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UNIVERSITY OF MICHIGAN

DANLI: Deliberative Agent for Following Natural Language Instructions

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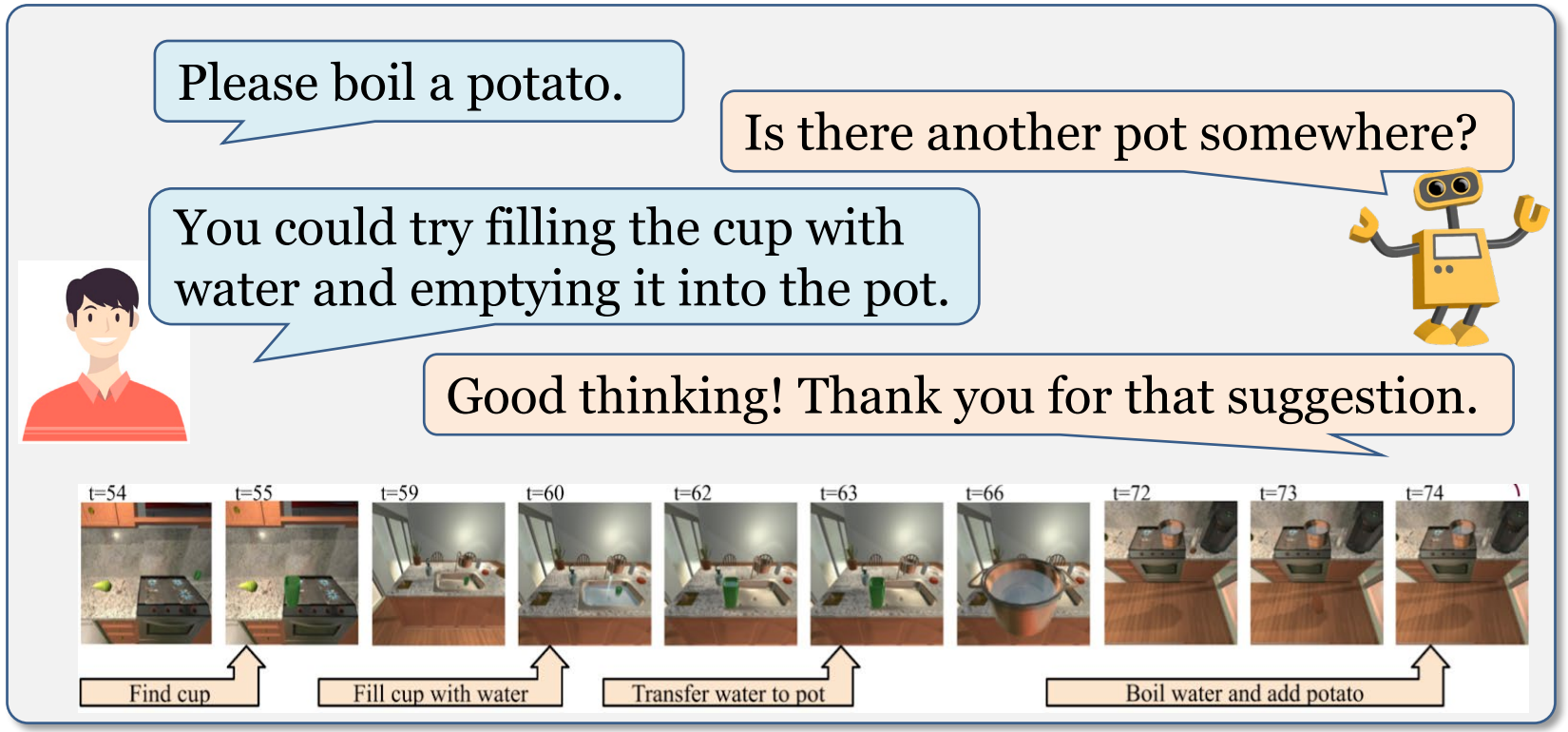
SLED

Problem Definition

- TEACh[1]: The agent is given a dialog history as input, and is expected to execute a sequence of actions to achieve the goal set out by the human commander.

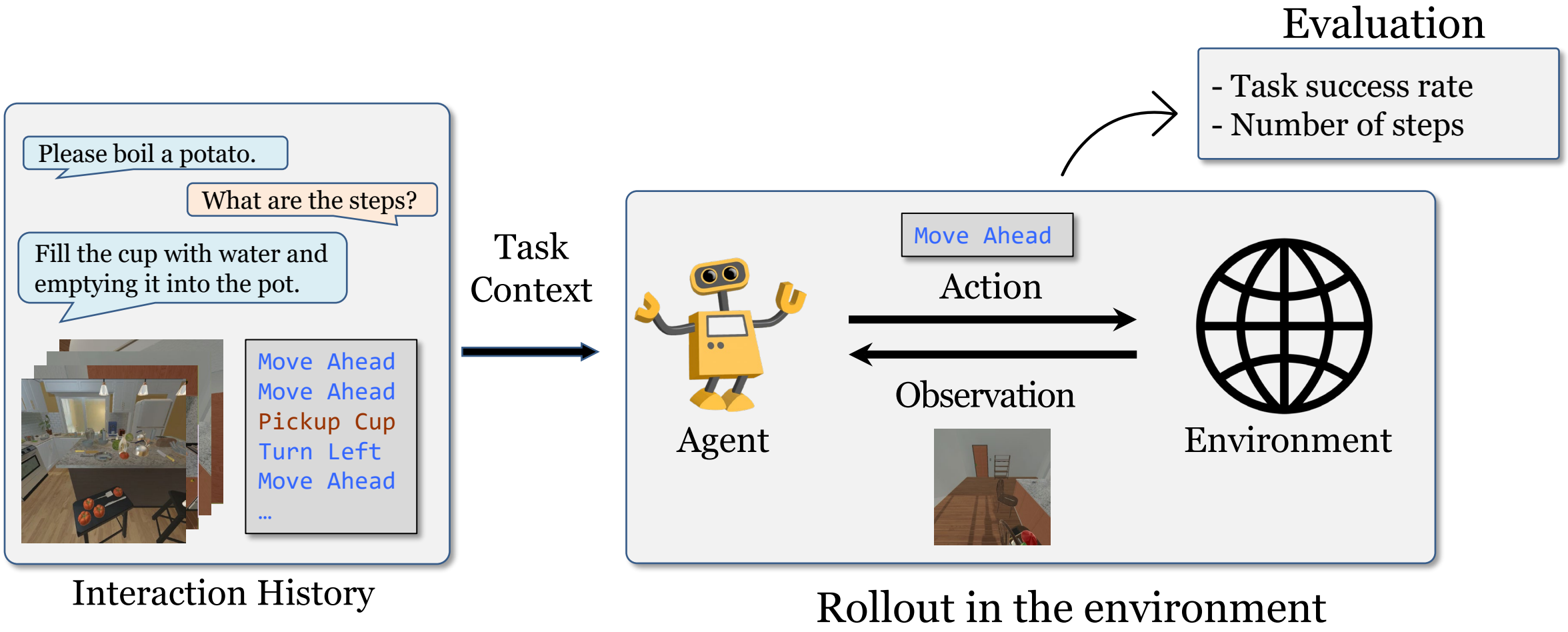


TEACh Tasks

- Water Plant
- Make Coffee
- Clean All X
- Put All X On Y
- Boil Potato
- Make Plate of Toast
- N Slices Of X In Y
- Put All X In One Y
- N Cooked X Slices In Y
- Prepare Sandwich
- Prepare Salad
- Prepare Breakfast

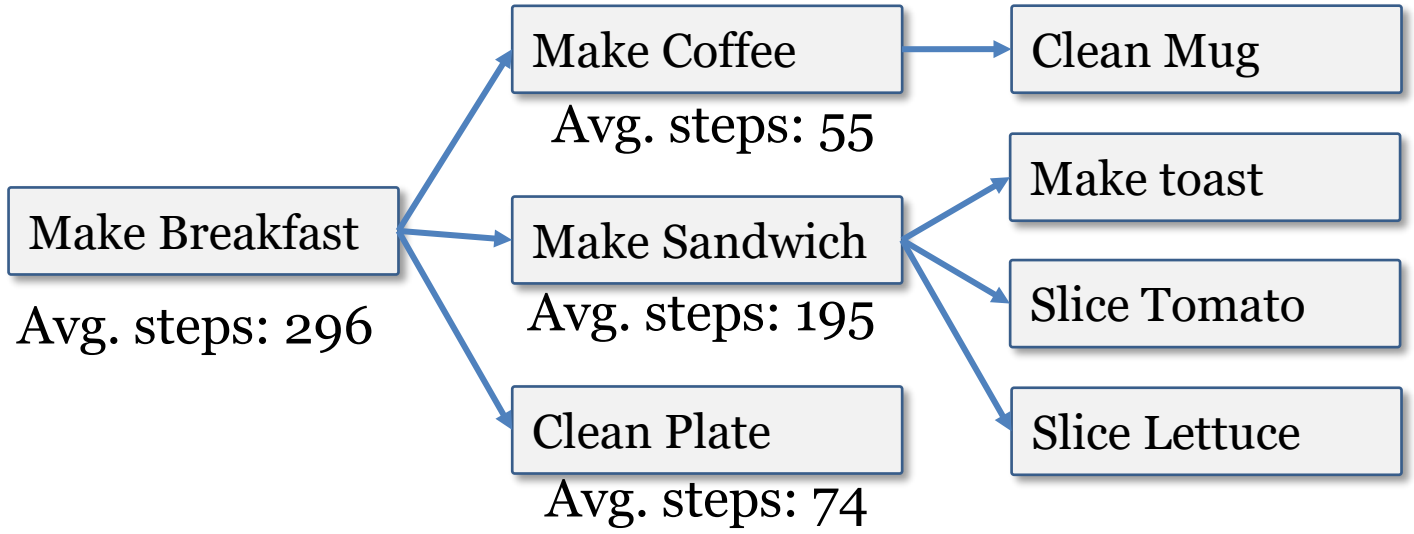
[1] Padmakumar A, Thomason J, Shrivastava A, Lange P, Narayan-Chen A, Gella S, Piramuthu R, Tur G, Hakkani-Tur D. Teach: Task-driven embodied agents that chat. AAAI 2022.

Execution From Dialog History (EDH)



Challenges

- Multi-modal situation and task understanding
- Partially observable and high-dimensional state
- Long-horizon and compositional tasks



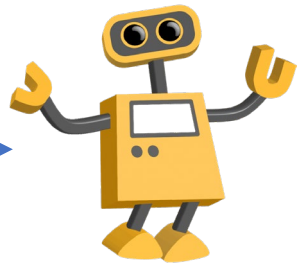
Motivation: From Reactive to Deliberative

Pashevich et al. 2021
Bulks et al. 2021
Zhang and Chai. 2021
Zhou et al. 2021
Singh et al. 2020
...

~ 7% success rate on TEACh-EDH 😢

Reactive

Situation

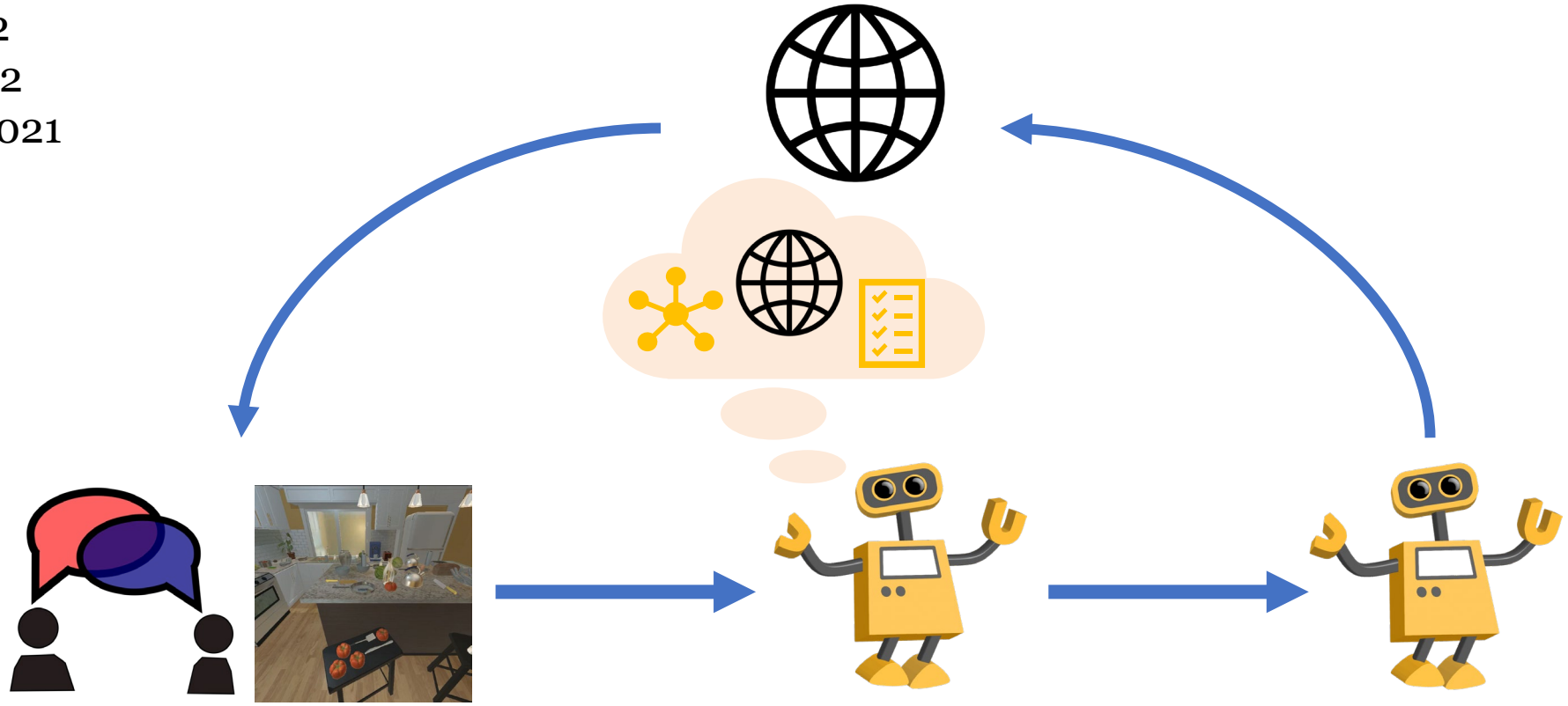


Action

Motivation: From Reactive to Deliberative

Agia et al., 2022
Wang et al., 2022
Srivastava et al., 2021
She et al., 2014
…

Deliberative



Situation

State Tracking & Planning

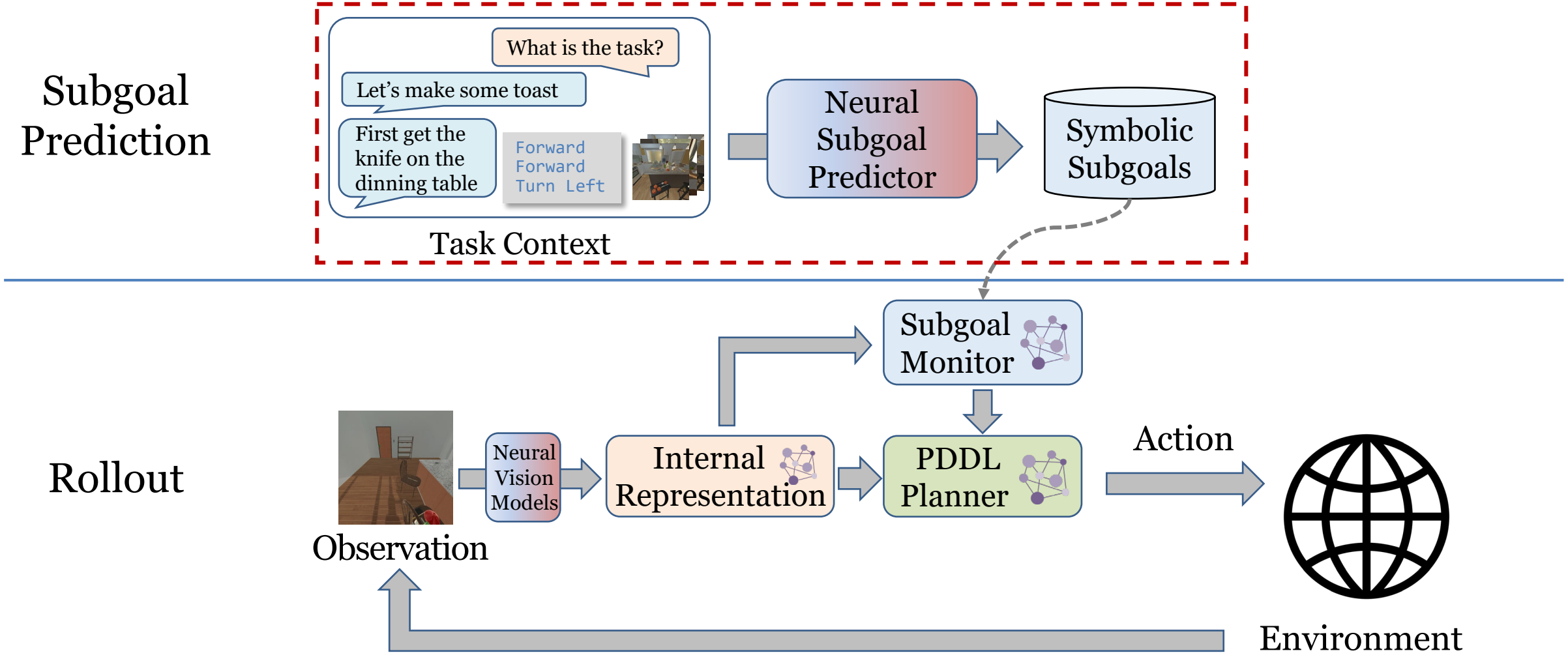
Action

Contributions

Deliberative Agent for following Natural Language Instructions (**DANLI**):

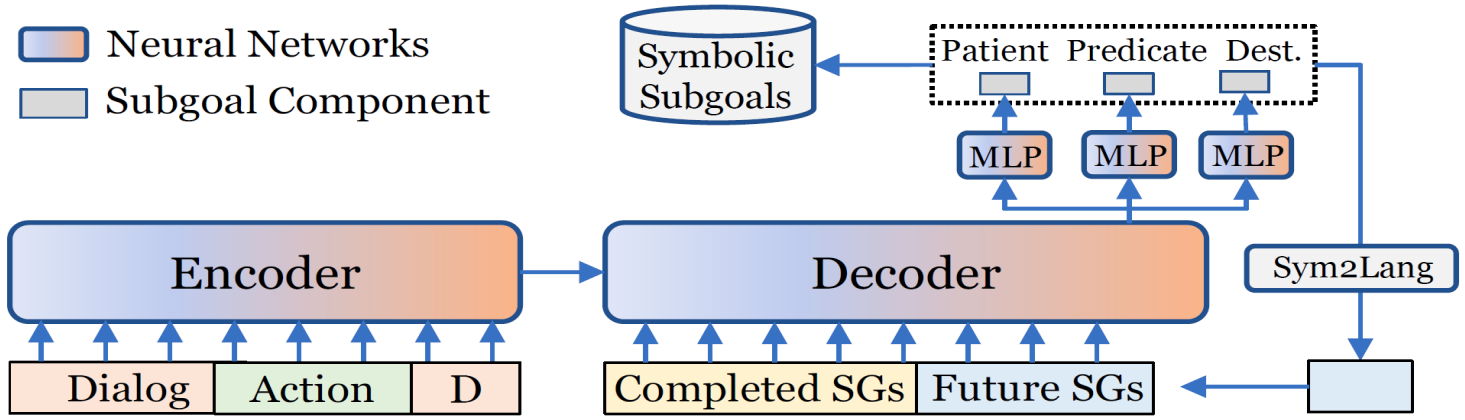
1. **Neural subgoal predictor** uses a language model to predict symbolic subgoals from situated dialog history
2. **Spatial-Symbolic world representation** tracks and grounds objects in a 3D voxel map to facilitate both path and task planning
3. **Online symbolic planner** generates efficient, interpretable plans while allowing online exception handling

Neuro-Symbolic System Architecture



Subgoal Learning From Dialog

- Neural encoder-decoder network for subgoal prediction from interaction history
- Joint progress estimation and future subgoal prediction



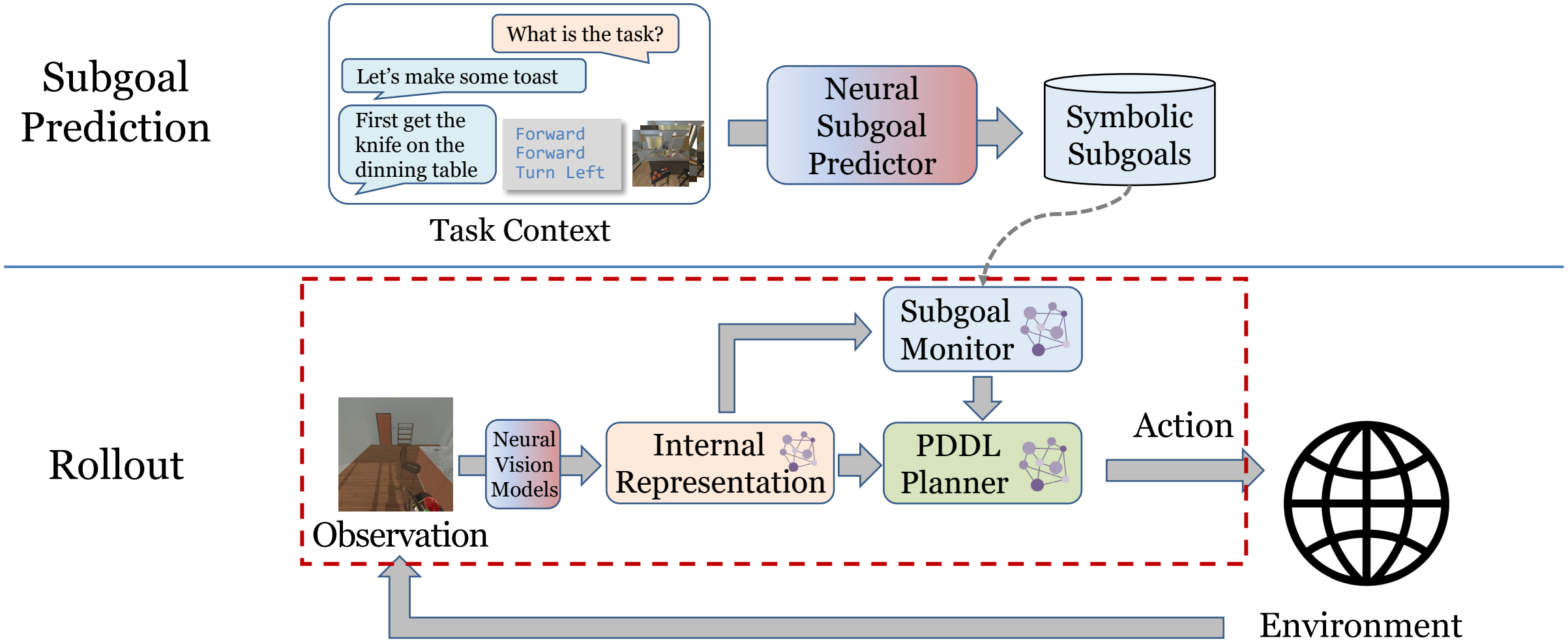
Example Dialog & Action History Input

Follower: Hi. What can I do for you? Commander: Find a cup. Follower go for cup, pick up cup. Commander : Put it on the table.

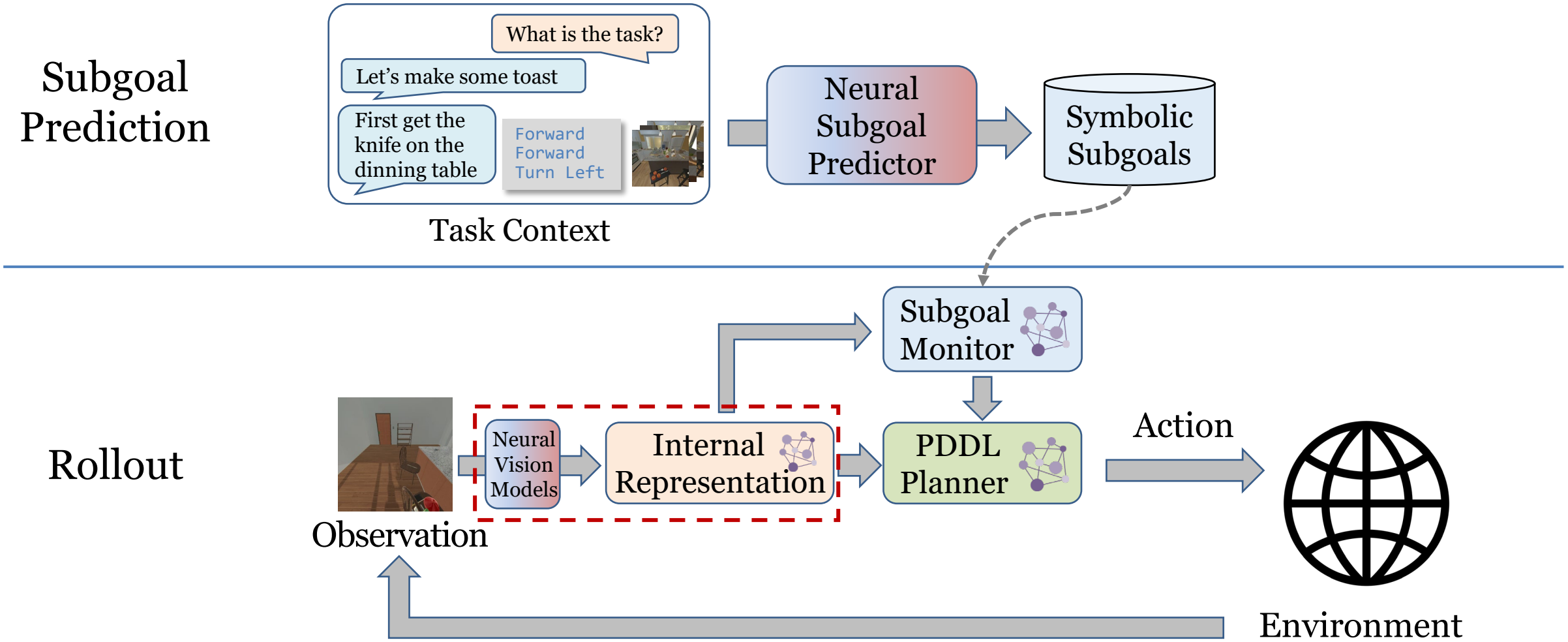
Example Completed & Future Subgoal Output

Completed SG: `(Cup,isPickedUp)`
Future SG: `(Cup,isPlacedTo,Table)`

Neuro-Symbolic System Architecture



Neuro-Symbolic System Architecture

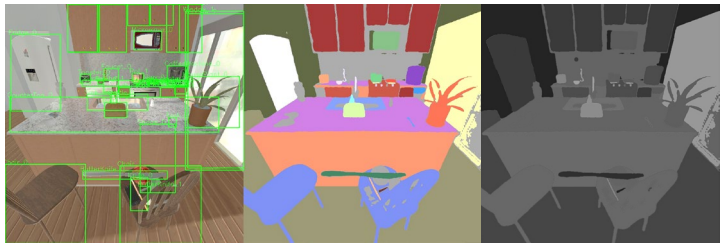


Spatial-Symbolic World Representation

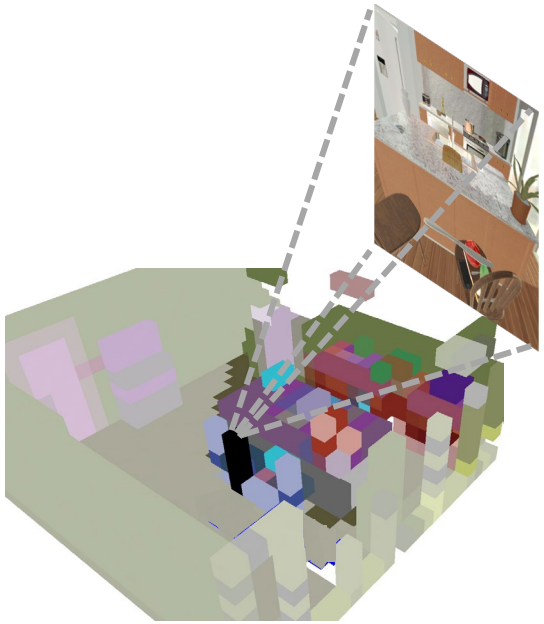
- Neural-powered 3D voxel map construction from ego-centric observations

RGB Observation

Neural Vision Models



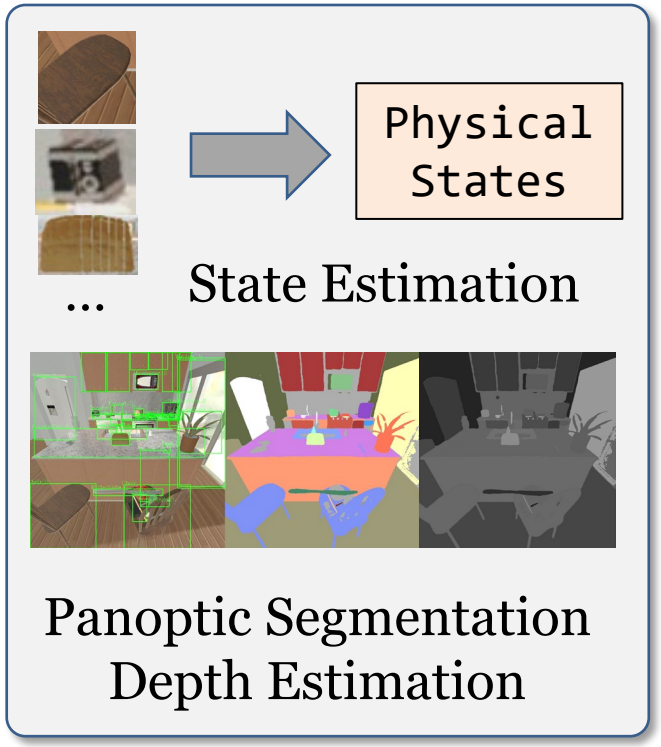
Panoptic Segmentation
Depth Estimation

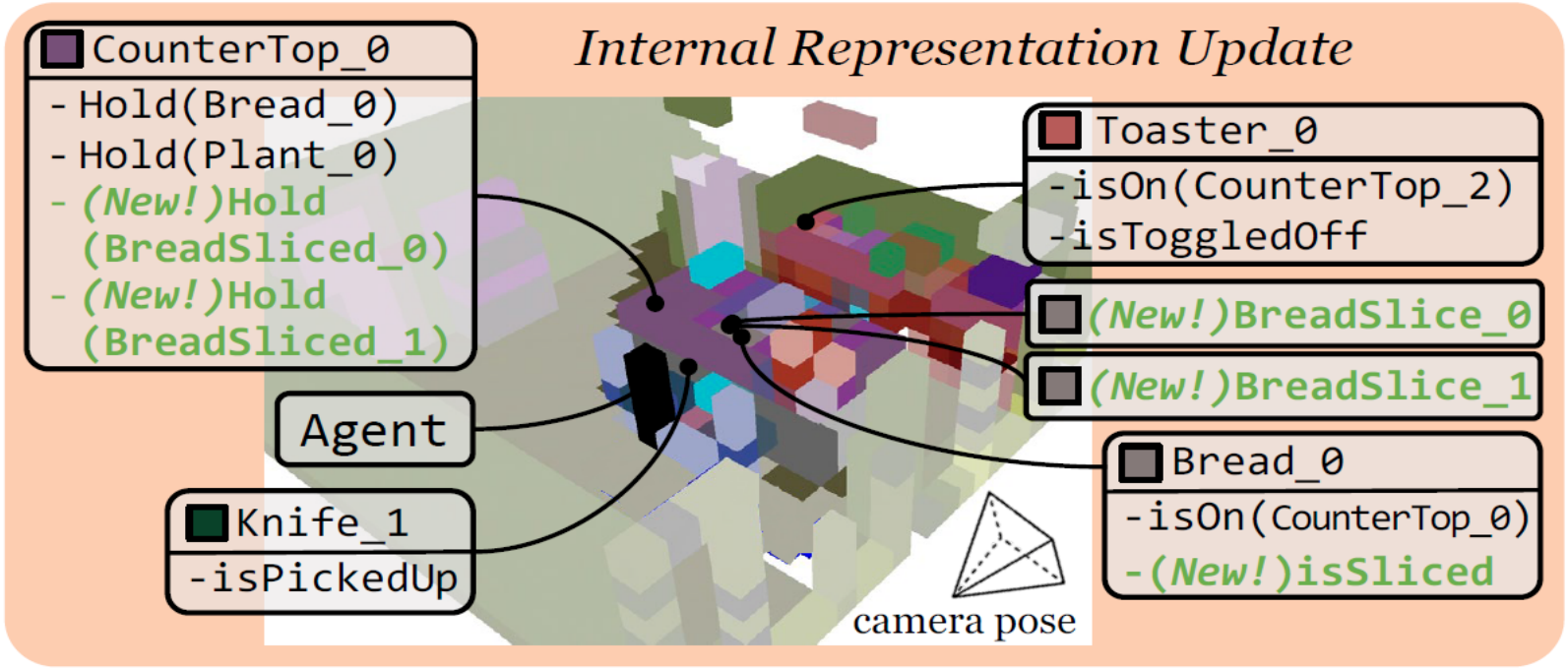


Voxel Map Construction

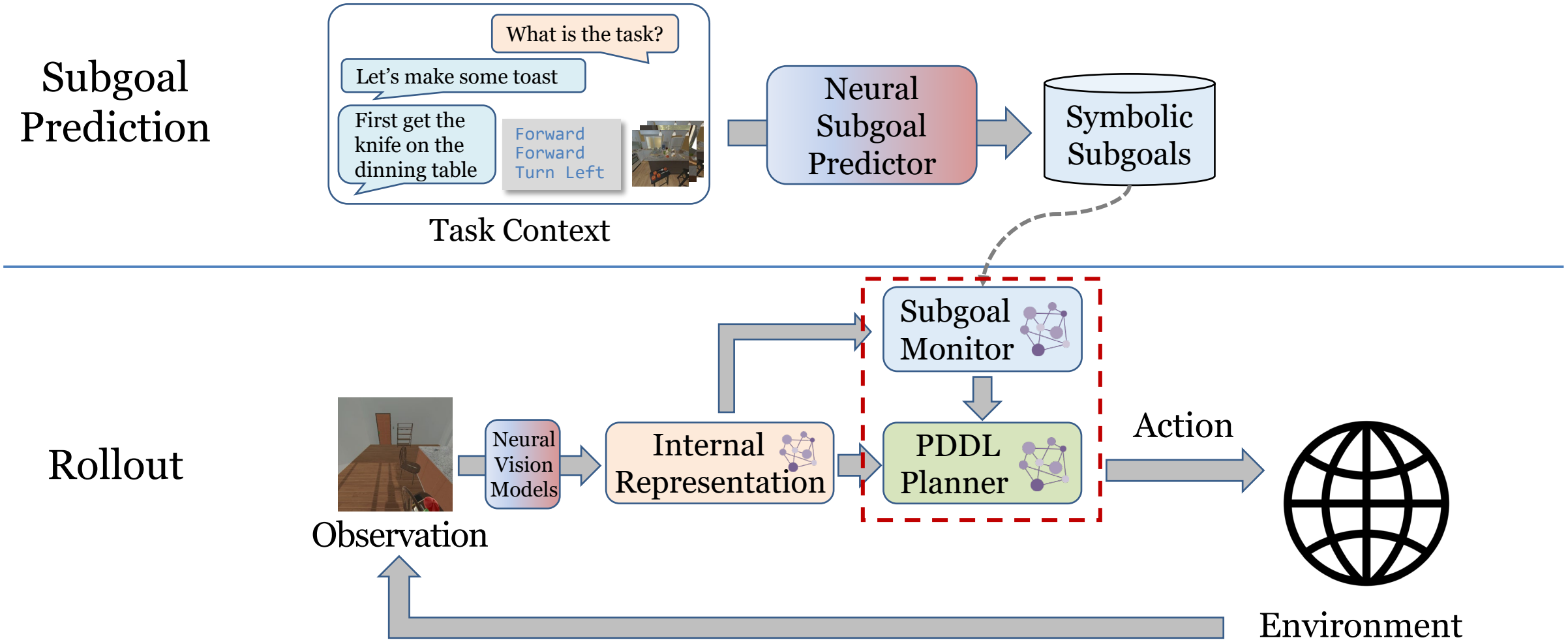
Spatial-Symbolic World Representation

- Recognize physical states of each object instance
- Update the spatial-symbolic world representation at every step

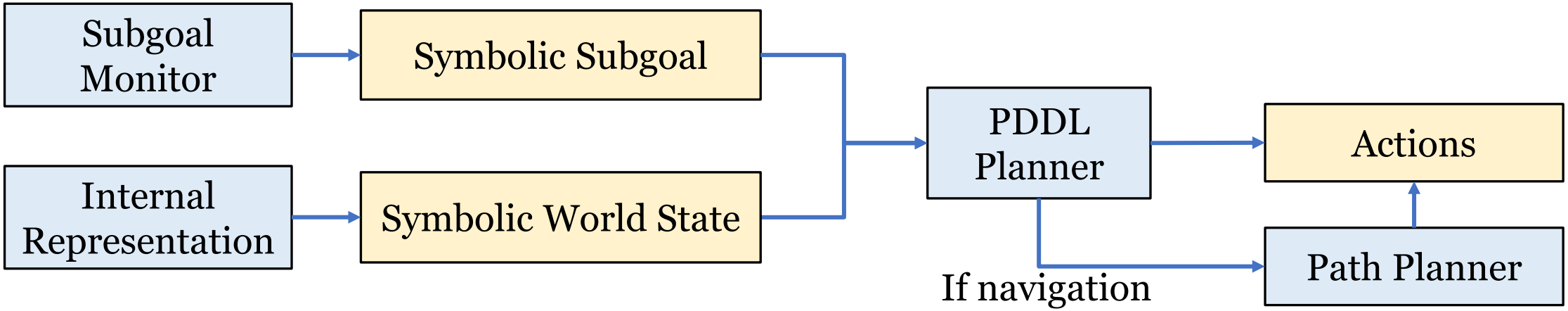




Neuro-Symbolic System Architecture



Symbolic Planning Pipeline



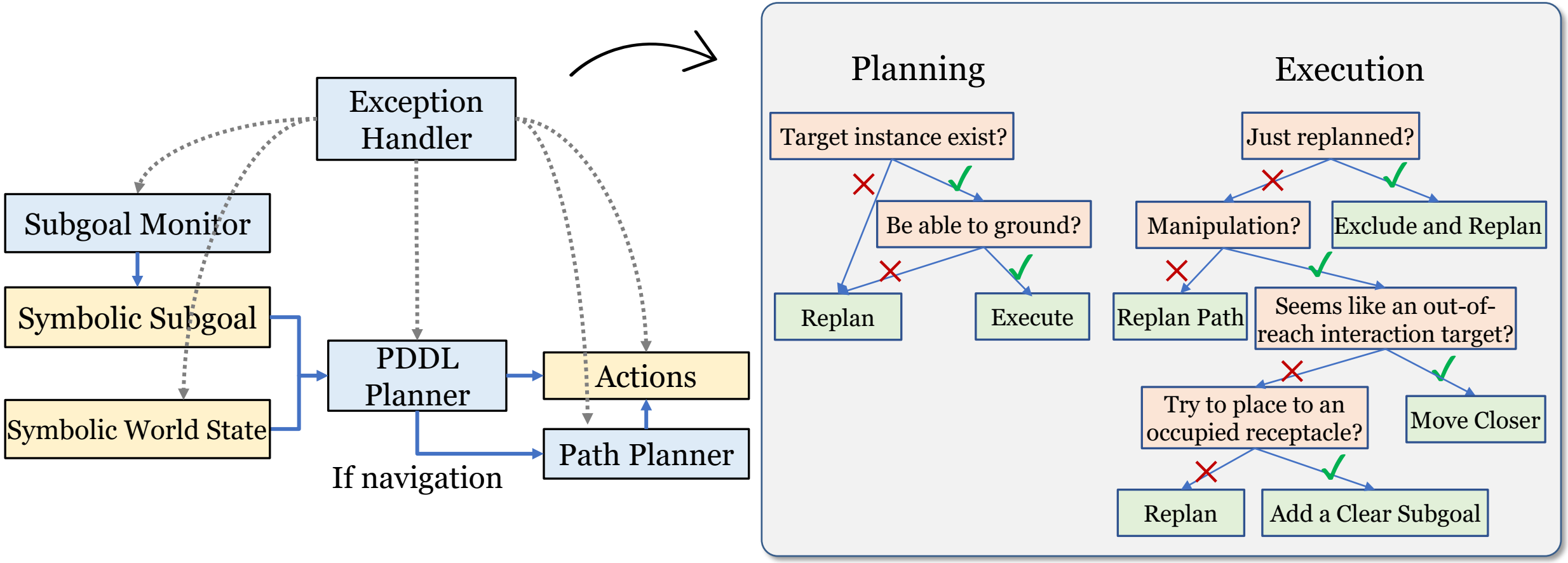

```
(:goal
    (and
        (exists (?o1 - BreadSliced ?o2 - Toaster)
            (and (parentReceptacles ?o1 ?o2))
        )
    )
)
```

Snapshot of an example subgoal "putting a piece of bread into toaster"

```
(:action Slice
    :parameters (?x - Sliceable ?y - Knives)
    :precondition (and (holding ?y) (isInteractable ?x) (not (isSliced ?x)) (not (isPickedUp ?x)))
    :effect (and
        (isSliced ?x)
        (not (isObserved ?x))
        (increase (total-cost) 15)
    )
)
```

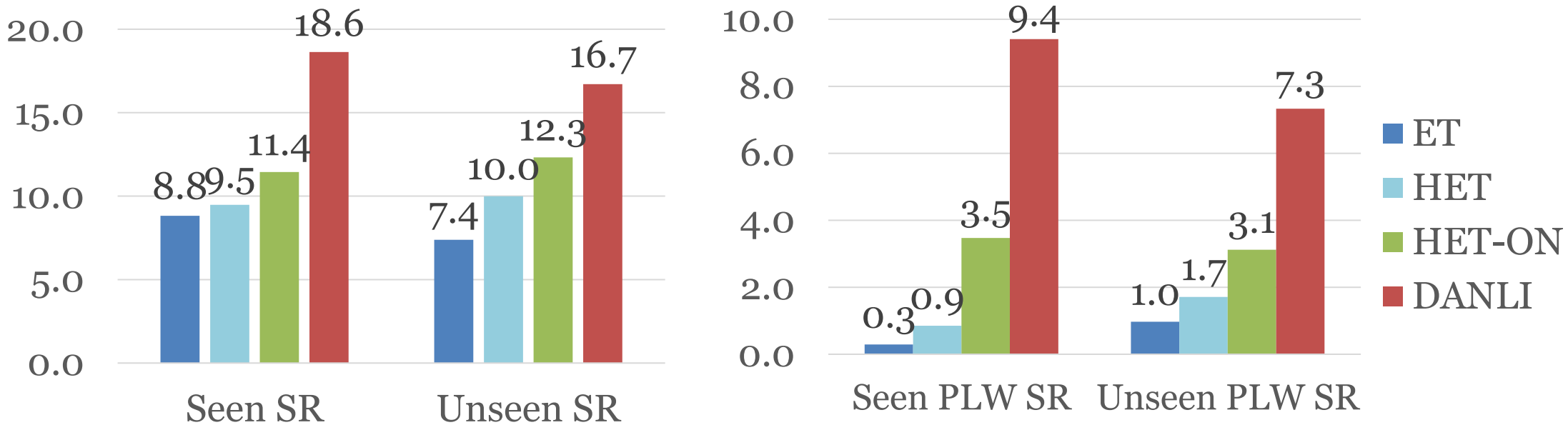
Snapshot of the action "Slice" defined in the PDDL domain

Exception Handling In Online Planning



Higher Success Rates

- DANLI outperforms reactive agents (ET, HET, HET-ON) by a large margin, especially when the task completion efficiency is considered

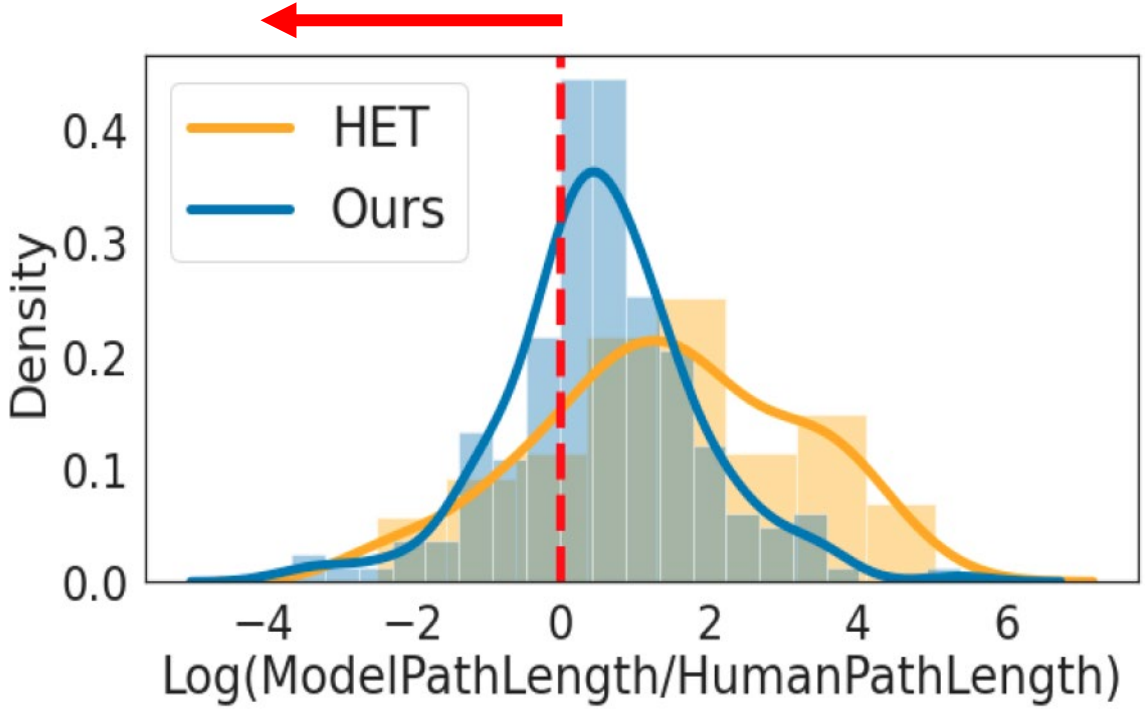


- Success Rate (SR): the proportion of successfully completed tasks
- Seen/Unseen: whether the evaluated scene is seen or unseen during training
- PLW SR: success rate weighted by the relative trajectory path length compared to humans

Higher Efficiency

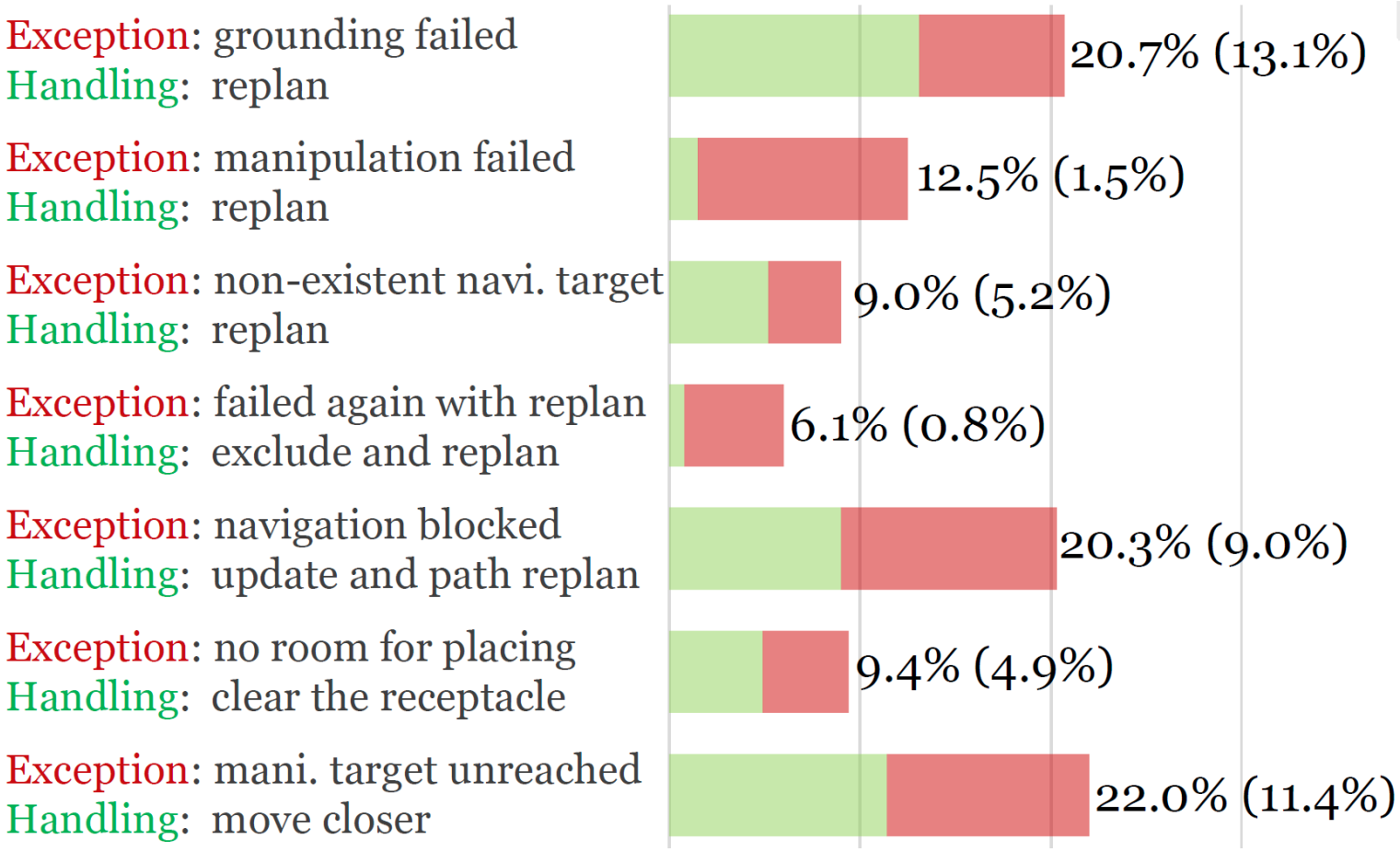
- DANLI completes tasks in fewer steps than reactive agents

Shorter path than human trajectories

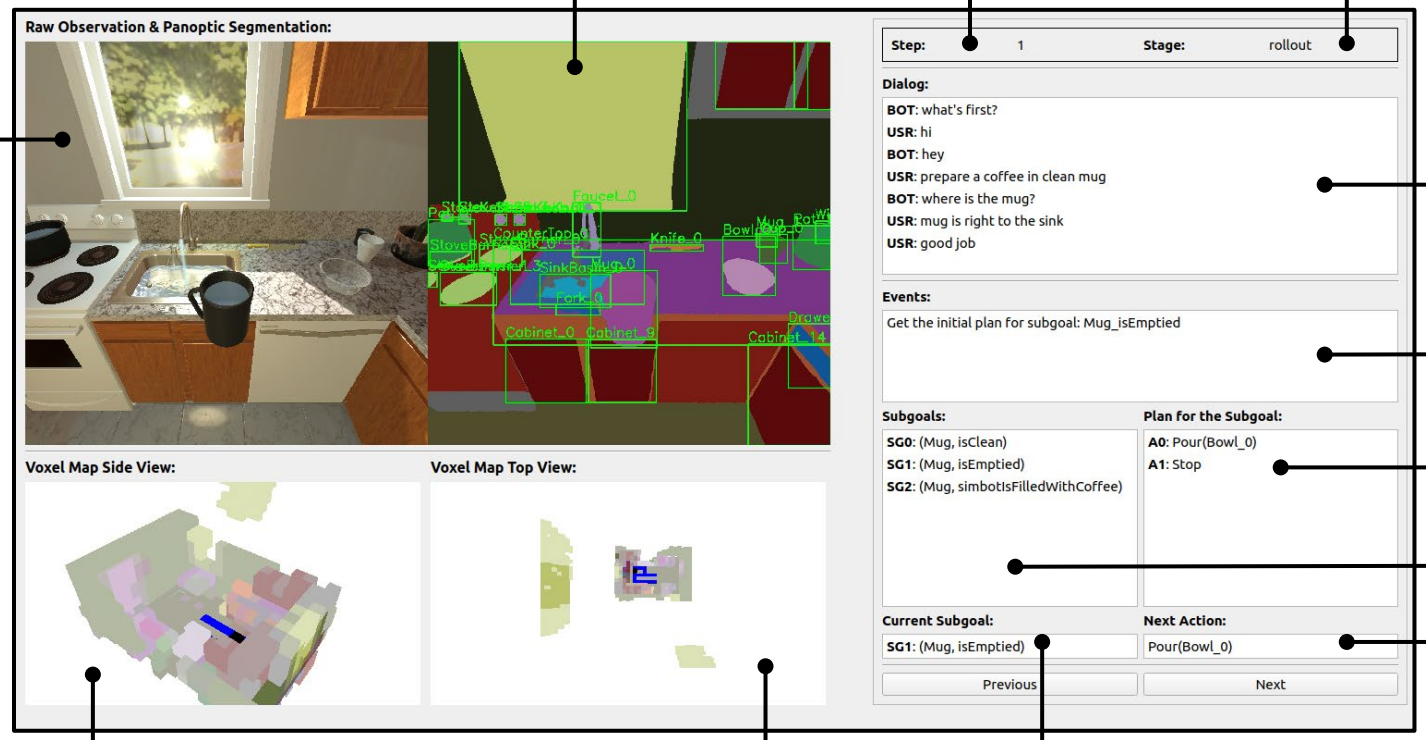


Interpretable Exception Handling

- Deliberative agent produces interpretable plans which allow fine-grain exception handling.



Demo



Panoptic Segmentation Output

Step Number

Stage: Replay/Rollout

Raw Observation

Dialog History

Key Reasoning Events

Action Plan for the Current SG

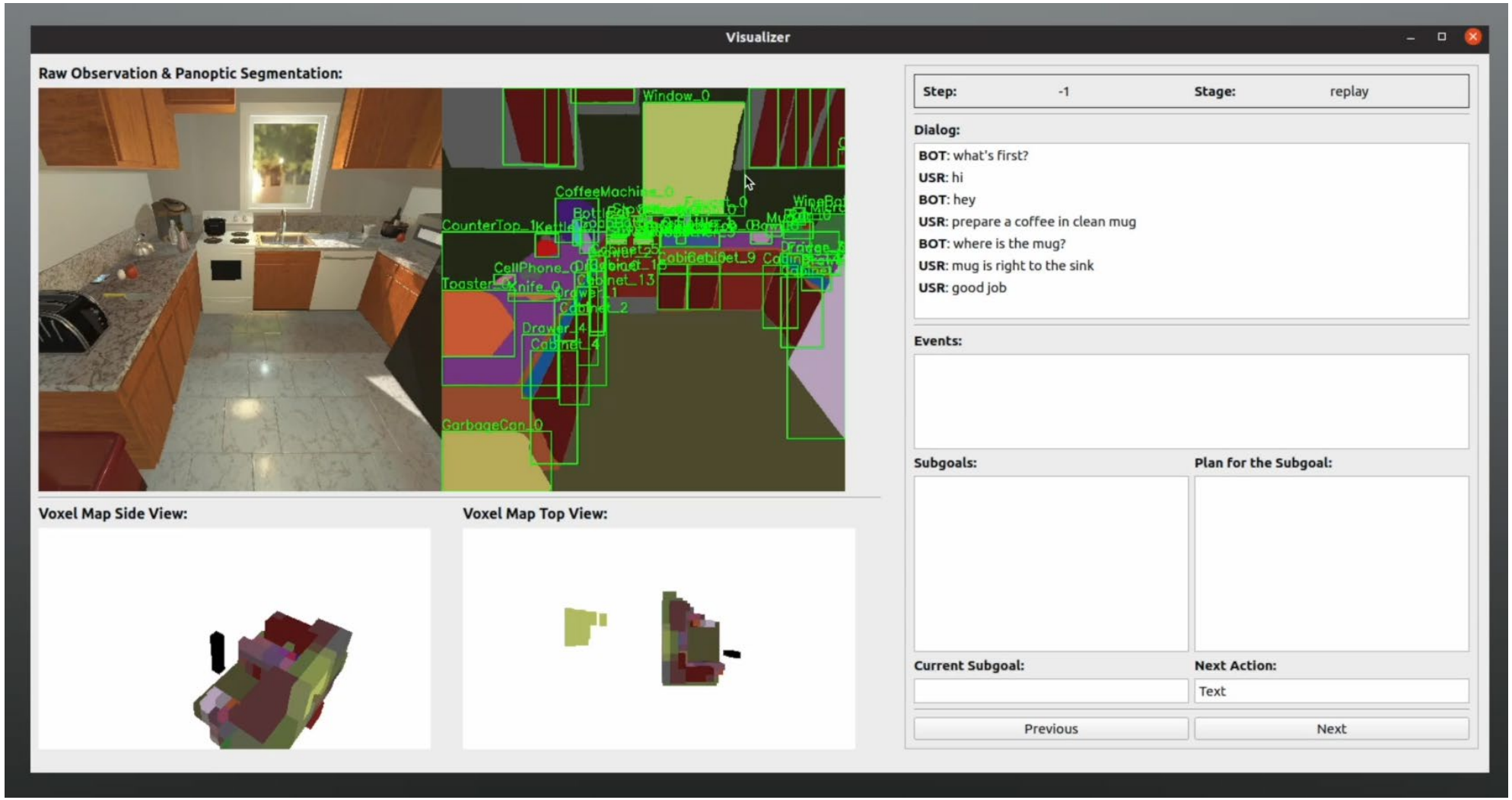
Subgoals predicted by DANLI

Voxel Map constructed by DANLI
Left: Side View / Right: Top-Down View

Current Subgoal

Next Action to Execute

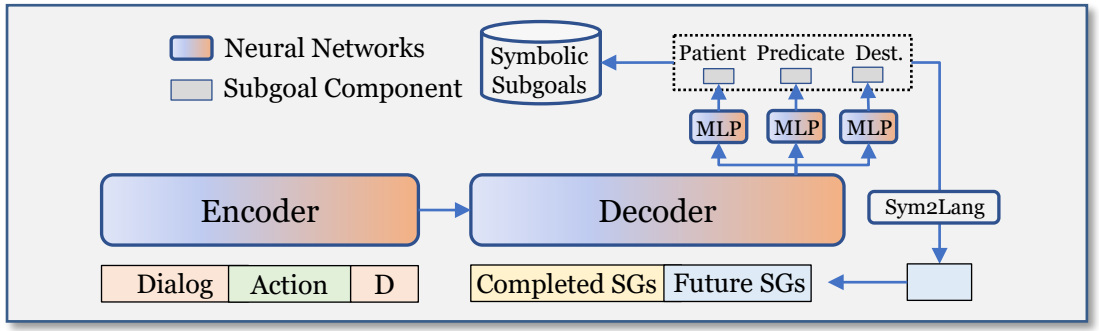
Demo


Visualizer
Raw Observation & Panoptic Segmentation:
Window_0
CoffeeMachine_0
CounterTop_1
CellPhone_0
Toaster_0
Knife_0
Drawer_4
Cabinet_4
Cabinet_13
Cabinet_9
GarbageCan_0
Voxel Map Side View:
Voxel Map Top View:
Step: -1
Stage: replay
Dialog:
BOT: what's first?
USR: hi
BOT: hey
USR: prepare a coffee in clean mug
BOT: where is the mug?
USR: mug is right to the sink
USR: good job
Events:
Subgoals:
Plan for the Subgoal:
Current Subgoal:
Next Action:
Text
Previous
Next

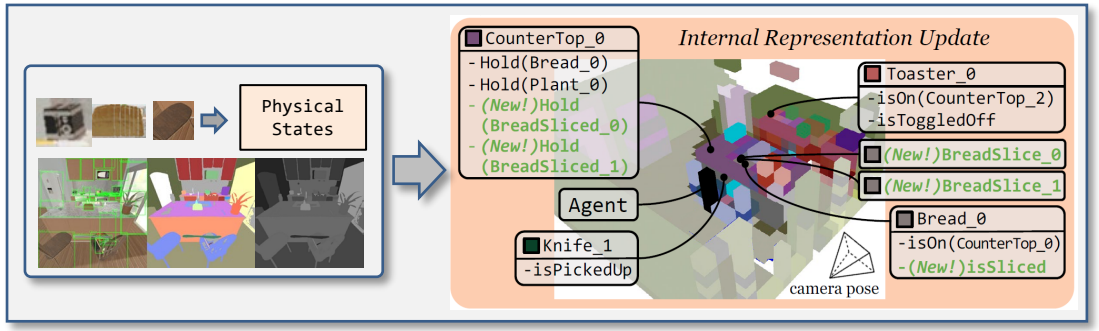
Summary - DANLI

Situated Language and Embodied Dialog (SLED) Lab

Neural Subgoal Predictor



Spatial-Symbolic World Representation



Symbolic Planner with Online Exception Handling