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Clarifying Feature Overspecification in Reward Learning from State Corrections via Follow Up Questions

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Motivation

Robots designed for assisting people in household tasks need to know what people want!

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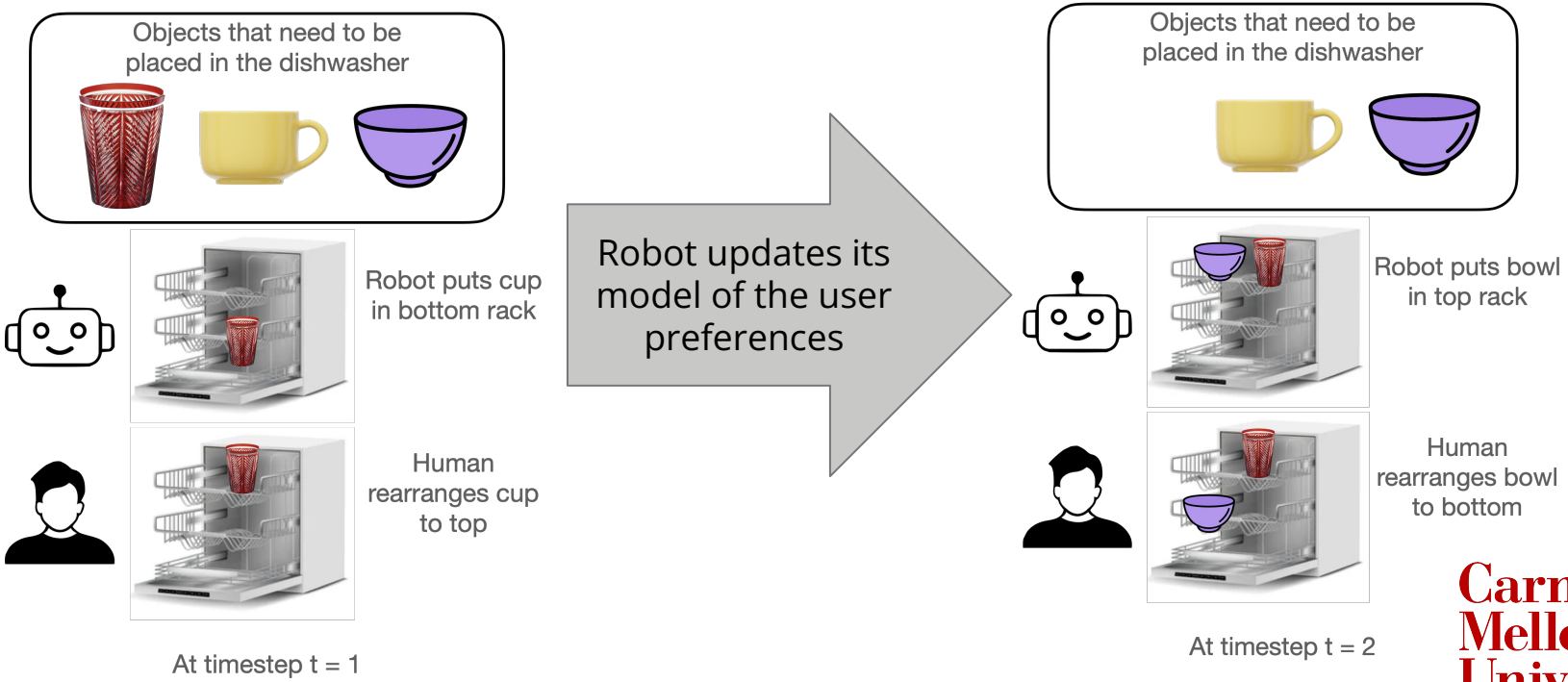
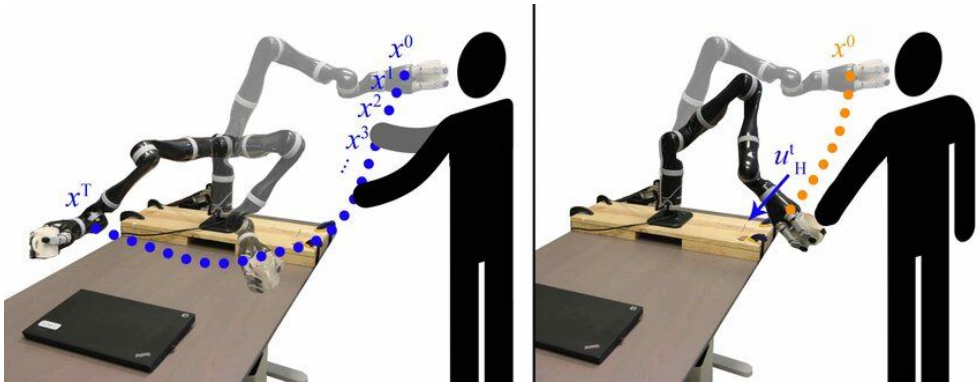
We envision an interaction in which the user can correct the state intermittently during the robot's task execution.



Conceptually, this differs from corrections to the robot's trajectory



Bobu et al. Quantifying Hypothesis Space Misspecification in Learning from Human-Robot Demonstrations and Physical Corrections

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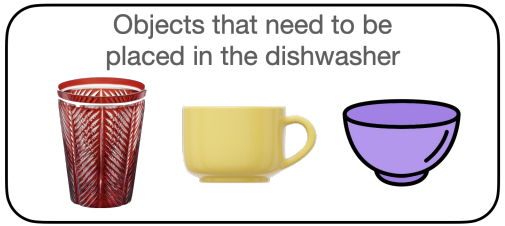
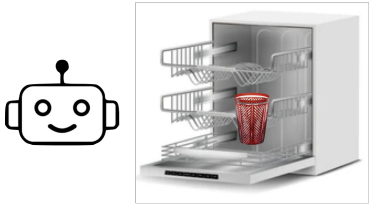
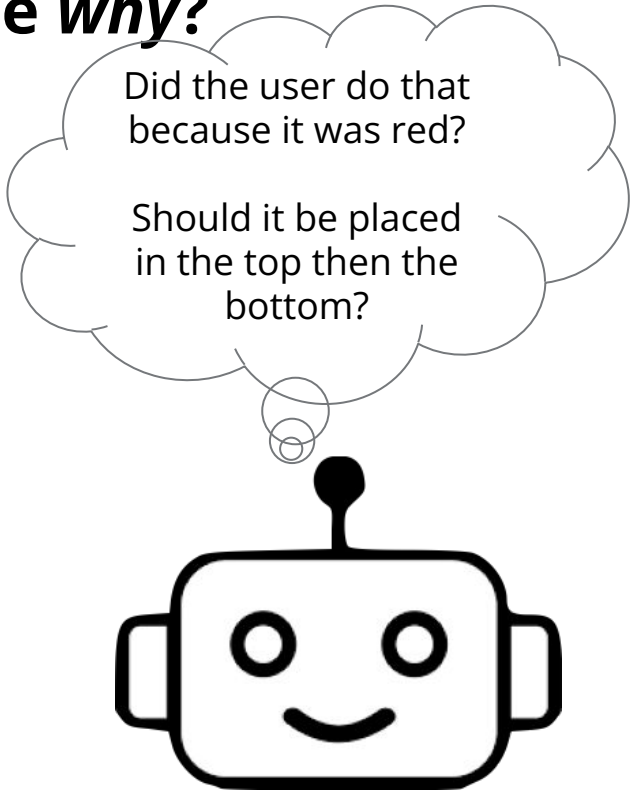
Upon observing a state correction, the robot may not understand the *why*?





At timestep t = 1



Robot updates its model of the user preferences

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Research Question

Can we enable robot learning from iterative state corrections and bootstrap learning via clarification questions?

Contributions:

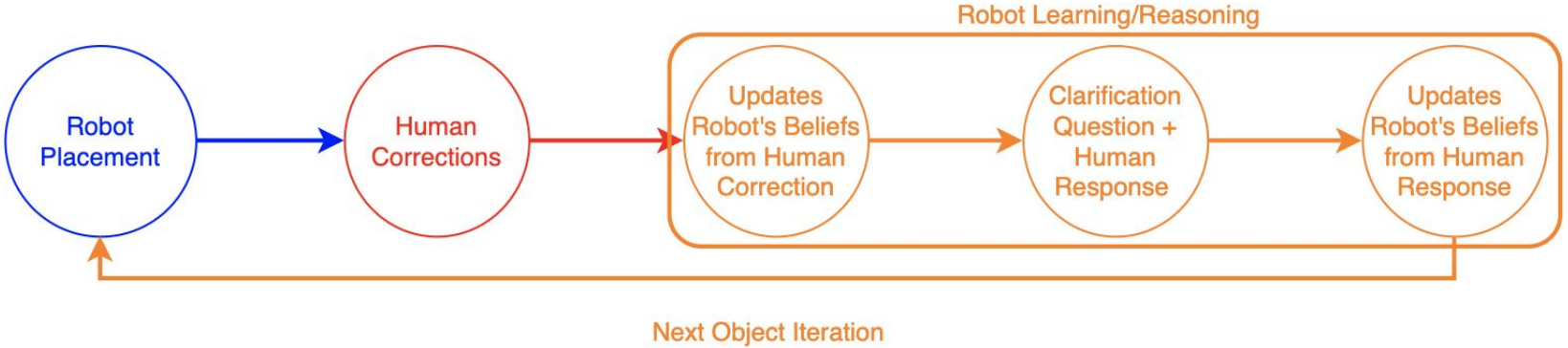
- Learning from Corrections:

  Robots learn from user state corrections to align with human preferences and enhance performance.

- Proactive Dialogue:

  Robots prompt for user guidance during uncertainty to improve efficiency and reduce errors.

Interactive Workflow



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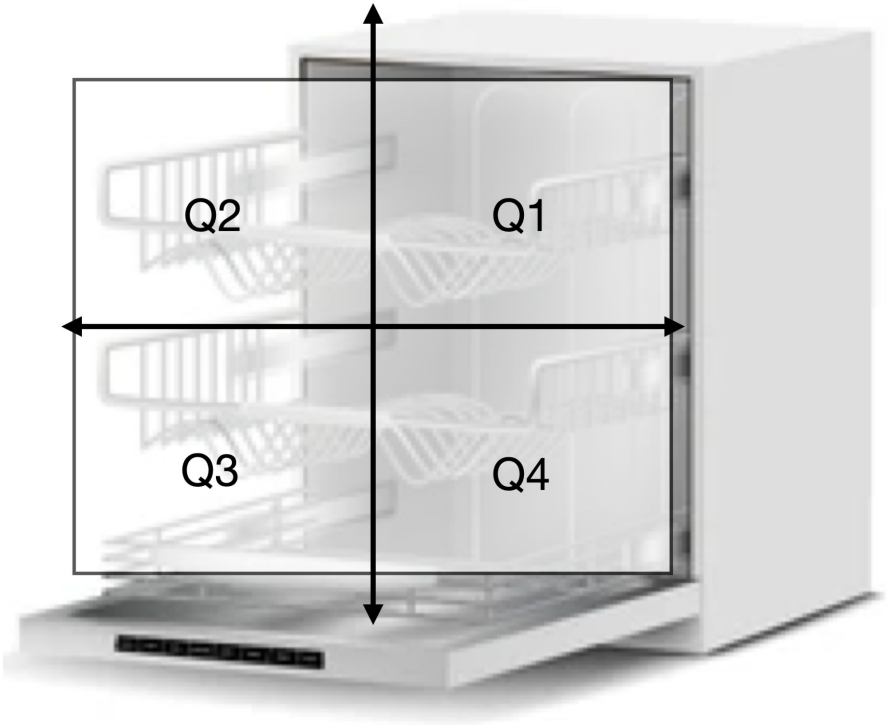
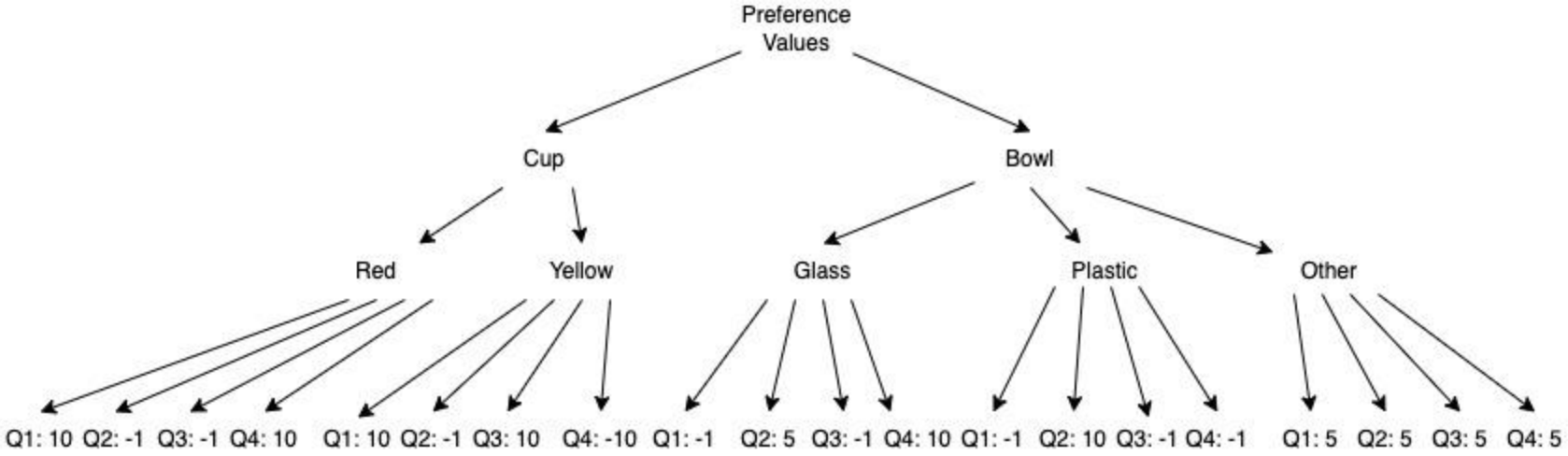
Interaction MDP

We represent the dishwasher as a grid.

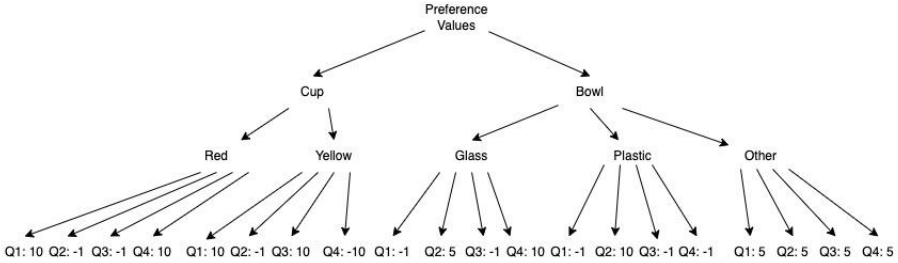
- State space S
- Robot action space A - movement of objects into quadrants
- Human action space A^h - for our context, this is identical to A.
- Transition function $T : S \times A \rightarrow S$
- Reward hypothesis space $\Theta = \{\theta_0, \ldots, \theta_H\}$
- Robot beliefs b

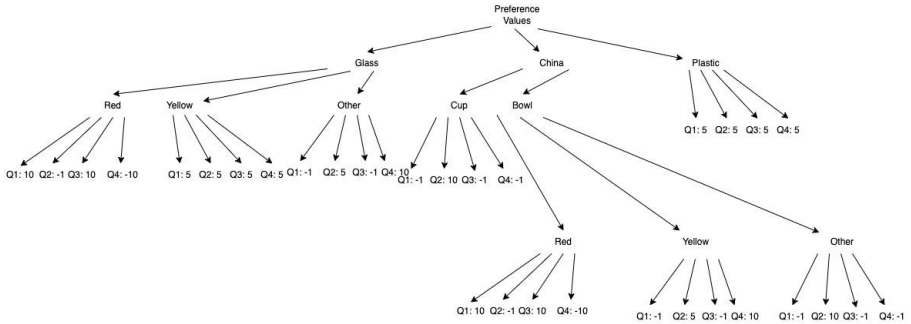


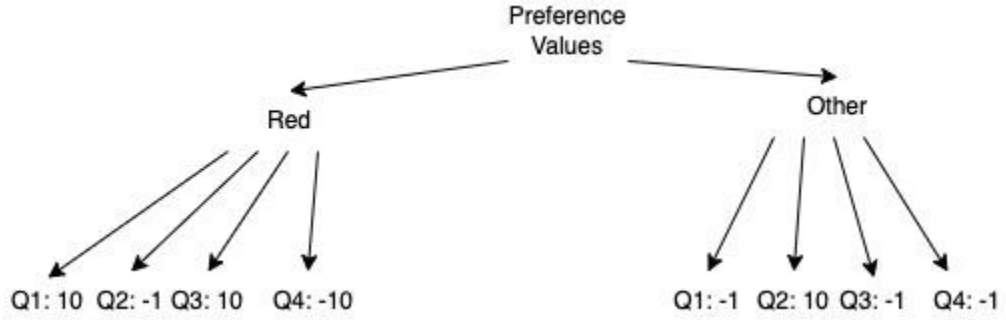
Each reward function in the Reward Hypothesis space is a tree



Reward Hypothesis space is a discrete set of trees







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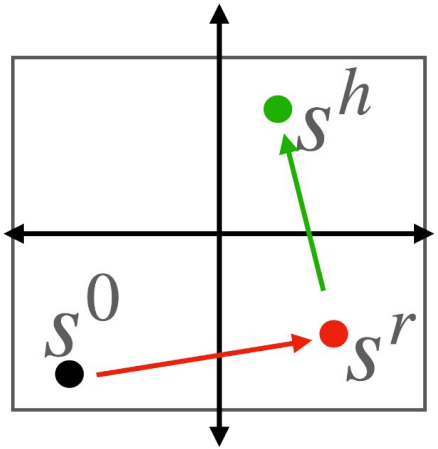
Iterative Interaction

1. Initial state s_0
2. Robot takes $\pi_b^r(s_0) \rightarrow a_0^r$. State transitions to s_0^r.
3. Human corrects $\pi^h(s_0^r) \rightarrow a_0^h$. State transitions to s_0^h.
4. Robot updates beliefs $b' \leftarrow CorrectionUpdate(b, s_0, s_0^r, s_0^h)$



Bayesian Update Given Corrected State

1. Check Possible Cases:

- S_2 != S_1 # Robot Placement is not the same as Human Correction
- S_2 == S_1 and S_0 != S_1 # Robot Placement is the same as Human Correction, Robot Placement is not the same as initial placement
- S_2 != S_0 # Human Correction is not the same as initial placement

2. Update:

$P(\theta_i \mid S^h > S^r) = P(\theta_i) * P(S^h > S^r \mid \theta_i)$

$$P(s^h > s^r \mid \theta_i) = \frac{e^{\beta R_{\theta_i}(s^h)}}{e^{\beta R_{\theta_i}(s^h)} + e^{\beta R_{\theta_i}(s^r)}}$$

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Feature Uncertainty Question

Environment States

- Clarification
  a. Real Question
  b. Hallucinated Question

Features

- Preference
  a. “Is the reason that you performed a^h in s because of {color, type, or material}?”

Hypothesis

- "I think you prefer objects to be placed closer to the center. Is that correct?"

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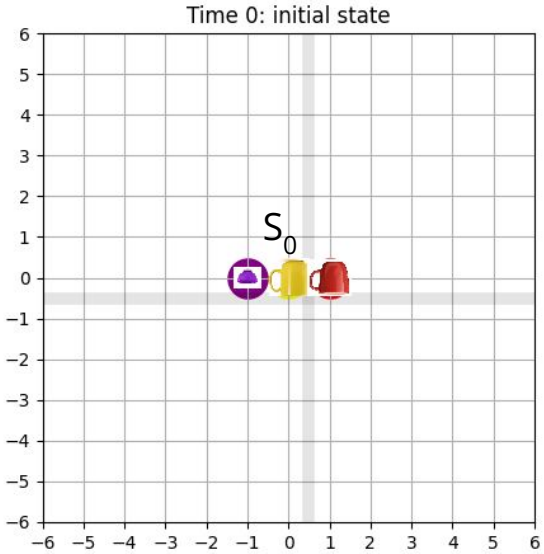
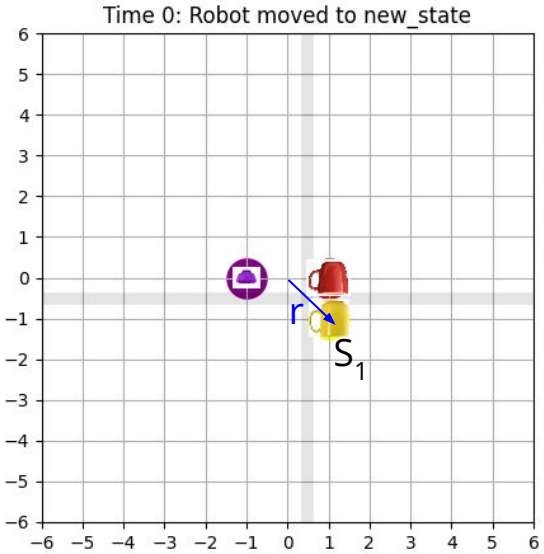
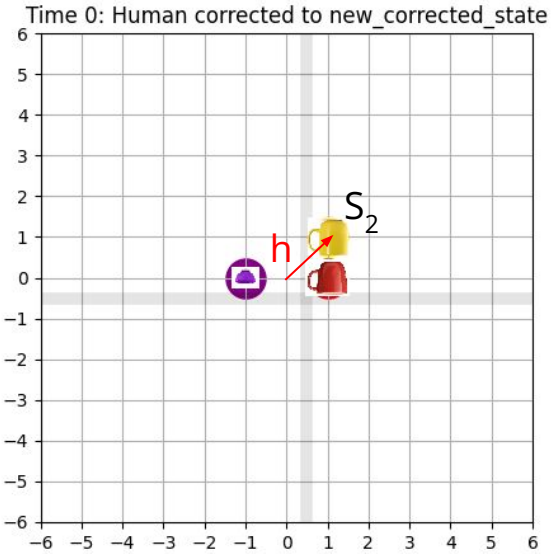
Resultant Interaction

Timestep t = 0

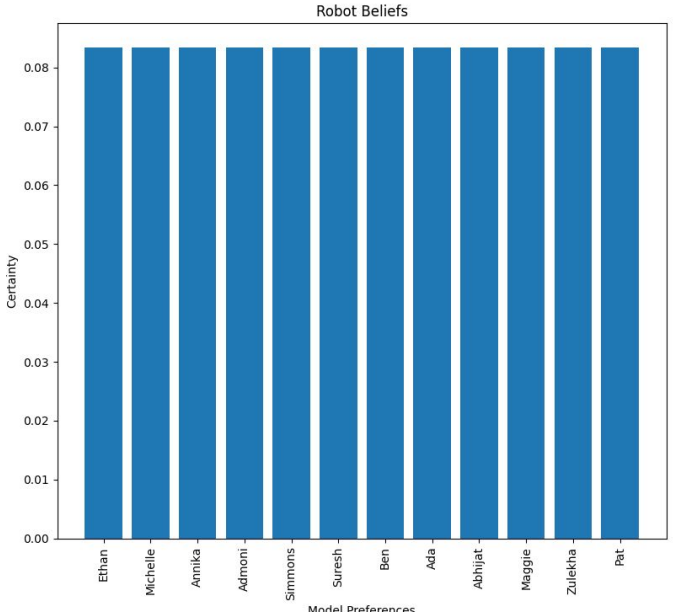


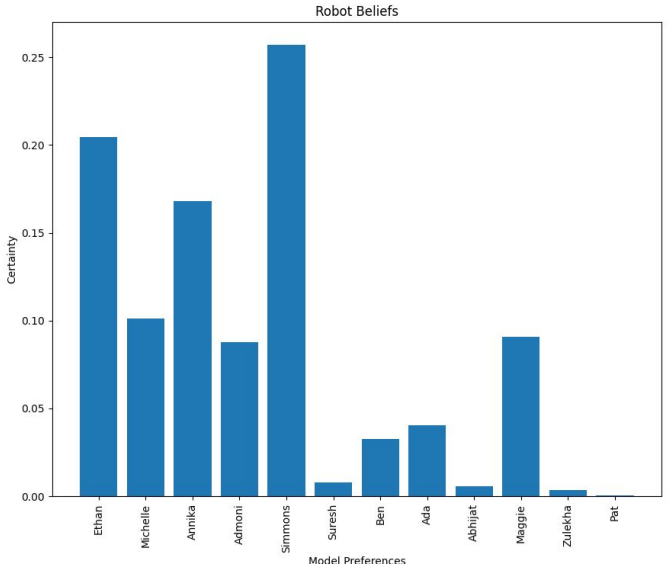




Resultant Interaction - Bayesian Update

Timestep t = 0 (inference)





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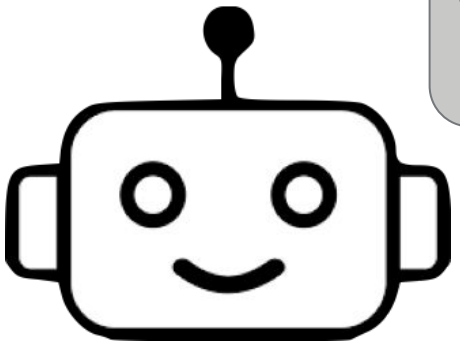
Resultant Interaction

Timestep t = 0 (inference)

Clarification Question Asked:



For the recent ['cup', 'yellow', 'glass'] object, which features of [color, type, and material] were relevant to the location it should be in?

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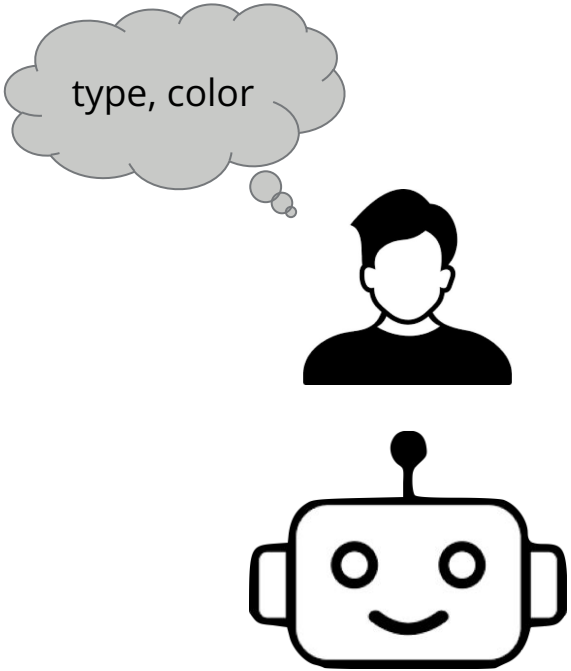
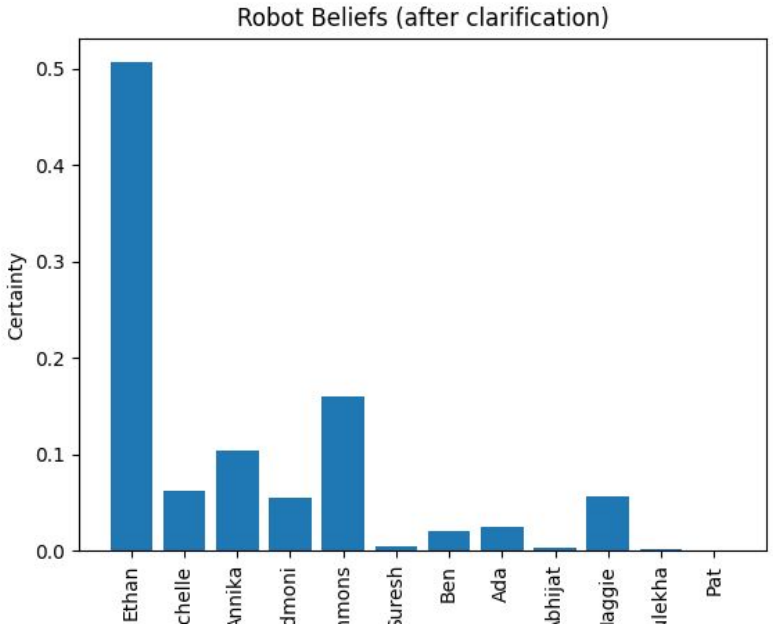
Resultant Interaction

Timestep t = 0 (update beliefs again)





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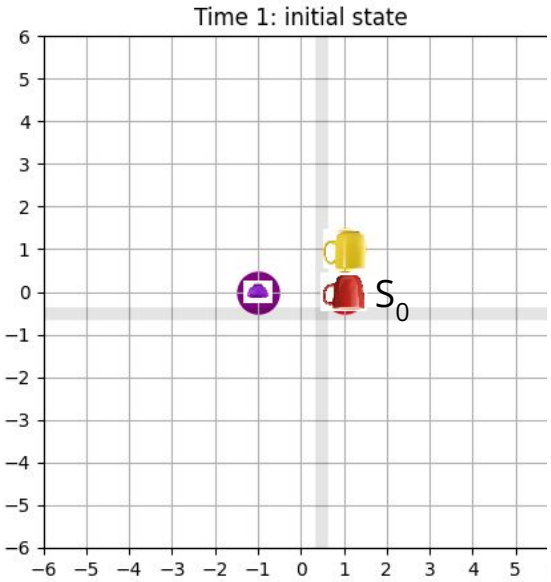
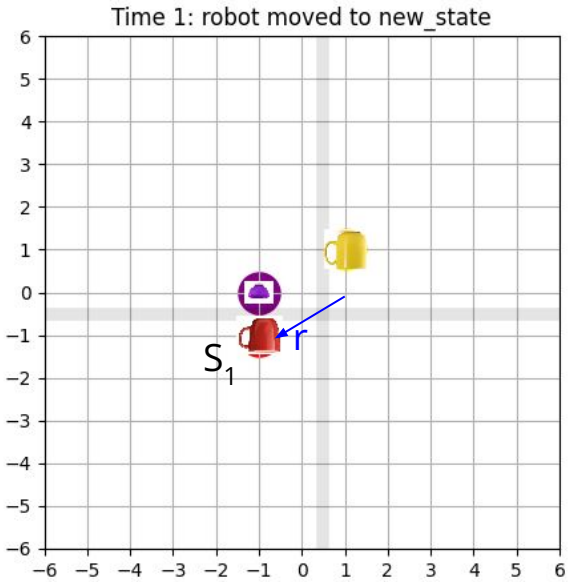
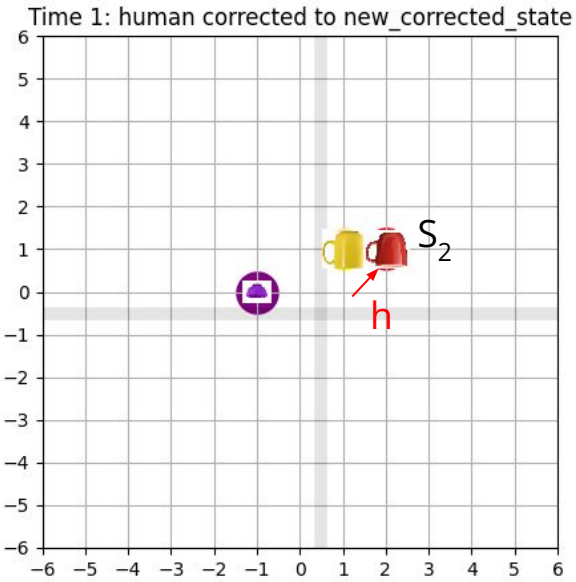
Resultant Interaction

Timestep t = 1

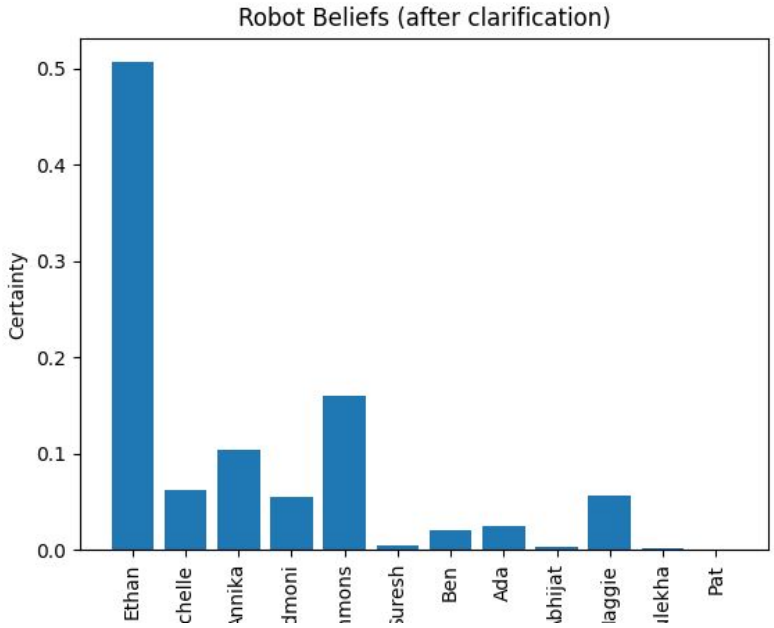






Resultant Interaction - Bayesian Update

Timestep t = 0 (inference)



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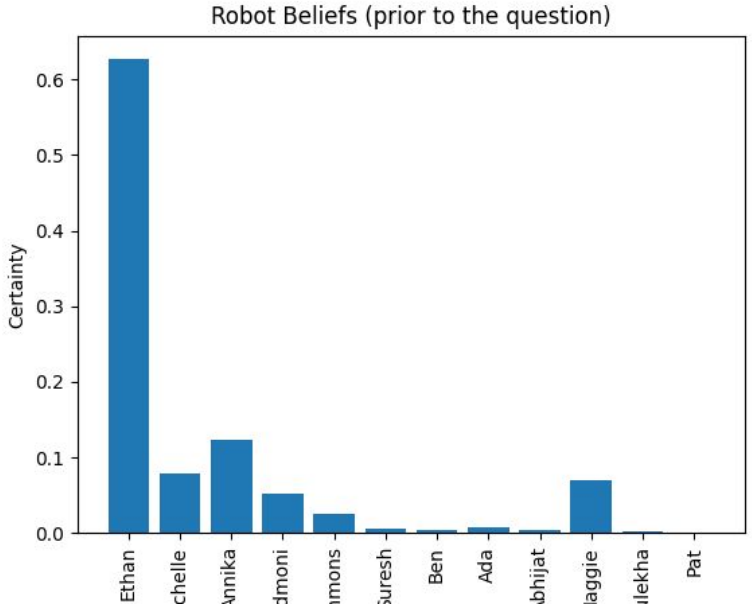
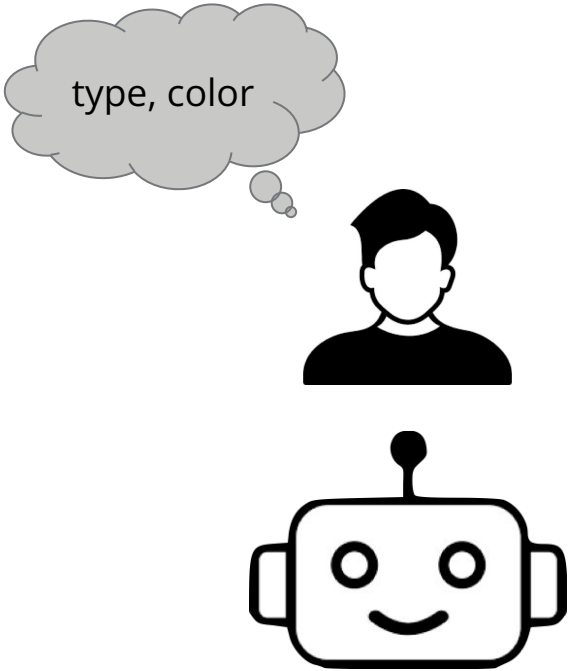
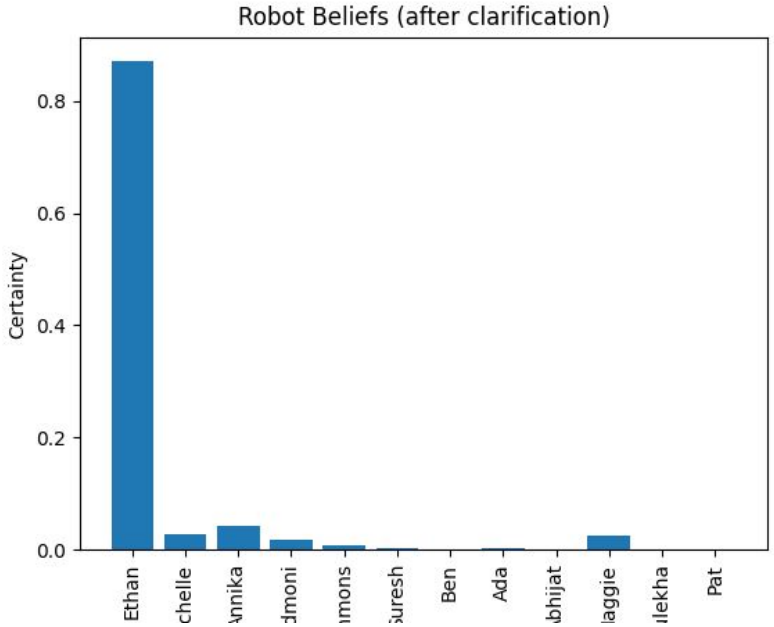


Resultant Interaction

Timestep t = 1 (update beliefs again)





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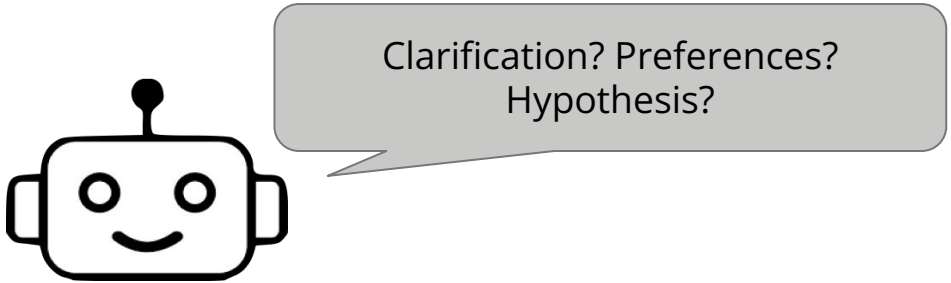
Future Work

- Continue Clarification Question Implementation
- Pilot User Study



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Thank you

RISS: Dr. John M. Dolan, Rachel Burcin

HARP & RASL Lab:
Michelle Zhao, Dr. Henny Admoni, Dr. Reid Simmons

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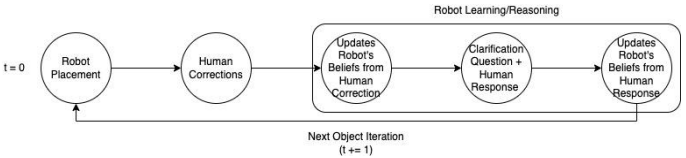
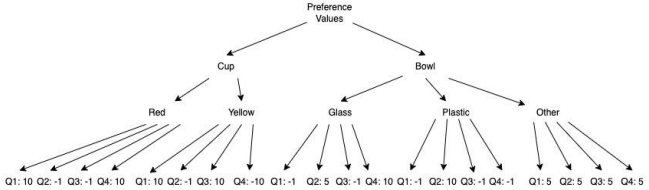
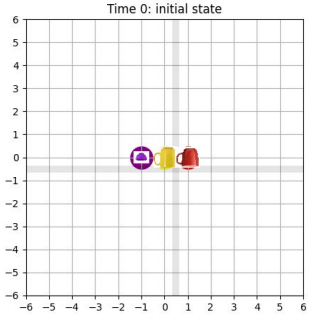
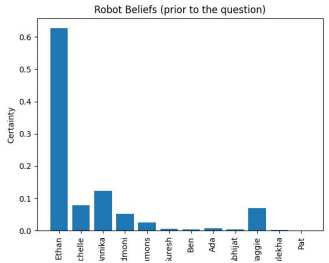
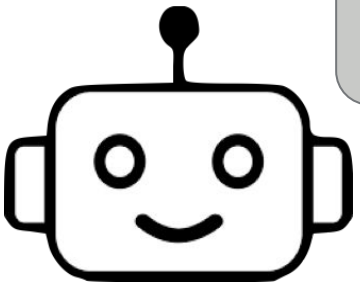
Questions?











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