AAAI 2025 Tutorial T04
Time: 2025-02-25 8:30-12:30
Location: 118A Pennsylvania Convention Center

Foundation Models Meet Embodied Agents

Manling Li
Northwestern

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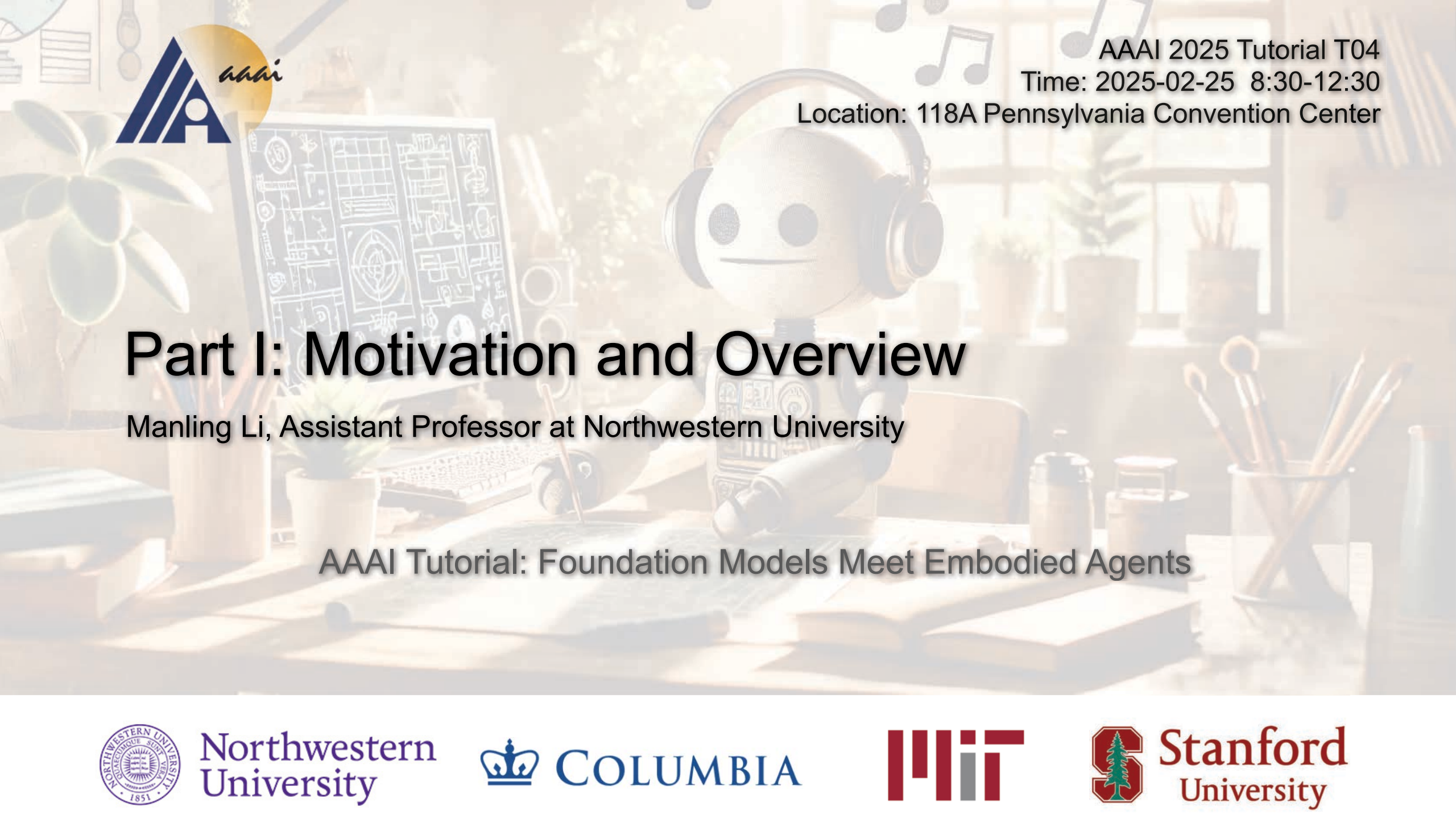

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Part I: Motivation and Overview

Manling Li, Assistant Professor at Northwestern University

AAAI Tutorial: Foundation Models Meet Embodied Agents

Northwestern University
COLUMBIA
MIT
Stanford University

What is a generalist agent?

What is a generalist agent?

Having a robot that can do many tasks, across many environments.

Figure credits: Jiayuan Mao


BEHAVIOR-1K
simulating and benchmarking robot tasks that matter to humans
https://behavior.stanford.edu/

BEHAVIOR-1K

tasks that matter

Observation

State: 3D assets & states

Transition Model

https://behavior.stanford.edu/

tasks that matter

What would you like a robot to help you with?

Cleaning the floor?

Images Generated by DALL-E 3

tasks that matter

What would you like a robot to help you with?

Folding Laundry?

Images Generated by DALL-E 3

https://behavior.stanford.edu/

tasks that matter

What would you like a robot to help you with?

Cooking Breakfast?

Images Generated by DALL-E 3

https://behavior.stanford.edu/

tasks that matter

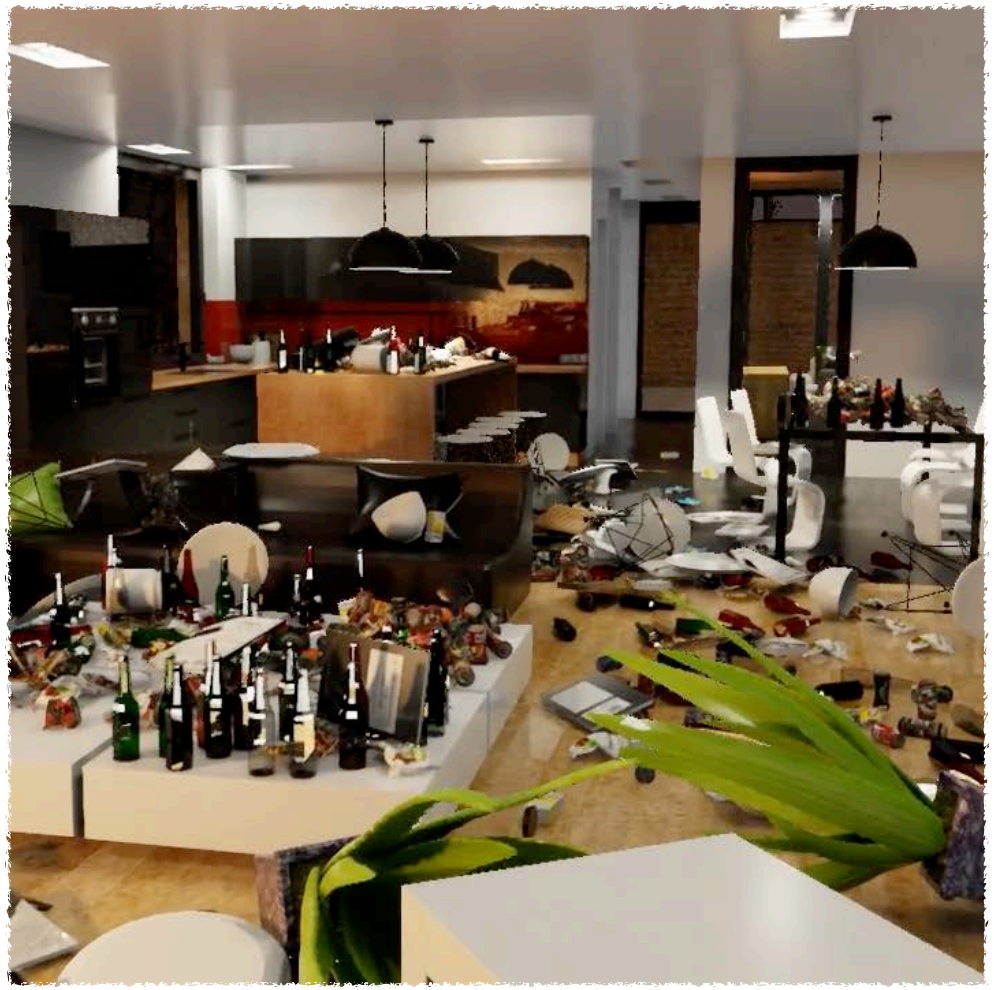
What would you like a robot to help you with?

Opening gifts?

Images Generated by DALL-E 3

tasks that matter

What would you like a robot to help you with?



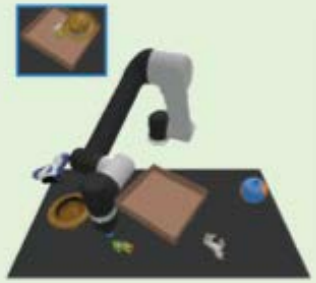
Cleaning after a wild party?

Images Generated by DALL-E 3

Typical Embodied Agent Tasks

Robotic Manipulation

Human: pack the yoshi figure in the brown box



LEO:

$$P = [0.1, -0.2, 0]$$
$$R = [0, 0, 0, 1]$$

Task Planning

Human: Organize and tidy up the bedroom.

LEO:

1. ***Clean the floor by sweeping to remove …***
2. ***Make the bed …***
3. ***Fold and organize …***

Embodied Navigation

Human: Find the pillow

LEO:

1. ***Move forward***
2. ***Turn right***
3. ***Move forward***
4. **…**

https://arxiv.org/pdf/2311.12871

What is “embodied decision making”?

Can we leverage MDP as a guiding principle to categorize “foundation models”?

Let us go back to MDPs (Markov Decision Processes)

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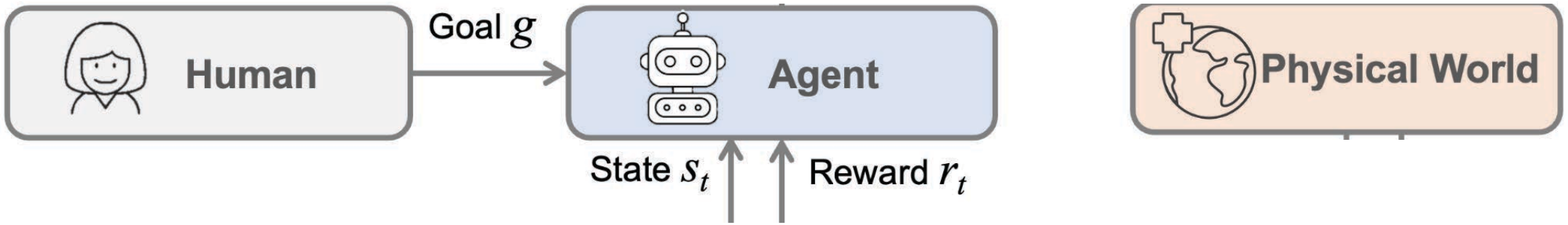

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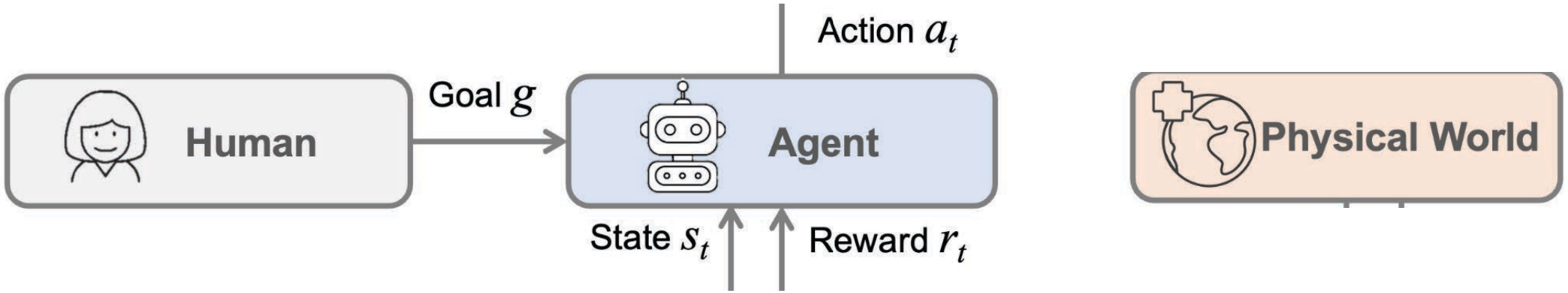

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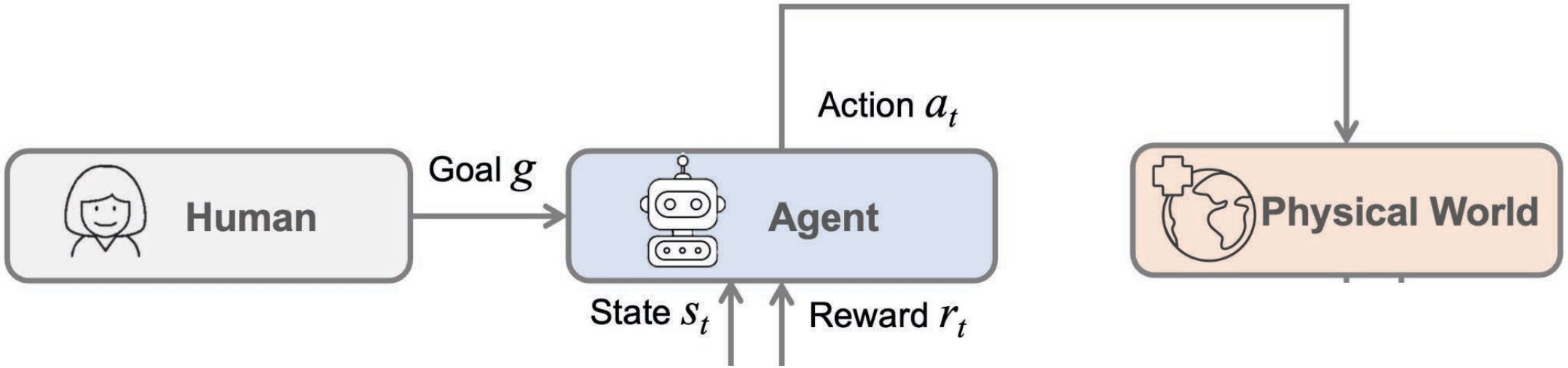

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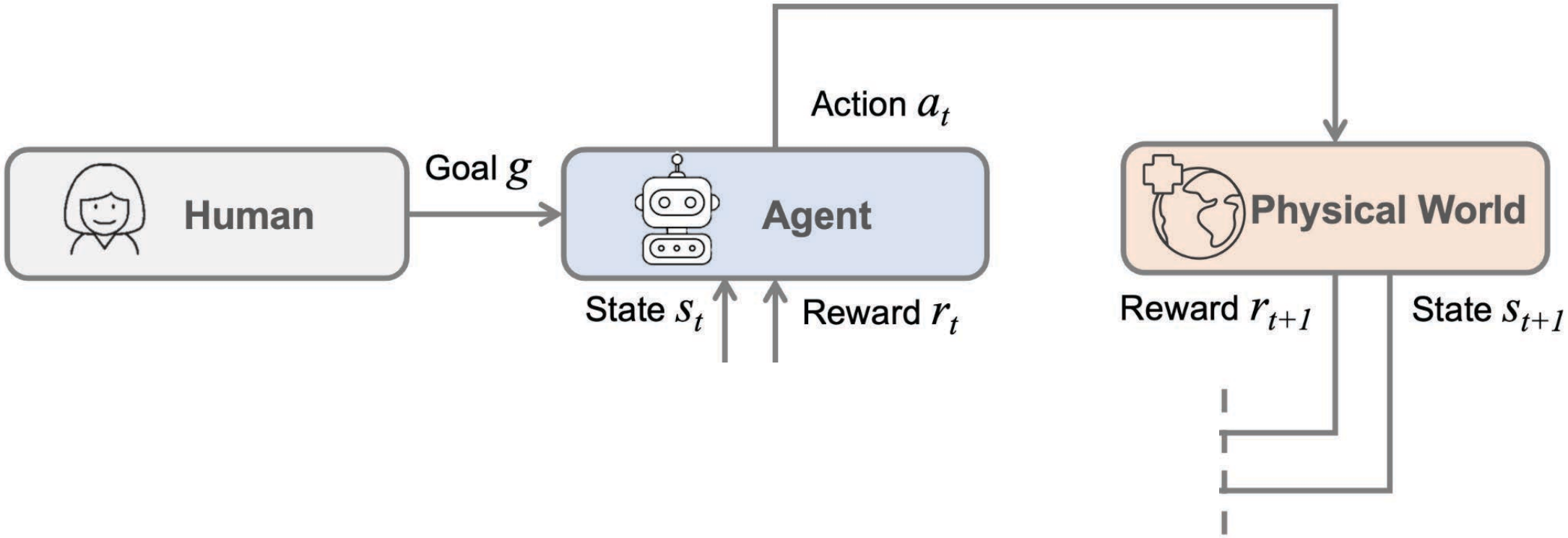

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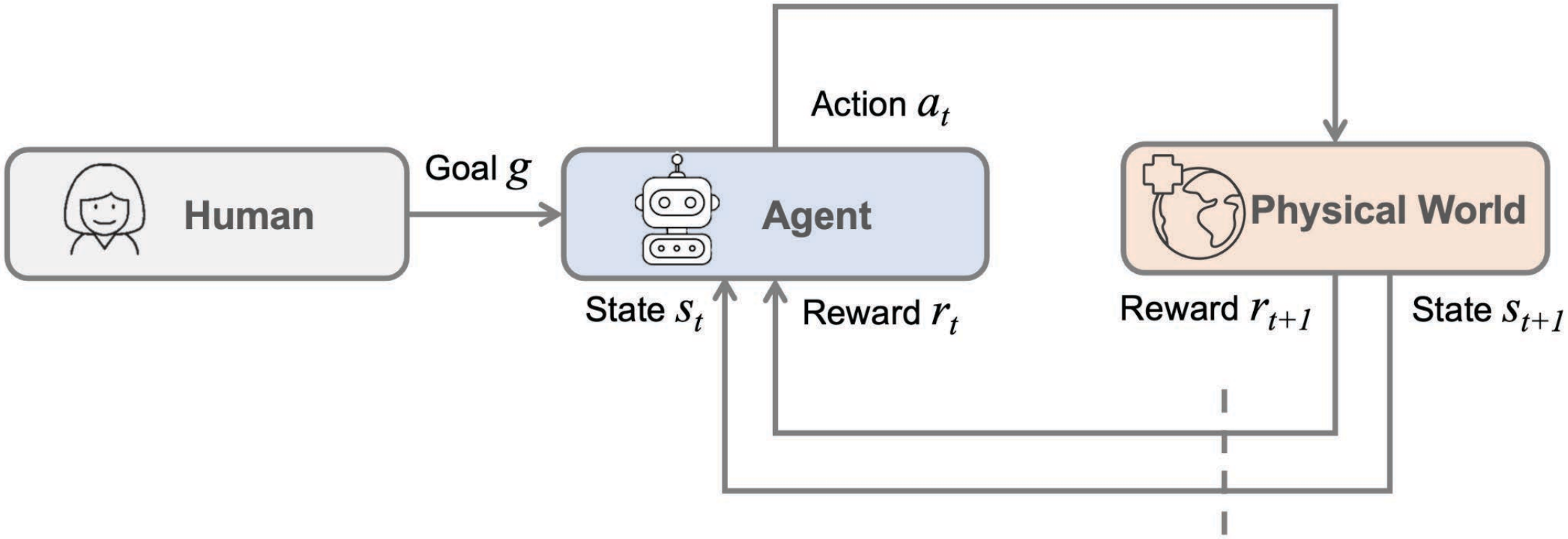

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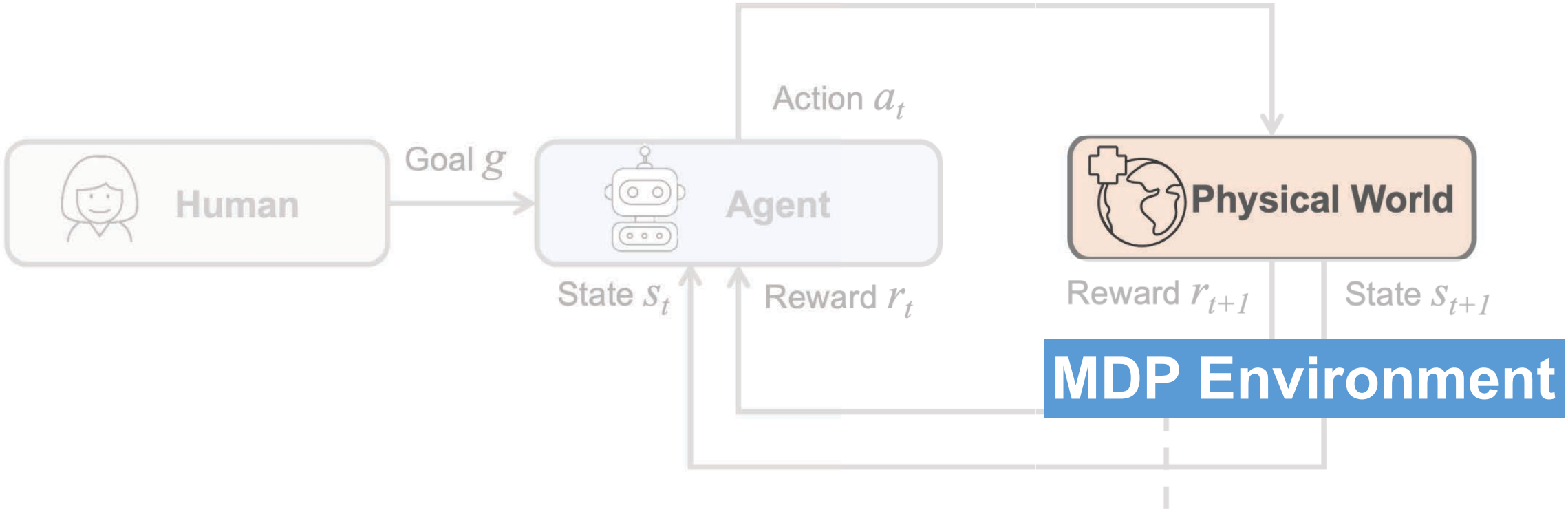
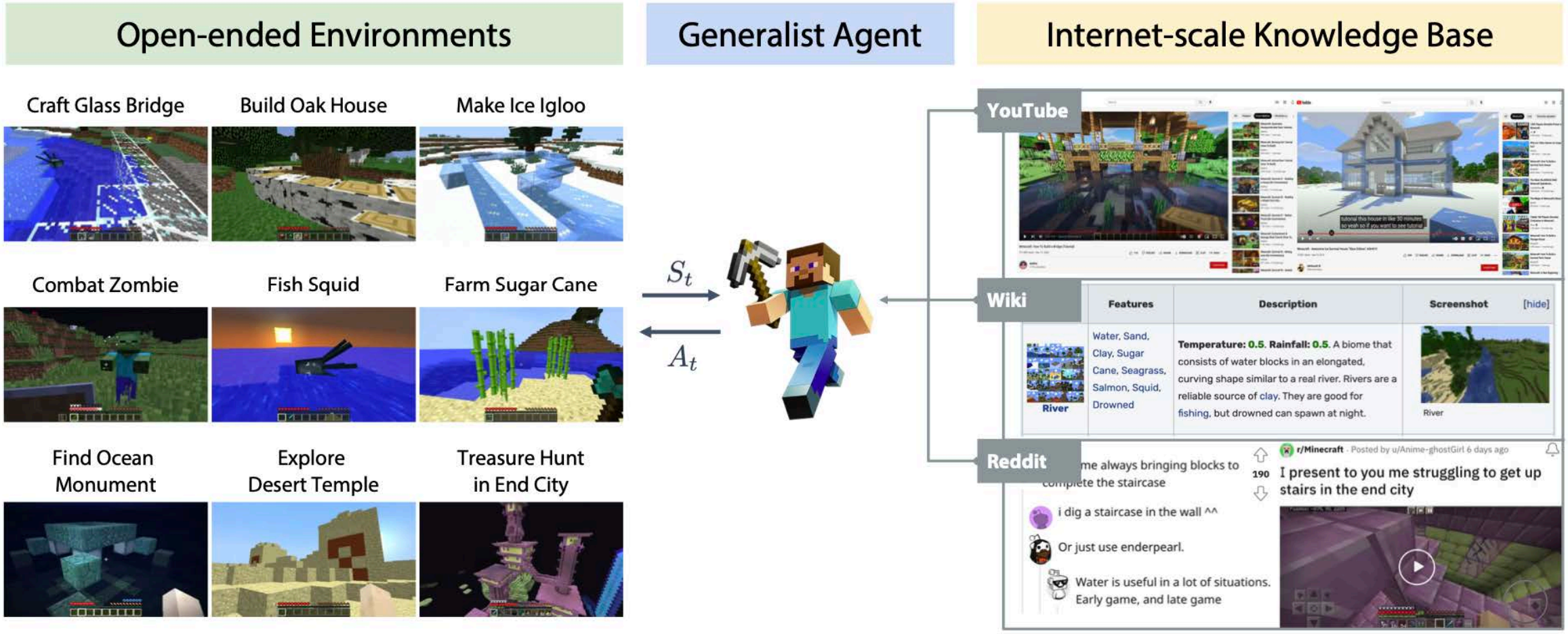


MDP Environment: MineCraft

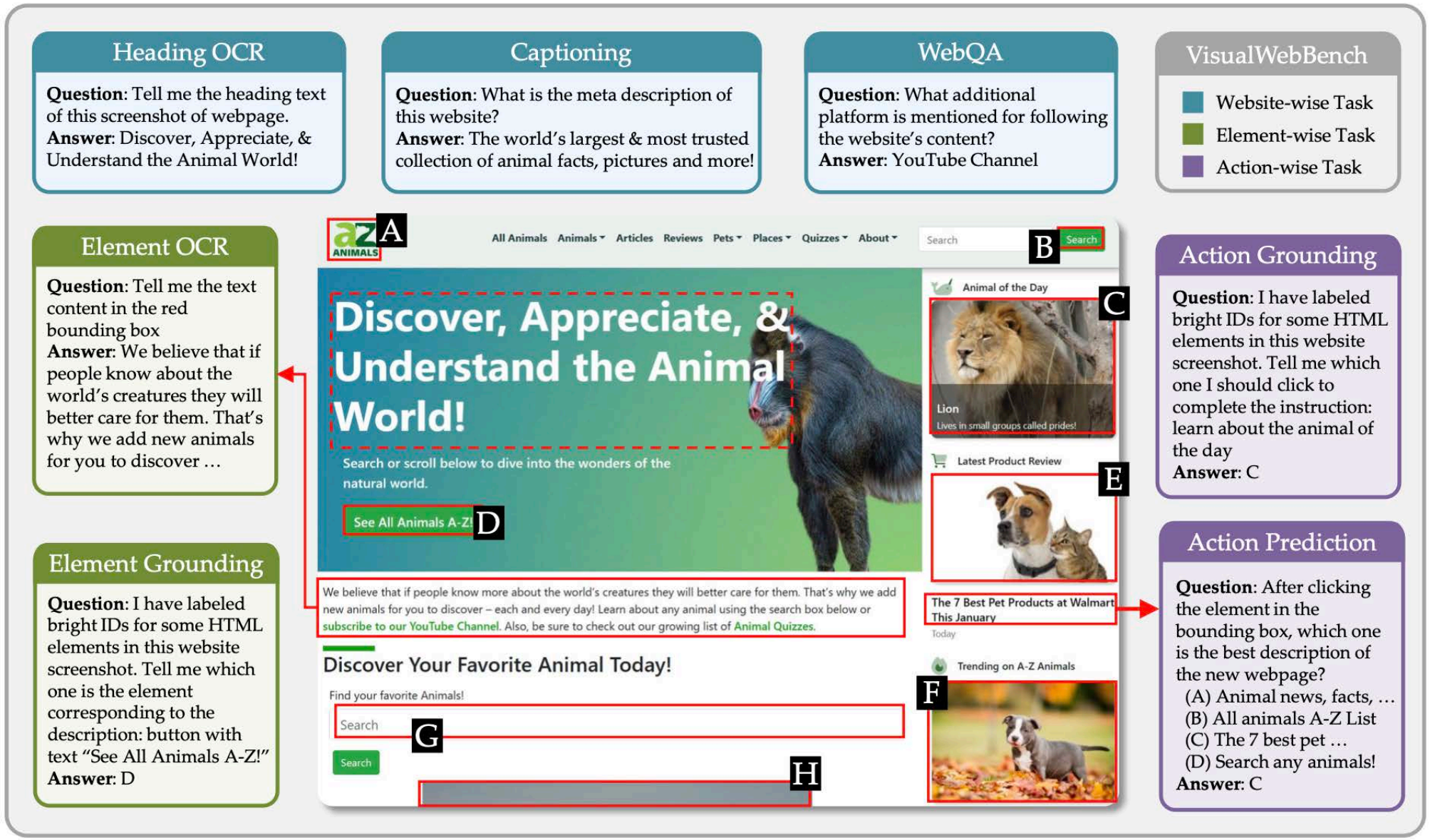


MineDojo

MineDojo: Building Open-Ended Embodied Agents with Internet-Scale Knowledge https://arxiv.org/abs/2206.08853

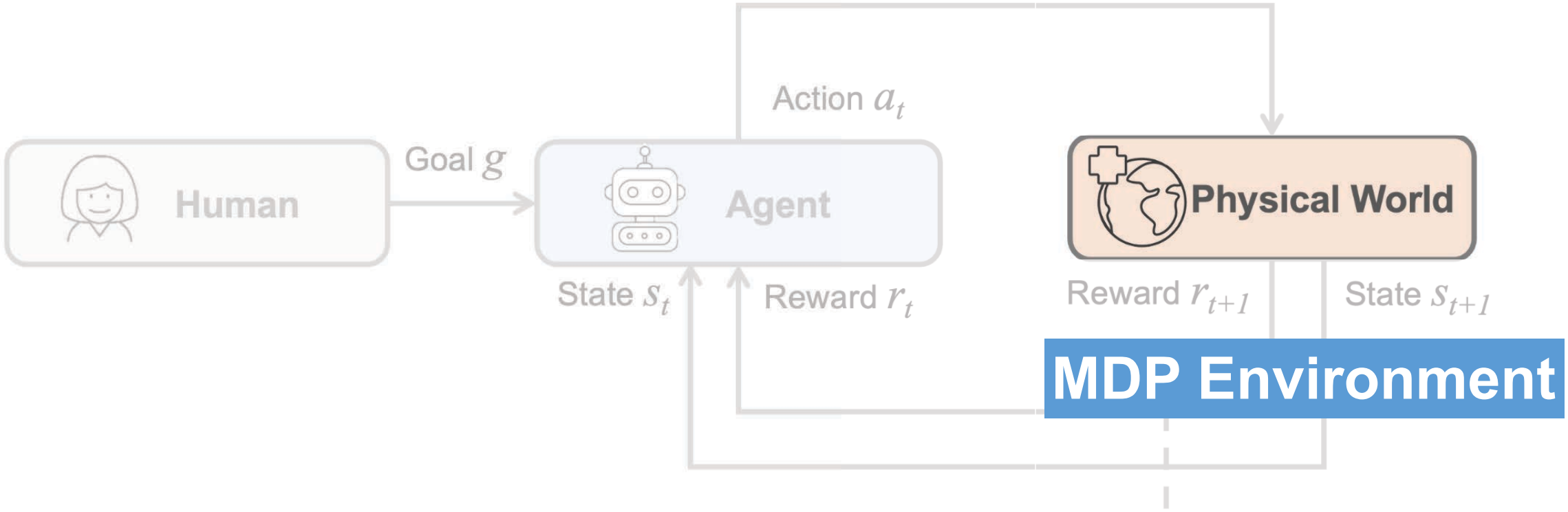
MDP Environment: GTA

MDP Environment: Web Agent Env



VisualWebBench: How Far Have Multimodal LLMs Evolved in Web Page Understanding and Grounding? https://arxiv.org/pdf/2404.05955

Let us go back to MDPs (Markov Decision Processes)



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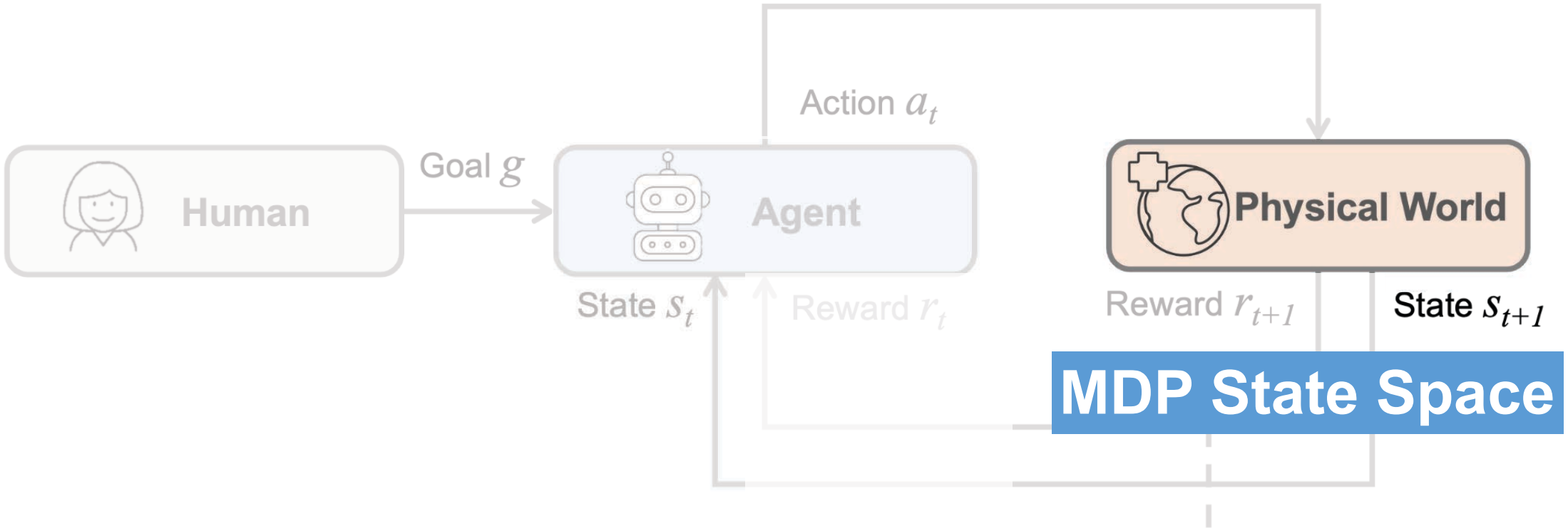

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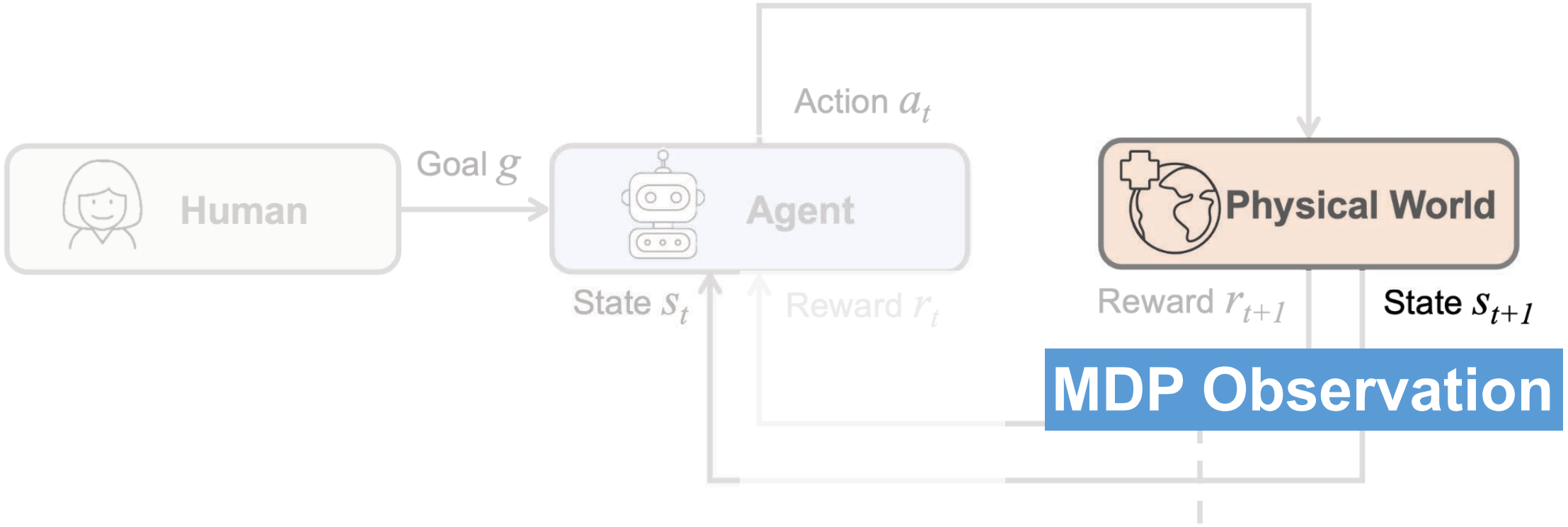
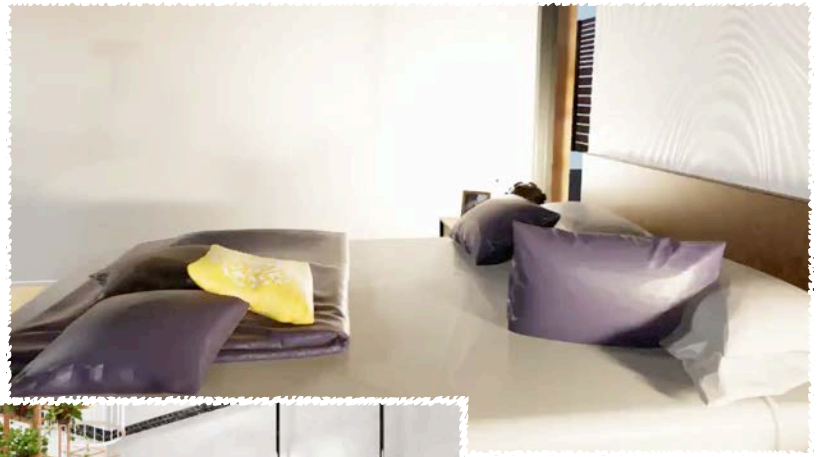


Environment：Observation (Rendered 2D Images)

Enabled by large dataset of realistic interactive scenes and objects

50 Scenes



https://behavior.stanford.edu/

Environment : Observation → State (3D Assets & States)

50 Scenes

Enabled by large dataset of realistic interactive scenes and objects






10000 Objects

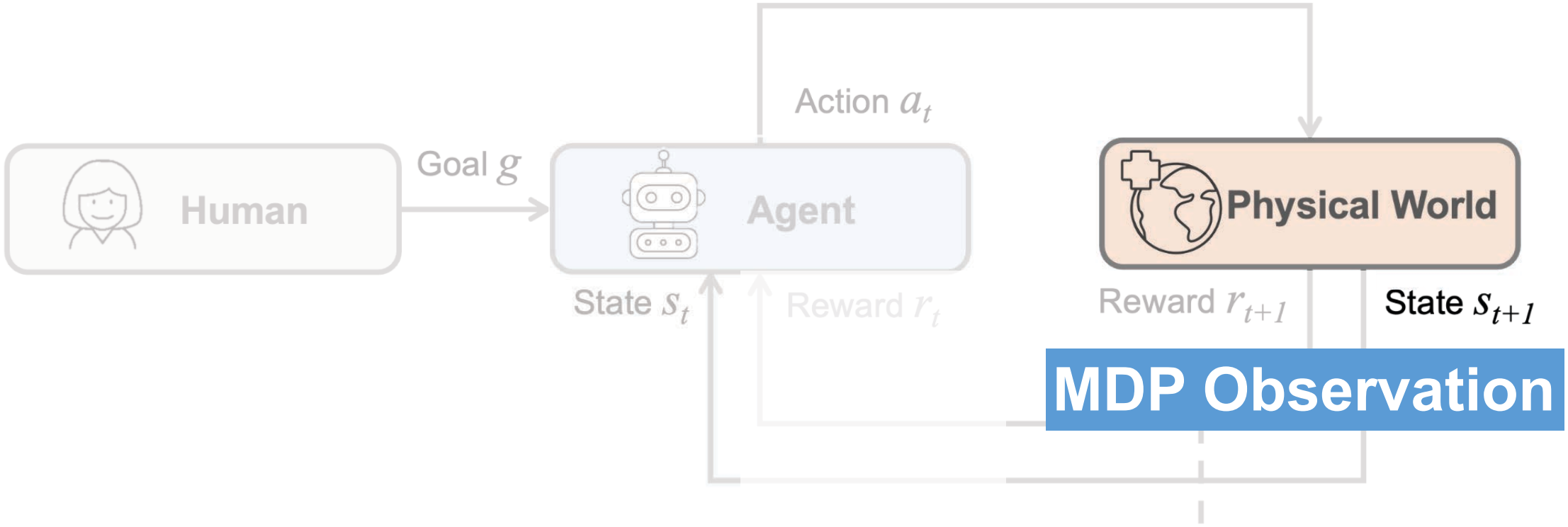
Semantic

Properties: cookable, sliceable, freezable, burnable, deformable
…
Cooking temperature: 58°C
…

Physical

Articulation annotation (joint type, origin, axis, limit)
Mass, friction, CoM, …
Canonical size and orientation

Let us go back to MDPs (Markov Decision Processes)



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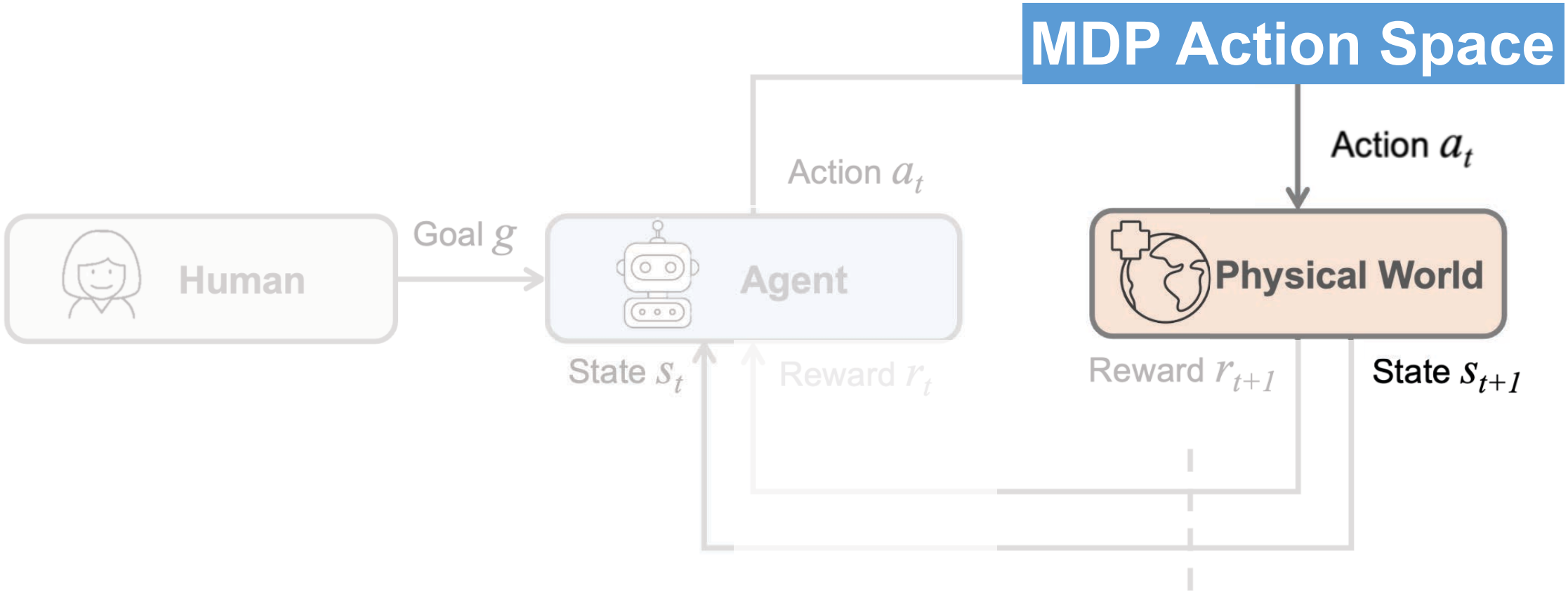
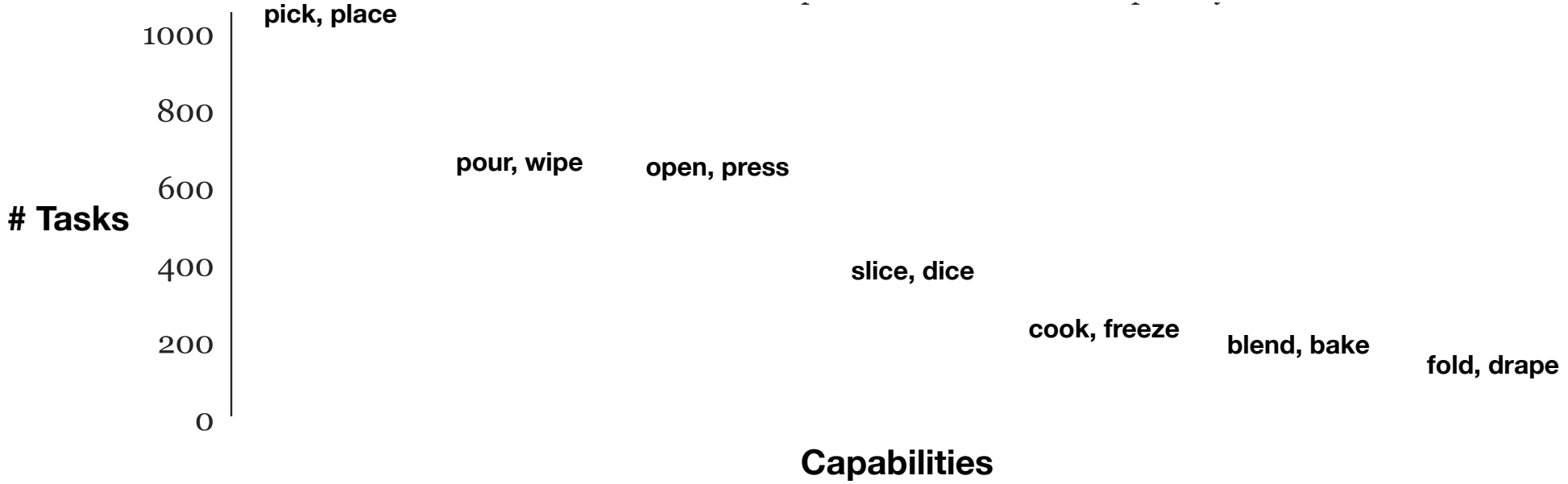


Action : can robots learn to solve these tasks?

→ What capabilities are needed?



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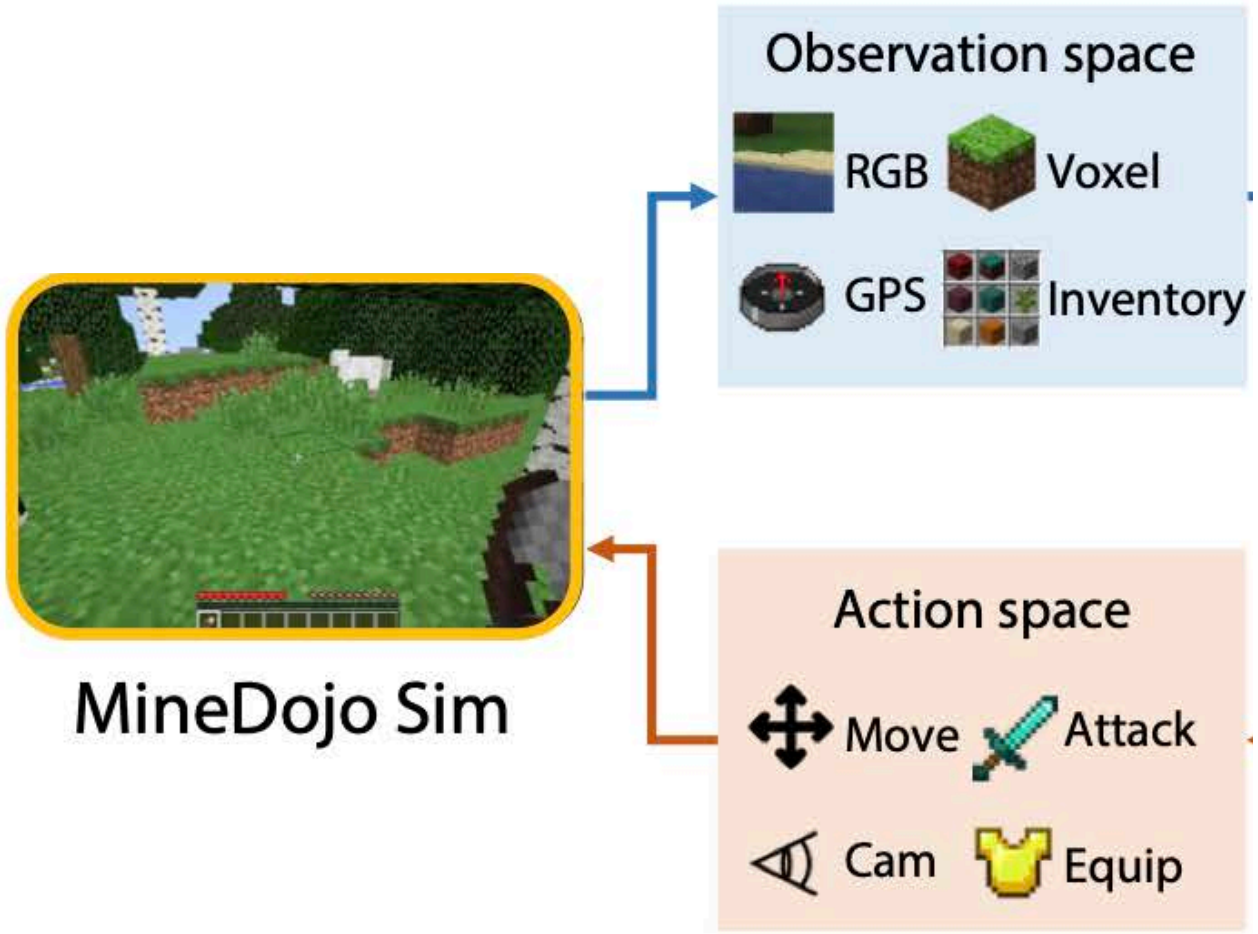
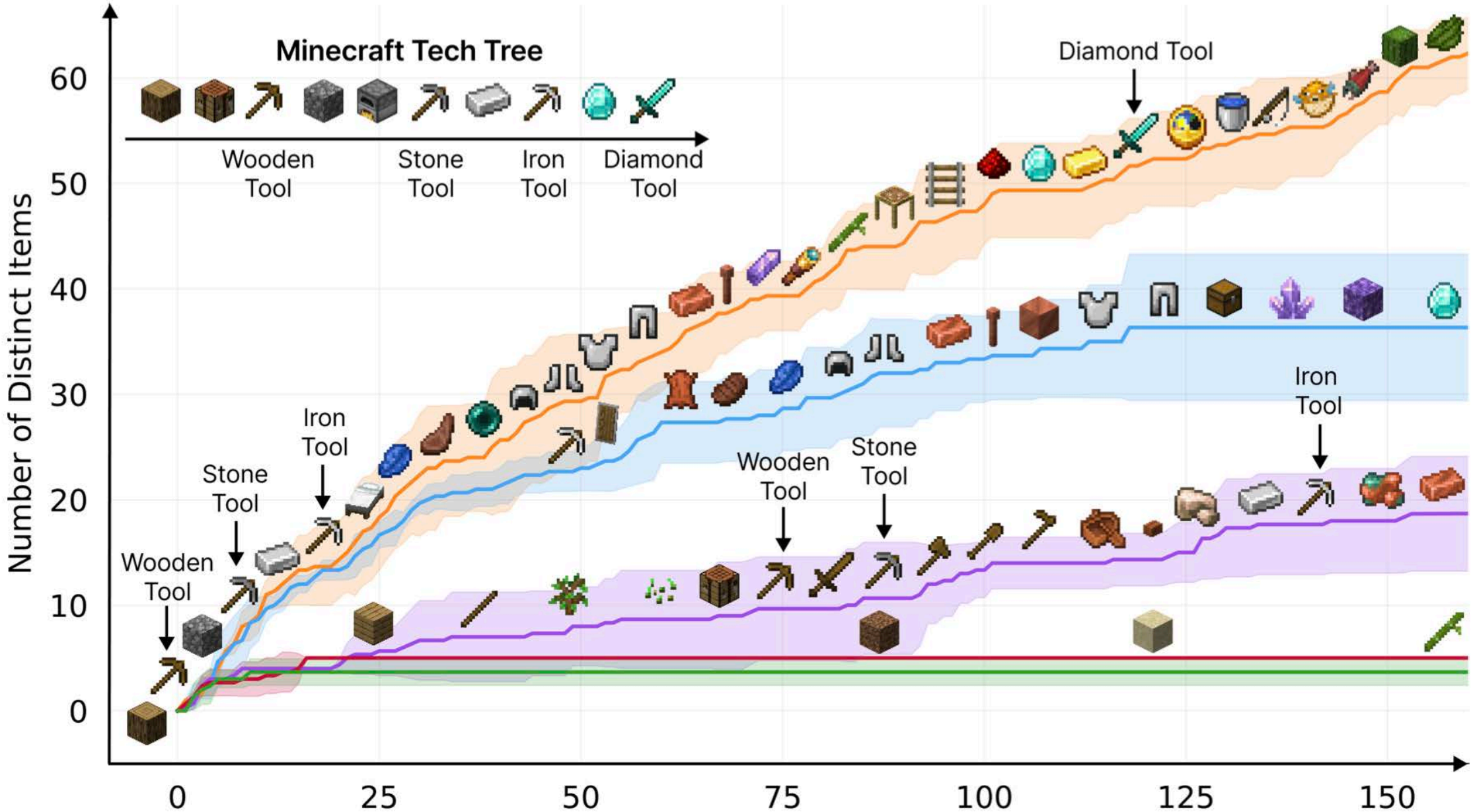
MDP Action Space: Skills



MDP Action Space: Skills



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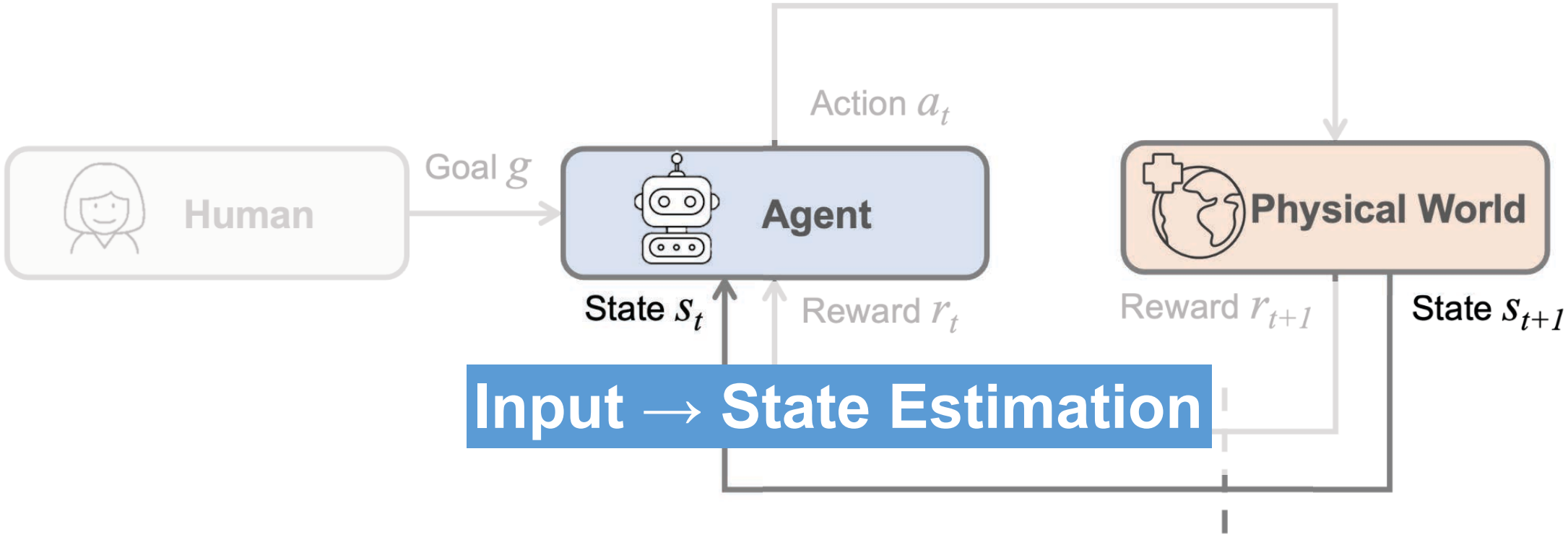


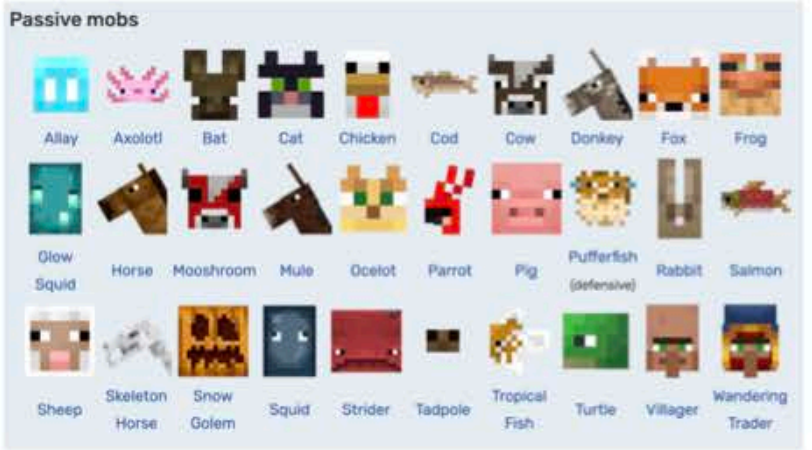
Perception / State Estimation

$o \rightarrow s$

Observation → State Estimation (Assets & States)

Observation (2D rendered scenes)

State (3D assets)



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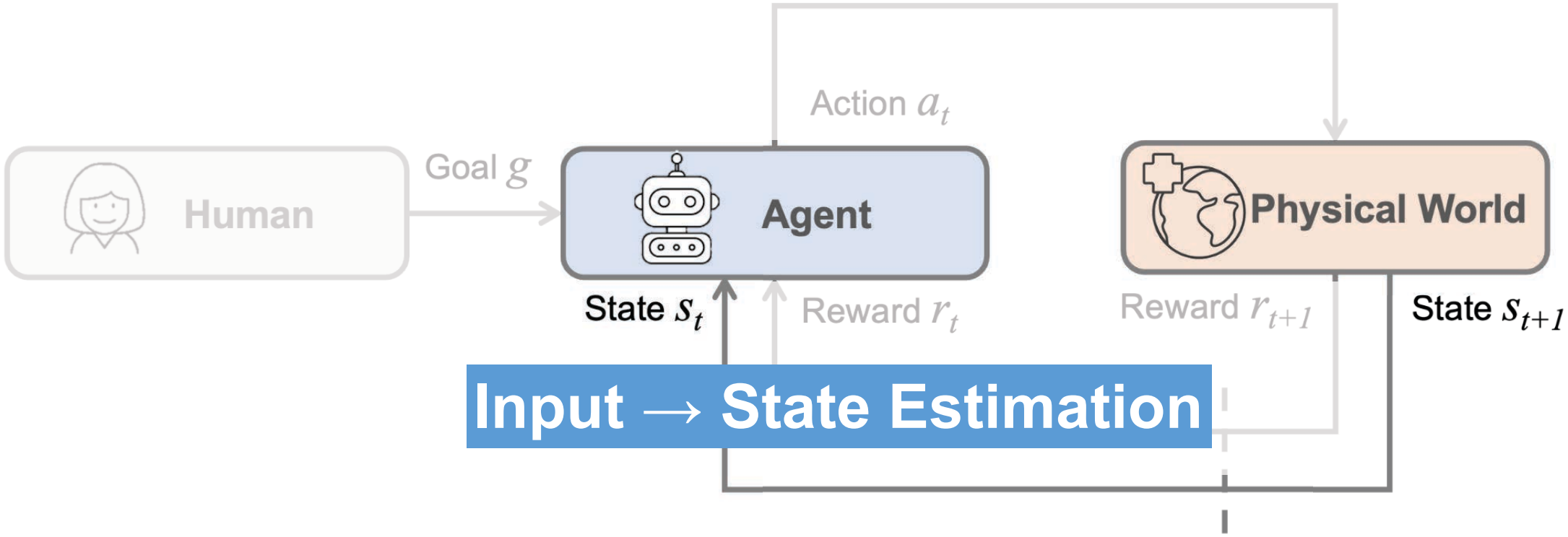

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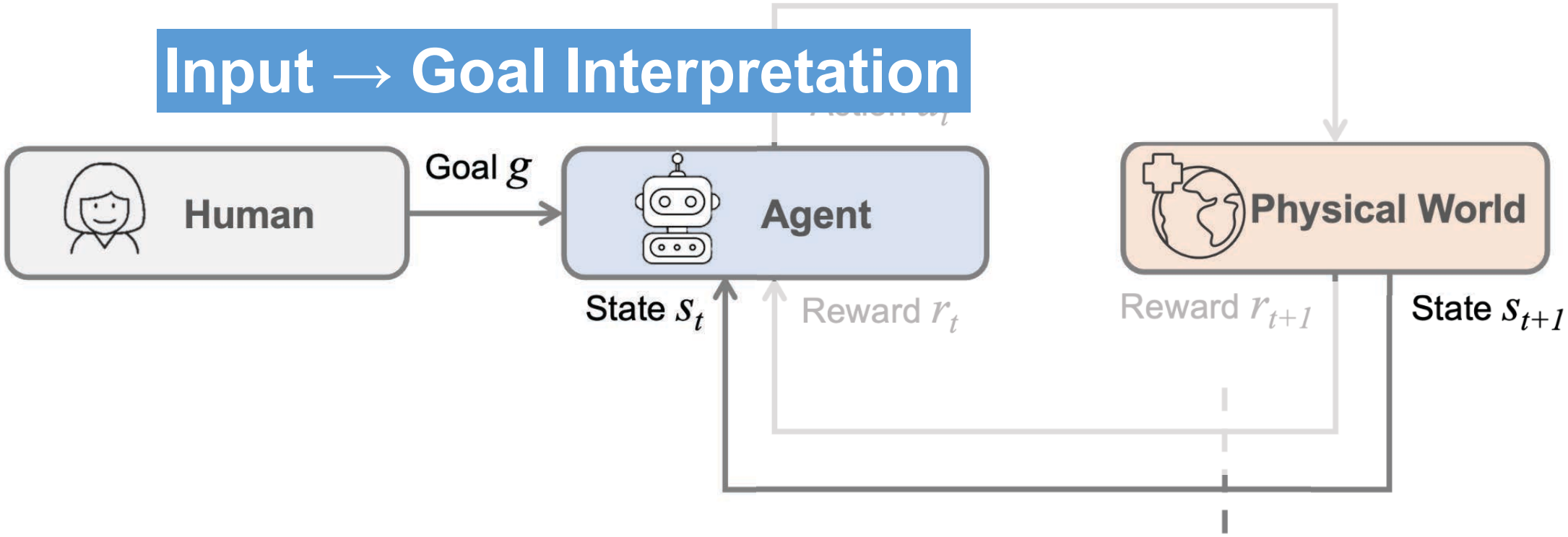


Goal Interpretation

g

Set up the table.

...

on_top_of (turkey, table)

...

LLM

Set up the table.

...

on_top_of (turkey, table)

...

LLM

Use the plates.

...

on_top_of (plate, table)

on_top_of (turkey, plate)

...

LLM

Goal : defines a task?

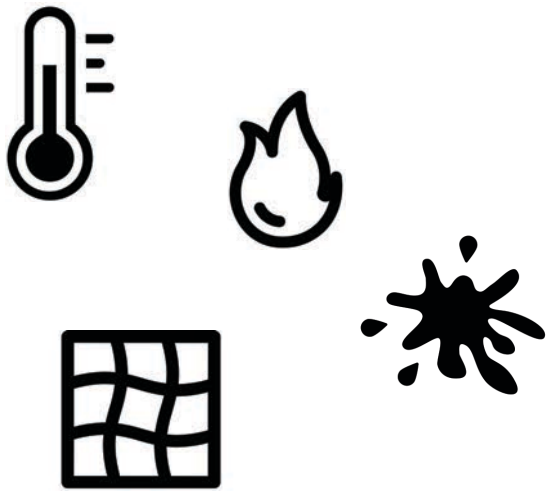
wikiHow to do anything

YouTube

“Pack lunch”

What objects?

What properties?

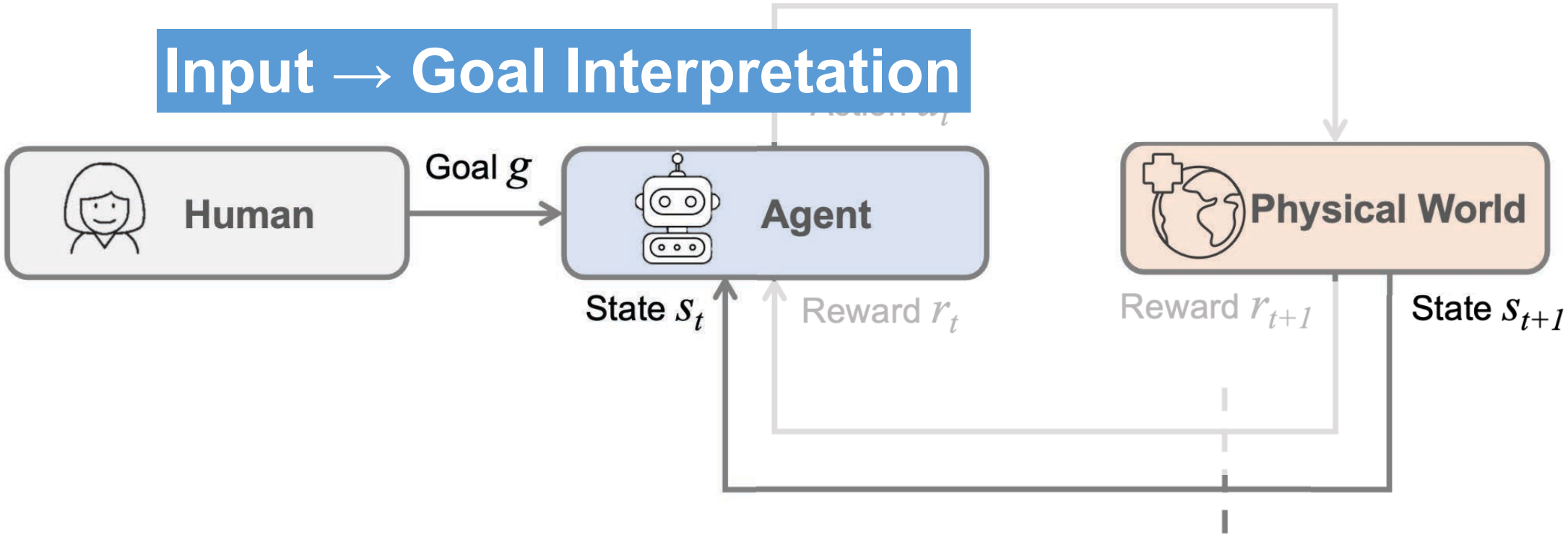


Start & Goal?

- **apple** in **fridge**
- **burger** in **fridge**
- **water bottle** in **fridge**
- **paper bag** on **counter**

https://behavior.stanford.edu/

Let us go back to MDPs (Markov Decision Processes)



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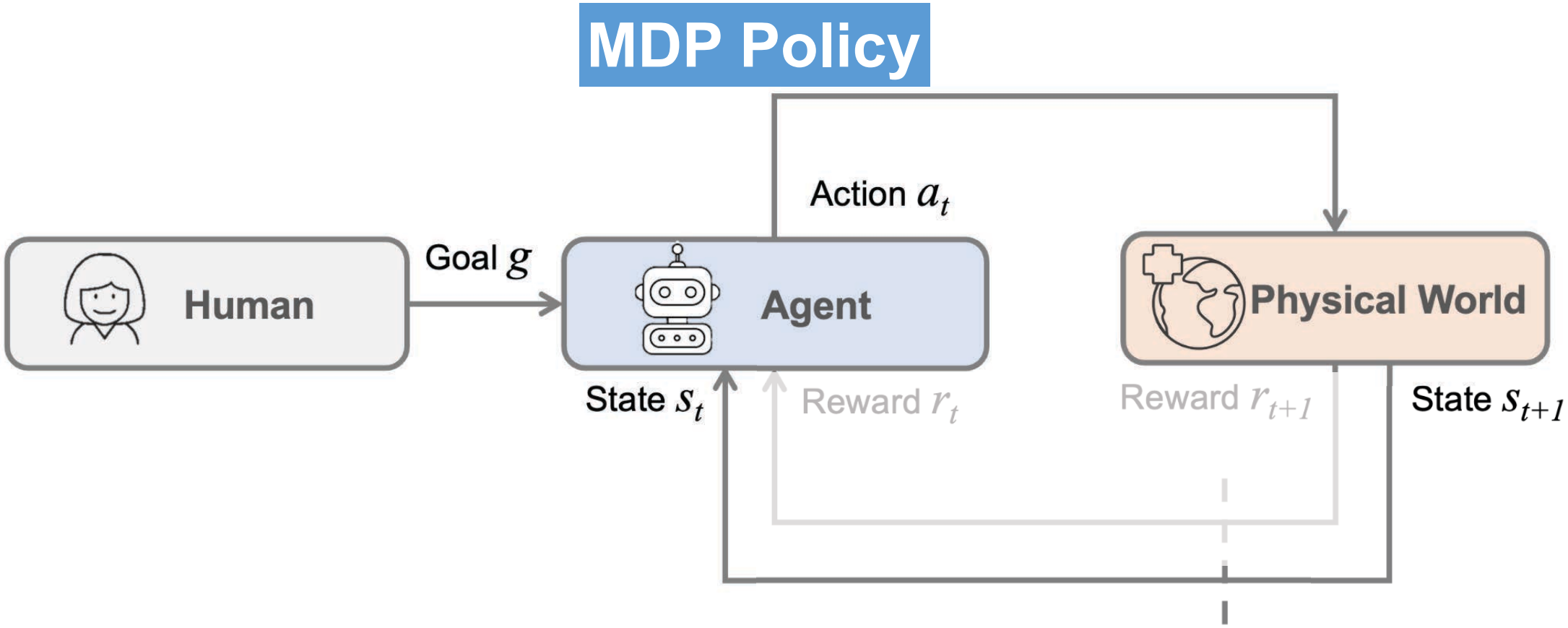

Policy

$$\pi(o, g) \rightarrow a$$

Input: Preserving food

Environment

… inside (strawberry, pan) …

Goal

… cooked (strawberry) …

Operator

BEHAVIOR

Action Trajectory

… ✓

A7 OPEN (oven) ✓

A8 RIGHT_GRASP(pan) ✓

A9 RIGHT_PLACE_INSIDE (oven)

A10 CLOSE(oven)

A11 COOK(strawberry)

…

LLM Output

This video is for demonstration only. There're no actual controller-level actions. For action execution examples, visit our repository: https://github.com/embodied-agent-interface/embodied-agent-interface.

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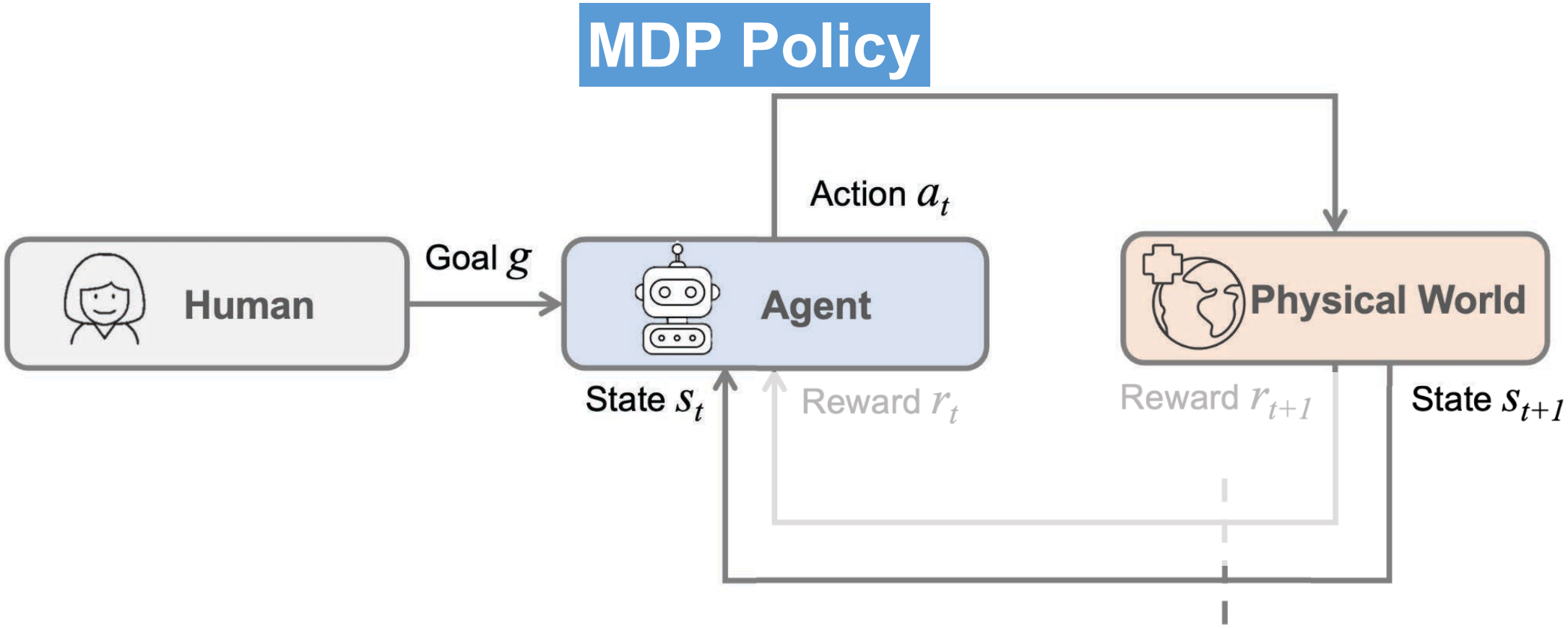

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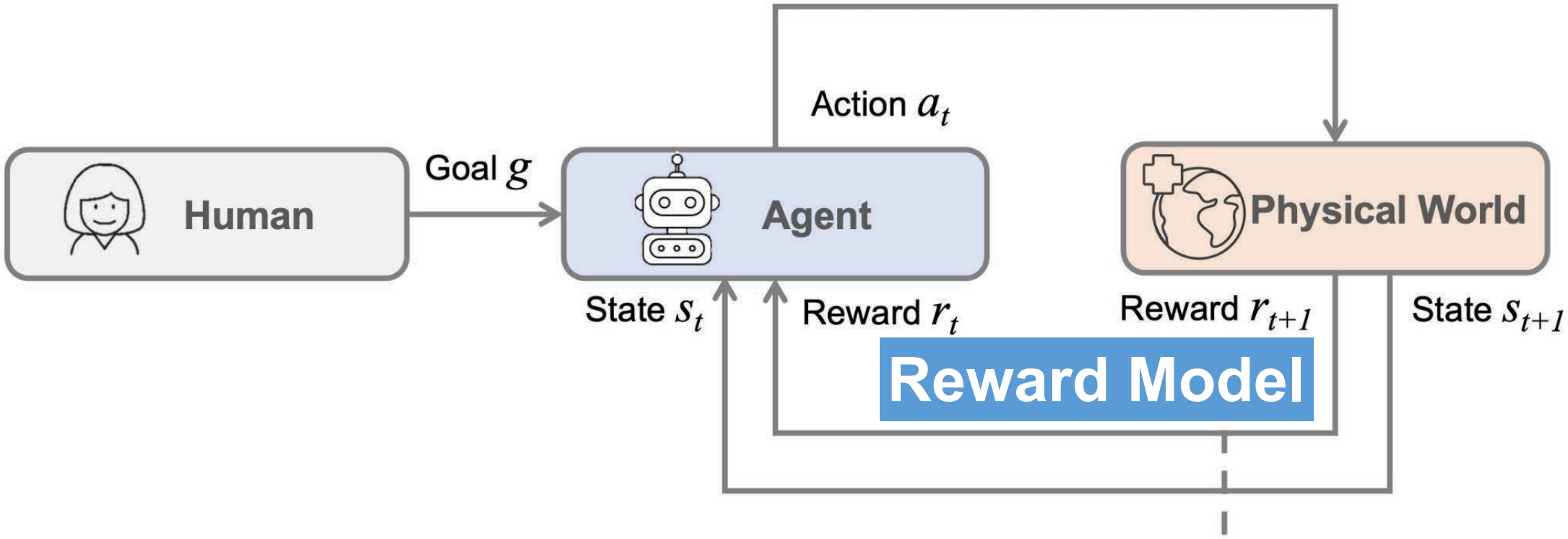
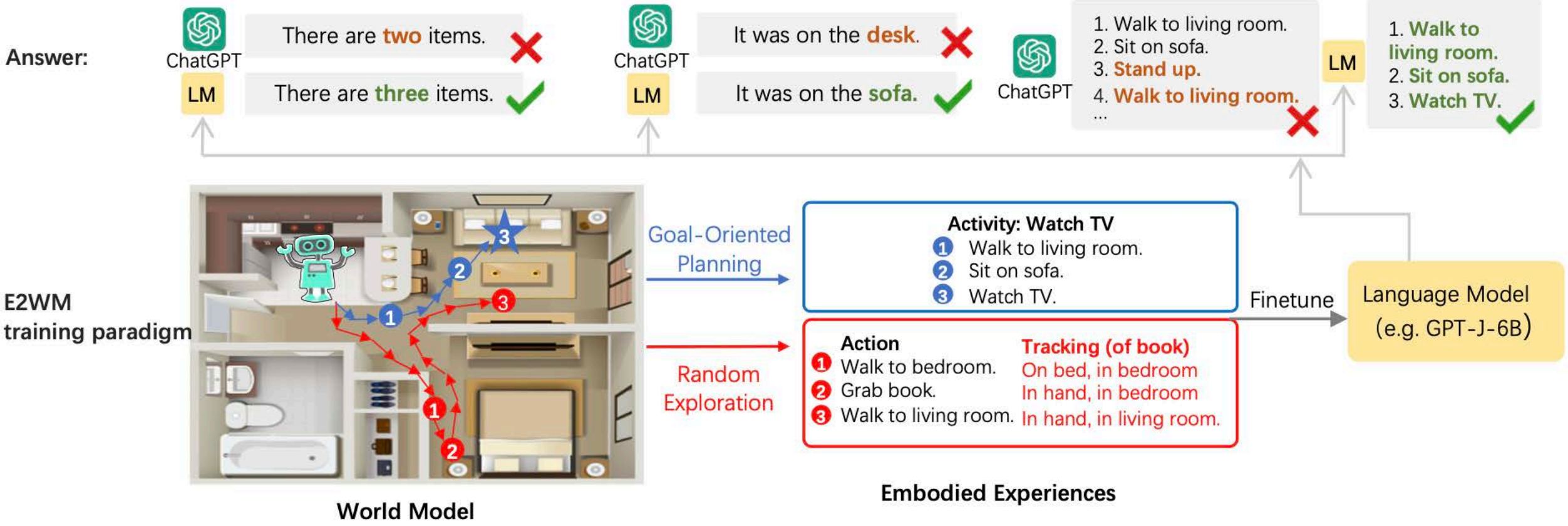


Reward Model

$o, a \rightarrow r$

Reward Model



https://arxiv.org/pdf/2305.10626

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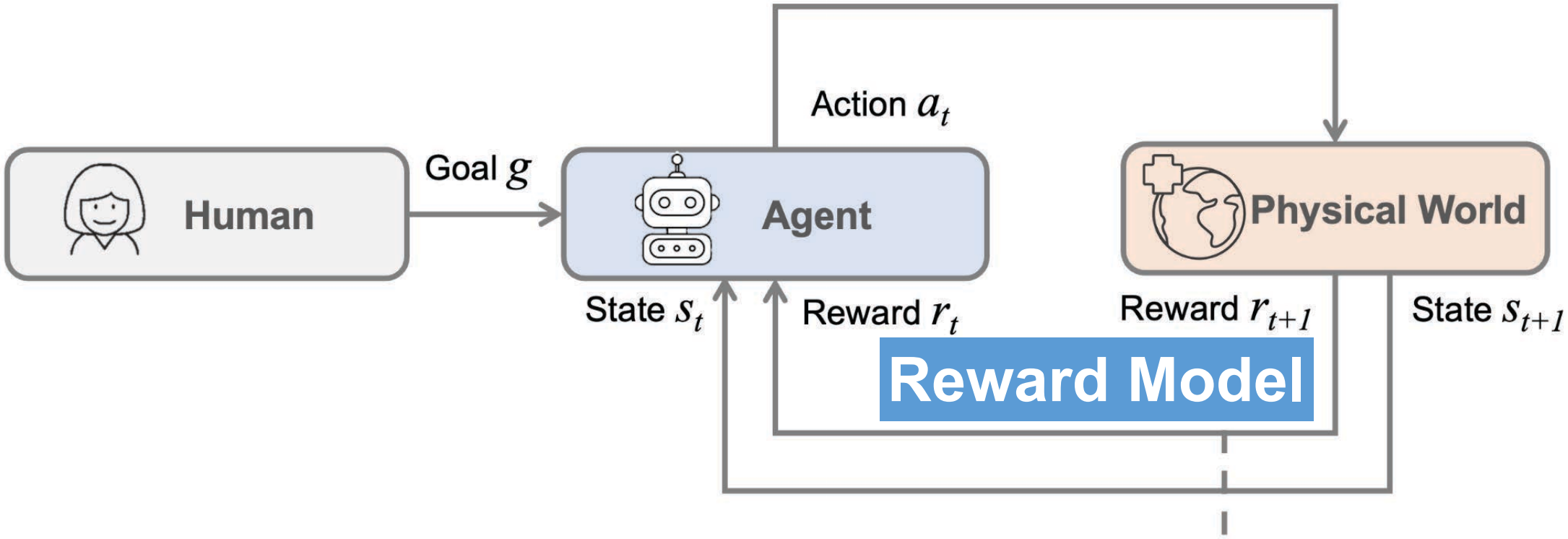

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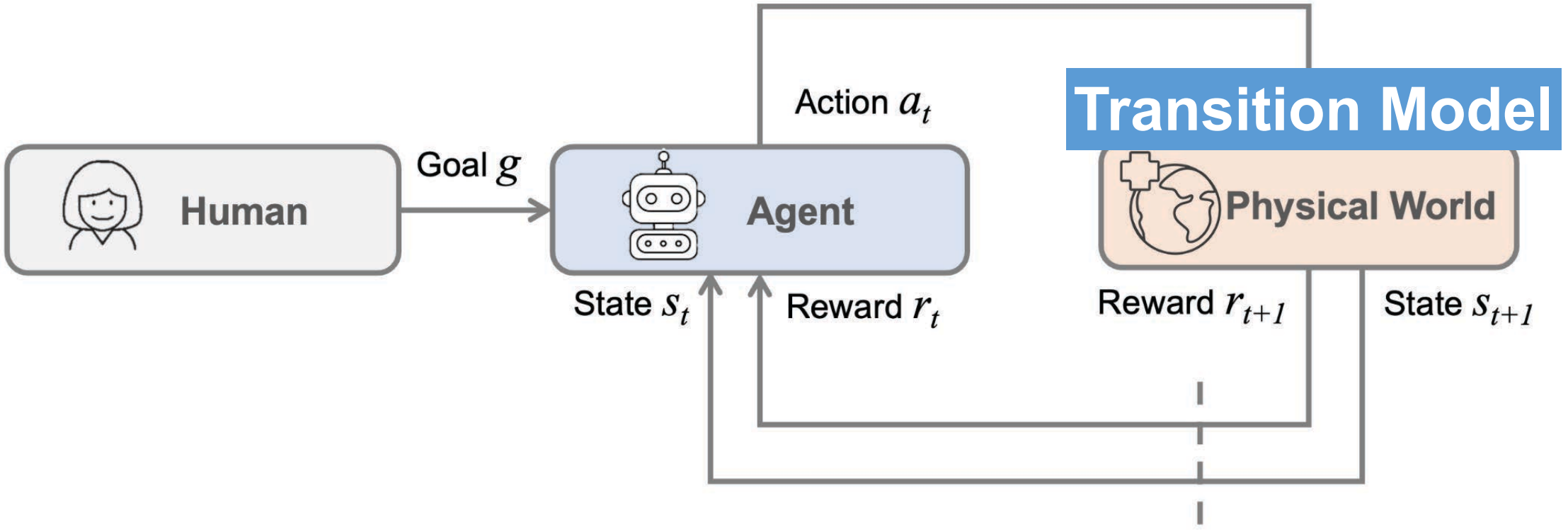


Transition Model

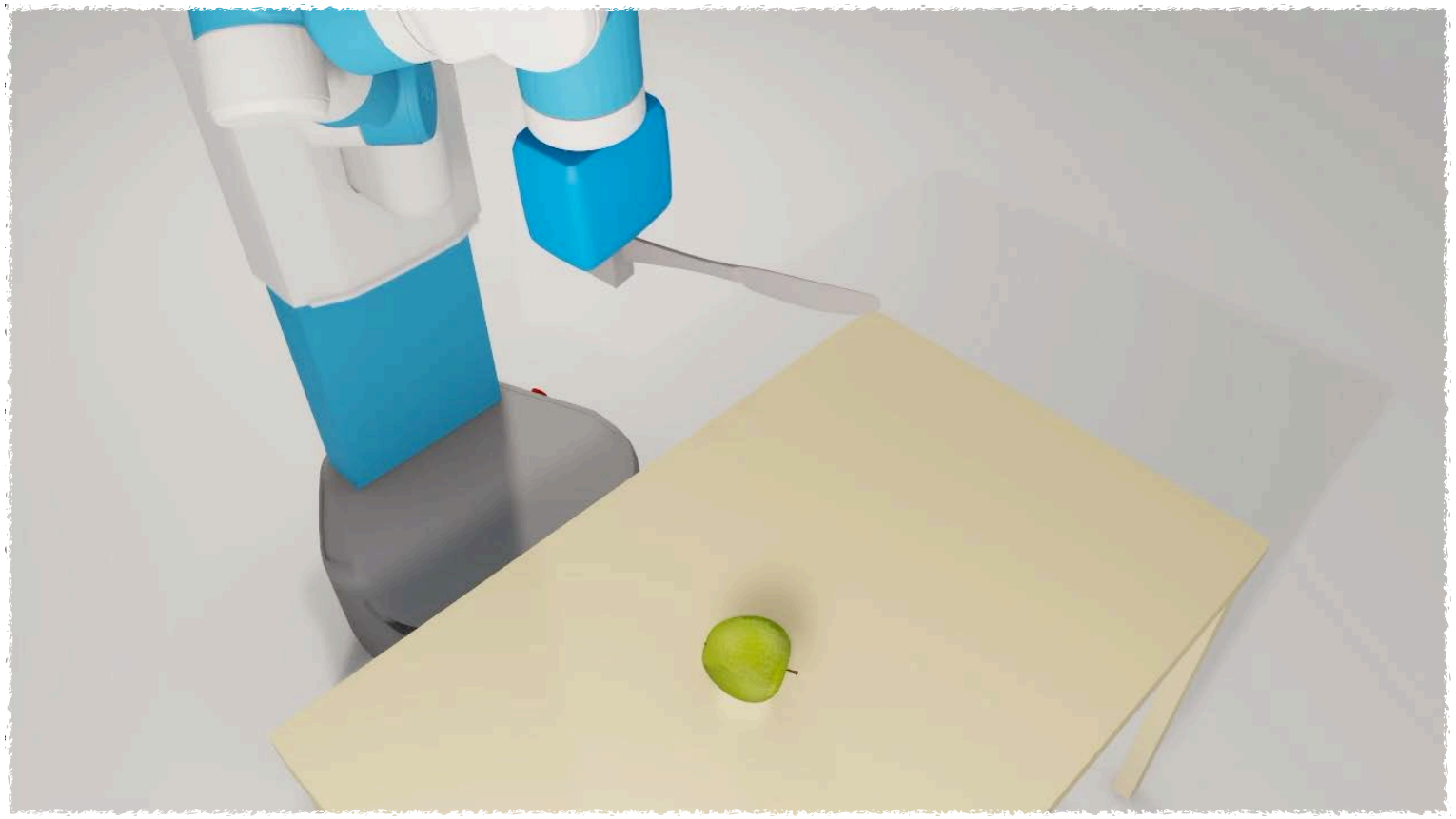
$$o_t, a \rightarrow o_{t+1}$$

"World Modeling"

OmniGibson

Physics Transition Examples

```
class SlicingRule:
```



https://behavior.stanford.edu/

OmniGibson

Physics Transition Interface

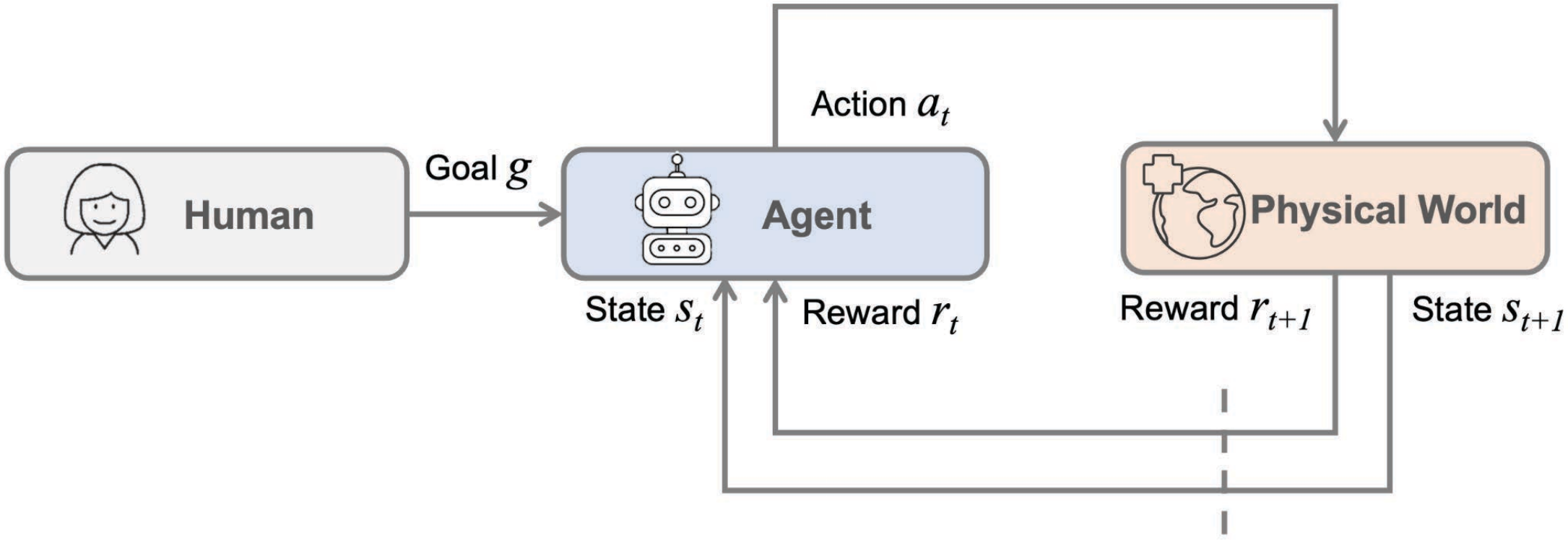
```
class TransitionRule:

def condition(self, *args) -> bool

def transition(self, *args)
```

Determines whether a transition should occur

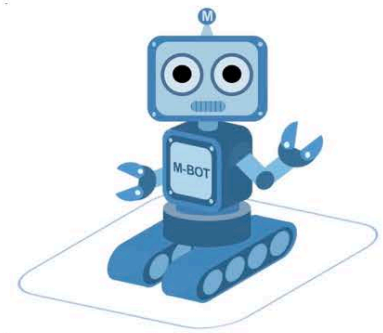
What should happen when a transition is triggered

Allows us to capture arbitrarily complex **physical phenomena**!

Let us go back to MDPs (Markov Decision Processes)



Virtual Agents vs Physical Agents



Different Instantiations of MDP

Perfect actuations

Perfect odometry

RGB only perception

Noisy actuations

Noisy odometry

Multiple perceptual modalities

https://embodiedqa.org/slides/eqa_matterport_slides.pdf

Outline

Content	Time	Presenter
1. Motivation and Overview	15min	Manling Li
2. Foundation Models meet Virtual Agents	45min	Manling Li
3. Foundation Models meet Physical Agents		
Overview & Perception	25min	Jiayuan Mao
High-level & Low-level Decision Making	50min	Wenlong Huang
Break		
4. Robotic Foundation Models	30min	Yunzhu Li
5. Remaining Challenges	15min	Yunzhu Li
QA	30min	