A Computational Model for Situated Task Learning with Interactive Instruction

Shiwali Mohan, James Kirk, John Laird

Computer Science and Engineering
University of Michigan

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Motivation

- Past 3 decades of cognitive science research
  - developed precise cognitive models of human behavior in various tasks.
  - developed cognitive architectures - theory of memories, representations, and processing.
  - relies on hand-coding of procedural knowledge.
  - provides limited understanding of how novel task knowledge is acquired.
    - Anderson 2007, Salvucci 2010

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  - provides limited understanding of how novel task knowledge is acquired.
    - Anderson 2007, Salvucci 2010
- How do people acquire knowledge for novel tasks?



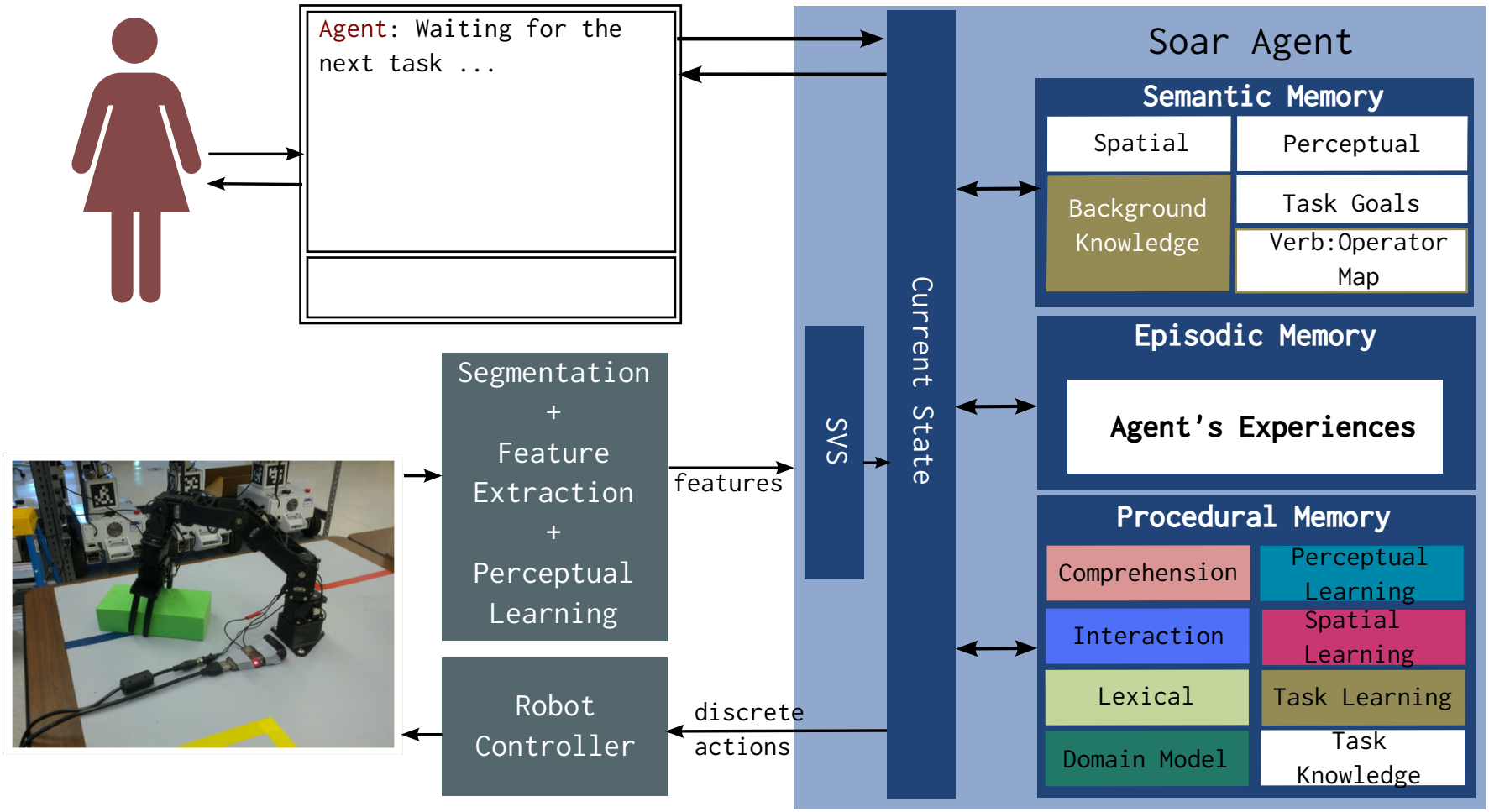

Situated Interactive Learning

exploits common ground, distributes initiative

Computational Requirements

1. Integrative Interaction (ACS 2012)
   - comprehend complex bi-directional interaction
   - maintain state of ongoing *task-oriented* interactions
2. Referential Comprehension (AAAI WS, 2012)
   - transform lexical items to internal representation of environmental state, task models
   - ambiguous language requires exploiting various extra-linguistic contexts
3. Situated Learning (ICCM 2013)
   - from specific task-solving experience to general task models
4. Active, Incremental Learning (ICCM 2013)
   - learner contributes to own learning
   - asks relevant questions, assimilates replies with prior knowledge

Architecture

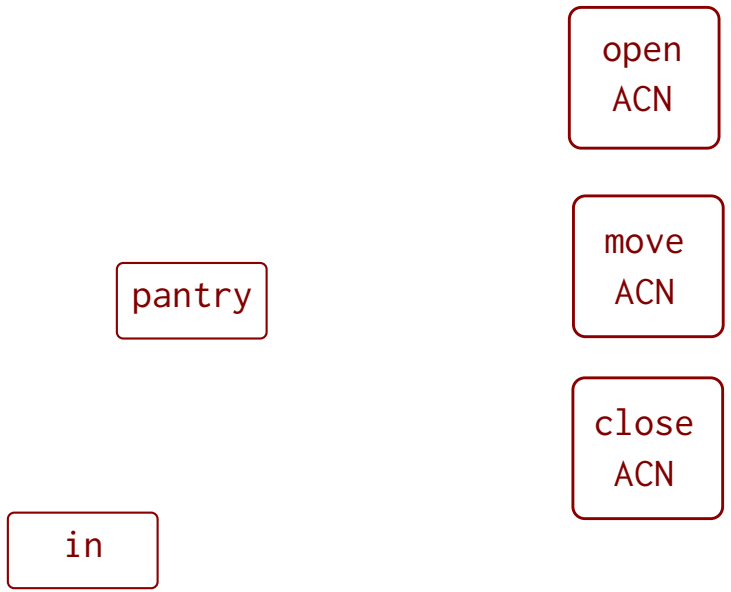


Task Learning

distributed across three knowledge classes

Interaction trace
Instructor: Store the green rectangle.

Semantic Memory



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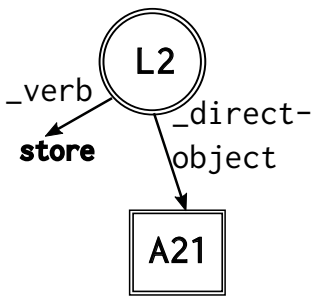

pantry

in

open ACN

move ACN

close ACN

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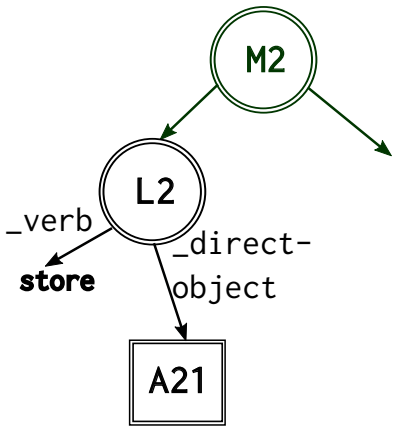

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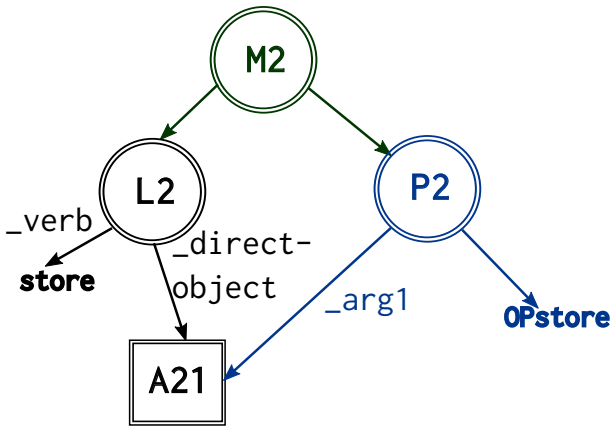

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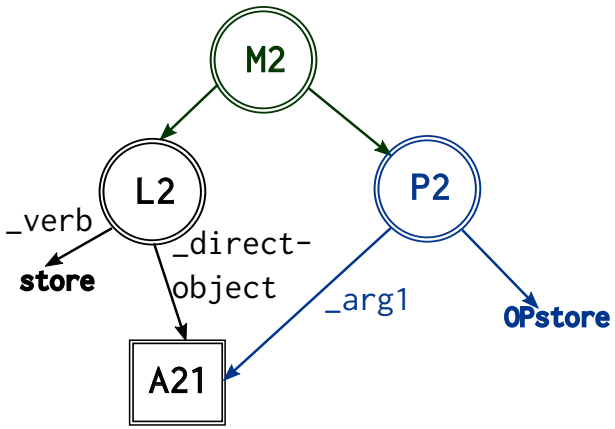

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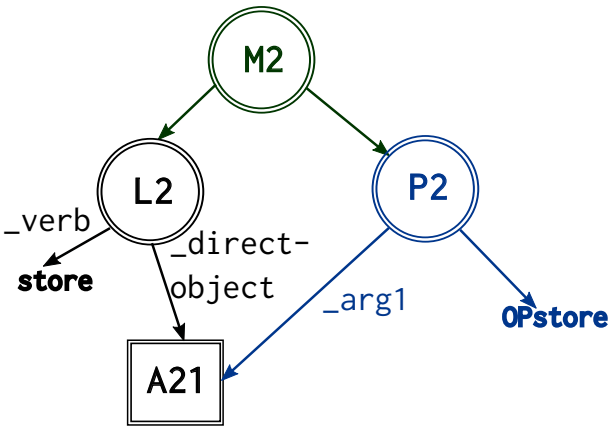

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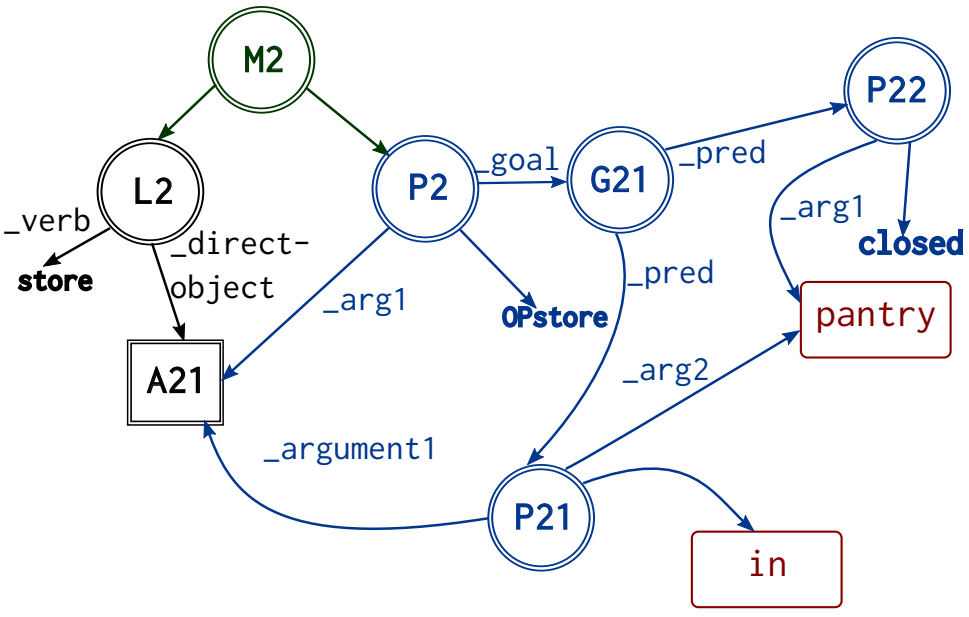

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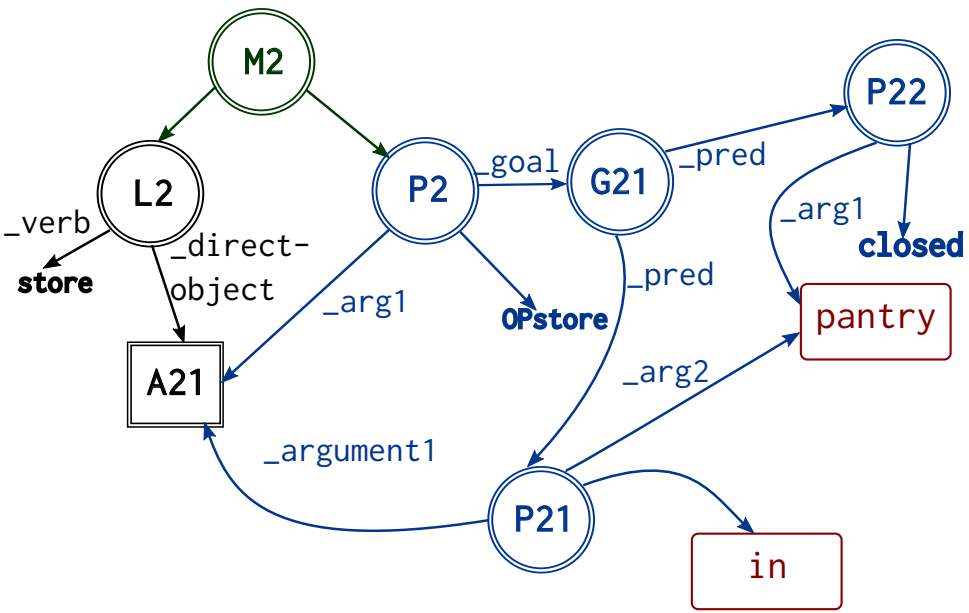

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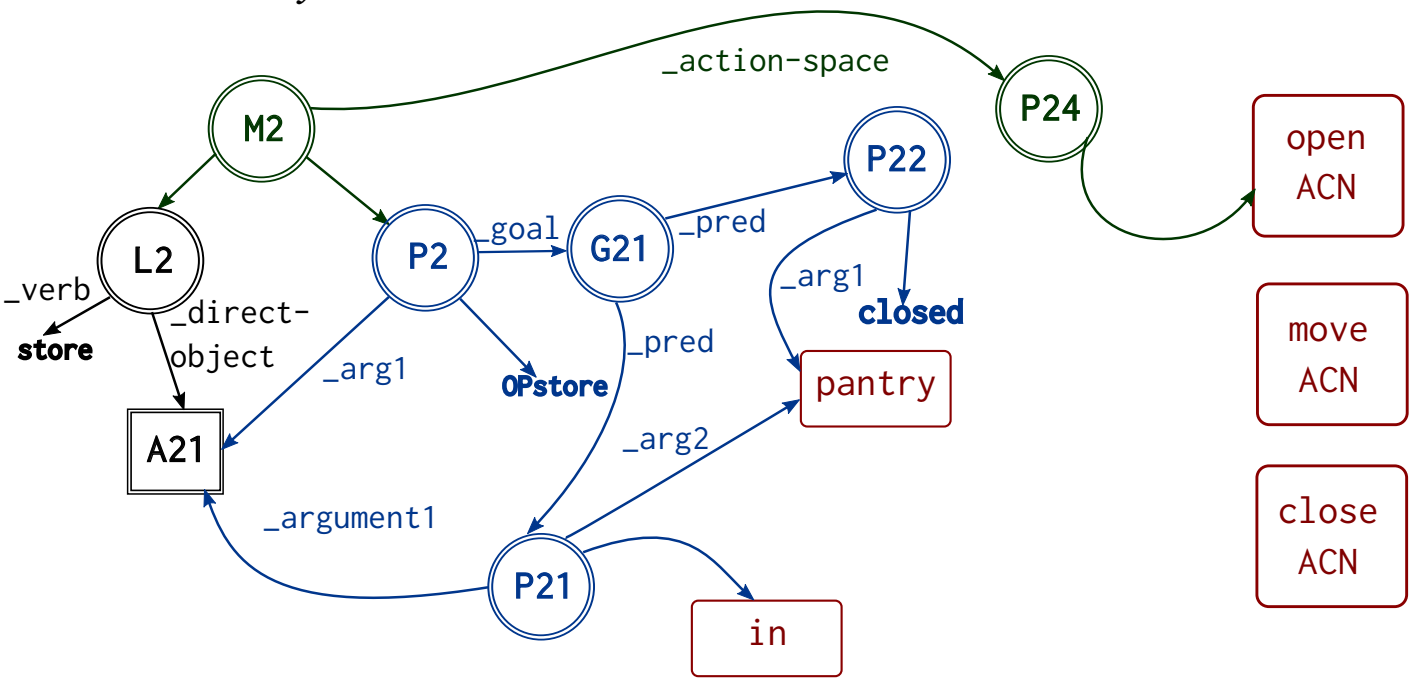

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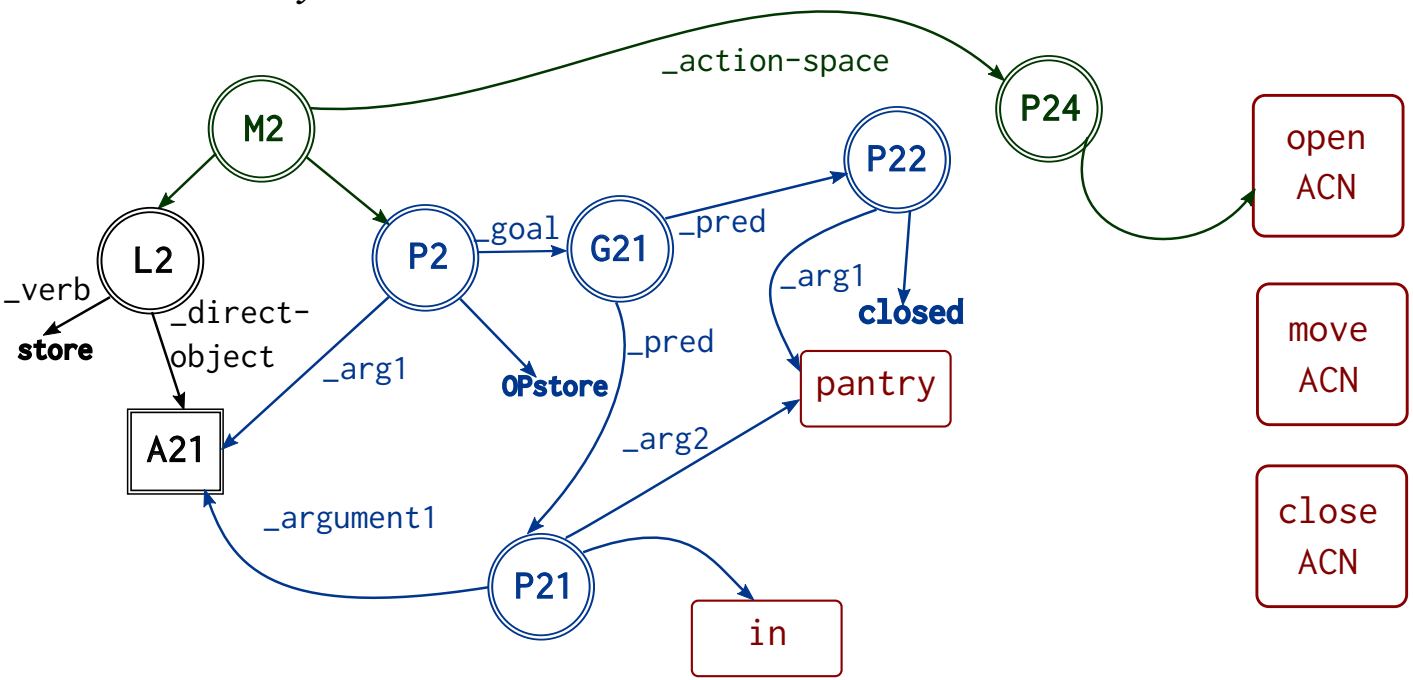

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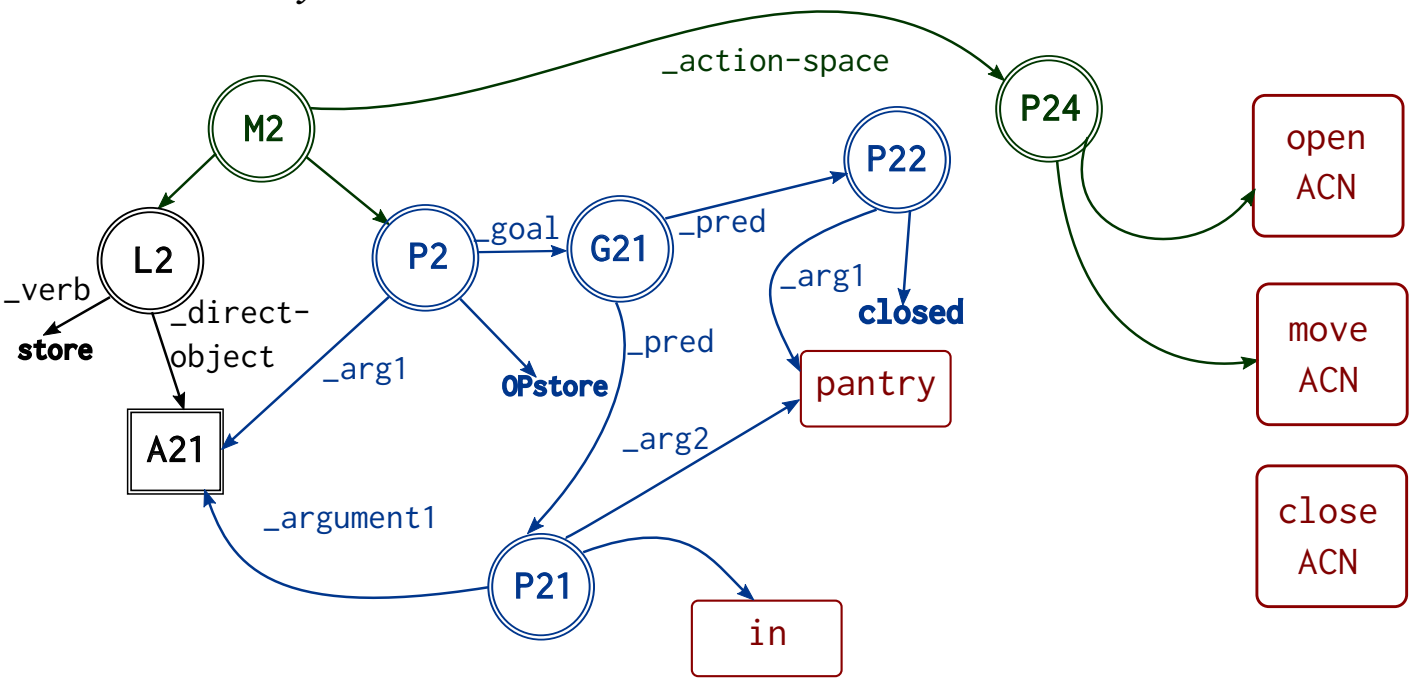

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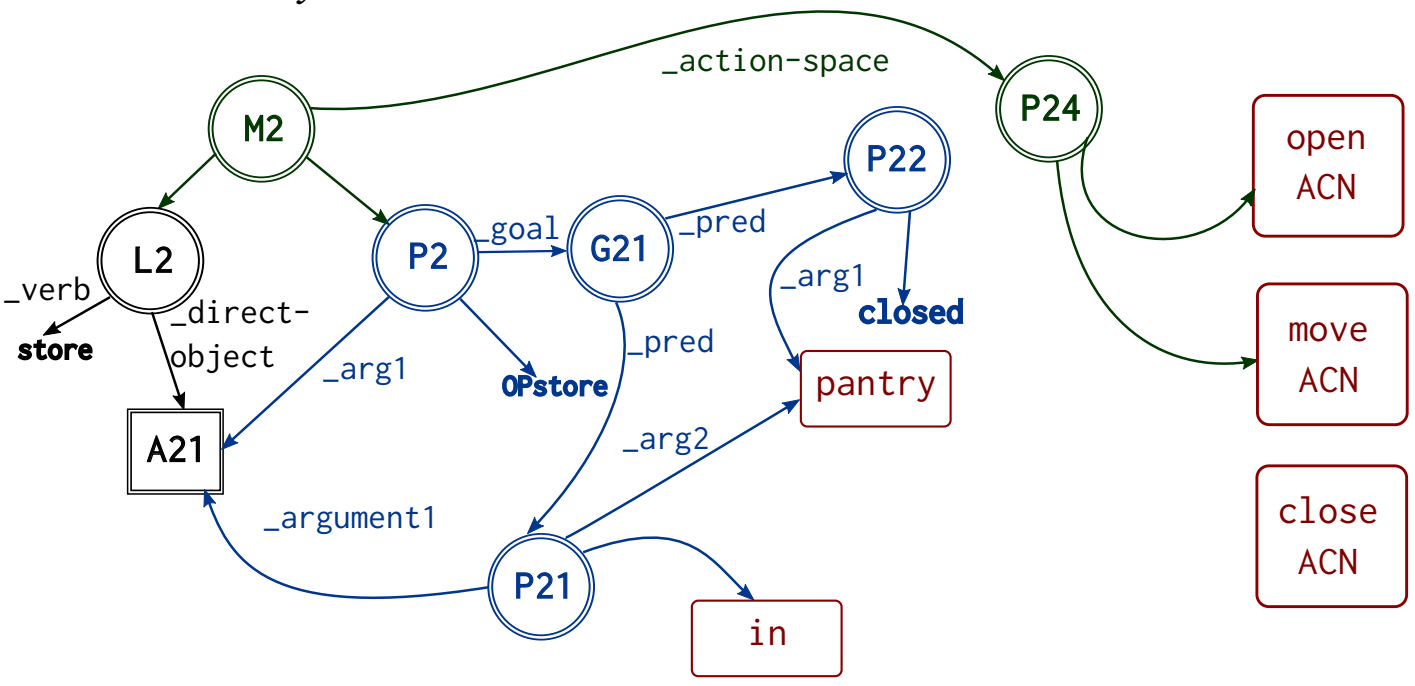

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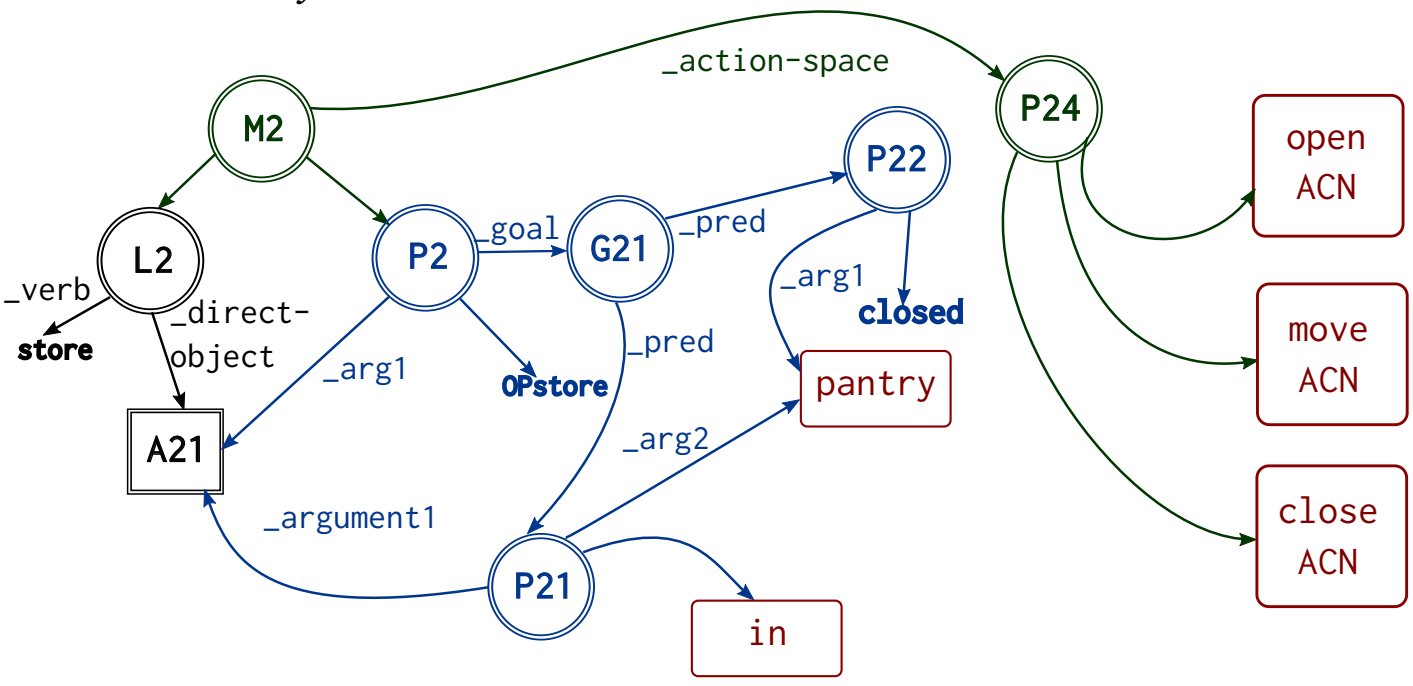

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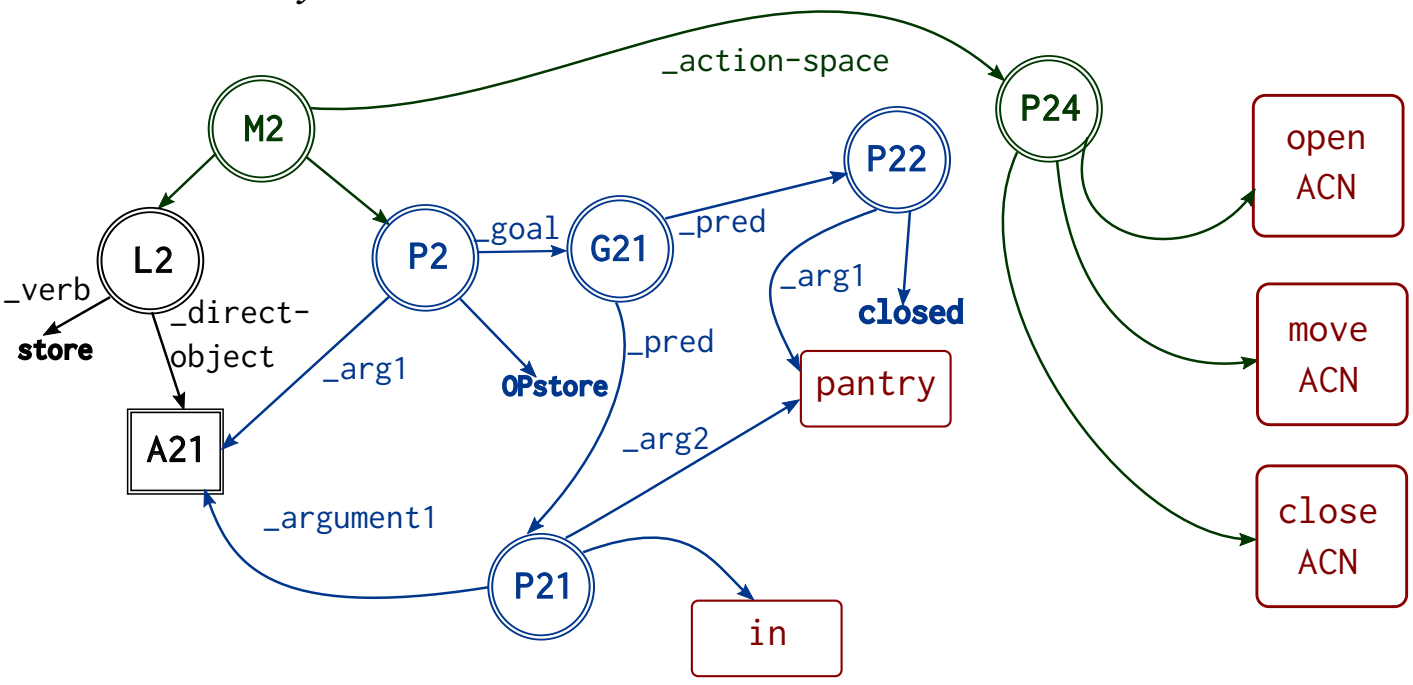

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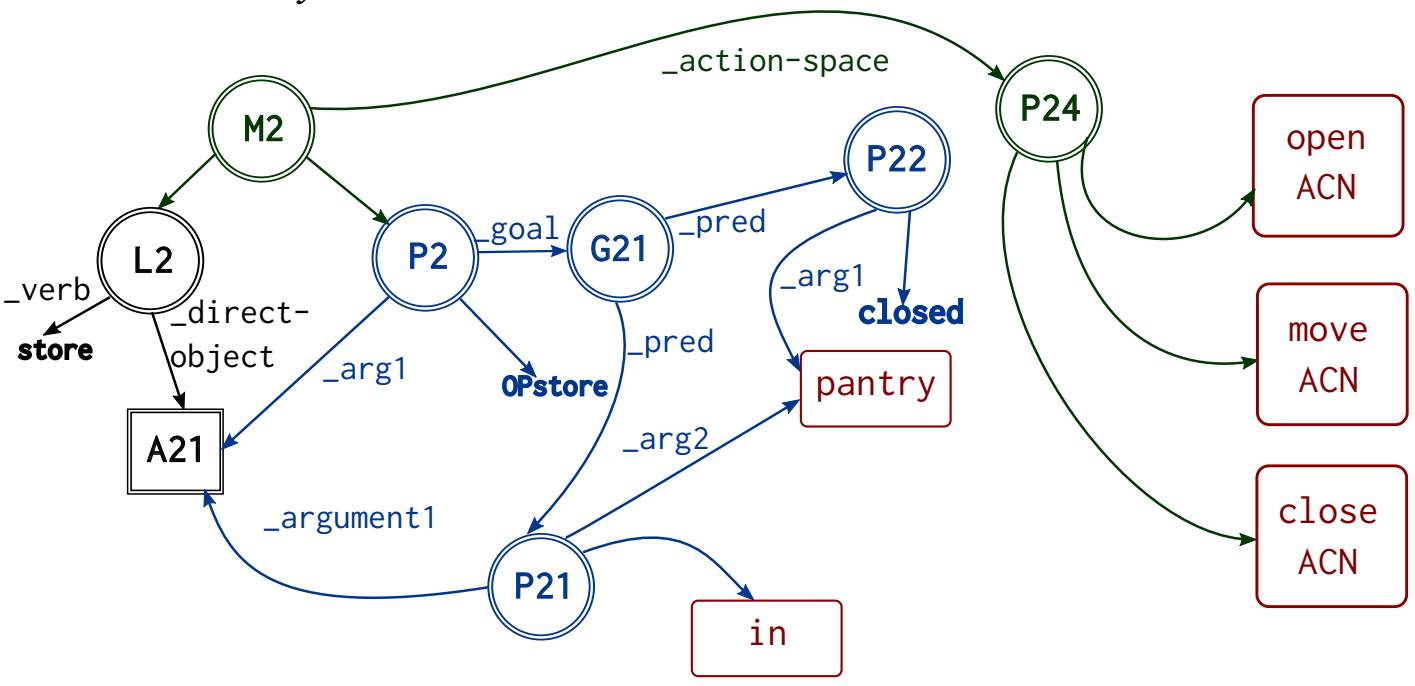

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map, task-concept network, procedural policy

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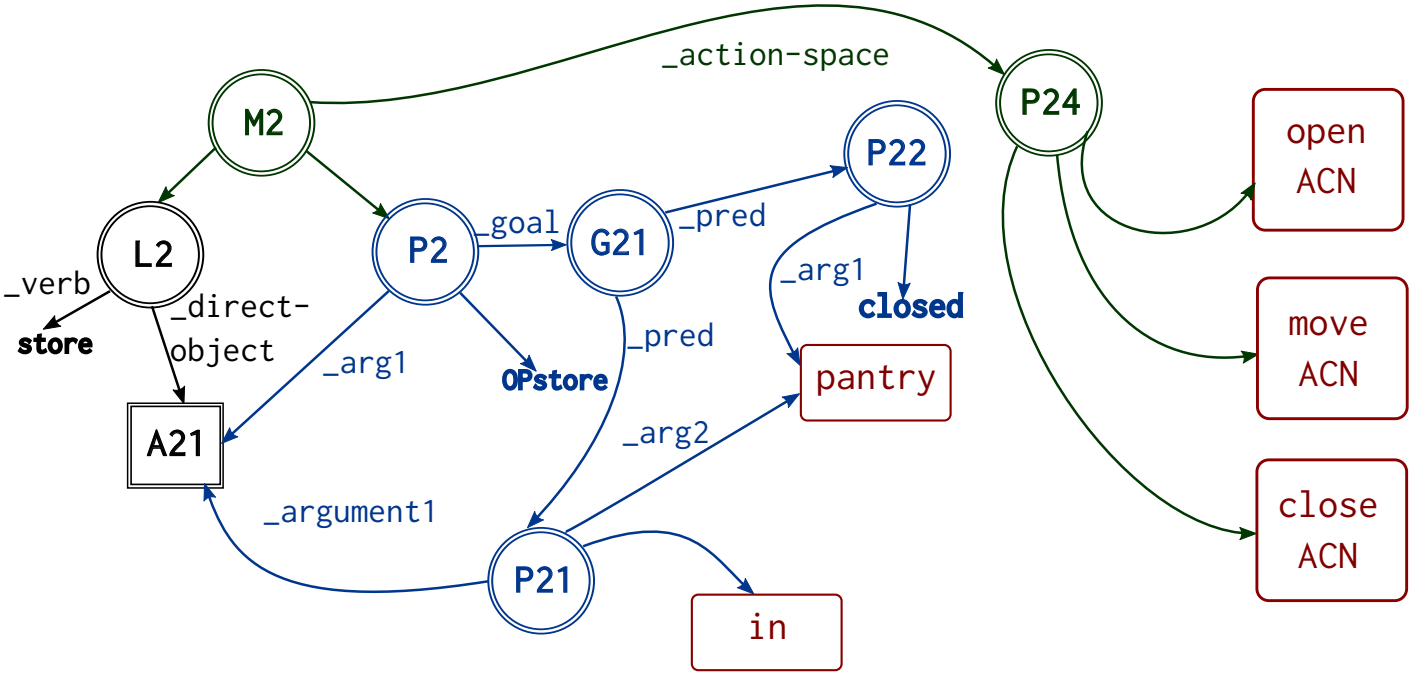

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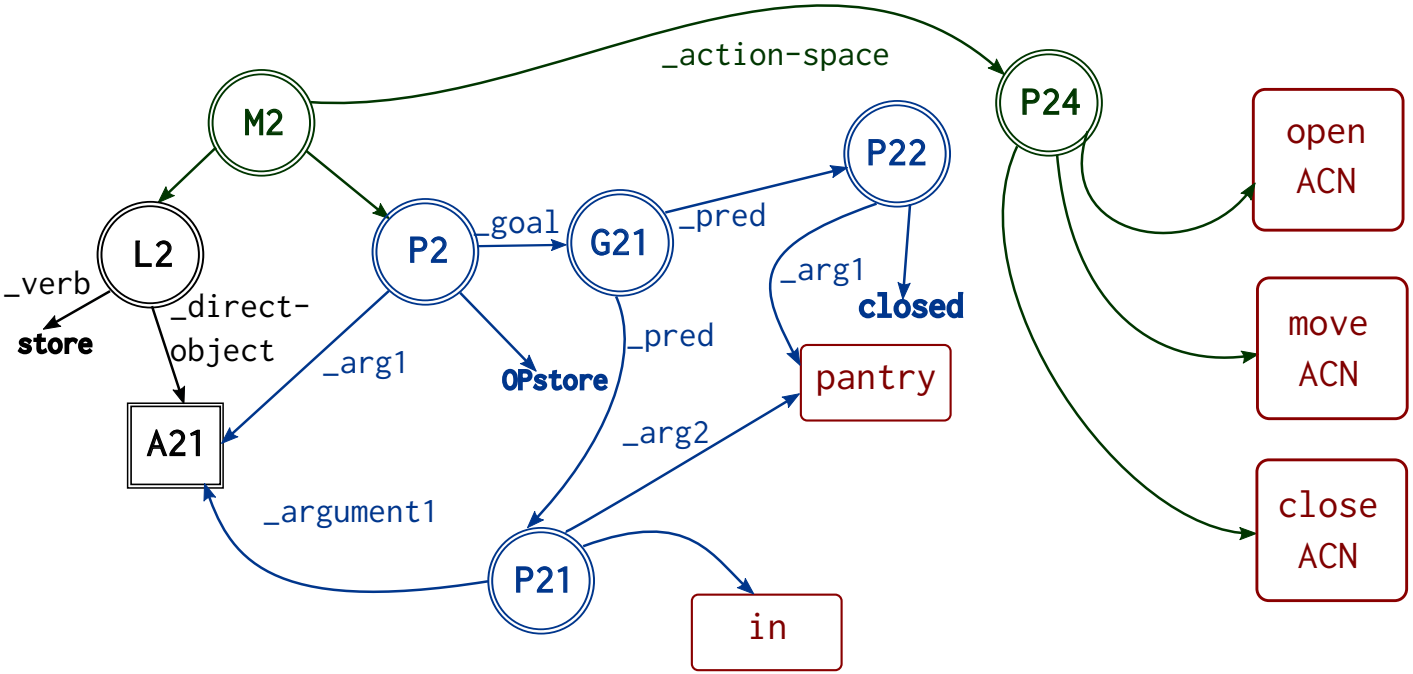


Procedural Memory

rule1: If operator is `OPstore` and `CLOSED(pantry)`
--> execute `open(pantry)`

rule2: If operator is `OPstore` and `arg1` is `[A21]` and `OPEN(pantry)`
--> execute `move([A21],pantry)`

rule3: If operator is `OPstore` and `arg1` is `[A21]` and `IN([A21],pantry)` and `OPEN(pantry)`
--> execute `CLOSE(pantry)`

Learning Demo

General Learning

Reasons about and removes superfluous instructions (actions).

Move the red block to the pantry.

The goal is red block in the pantry.
Pick up the red block.
Put the block in the garbage.
Pick up the red block.
Put the block in the pantry.

General Learning

Reasons about and removes superfluous instructions (actions).

Move the red block to the pantry.

The goal is red block in the pantry.

Pick up the red block.

~~Put the block in the garbage.~~

~~Pick up the red block.~~

Put the block in the pantry.

General Learning

Learns a policy rather than a script

Scenario 1

State: `-Holding`

Command: *Move the red block to the pantry.*

Actions: `Pick up the red block, Put the block in the pantry.`

Scenario 2

State: `Holding(red block)`

Command: *Move the red block to the pantry.*

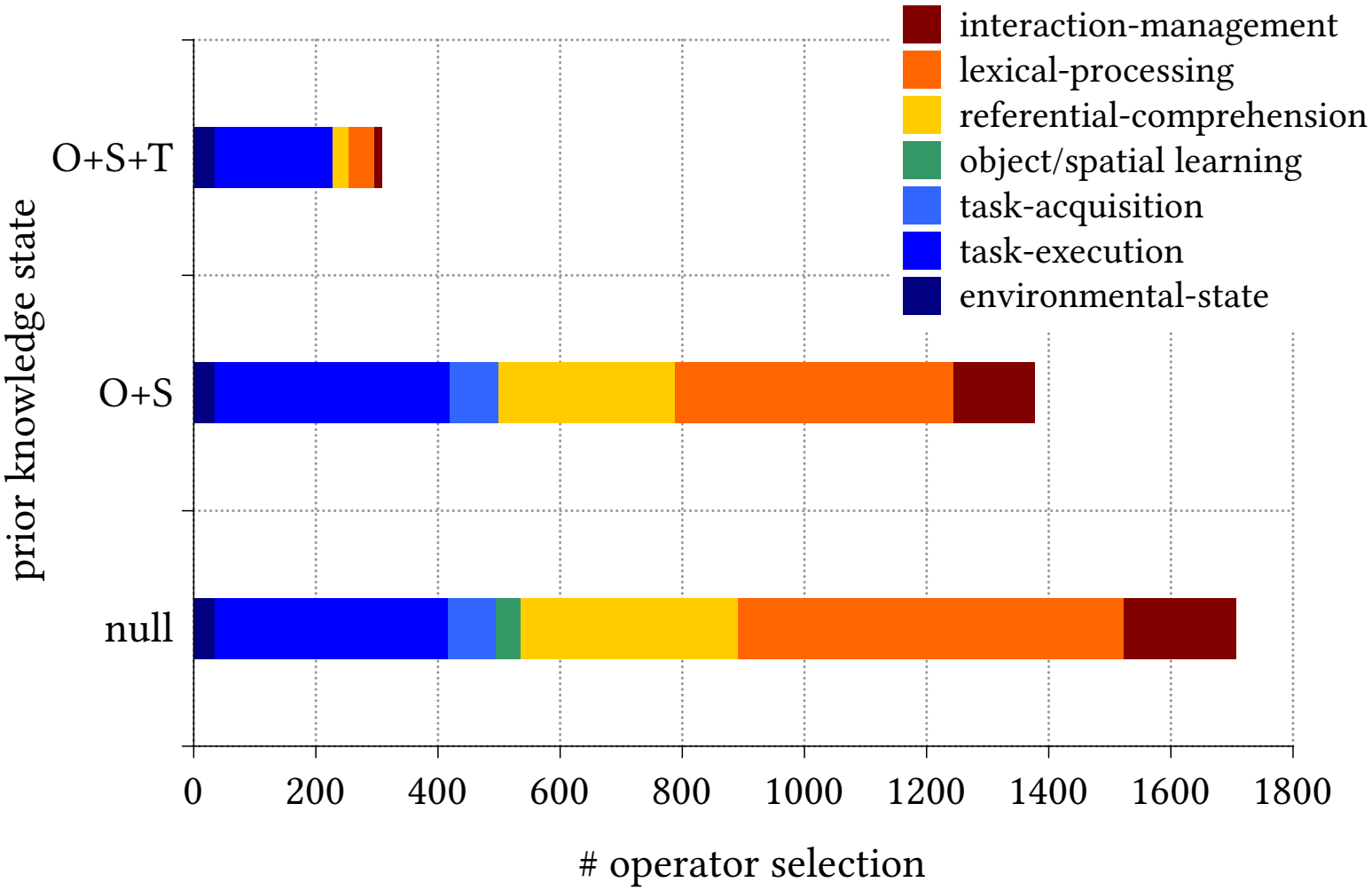
Actions: `Put the red block in the pantry.`

General Representation

- Implicit v/s explicit argumentation
  - `move [obj] to [loc]`
  - `store [obj]`
- Different types of *grounded* goal predicates
  - goal of `store [obj]` is `IN(obj, pantry)` & `closed(pantry)`
- Hierarchical policy
  - `store [obj]`
  - `open(pantry)`, `pick-up(obj)`, `put-down(obj,pantry,IN)`, `close(pantry)`
  - `open(pantry)`, `move(obj,pantry)`, `close(pantry)`

Knowledge-State Sensitive Processing

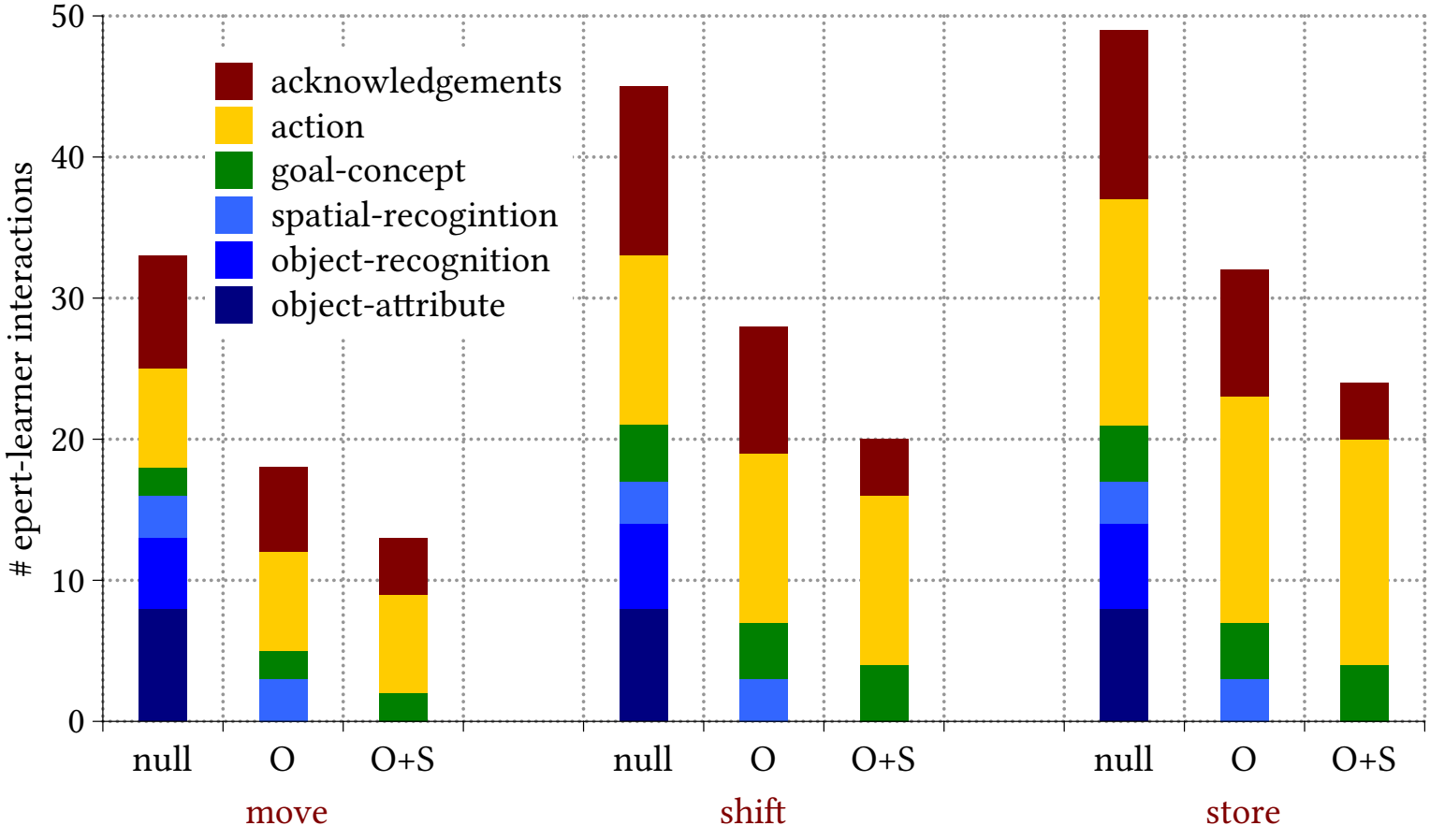
`store[obj]`



O+S+T = objects + spatial reasoning + task (move); O+S = objects + spatial reasoning; null = no knowledge

Flexible Instruction

`move(obj,table)`, `shift(obj,pantry)`, `store(obj)`



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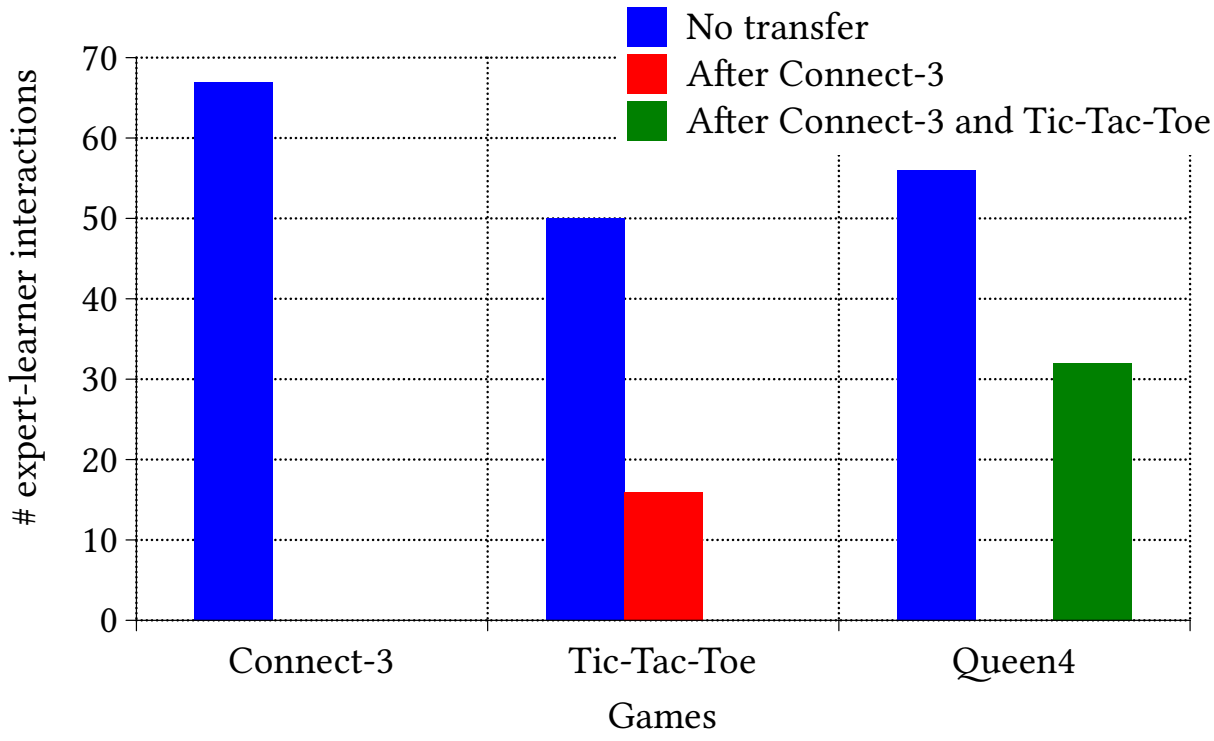
Game Learning

- Learned task-knowledge can be composed together to learn and play games.
- Games taught
  - 5-puzzle, Tic-tac-toe, Frogs and Toad puzzle, Towers of Hanoi, Connect-3, Bishop swap, Queens puzzle
- Transfer in games



- If Tic-tac-toe is taught last, it can be taught in 5 interactions!

Gameplay Demo