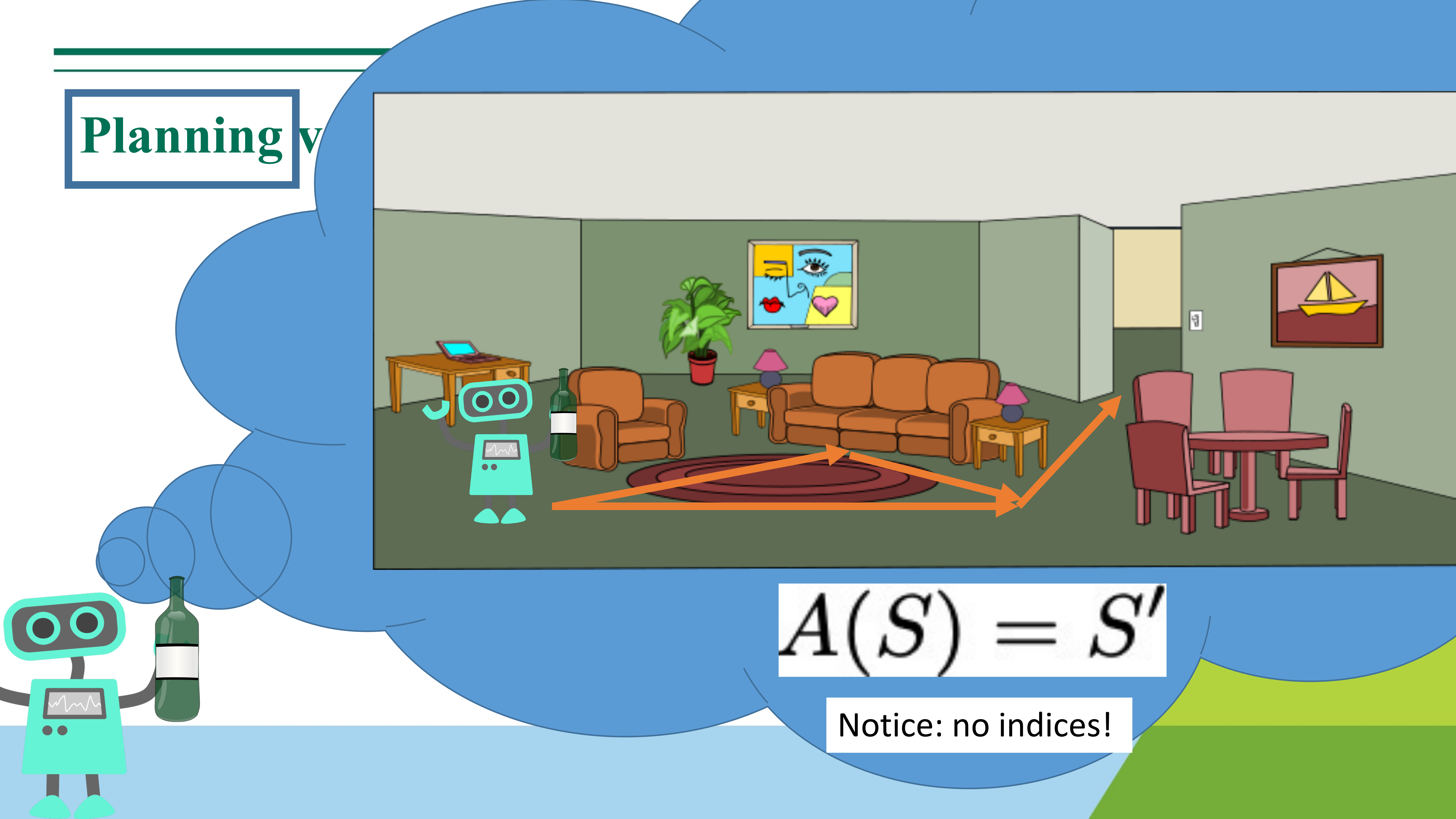
Actions are (named) functions from state to state.

Planning vs. *ad hoc* action selection

```
While goal not met:
   move towards goal location
   if obstructed, rotate random angle
```



Planning v



$$A(S) = S'$$

Notice: no indices!

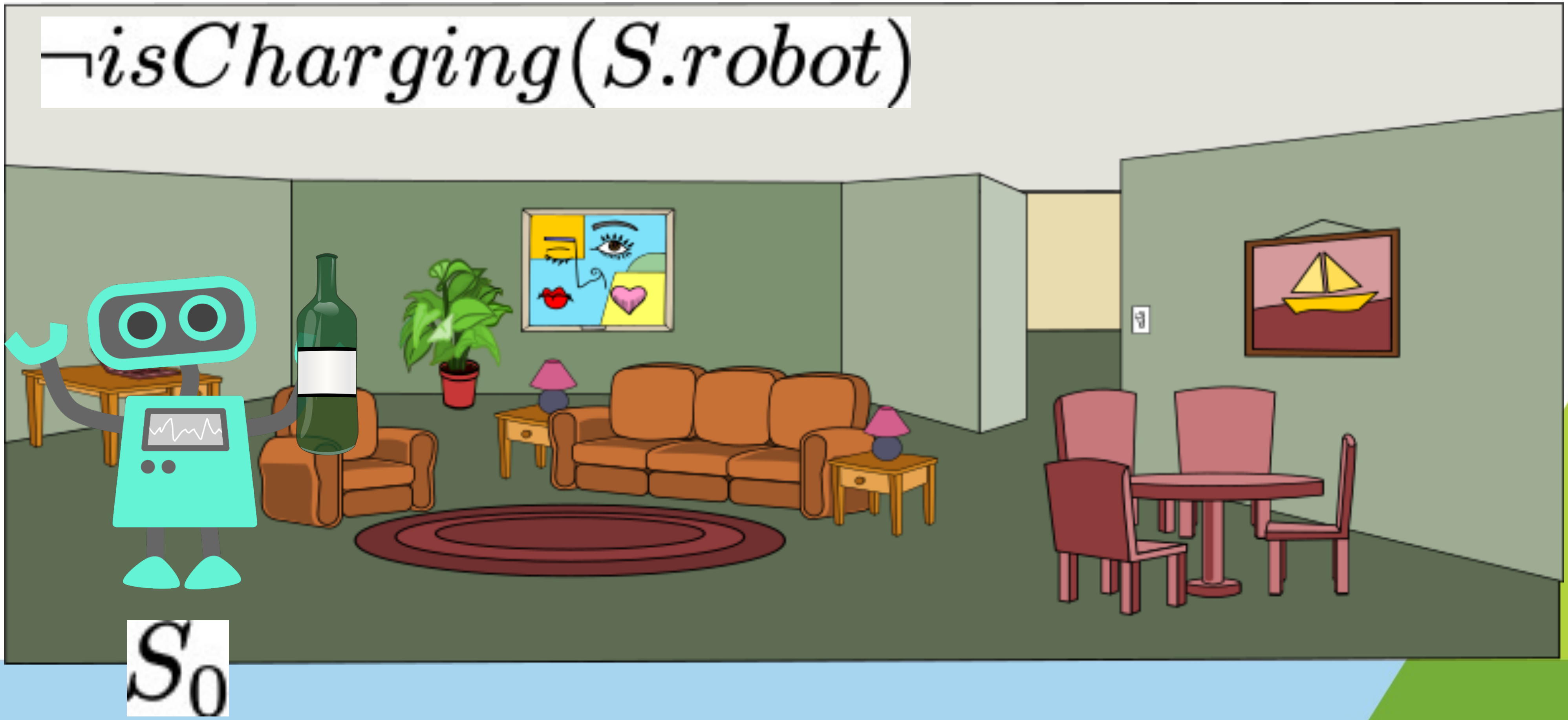
How?

Each action function can only be applied when certain things are true

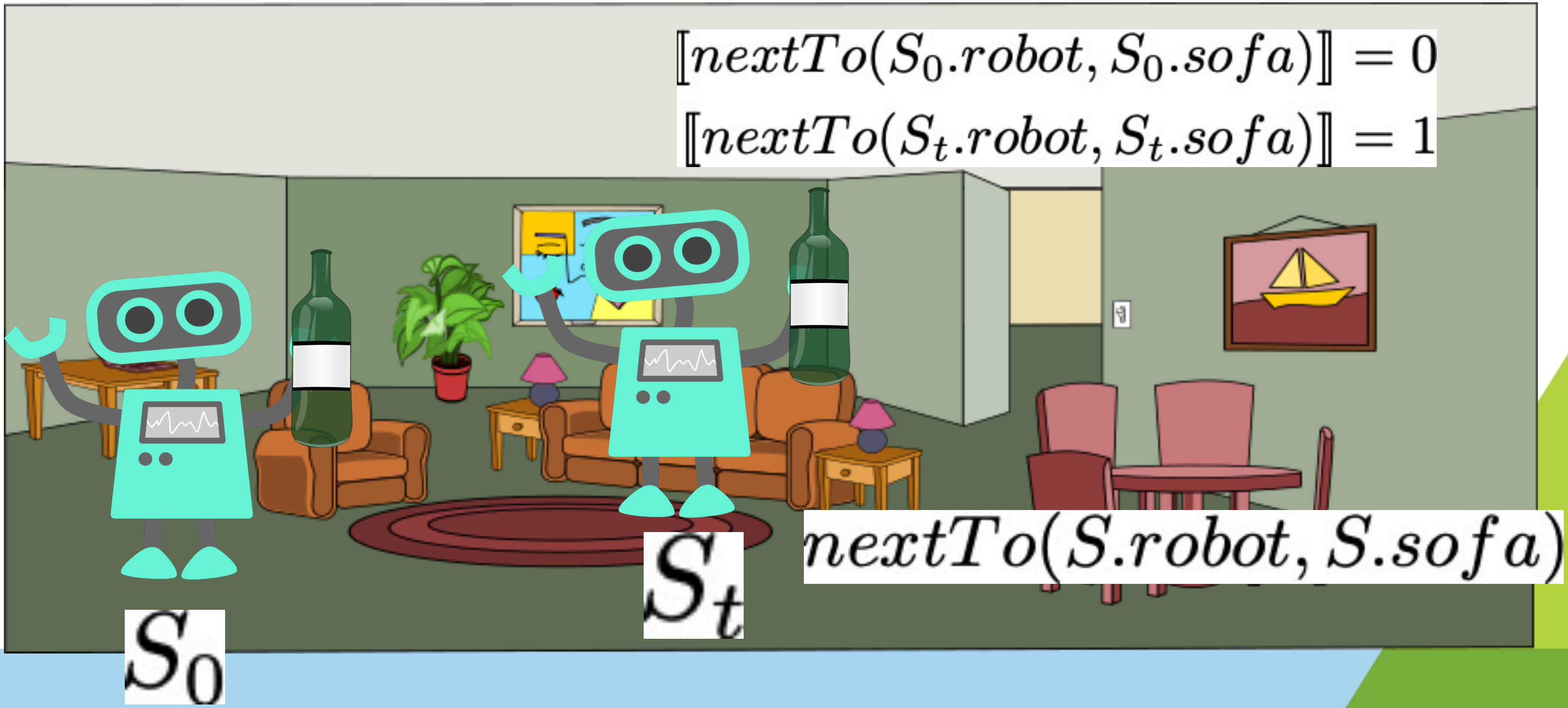
- We can represent these ***preconditions*** with propositional formulas

Each action function has a possible ***effect*** that may cause the outputs of some predicates to change

Actions have preconditions



Actions have effects



Logical inference as planning?

What are the goals?

What are the actions?

What is the environment?

What is the current state?

What are the invariants?

Switch to board or OH projector here

Resolution as planning?

What are the goals?

What are the actions?

What is the environment?

What is the current state?

What are the invariants?

Switch to board or OH projector here

Planning via graphs

- Basic idea: single start state, single goal state
- Edges are permissible actions, directed to next state
- Next states are updated with the effects of actions

Next slide: back to slides

Are these really planning problems?

Planning is the selection of ***actions*** to achieve a ***goal*** without interacting with an ***environment***.

- Should planning require a model of the environment?
- Does planning need to be relational?

(very!) Recent results using AI + DL for proof search

Formal Mathematics Statement Curriculum Learning

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arXiv:2202.01344v1 [cs.LG] 3 Feb 2022

Abstract

We explore the use of expert iteration in the context of language modeling applied to formal mathematics. We show that at same compute budget, expert iteration, by which we mean proof search interleaved with learning, d... performs proof search only. We a... when applied to a collection of fo... of sufficiently varied difficulty, e... capable of finding and solving a ... creasingly difficult problems, wit... associated ground-truth proofs. F... ing this expert iteration to a man... of problem statements, we achiev... on the *miniF2F* benchmark, autor... multiple challenging problems d... school olympiads.

1. Introduction

Deep learning has enjoyed spectacula... mains, including language (Brown et a... 2018; Wu et al., 2016), vision (Radf... & Le, 2019), and image generation (... Karras et al., 2019). One domain whe... not yet enjoyed a comparable succe... quire extensive *planning* and *symboli*... exception of two-player games (Silv... Berner et al., 2019; Vinyals et al., 20... deep learning systems exhibit a consi... soning, especially when trained wit... with a search procedure such as Mon... (MCTS) (Browne et al., 2012). But th... abilities achieved are limited due to ... scope of games.

As such, theorem proving in interacti... formal mathematics, appears as an interesting game-like domain to tackle due to its increased scope. Like games, formal mathematics has an automated way of determining whether a trajectory (*i.e.* a proof) is successful (*i.e.* formally correct). But the vast scope of formal mathematics means that any strong reasoning result obtained in it will be more meaningful than comparable results in games (*e.g.* finding proofs to mathematical conjectures), and could even be applicable to important practical problems (*e.g.* software

... propose instead to supply auxiliary sets of problem statements (without requiring proofs) of varying difficulty. We empirically show that, when the difficulty of these auxiliary problems is varied enough, a simple expert iteration procedure is able to solve a curriculum of increasingly difficult problems, eventually generalizing to our target distribution. We show that this works with both automatically-generated and manually-curated auxiliary distributions of

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Preprint. Under review.

- (i) **Infinite action space**: not only does formal mathematics have an extremely large search space (like Go for example), it also has an infinite action space. At each step of a proof search, the model must choose not from a well-behaved finite set of actions, but a complex and infinite set of tactics, involving exogenous mathematical term... that have to be generated (e.g., generating a mathema...al statement to be used as a witness, an object used in ste... "there exists an x s.t. …", or a cut, the introdu... of a lemma in the middle of a proof).

BLOG ABOUT

READ PAPER

We achieved a ne... benchmark, a challengin... problems. Our approach, whic...

Aside: predicates vs. propositions and the generality of our vocabulary

Expressing invariants

$$S_0 A_0 S_1 A_1 \ldots S_{T-1} A_{T-1} S_T A_T$$

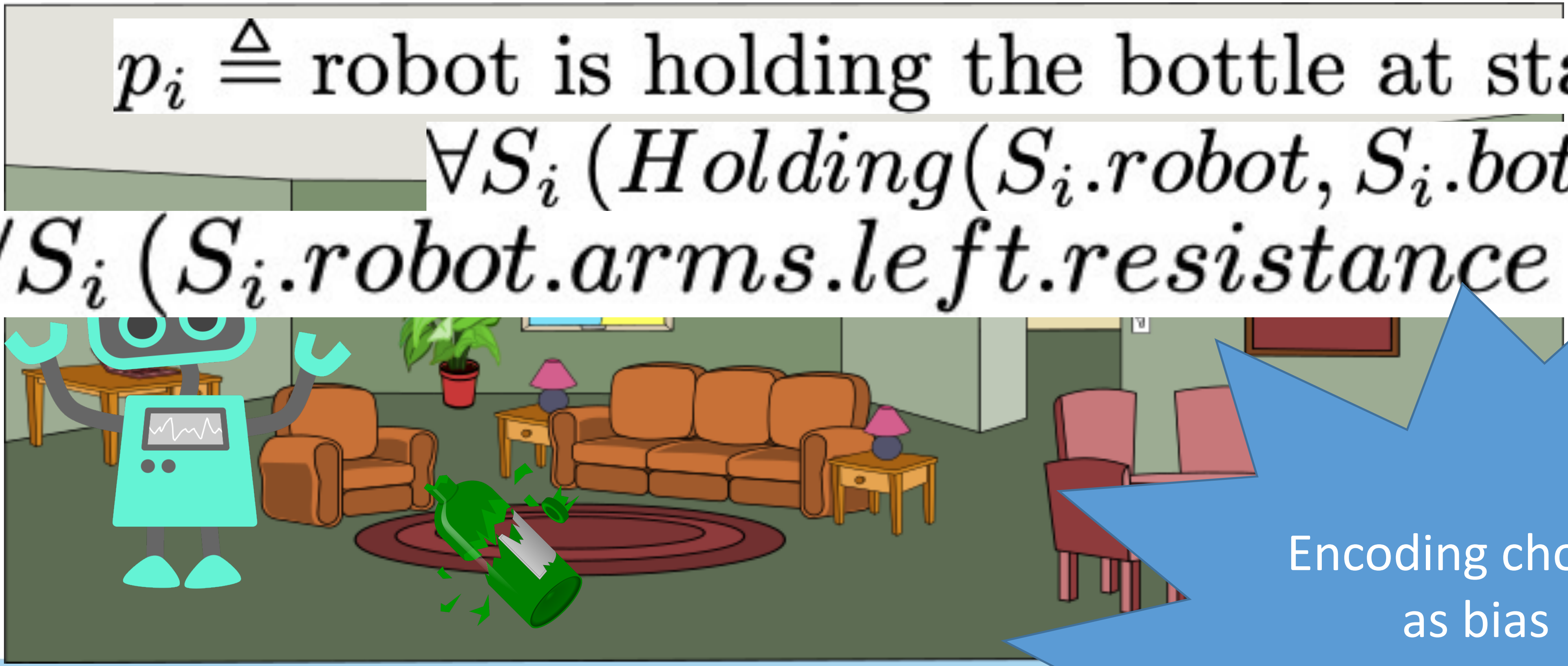
$$\forall S_i \left(Holding(S_i.robot, S_i.bottle)\right)$$

$$\forall S_i \left(S_i.robot.arms.left.resistance > 2\right)$$

Goal: get to the door **without** dropping the bottle.

Problem complexity & choice of abstraction

$$S_0 A_0 S_1 A_1 \ldots S_{T-1} A_{T-1} S_T A_T$$



$$p_i \triangleq \text{robot is holding the bottle at state } i$$

$$\forall S_i \, (Holding(S_i.robot, S_i.bottle))$$

$$\forall S_i \, (S_i.robot.arms.left.resistance > 2)$$

Encoding choices as bias

Goal: get to the door **without** dropping th

- Inference rules don’t change over time
- Language, classifiers, legal judgements do
- Interaction between invariants and variables causes problems

What Can AI Do?

At this point in its development, AI is good … ding items that meet human-d… detecting patterns in data. In other words, … e out what makes a pa… distinguishes it from a koala--which lets it fi… a collection of … are sometimes called "search-and-find type" …

Once it's identified something, the AI can then … case of legal work, an AI can carry out tasks lik…

- IF this document is a non-disclosure agre… review
- IF this NDA …
- FIND all my con… they renew
- TELL ME which patent…

According to Stefanie Yuen Thio, … in Singapore, legal work that's rep… template will become …

> *judicia… become the… processing powe…*

AI can help consumers by prov… able to afford a lawyer. The f… chatbot that lets users c… took on 250,000 case… The same program … $25,000--though it …

…: AI vs ML

- … disc… of bias in “AI”
- … tive bias” in ML
- … gal reasoning
- … e the bias issues?
- … nationality act, French … e-checked formal
- … COTUS)
- … ements abou… plicability, novelty
- … of application of rules, precedence, atomicity