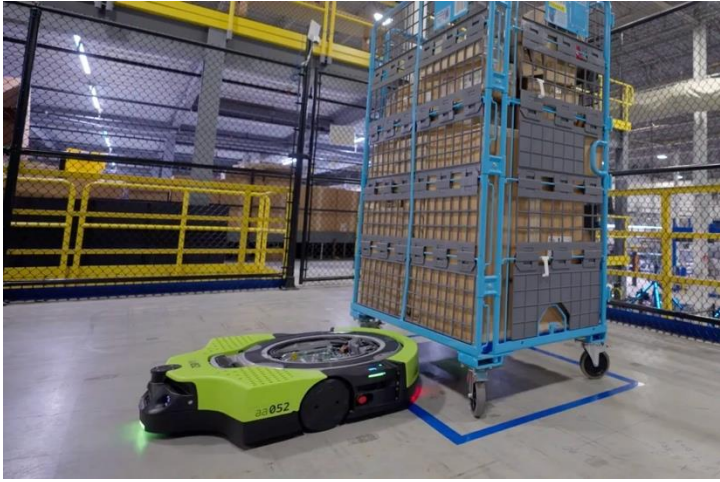


Using Explainable AI and Hierarchical Planning for Outreach with Robots

Rushang Karia*, Jayesh Nagpal*, Daksh Dobhal*, Pulkit Verma,
Rashmeet Kaur Nayyar, Naman Shah, Siddharth Srivastava



Increasing Prevalence of Taskable Robots



Using Explainable AI and Hierarchical Planning for Outreach with Robots

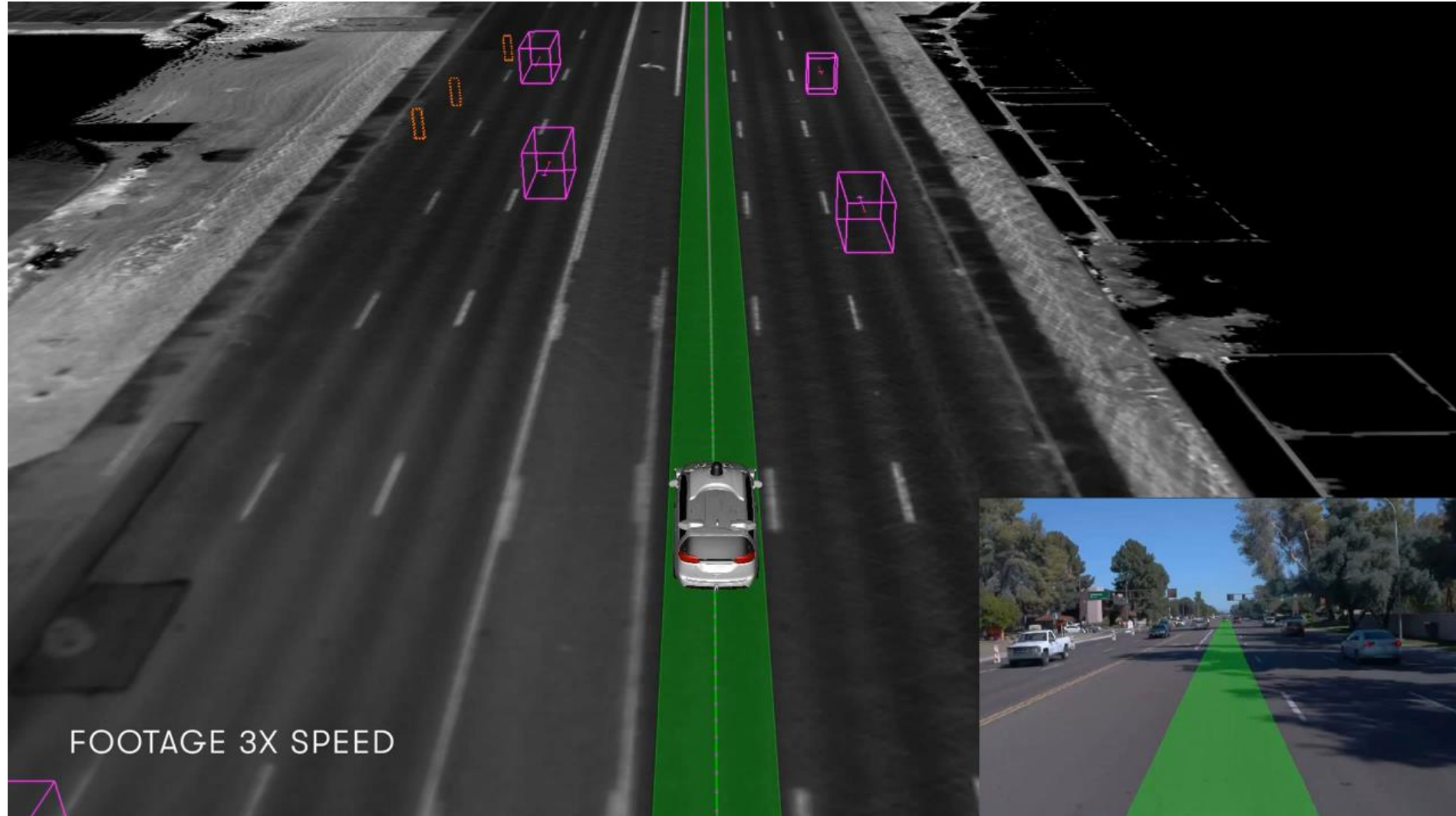
What do we want robots to do?

- ✓ Assist humans with accomplishing tasks
- ✓ Accomplish tasks without requiring a lot of human hand-holding
- ✓ Be versatile
 - Do the dishes, prepare the food
 - Mow the lawn
 - Vacuum the houseand so on...

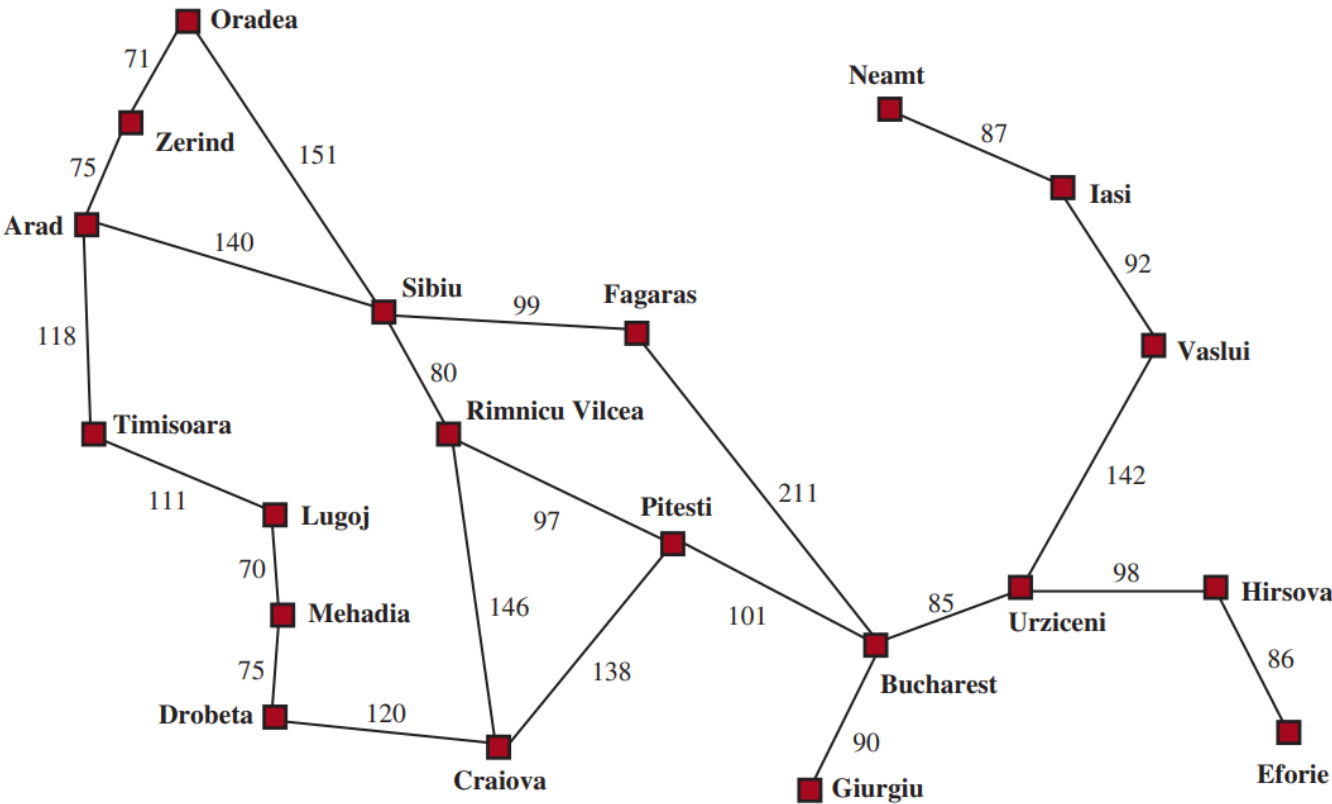
What we see robots doing



What goes on under the hood!



What goes on under the hood!



Human Plan

1. Drive from Arad to Sibiu
2. Drive from Sibiu to Fagaras
3. Drive from Fagaras to Bucharest

Robot Plan for the Human Plan

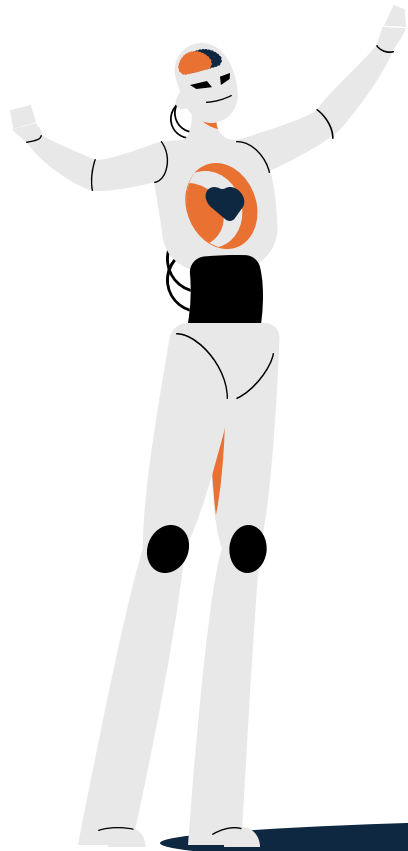
1. [0.0, 0.0, 0.0, ..., 1.2]
2. [1.2, 3.2, 4.X, ..., 3.XX]
3. ...
174. [200.9, 3.142, 2.1, ..., 44.X]
175.
555. [400.X, 3.2, 3.X, ..., 9784.X]
556. [521.X, 5.6, 3.X, ..., 10023.X]

Robot's need to search in the space of joint values!

Plans are much longer too and takes a lot of time to compute

Open Questions and Challenges

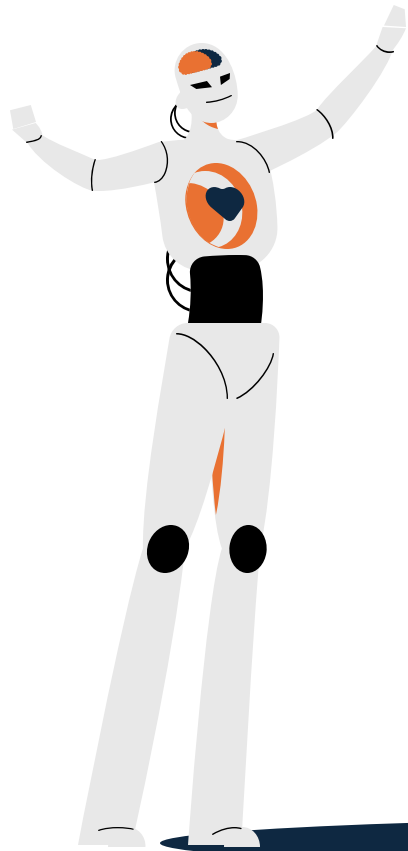
Humans want to instruct robots at a “high-level”
Robots expect humans to instruct at a “low-level”



Open Questions and Challenges

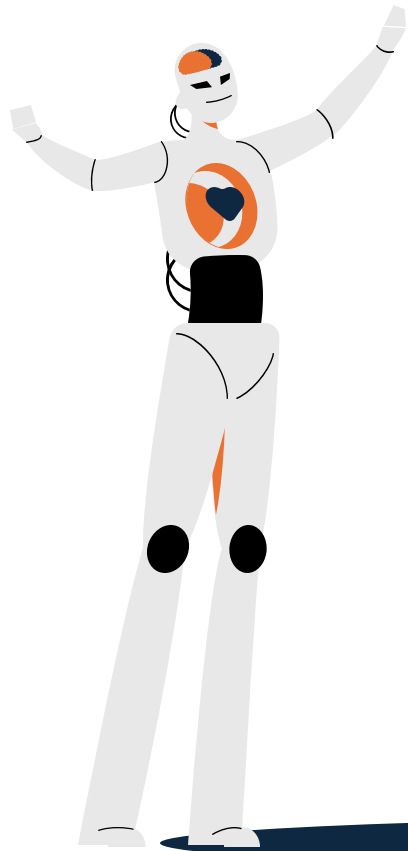
Humans want to instruct robots at a “high-level”
Robots expect humans to instruct at a “low-level”

Q. Do humans need to know robot programming to operate robots safely and productively?



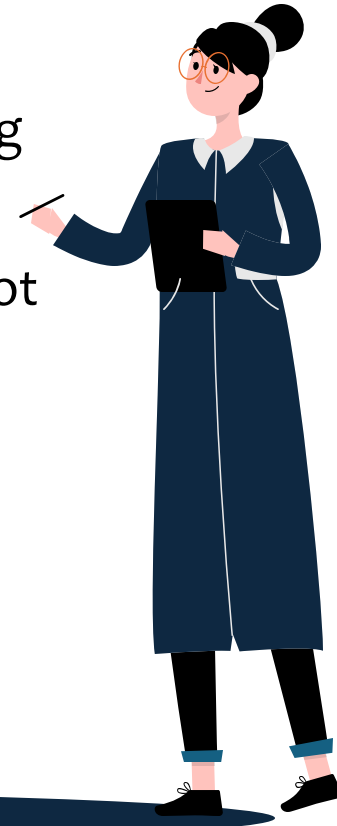
Open Questions and Challenges

Humans want to instruct robots at a “high-level”
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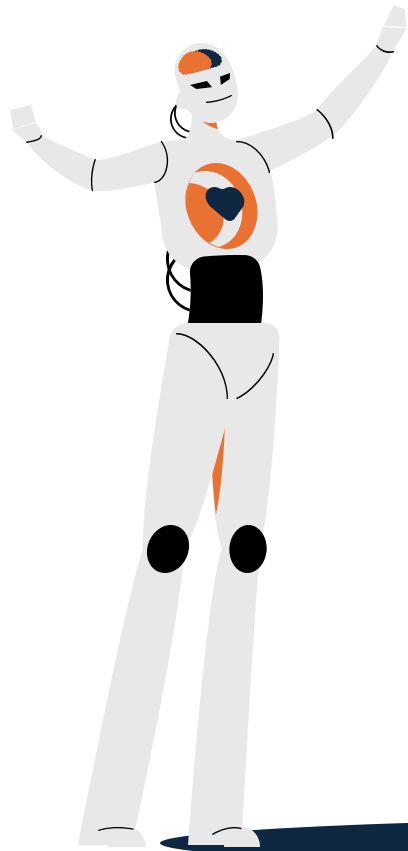
Q. Do humans need to know robot programming to operate robots safely and productively?

Q. How can we bridge the gap between the robot and the user’s understanding of the robot?



What we need

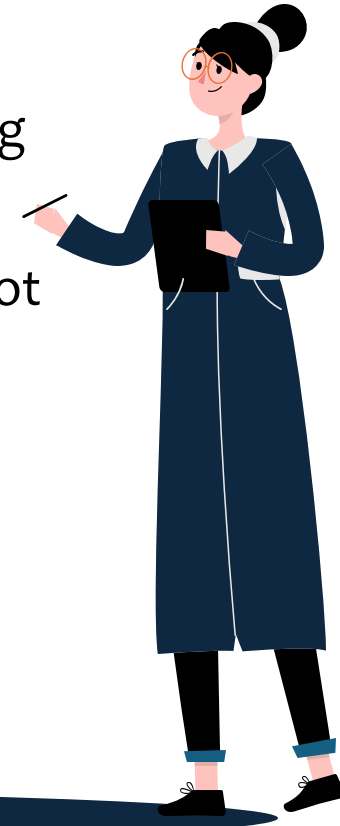
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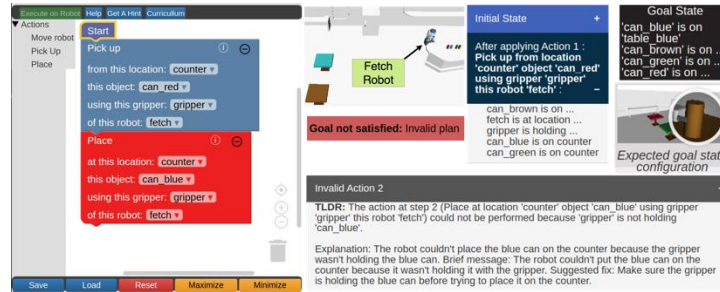
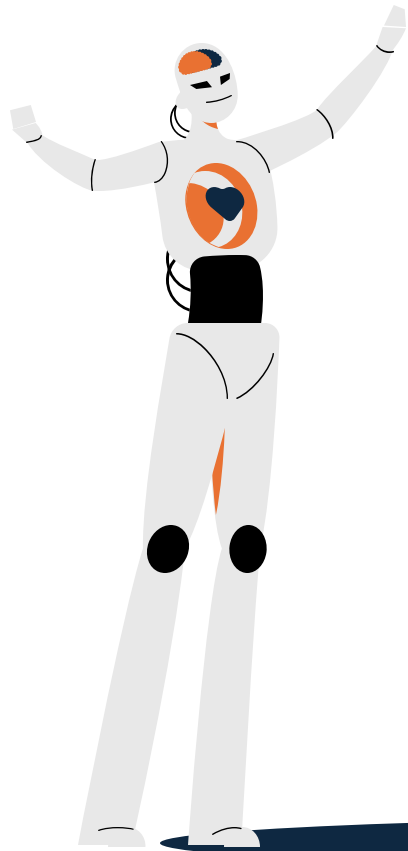
Q. Do humans need to know robot programming to operate robots safely and productively?

Q. How can we bridge the gap between the robot and the user’s understanding of the robot?

Need a tool that enables non-experts to learn and use robots



Introducing JEDAI.Ed – JEDAI Explains Decision-making AI



JEDAI.Ed:
**An easy-to-use GUI tool that allows
programming robots via human plans**



Our Contributions

JEDAI.Ed, an online platform that:

- **Teaches users to understand reasoning** and quickly provide high-level instructions to robots to perform tasks.

Our Contributions

JEDAI.Ed, an online platform that:

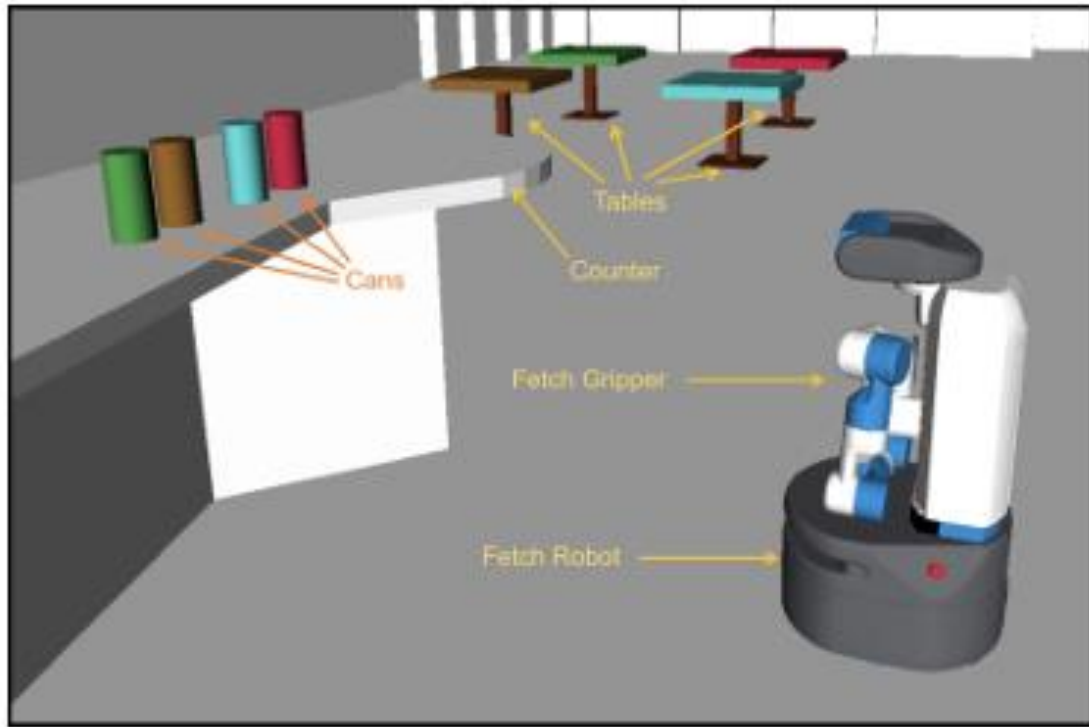
- **Teaches users to understand reasoning** and quickly provide high-level instructions to robots to perform tasks.
- **Identifies and explains bugs in user instructions** so that users learn more about the capabilities of the robot and update the instructions.

Our Contributions

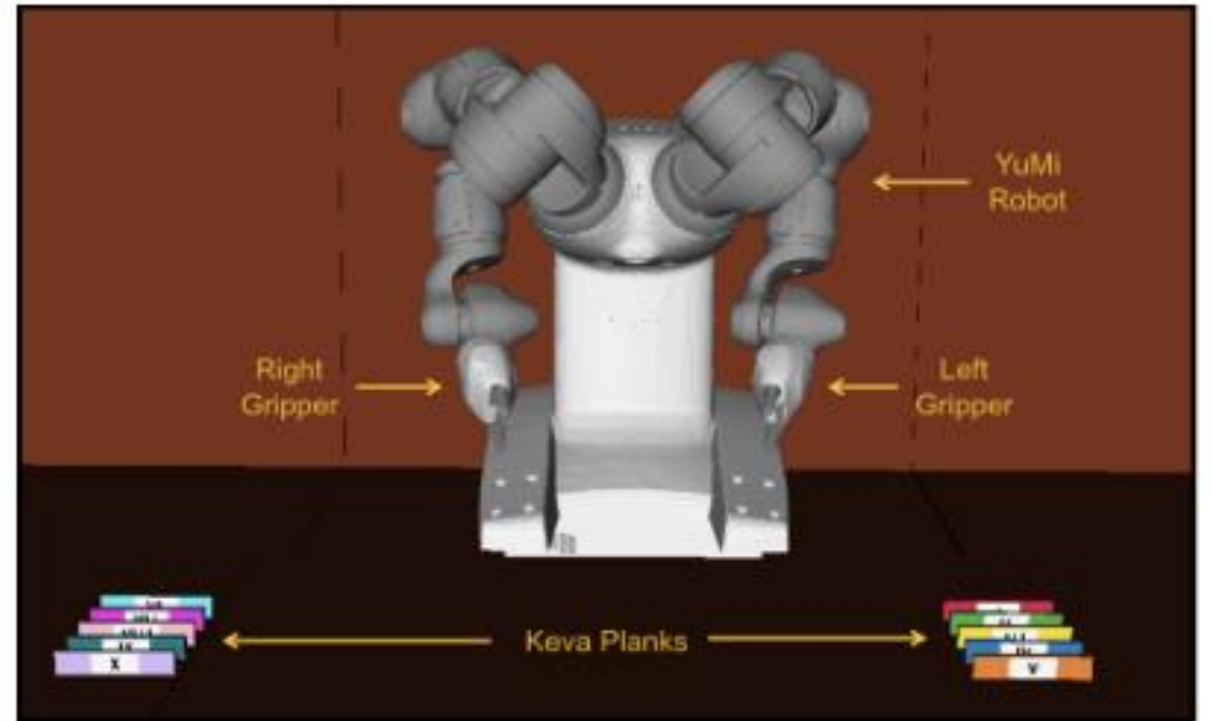
JEDAI.Ed, an online platform that:

- **Teaches users to understand reasoning** and quickly provide high-level instructions to robots to perform tasks.
- **Identifies and explains bugs in user instructions** so that users learn more about the capabilities of the robot and update the instructions.
- **Adaptively generates problems tailored to the user's understanding.**

Example Environments



Coffee Shop



Keva

JEDAI.Ed Interface

The interface is divided into several sections:

- Top Bar:** Contains buttons for 'Execute on Robot', 'Help', 'Get A Hint', and 'Curriculum'.
- Left Panel:** A list of actions: 'Move robot', 'Pick Up', and 'Place'. A 'Start' button is highlighted.
- Action Configuration:** Two panels are visible:
 - Pick up (blue):** from this location: counter, this object: can_red, using this gripper: gripper, of this robot: fetch.
 - Place (red):** at this location: counter, this object: can_blue, using this gripper: gripper, of this robot: fetch.
- Simulation View:** A top-down view of a robot labeled 'Fetch Robot' in a room with a counter and various objects.
- Initial State (blue box):** After applying Action 1: Pick up from location 'counter' object 'can_red' using gripper 'gripper' this robot 'fetch'.
- Goal State (black box):** 'can_blue' is on 'table_blue', 'can_brown' is on ..., 'can_green' is on ..., 'can_red' is on ...
- Expected goal state configuration:** A 3D rendering of the goal state with a circular highlight on a brown can.
- Invalid Action 2 (grey box):** TLDR: The action at step 2 (Place at location 'counter' object 'can_blue' using gripper 'gripper' this robot 'fetch') could not be performed because 'gripper' is not holding 'can_blue'.
Explanation: The robot couldn't place the blue can on the counter because the gripper wasn't holding the blue can. Brief message: The robot couldn't put the blue can on the counter because it wasn't holding it with the gripper. Suggested fix: Make sure the gripper is holding the blue can before trying to place it on the counter.
- Bottom Bar:** Contains buttons for 'Save', 'Load', 'Reset', 'Maximize', and 'Minimize'.

JEDAI.Ed Interface: Domain and Task

The screenshot displays the JEDAI.Ed interface. On the left, a menu lists actions: 'Start', 'Move robot', 'Pick Up', and 'Place'. The 'Start' action is expanded, showing a sequence of steps: 'Pick up' (from location 'counter', object 'can_red', using gripper 'gripper' of robot 'fetch') and 'Place' (at location 'counter', object 'can_blue', using gripper 'gripper' of robot 'fetch').

The central simulation area shows a robot labeled 'Fetch Robot' in a virtual environment. A red banner at the bottom of the simulation area reads 'Goal not satisfied: Invalid plan'.

On the right, a panel titled 'Initial State' shows the state after applying Action 1: 'Pick up from location 'counter' object 'can_red' using gripper 'gripper' this robot 'fetch':'. Below this, a list of objects is shown: 'can_brown is on ...', 'fetch is at location ...', 'gripper is holding ...', 'can_blue is on counter', and 'can_green is on counter'.

Next to it, a panel titled 'Goal State' lists the goal conditions: 'can_blue' is on 'table_blue', 'can_brown' is on ..., 'can_green' is on ..., and 'can_red' is on

Below the goal state, a small 3D rendering shows a brown can on a table, with a white circle highlighting it. The text below the rendering reads 'Expected goal state configuration'.

At the bottom, a panel titled 'Invalid Action 2' provides a TLDR: 'The action at step 2 (Place at location 'counter' object 'can_blue' using gripper 'gripper' this robot 'fetch') could not be performed because 'gripper' is not holding 'can_blue'.', followed by an explanation: 'The robot couldn't place the blue can on the counter because the gripper wasn't holding the blue can. Brief message: The robot couldn't put the blue can on the counter because it wasn't holding it with the gripper. Suggested fix: Make sure the gripper is holding the blue can before trying to place it on the counter.'

At the bottom of the interface, there are buttons for 'Save', 'Load', 'Reset', 'Maximize', and 'Minimize'.

JEDAI.Ed Interface: Generating a Plan

Execute on Robot Help Get A Hint Curriculum

Actions

- Move robot
- Pick Up
- Place

Start

Pick up

from this location: counter

this object: can_red

using this gripper: gripper

of this robot: fetch

Place

at this location: counter

this object: can_blue

using this gripper: gripper

of this robot: fetch

Fetch Robot

Initial State

After applying Action 1 :
Pick up from location 'counter' object 'can_red' using gripper 'gripper' this robot 'fetch' :

Goal State

'can_blue' is on 'table_blue'
'can_brown' is on ...
'can_green' is on ...
'can_red' is on ...

Goal not satisfied: Invalid plan

can_brown is on ...
fetch is at location ...
gripper is holding ...
can_blue is on counter
can_green is on counter

Expected goal state configuration

Invalid Action 2

TLDR: The action at step 2 (Place at location 'counter' object 'can_blue' using gripper 'gripper' this robot 'fetch') could not be performed because 'gripper' is not holding 'can_blue'.

Explanation: The robot couldn't place the blue can on the counter because the gripper wasn't holding the blue can. Brief message: The robot couldn't put the blue can on the counter because it wasn't holding it with the gripper. Suggested fix: Make sure the gripper is holding the blue can before trying to place it on the counter.

Save Load Reset Maximize Minimize

JEDAI.Ed Interface: Plan Execution

Execute on Robot Help Get A Hint Curriculum

Actions

- Move robot
- Pick Up
- Place

Start

Pick up

from this location: counter

this object: can_red

using this gripper: gripper

of this robot: fetch

Place

at this location: counter

this object: can_blue

using this gripper: gripper

of this robot: fetch

Fetch Robot

Goal not satisfied: Invalid plan

Initial State

After applying Action 1 :
Pick up from location 'counter' object 'can_red' using gripper 'gripper' this robot 'fetch' :

Goal State

'can_blue' is on 'table_blue'
'can_brown' is on ...
'can_green' is on ...
'can_red' is on ...

can_brown is on ...
fetch is at location ...
gripper is holding ...
can_blue is on counter
can_green is on counter

Expected goal state configuration

Invalid Action 2

TLDR: The action at step 2 (Place at location 'counter' object 'can_blue' using gripper 'gripper' this robot 'fetch') could not be performed because 'gripper' is not holding 'can_blue'.

Explanation: The robot couldn't place the blue can on the counter because the gripper wasn't holding the blue can. Brief message: The robot couldn't put the blue can on the counter because it wasn't holding it with the gripper. Suggested fix: Make sure the gripper is holding the blue can before trying to place it on the counter.

Save Load Reset Maximize Minimize

JEDAI.Ed Interface: Explanation for Errors

The screenshot displays the JEDAI.Ed interface, which includes a top navigation bar with 'Execute on Robot', 'Help', 'Get A Hint', and 'Curriculum'. On the left, an 'Actions' menu lists 'Move robot', 'Pick Up', and 'Place'. The main workspace shows a 3D simulation of a robot on a table with various objects. A 'Fetch Robot' label points to the robot. A plan editor is open, showing two actions: 'Pick up' (blue) and 'Place' (red). The 'Pick up' action is configured with location 'counter', object 'can_red', gripper 'gripper', and robot 'fetch'. The 'Place' action is configured with location 'counter', object 'can_blue', gripper 'gripper', and robot 'fetch'. Below the plan editor, a red banner reads 'Goal not satisfied: Invalid plan'. To the right, a panel shows the 'Initial State' and 'Goal State'. The 'Initial State' is 'After applying Action 1: Pick up from location 'counter' object 'can_red' using gripper 'gripper' this robot 'fetch':'. The 'Goal State' is 'can_blue is on table_blue, can_brown is on ..., can_green is on ..., can_red is on ...'. Below this, a section titled 'Invalid Action 2' explains the error: 'TLDR: The action at step 2 (Place at location 'counter' object 'can_blue' using gripper 'gripper' this robot 'fetch') could not be performed because 'gripper' is not holding 'can_blue'. Explanation: The robot couldn't place the blue can on the counter because the gripper wasn't holding the blue can. Brief message: The robot couldn't put the blue can on the counter because it wasn't holding it with the gripper. Suggested fix: Make sure the gripper is holding the blue can before trying to place it on the counter.' At the bottom, there are buttons for 'Save', 'Load', 'Reset', 'Maximize', and 'Minimize'.

Execute on Robot Help Get A Hint Curriculum

Actions

Start

Pick up

from this location: counter

this object: can_red

using this gripper: gripper

of this robot: fetch

Place

at this location: counter

this object: can_blue

using this gripper: gripper

of this robot: fetch

Fetch Robot

Goal not satisfied: Invalid plan

Initial State

After applying Action 1 :
Pick up from location
'counter' object 'can_red'
using gripper 'gripper'
this robot 'fetch' :

Goal State

'can_blue' is on
'table_blue'
'can_brown' is on ...
'can_green' is on ...
'can_red' is on ...

can_brown is on ...
fetch is at location ...
gripper is holding ...
can_blue is on counter
can_green is on counter

Expected goal state configuration

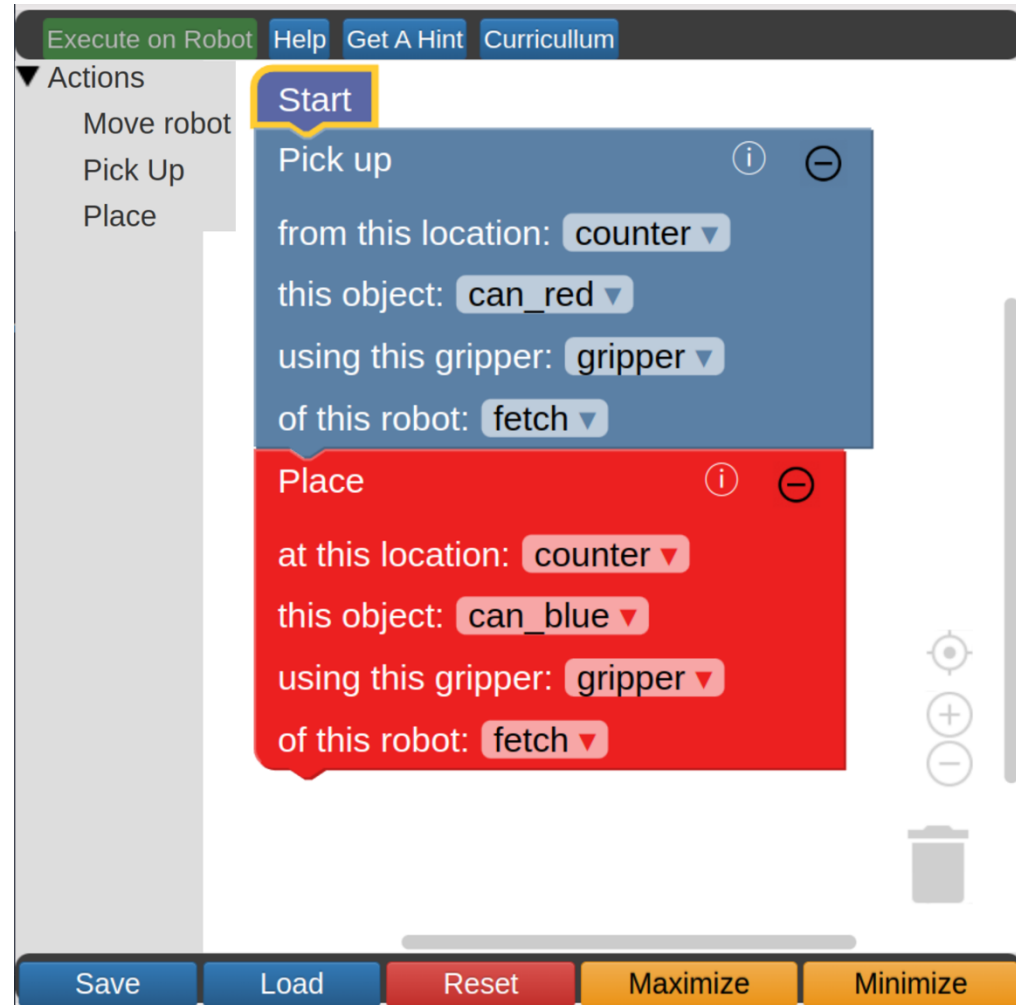
Invalid Action 2

TLDR: The action at step 2 (Place at location 'counter' object 'can_blue' using gripper 'gripper' this robot 'fetch') could not be performed because 'gripper' is not holding 'can_blue'.

Explanation: The robot couldn't place the blue can on the counter because the gripper wasn't holding the blue can. Brief message: The robot couldn't put the blue can on the counter because it wasn't holding it with the gripper. Suggested fix: Make sure the gripper is holding the blue can before trying to place it on the counter.

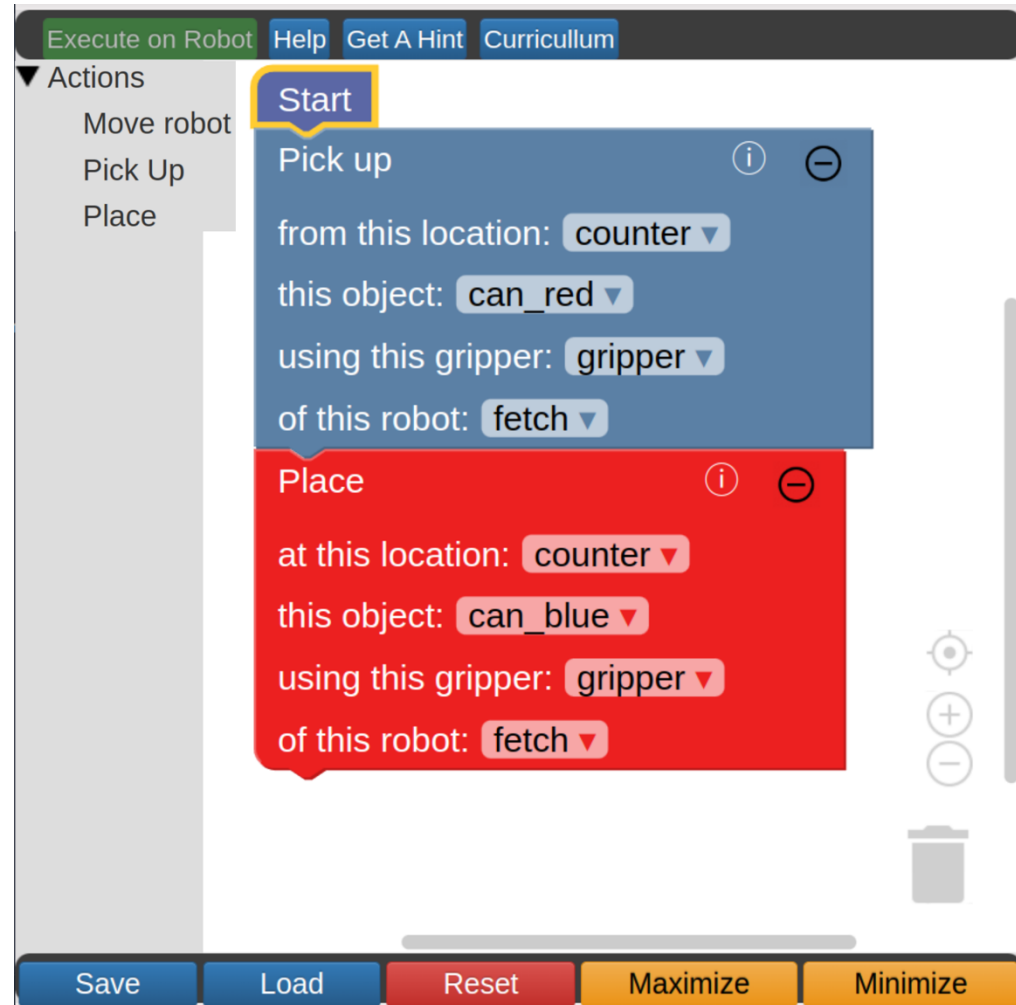
Save Load Reset Maximize Minimize

JEDAI.Ed Interface: Hints



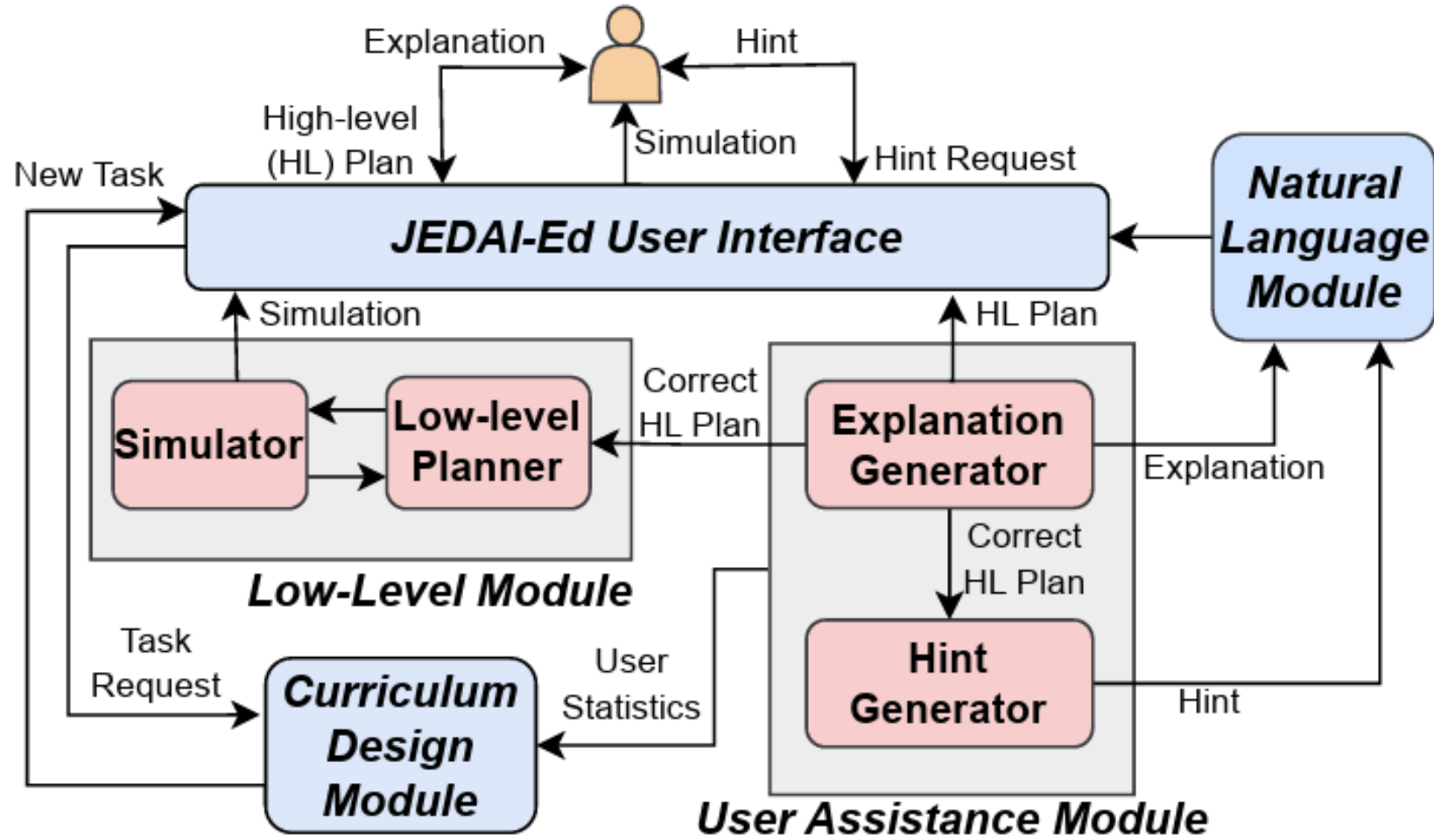
Users can take help from a hint!

JEDAI.Ed Interface: Curriculum Design



Curriculum design adjusts problem complexity based on user understanding!

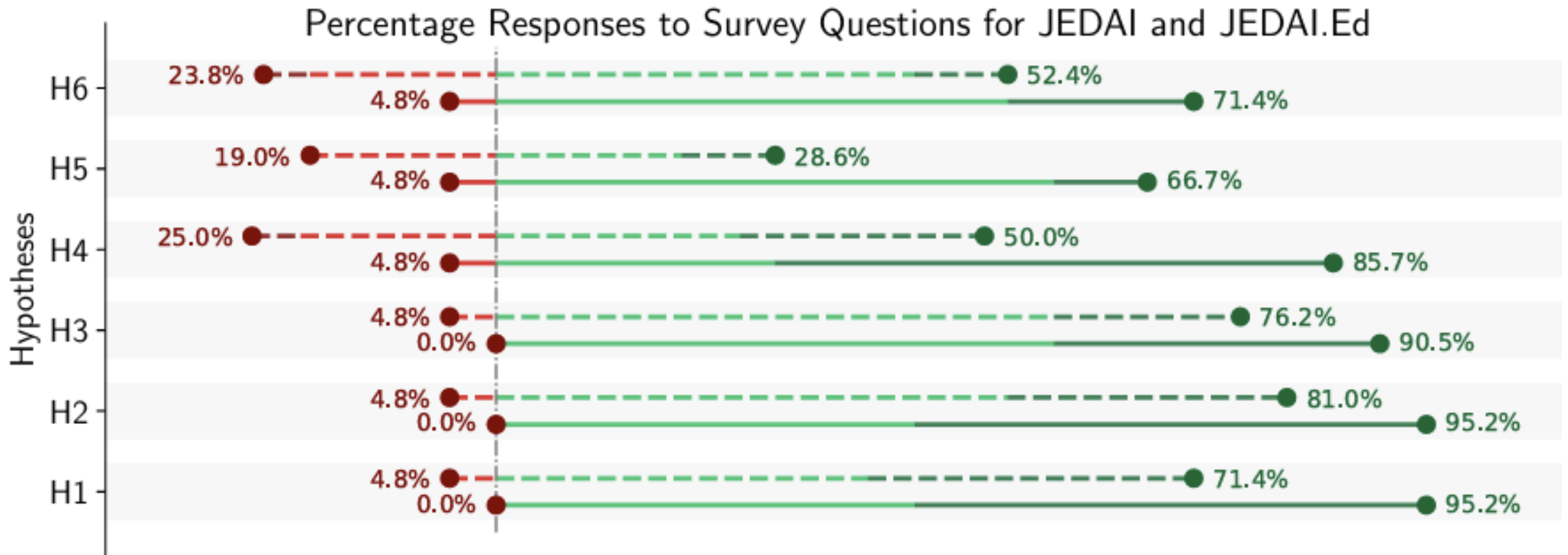
JEDAI.Ed Architecture



Empirical Evaluation

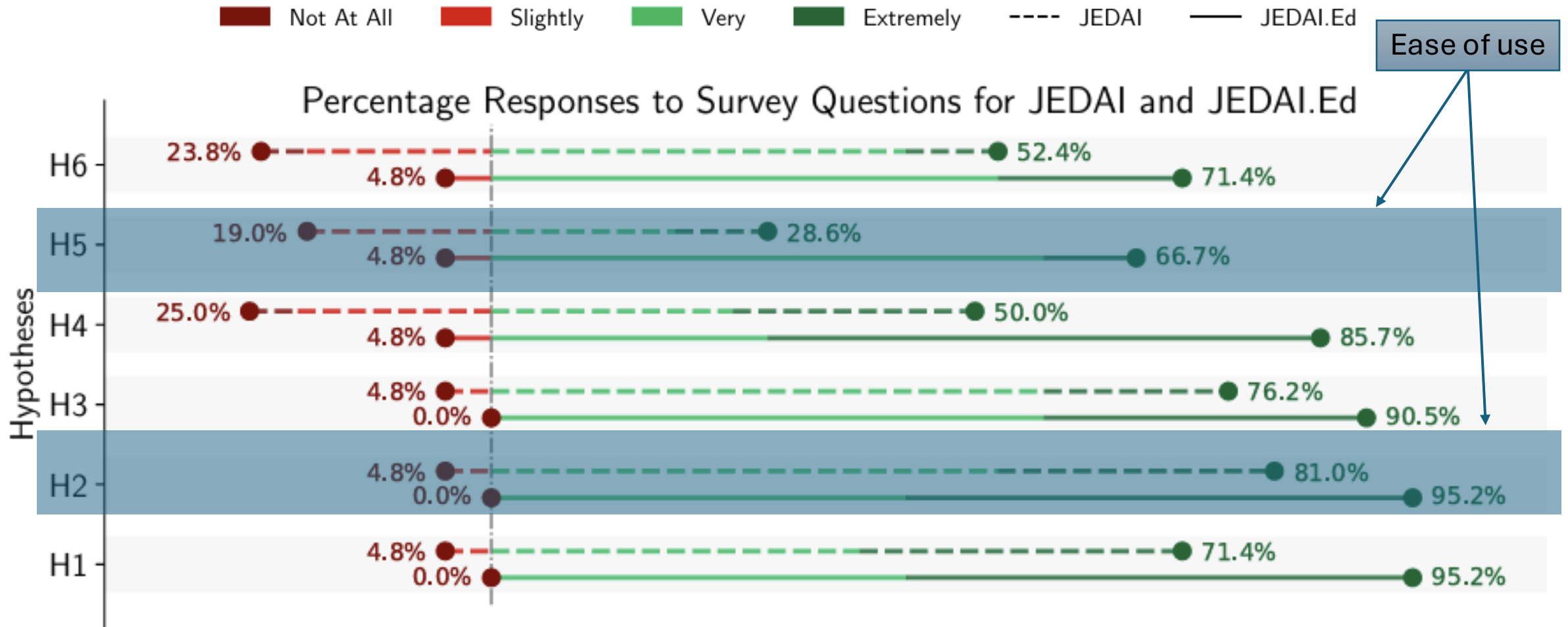
Responses from User Study with 42 participants

Not At All Slightly Very Extremely JEDAI JEDAI.Ed



Empirical Evaluation

Responses from User Study with 42 participants

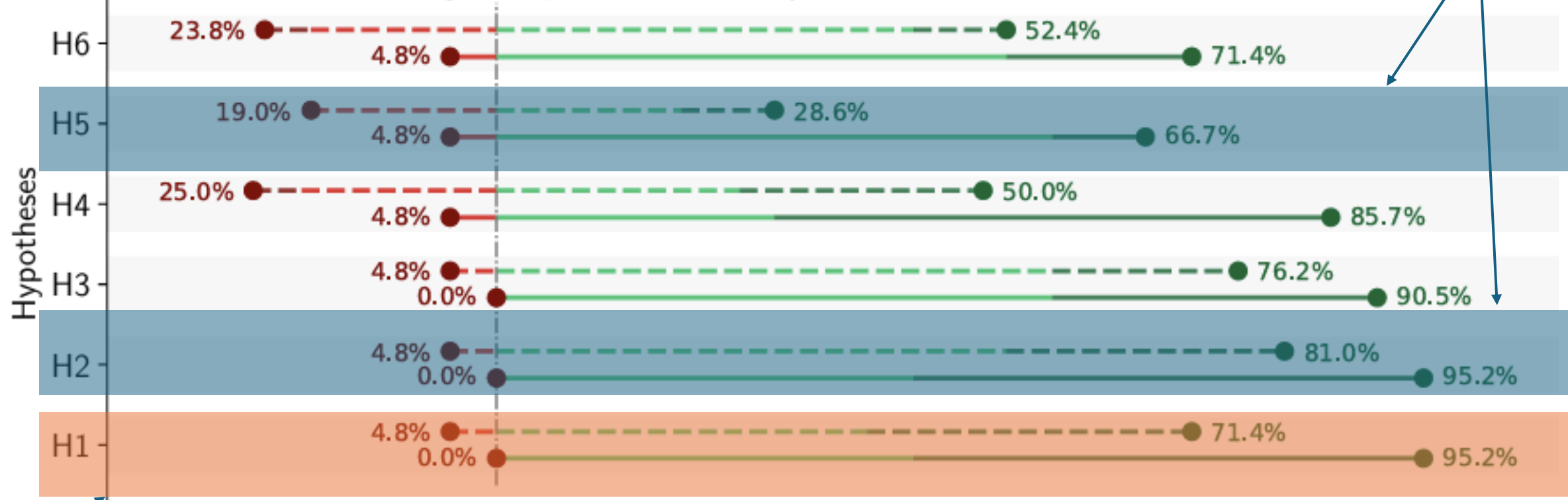


Empirical Evaluation

Responses from User Study with 42 participants

■ Not At All
 ■ Slightly
 ■ Very
 ■ Extremely
 - - - JEDAI
 — JEDAI.Ed

Percentage Responses to Survey Questions for JEDAI and JEDAI.Ed



Ease of use

Curiosity

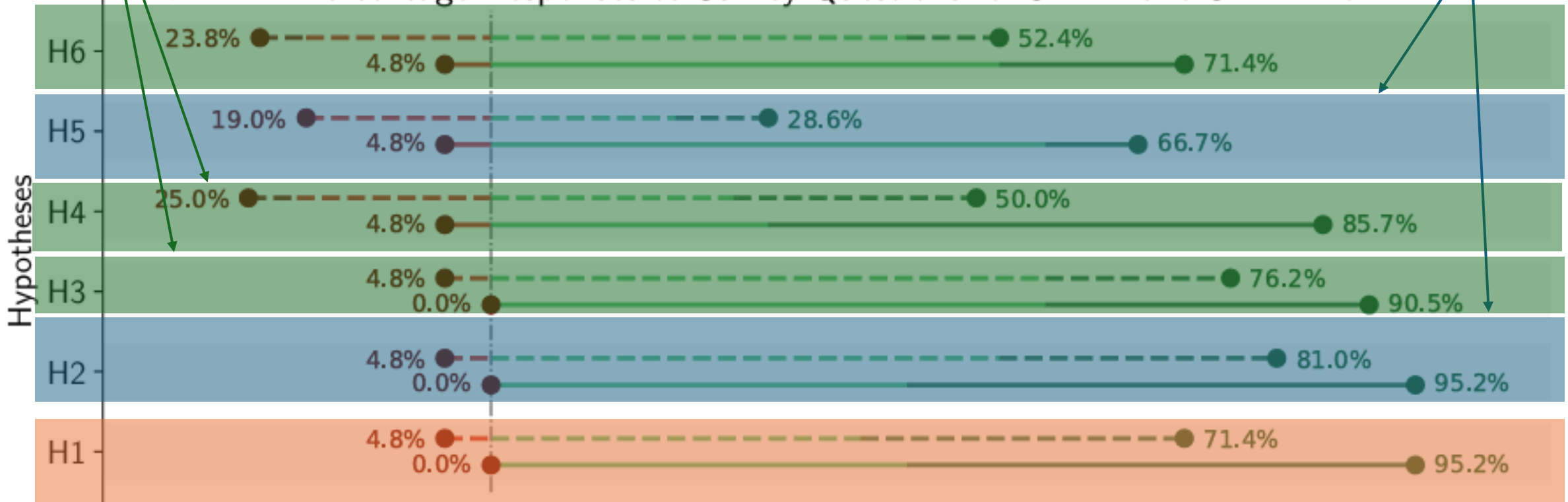
Usefulness
(understanding,
helpfulness,
confidence)

Responses from User Study with 42 participants

Not At All Slightly Very Extremely ----- JEDAI ——— JEDAI.Ed

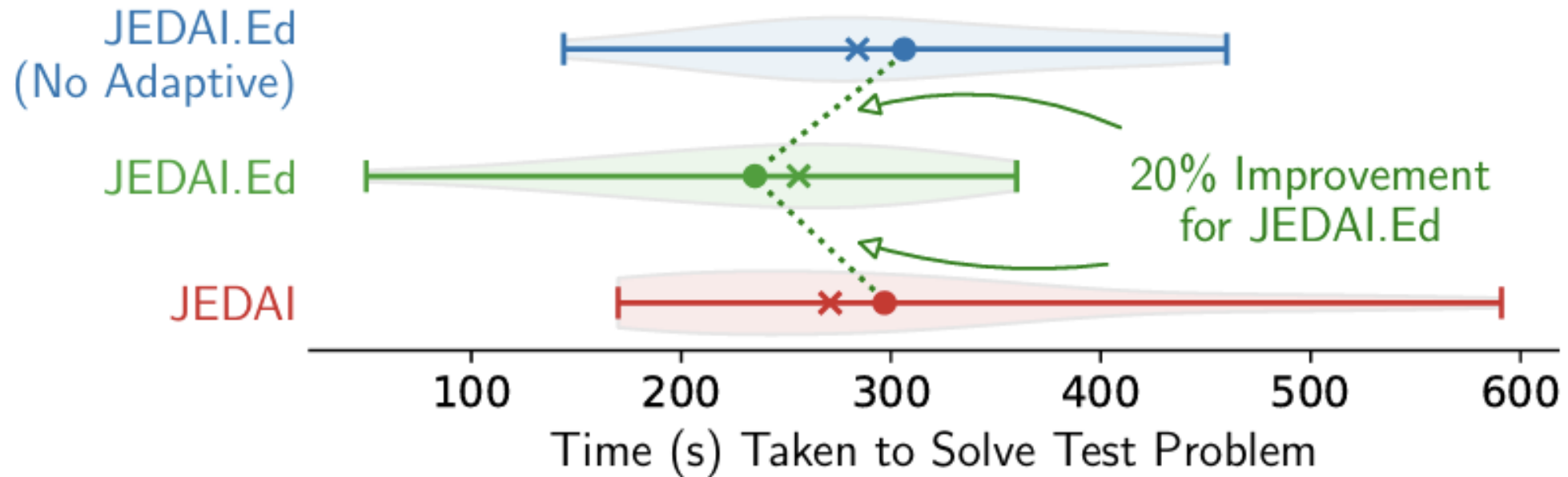
Ease of use

Percentage Responses to Survey Questions for JEDAI and JEDAI.Ed



Curiosity

Empirical Evaluation: Test Times



20% improvement in test times!!

Engagement in JEDAI.Ed's pilot program on 2 high schools (90 students)



Open-Source Code for JEDAI.Ed

Source code is available at: <https://github.com/AAIR-lab/jedai>

The screenshot displays the JEDAI.Ed interface. On the left, a sidebar lists actions: 'Move robot', 'Pick Up', and 'Place'. The main area shows a task plan with two actions: 'Pick up' and 'Place'. The 'Pick up' action is highlighted in blue and includes details: 'from this location: counter', 'this object: can_red', 'using this gripper: gripper', and 'of this robot: fetch'. The 'Place' action is highlighted in red and includes details: 'at this location: counter', 'this object: can_blue', 'using this gripper: gripper', and 'of this robot: fetch'. Below the actions, a red banner reads 'Goal not satisfied: Invalid plan'. To the right, a 3D simulation shows a robot arm with a gripper. A green box labeled 'Fetch Robot' points to the robot. Below the simulation, a blue box titled 'Initial State' contains the text: 'After applying Action 1 : Pick up from location 'counter' object 'can_red' using gripper 'gripper' this robot 'fetch' :'. Below this, a list of objects is shown: 'can_brown is on ...', 'fetch is at location ...', 'gripper is holding ...', 'can_blue is on counter', and 'can_green is on counter'. To the right of the simulation, a black box titled 'Goal State' contains the text: ''can_blue' is on 'table_blue'', ''can_brown' is on ...', ''can_green' is on ...', and ''can_red' is on ...'. Below the goal state, a 3D simulation shows a table with a blue can and a brown can. A red circle highlights the blue can, and the text 'Expected goal state configuration' is written below it. At the bottom, a grey box titled 'Invalid Action 2' contains the text: 'TLDR: The action at step 2 (Place at location 'counter' object 'can_blue' using gripper 'gripper' this robot 'fetch') could not be performed because 'gripper' is not holding 'can_blue'. Explanation: The robot couldn't place the blue can on the counter because the gripper wasn't holding the blue can. Brief message: The robot couldn't put the blue can on the counter because it wasn't holding it with the gripper. Suggested fix: Make sure the gripper is holding the blue can before trying to place it on the counter.'

