# Towards an Architecture for Learning with Instruction

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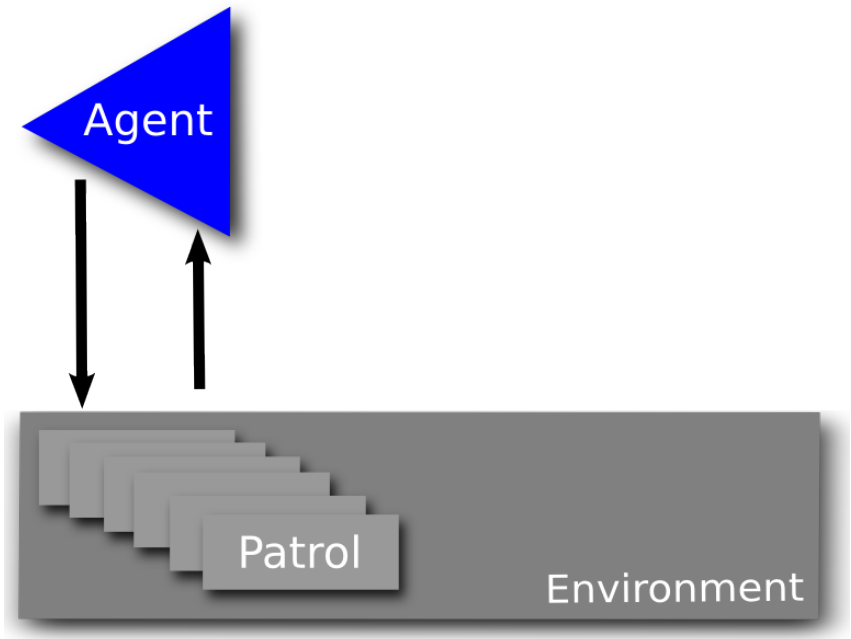
# Outline

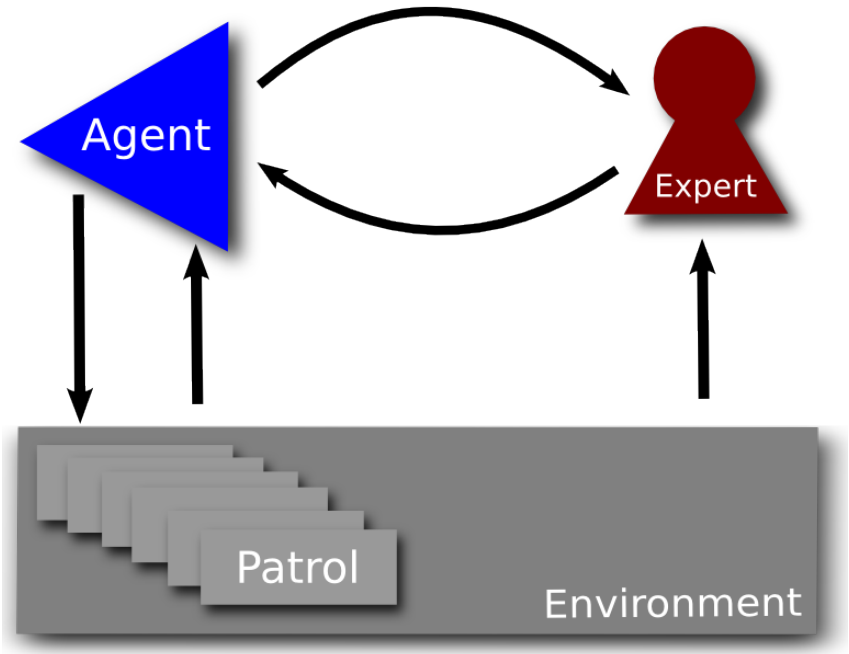
# Motivation

- Long living, general, intelligent agents
  - demonstrate a wide range of behavior
  - on a variety of task
  - knowledge must be added throughout the lifetime of the agent



# Motivation

- Long living, general, intelligent agents
  - demonstrate a wide range of behavior
  - on a variety of task
  - knowledge must be added throughout the lifetime of the agent
- Instruction
  - agent can be *taught* to learn new procedures
  - knowledge/information that can be trusted
  - situated, interactive instruction produces strong human learning[1]
  - semantic, procedural, problem solving etc




[1] Bloom, B. S. (1986). The 2 Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-One Tutoring. *Educational Researcher*, 13(6):4–16

# Related Work

- Robo-Soar[1]
  - search guidance in case of an *operator tie*

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- Task Learning by Instruction: Benefits and Challenges for Intelligent Interactive Systems[4]
  - integration of various learning and reasoning components

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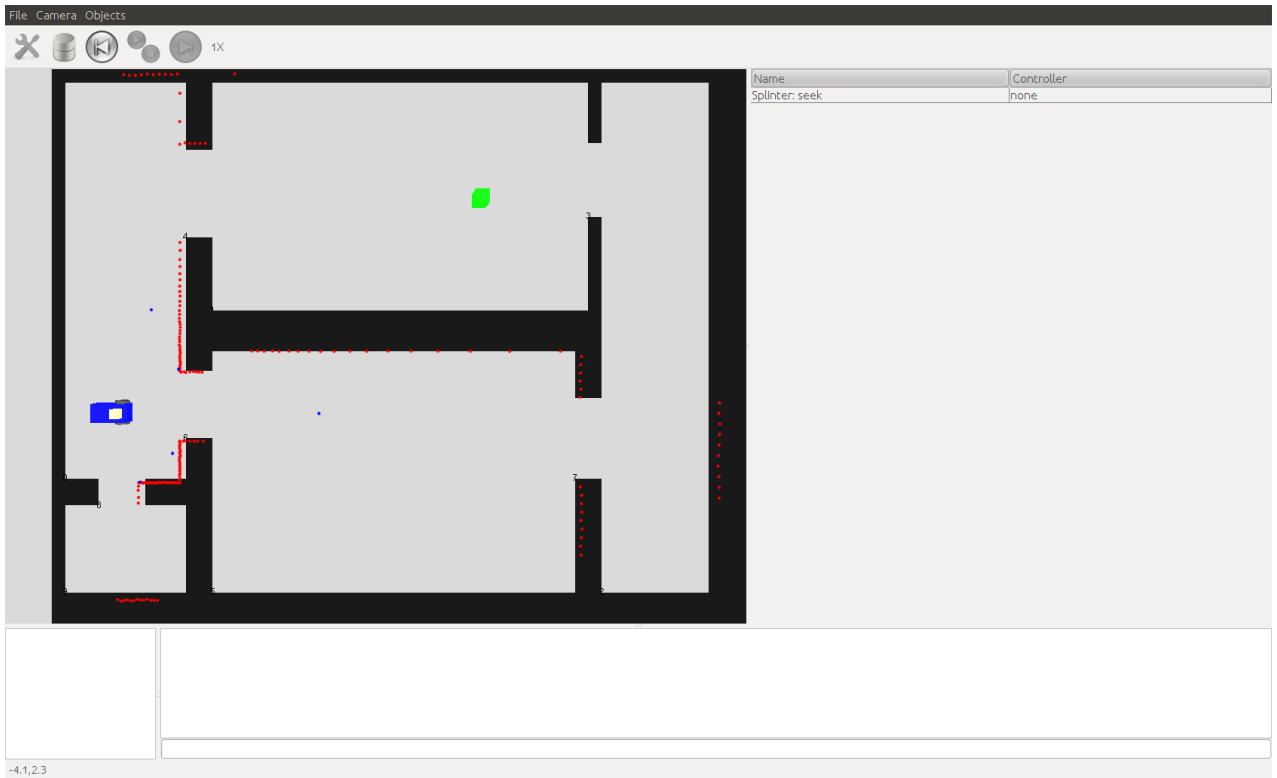
# Domain




**Given** a set of primitive actions:

```
go-to <area-id>, go-to-room <room-id>,
open-door <door-id>, close-door <door-id>,
turn-lights-on, turn-lights-off,
pick-up <object-id>, put-down <object-id>,
```

**Learn** *abstract* actions:

```
patrol [list-of-rooms]
turn-all-lights-off
get-object <object-id>
```

# Goals

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  - different kinds of knowledge, different modes of instruction

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  - inference, chunking, inductive reasoning, explanation-based generalization

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- Develop a comprehensive model of learning that uses different reasoning and learning modules
  - inference, chunking, inductive reasoning, explanation-based generalization
- Develop evaluation metrics

# Characterizing Instructions: Taxonomy

- Scope
  - Tutorial: instruct as the agent is acting [5]
  - Instruction Manual: instruct before the agent begins acting

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- Communication
  - Agent Initiated: agent does not know how to proceed
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- Task Structuring
  - Composite: learn *turn-all-lights-off*
  - Incremental: learn *patrol*, modify *patrol* to include *turning off lights*

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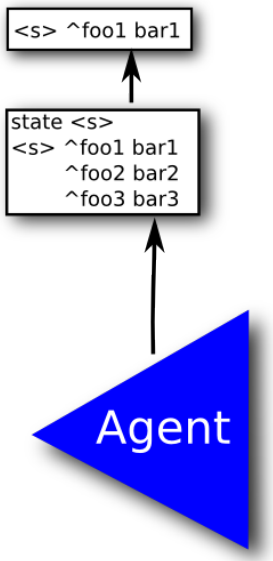
- Knowledge
  - Proposal and goal conditions: *turn-lights-off* when *in a room* and *light is on*
  - Control: *reporting non-friendly persons is more important than picking up objects*
  - Semantic: *objects with color=blue are dangerous*
  - Meta: arguments are sequential, random

# Requirements on Agent Design

- The *Communication* Problem
  - The *Content* Problem
    - What information has to be communicated?
    - Model of the instructor
    - Assumption of shared environment, similar observations

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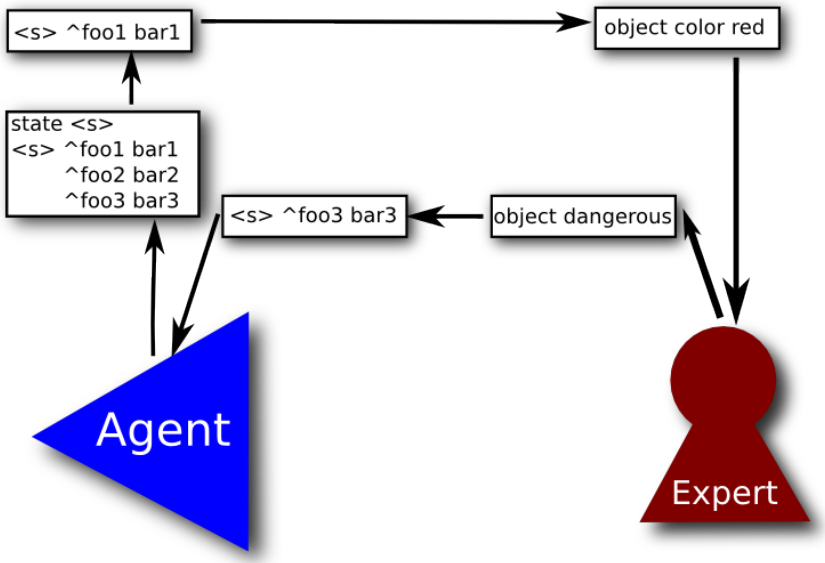

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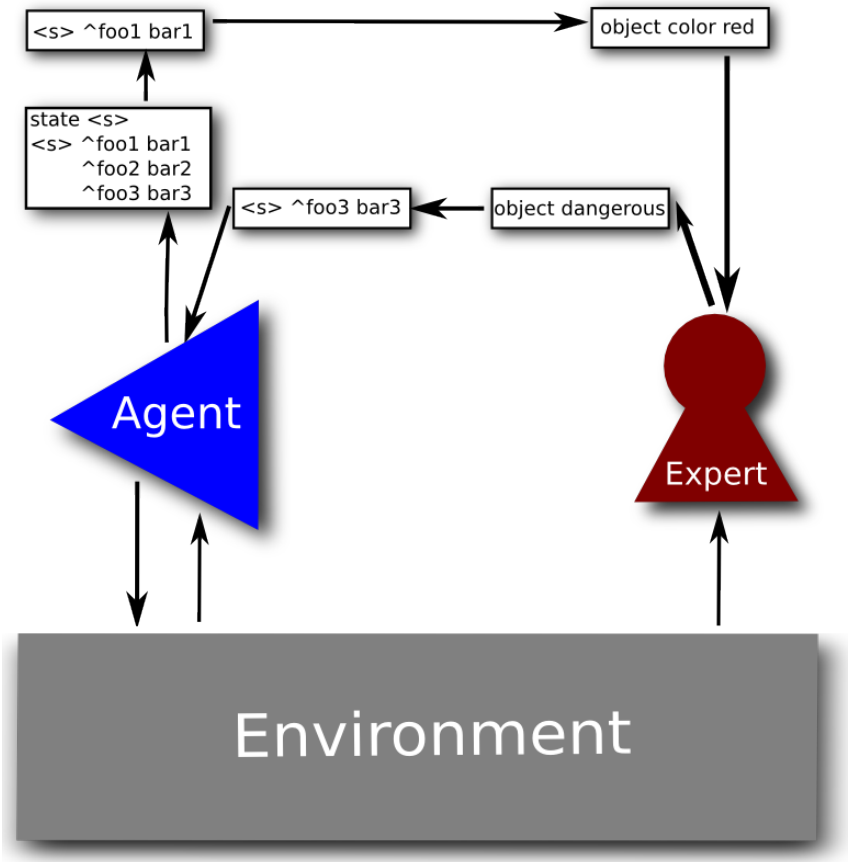
  - The *Interaction* Problem
    - Maintaining a dialog
    - Integrating communication, learning and acting



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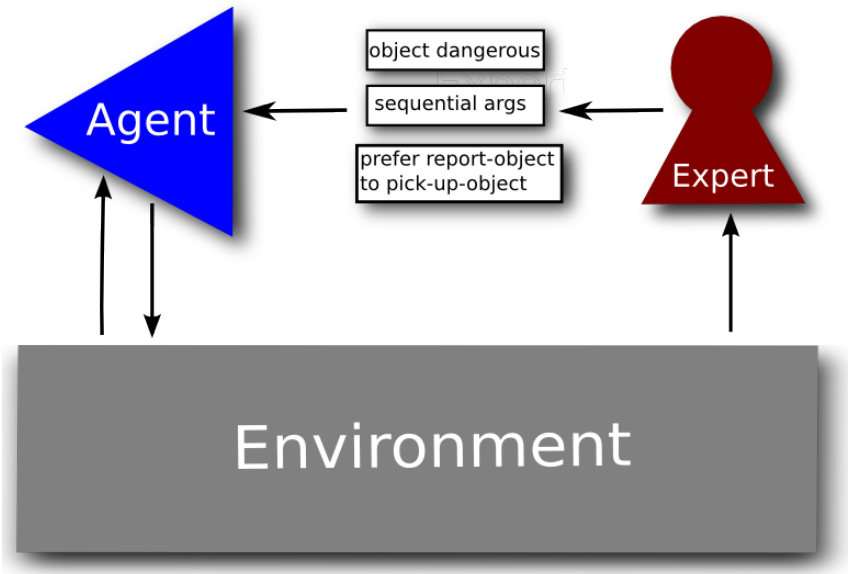
    - Using one kind of knowledge to learn a different kind (semantic → procedural)



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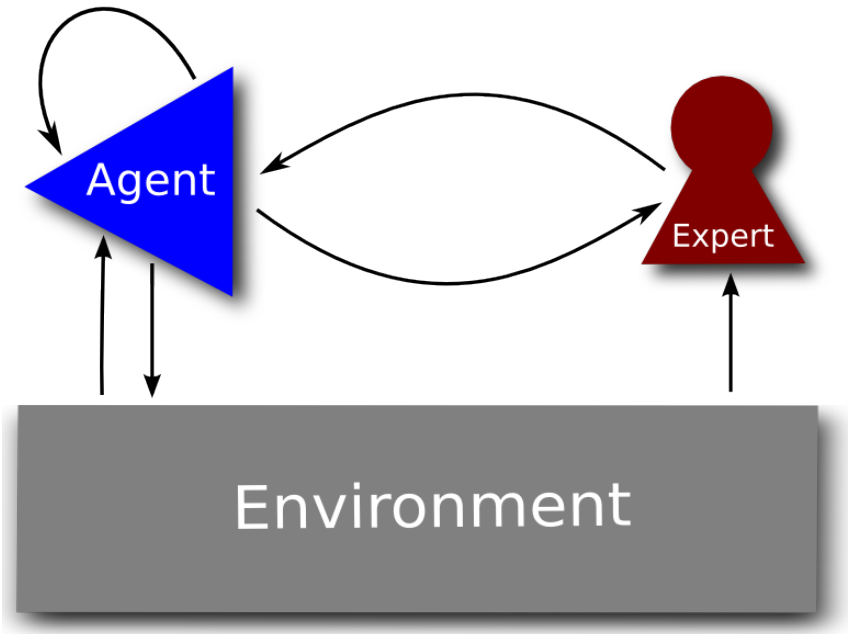
  - The *Transfer* Problem
    - Learning generally applicable knowledge
    - Transfer to appropriate conditions in future



# Learning from Instruction with Soar: An Example

- Learns abstract action, *patrol*

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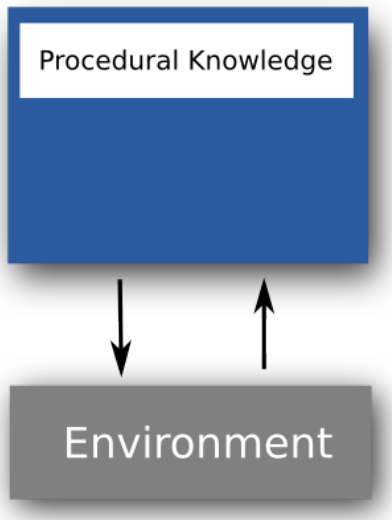
- Soar architecture components
  - Procedural, semantic, working memory

# Knowledge Levels

- Procedural Knowledge
  - Immediate application
  - *state-no-change*: implies lack of procedural knowledge for current state



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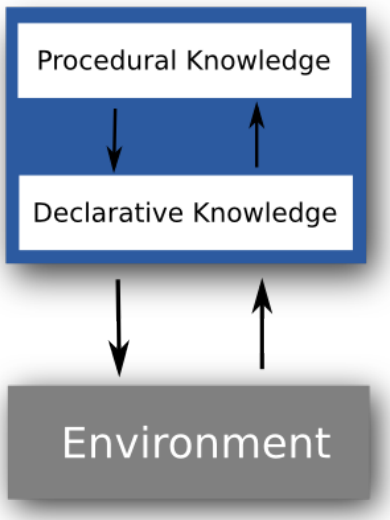

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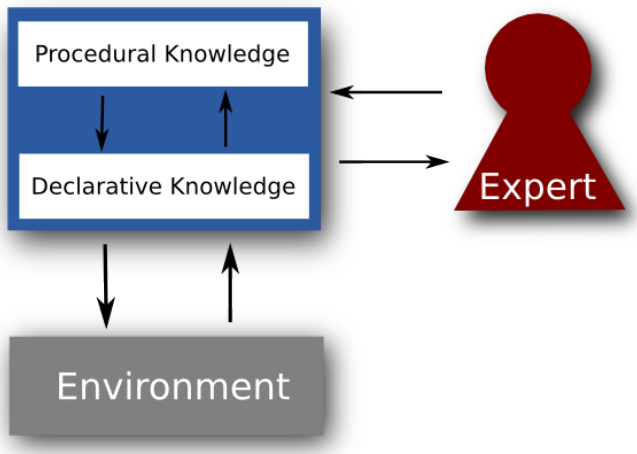
- Human Instructor
  - Deliberate questions
  - Incomplete/incorrect/specific knowledge
    - requires inference
    - generalization
    - *situated explanation* (Huffman and Laird, 1995)[1]

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# The Instruction Cycle

- *Detect* lack of knowledge to proceed further [knowledge]
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- *Explain*: ? [transfer]

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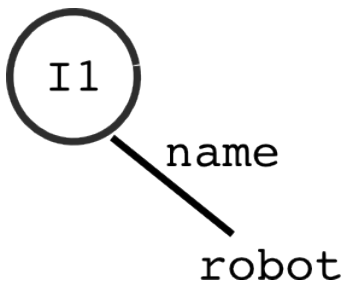
  `state-no-change`



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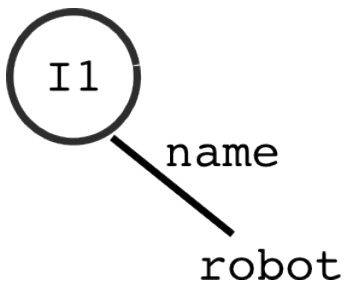

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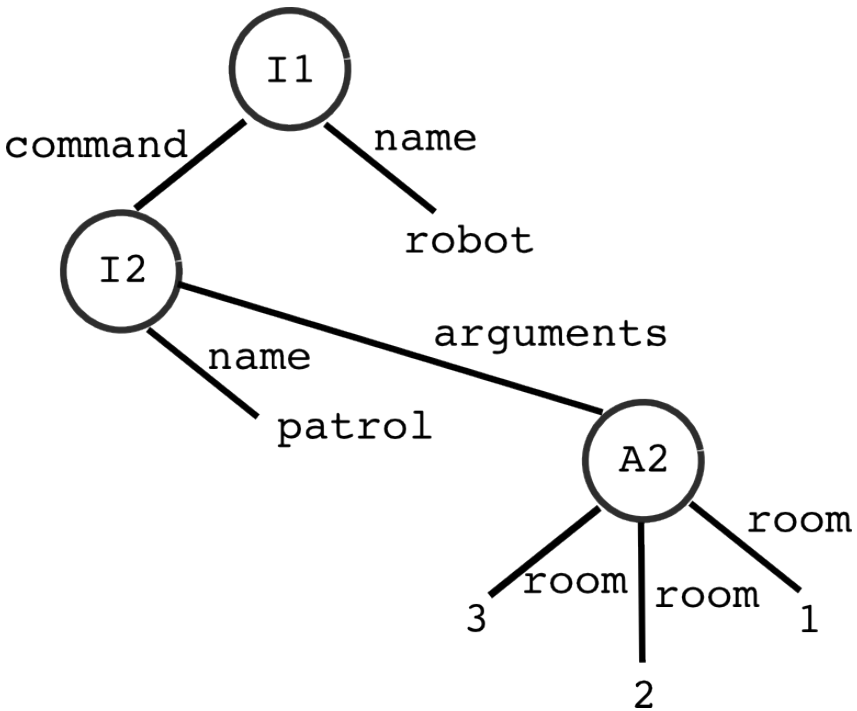
  agent: "robot"
  instructor: "patrol room 1 room 2 room 3"

  S1 (robot): store-instruction



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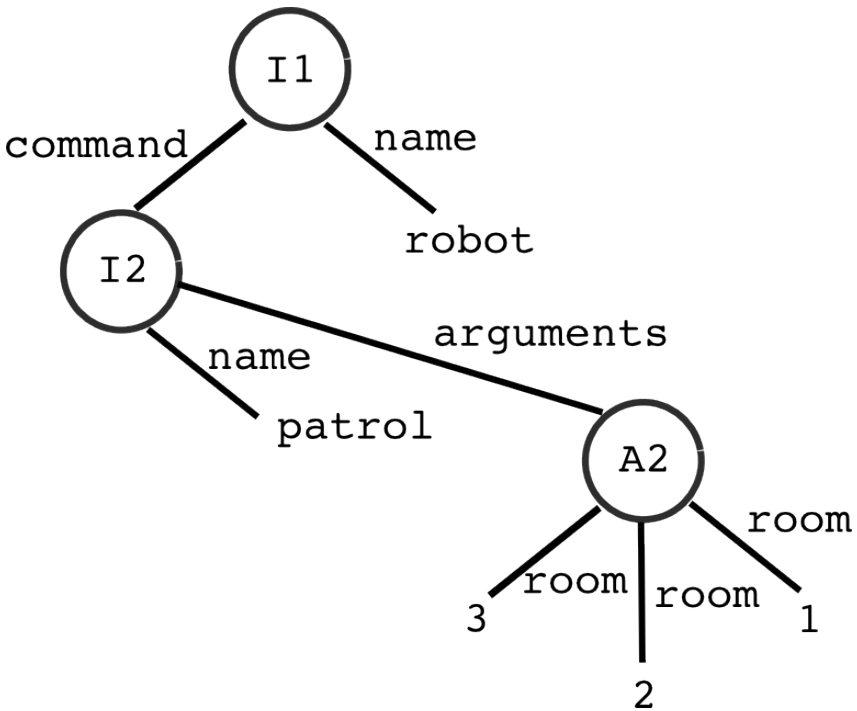

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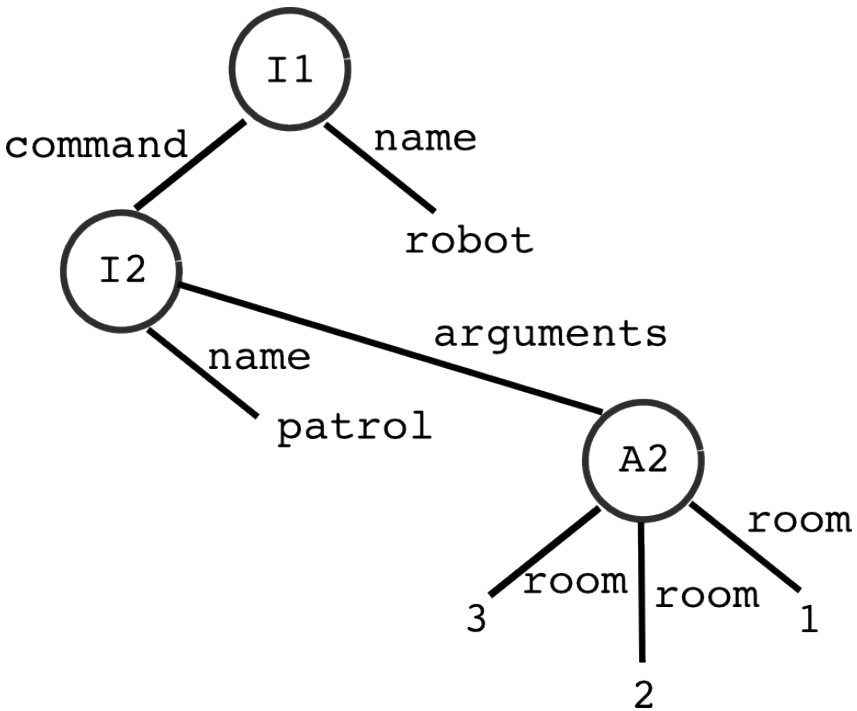
- S2 (lookup-memory): retrieve-next
  success
  S2 (lookup-memory): propose patrol in S1



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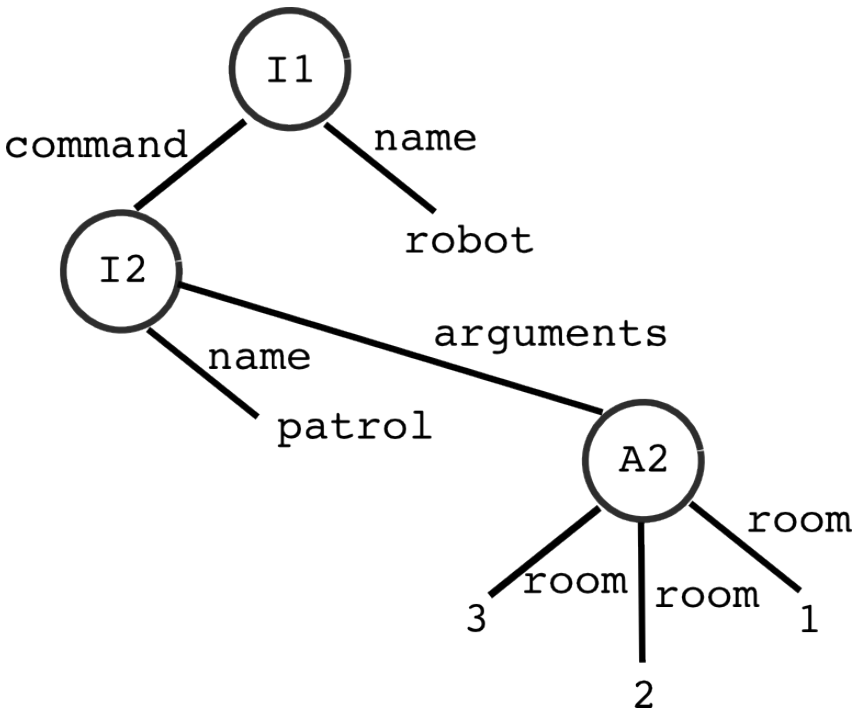
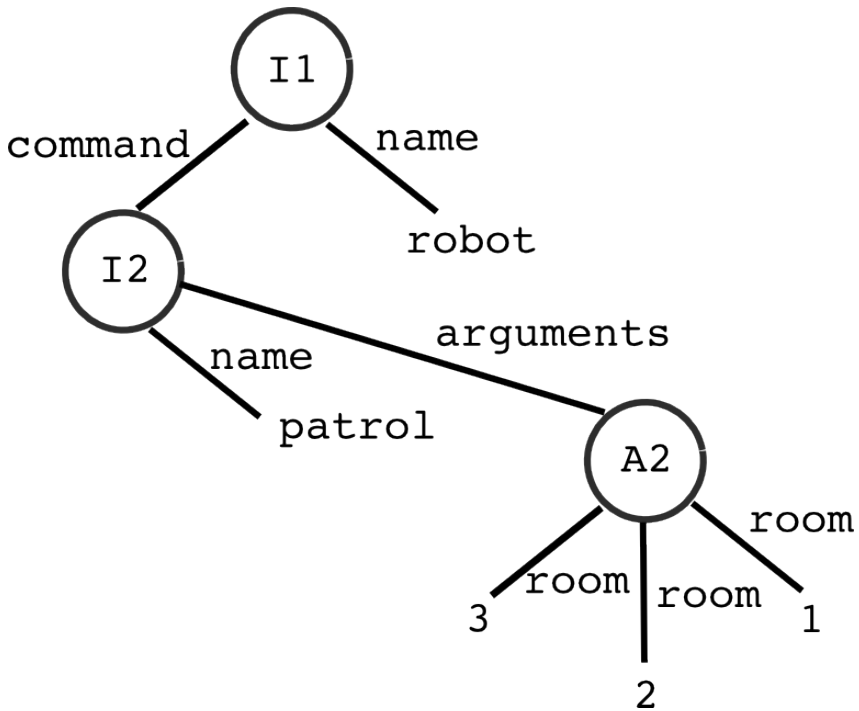
  S2 (lookup-memory): propose patrol in S1
- S1 (robot): patrol
  operator-no-change



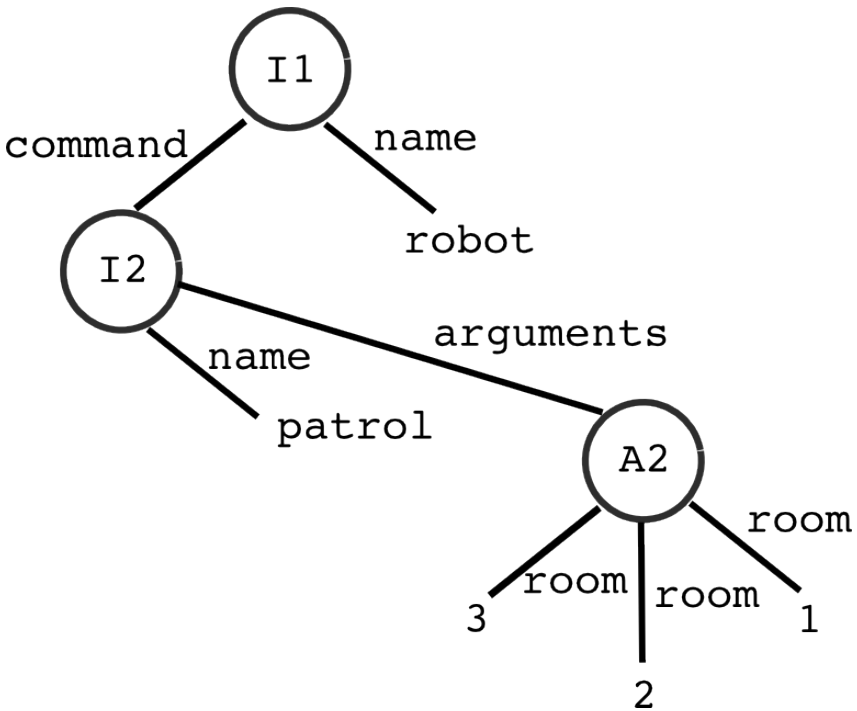
# Example Execution

- `S2 (patrol): ?`
  `state-no-change`



# Example Execution

- `S2 (patrol): ?`
  `state-no-change`
- `S3 (lookup-memory): retrieve-next`
  `failure`
  `S2 (lookup-memory): store-information`

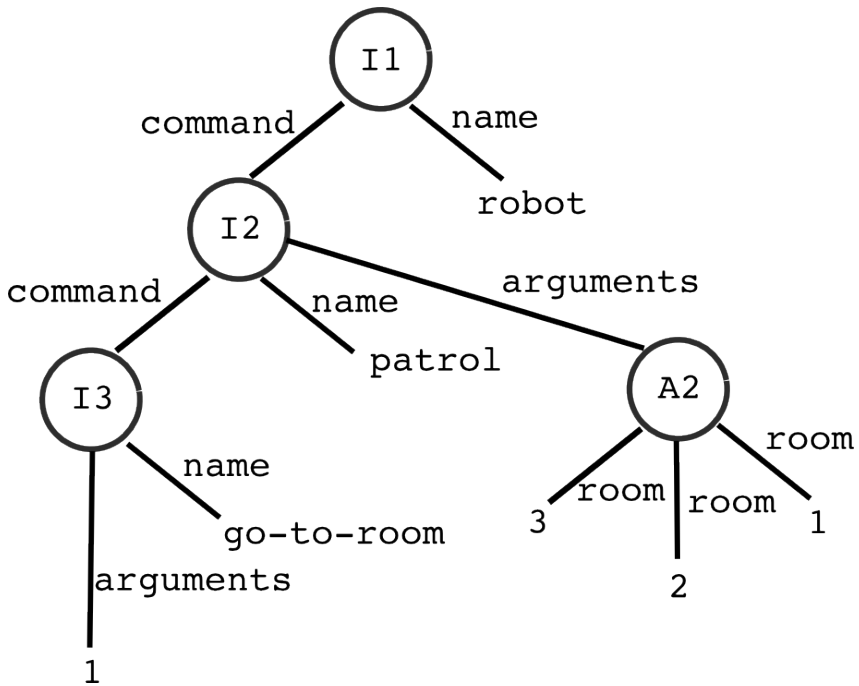


# Example Execution

- S2 (patrol): ?
  state-no-change
- S3 (lookup-memory): retrieve-next
  failure
  S2 (lookup-memory): store-information
- S1 (robot): ask-instructor

  agent: "patrol"
  instructor: "go-to-room 1"

  S1 (robot): store-instruction

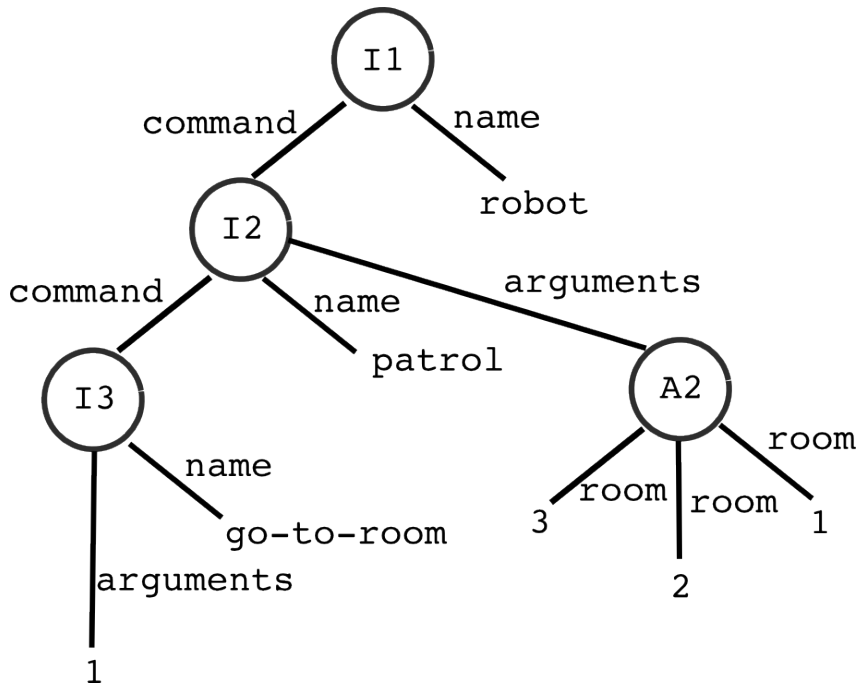


# Example Execution

- S2 (patrol): ?
  state-no-change
- S3 (lookup-memory): retrieve-next
  failure
  S2 (lookup-memory): store-information
- S1 (robot): ask-instructor

  agent: "patrol"
  instructor: "go-to-room 1"

  S1 (robot): store-instruction
- S1 (topstate): ?
  state-no-change

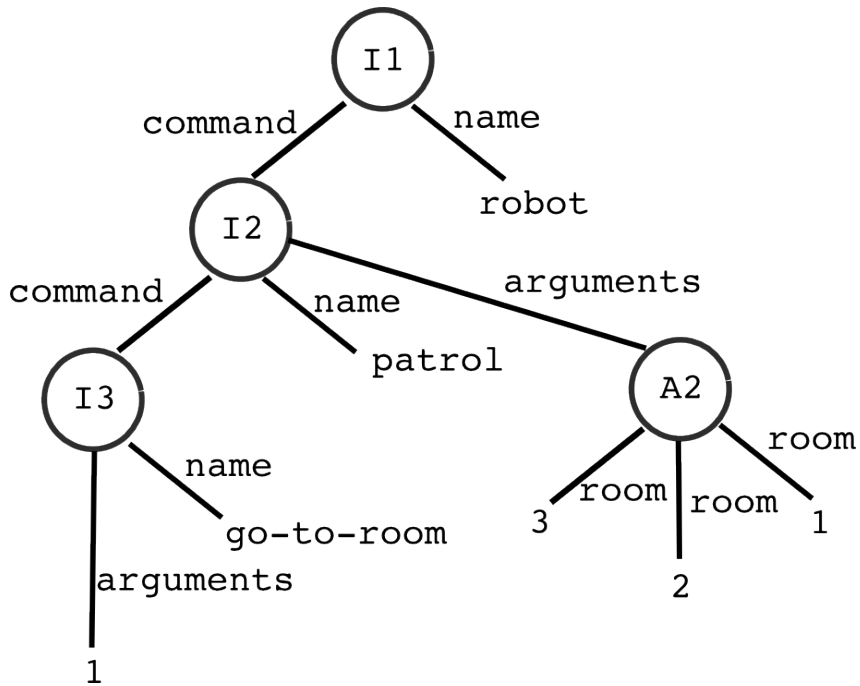


# Example Execution

- S2 (patrol): ?
  state-no-change
- S3 (lookup-memory): retrieve-next
  failure
  S2 (lookup-memory): store-information
- S1 (robot): ask-instructor

  agent: "patrol"
  instructor: "go-to-room 1"

  S1 (robot): store-instruction
- S1 (topstate): ?
  state-no-change
- S2 (lookup-memory): retrieve-next
  success
  S2 (lookup-memory): propose patrol in S1

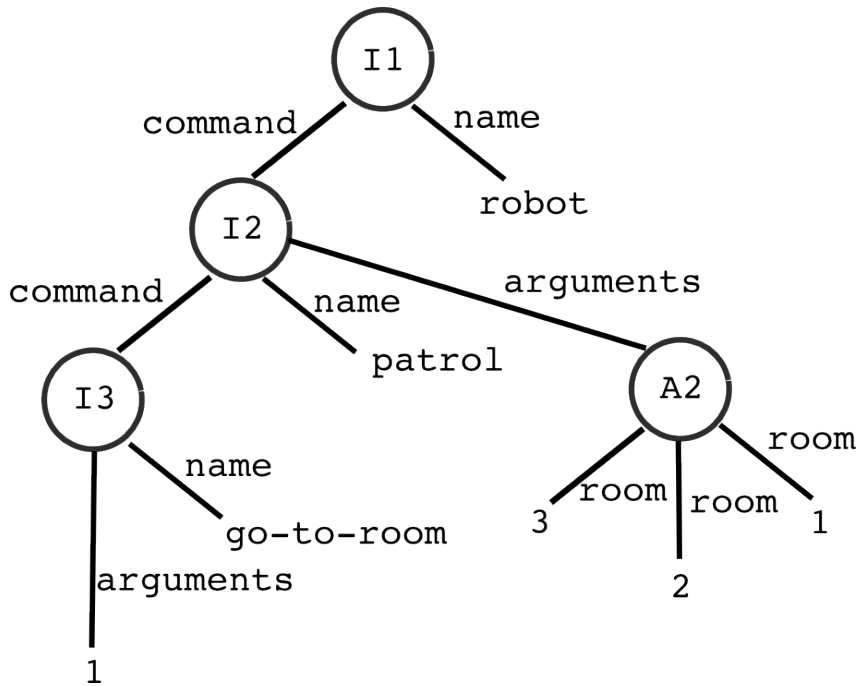


# Example Execution

- S2 (patrol): ?
  state-no-change
- S3 (lookup-memory): retrieve-next
  failure
  S2 (lookup-memory): store-information
- S1 (robot): ask-instructor

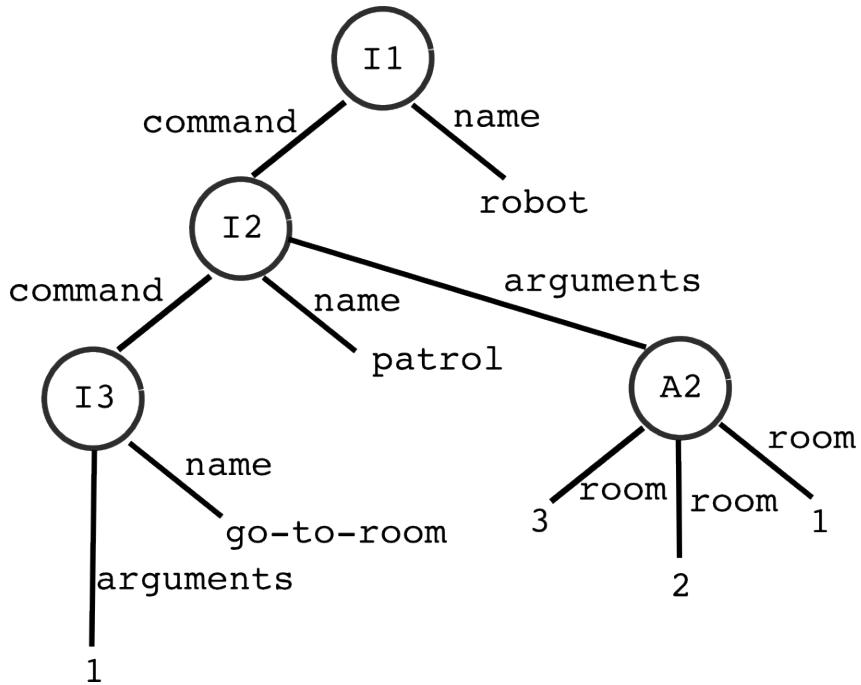
  agent: "patrol"
  instructor: "go-to-room 1"

  S1 (robot): store-instruction
- S1 (topstate): ?
  state-no-change
- S2 (lookup-memory): retrieve-next
  success
  S2 (lookup-memory): propose patrol in S1
- S1 (robot): patrol
  operator-no-change



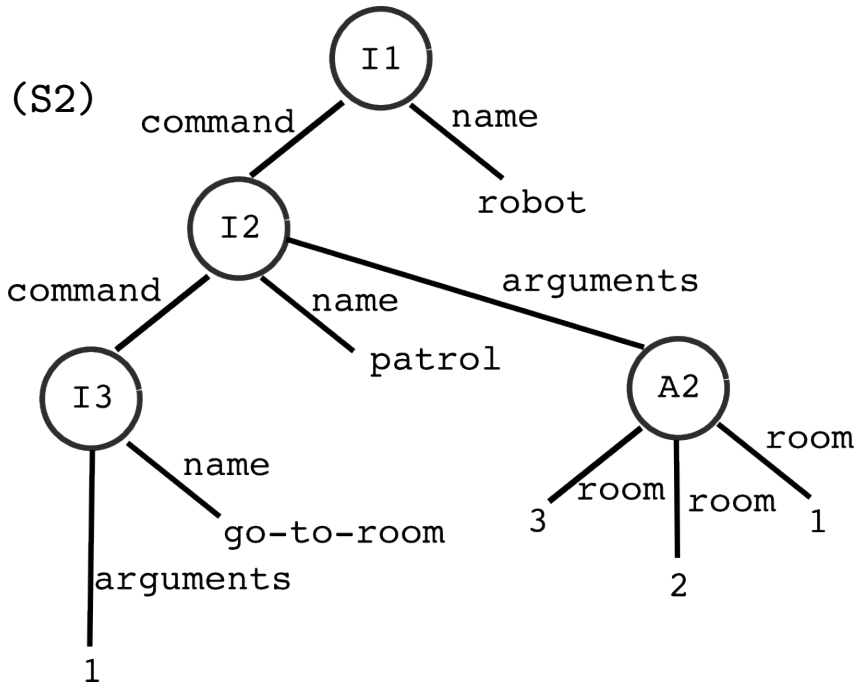
# Example Execution

- `S2 (patrol): ? state-no-change`



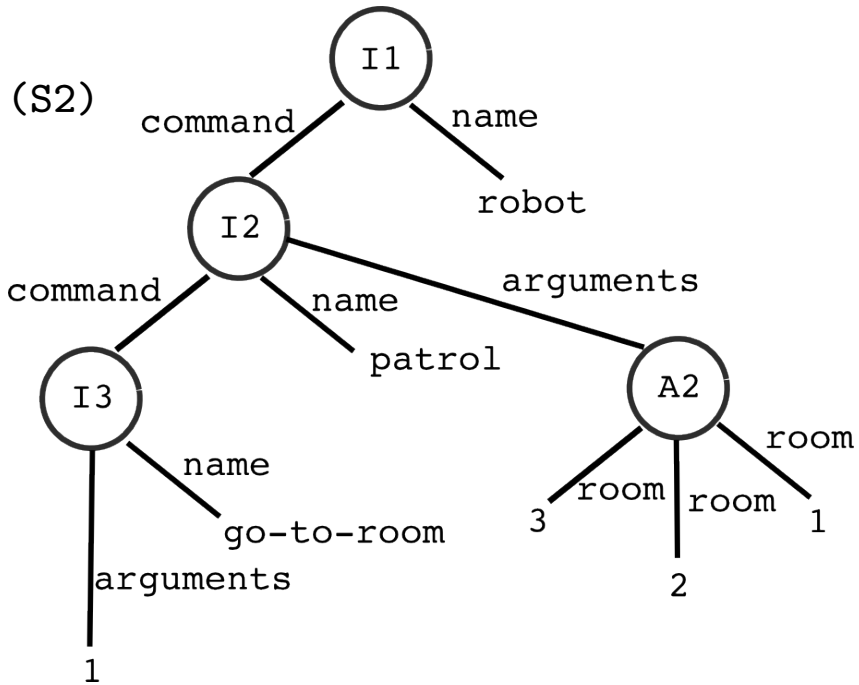
# Example Execution

- `S2 (patrol): ?`
  `state-no-change`
- `S3 (lookup-memory): retrieve-next`
  `success`
  `S2 (lookup-memory): propose go-to-room 1 (S2)`



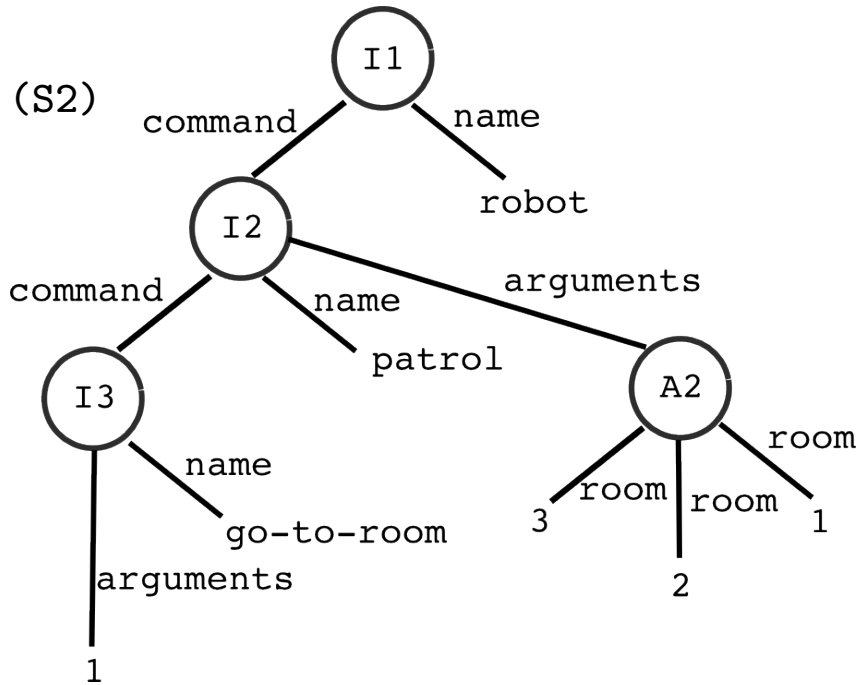
# Example Execution

- S2 (patrol): ?
  state-no-change
- S3 (lookup-memory): retrieve-next
  success
  S2 (lookup-memory): propose go-to-room 1 (S2)
- S2 (patrol): go-to-room 1
  S2 (patrol): ?
  state-no-change



# Example Execution

- S2 (patrol): ?
  state-no-change
- S3 (lookup-memory): retrieve-next
  success
  S2 (lookup-memory): propose go-to-room 1 (S2)
- S2 (patrol): go-to-room 1
  S2 (patrol): ?
  state-no-change
- S3 (lookup-memory): retrieve-next
  failure
  S2 (lookup-memory): store-information

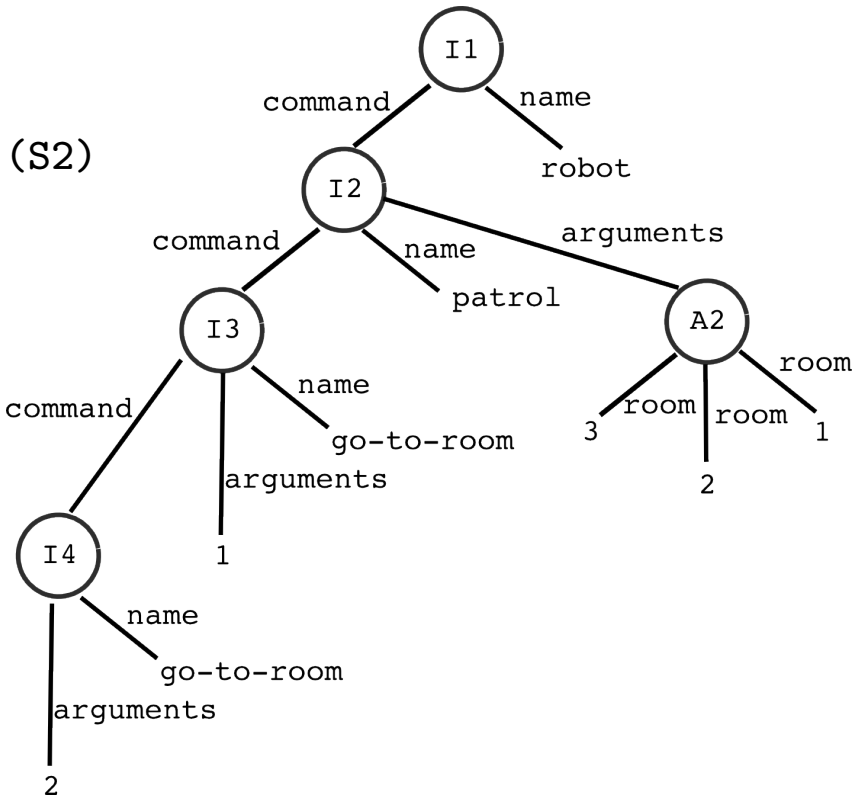


# Example Execution

- S2 (patrol): ?
  state-no-change
- S3 (lookup-memory): retrieve-next
  success
  S2 (lookup-memory): propose go-to-room 1 (S2)
- S2 (patrol): go-to-room 1
  S2 (patrol): ?
  state-no-change
- S3 (lookup-memory): retrieve-next
  failure
  S2 (lookup-memory): store-information
- S1 (robot): ask-instructor

  agent: "go-to-room 1"
  instructor: "go-to-room 2"

  S1 (robot): store-instruction

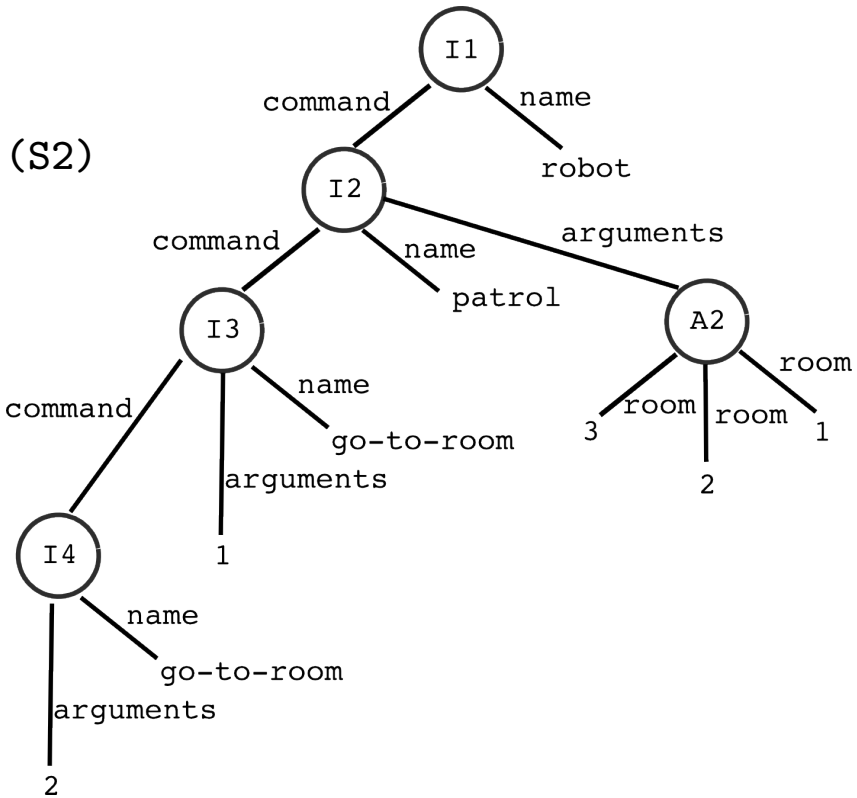


# Example Execution

- S2 (patrol): ?
  state-no-change
- S3 (lookup-memory): retrieve-next
  success
  S2 (lookup-memory): propose go-to-room 1 (S2)
- S2 (patrol): go-to-room 1
  S2 (patrol): ?
  state-no-change
- S3 (lookup-memory): retrieve-next
  failure
  S2 (lookup-memory): store-information
- S1 (robot): ask-instructor

  agent: "go-to-room 1"
  instructor: "go-to-room 2"

  S1 (robot): store-instruction
- ...



# Conclusions

- Limitations
  - very limited in scope
  - learns by rote
  - agent initiated communication only

# Conclusions

- Limitations
  - very limited in scope
  - learns by rote
  - agent initiated communication only
- Future Work
  - Understanding and solving the *transfer* problem for this instruction set
  - Using episodic memory
  - More detailed investigation of various kinds of instruction

# Nuggets and Coal

- Nuggets
  - Have a proof of concept of how instruction can be used for acting
  - Learns ‘patrol’ and can learn other commands in a similar fashion
- Coal
  - Cannot learn general conditions yet
  - Not a good idea of what the goal of ‘patrol’ is