Representing and Reasoning with Intentional Actions on a Robot

PlanRob - Architectures and Frameworks
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Talk Outline

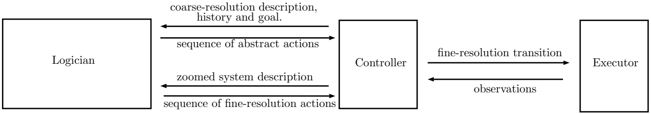
- Motivation and architecture overview.
- Knowledge representation and reasoning.
- Adapted Theory of Intentions.
- Experiments and conclusions.

Architecture Overview

Design architecture for robots that:

- Use qualitative and quantitative descriptions of incomplete knowledge to improve quality and efficiency of decision making.
  "books are usually in the library"
  "I am 90% certain the book is on the table"
- Work in complex dynamic domain where unexpected things happen.
- Receive more sensor data than it can handle at reasoning level.

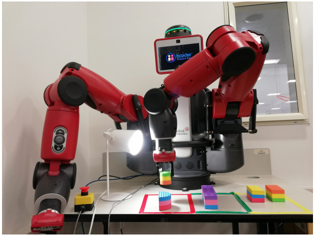
Architecture Overview



Architecture Overview

- Combine strengths of declarative programming and probabilistic models.
- Formal relationship between transition diagrams. Tight coupling, not a "switch".
- Support non-monotonic logic and probabilistic representations of incomplete domain knowledge and uncertainty.
- Interactive and cumulative relational learning; classical and reinforcement, procedural and knowledge-based.
- Implemented on robots interacting with dynamic environmetns, and in simulation.

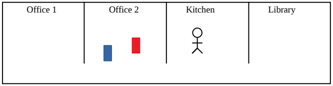
Illustrative Domain: Robot Moving Objects



- Robot assistant moving objects to specific places.
- Sorts: $robot$, $place$, $object$, $entity$, $book$ etc; hierarchical arrangement.
- Instances, e.g., place = $\{office, kitchen, library\}$ or $\{red\_area, green\_area, yellow\_area\}$ for tabletop manipulatior.

Illustrative Domain: Robot Moving Objects

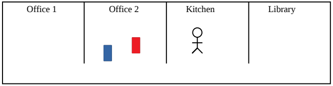
Let us assume that the robot is in the *kitchen* and its goal is to put the two books in the *library*.



In traditional planning the robot would:

- Create a plan as a sequence of actions, taking into consideration current beliefs and goal.
- Execute the actions of the sequence until one action does not have the expected output.
- Replan if necessary.

Illustrative Domain: Robot Moving Objects



In a dynamic domain we can have different scenarios:

- While the robot is moving the first book, the second book is moved to the library (unexpected success).
- While to robot is moving the first book, the second book is moved to office 1 (not expected to achieve goal - case 1).
- While to robot is moving the first book, the second book is moved to the kitchen (not expected to achieve goal - case 2).
- The robot moves the first book in the library, and when he is putting down the second book, the first book is being moved to another room(failure to achieve the goal).

Action Language AL_d

- Formal models of parts of natural language used for describing transition diagrams.
- Hierarchy of basic sorts, statics, fluents (basic and defined) and actions.
- Five types of statements:
  - Deterministic causal law.
  - Non-deterministic causal law.
  - State constraint.
  - Definition.
  - Executability condition.

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Logician's System Description

- Collection of statements of AL_d forms system description $\mathscr{D}_H$, includes sorted signature Σ_H and axioms.

- Statics: $next\_to(kitchen, library)$.

- Fluents:
  $loc : robot \rightarrow place$
  $in\_hand : robot \times book \rightarrow boolean$

- Actions:
  $move(robot, place)$
  $pickup(robot, book)$

Logician's System Description

- Causal laws:

$$move(rob_1, Pl) \ \textbf{causes} \ loc(rob_1) = Pl$$
$$pickup(rob_1, B) \ \textbf{causes} \ in\_hand(rob_1, B)$$

- State constraints:

$$loc(B) = Pl \ \textbf{if} \ loc(rob_1) = Pl, \ \ in\_hand(rob_1, B)$$
$$loc(Th) \neq Pl_1 \ \textbf{if} \ loc(Th) = Pl_2, \ Pl_1 \neq Pl_2$$

- Executability conditions:

$$\textbf{impossible} \ \ pickup(rob_1, O) \ \textbf{if} \ loc(rob_1) \neq \ loc(O)$$
$$\textbf{impossible} \ \ pickup(rob_1, O1) \ \textbf{if} \ in\_hand(rob_1, O2)$$

Logician’s Reasoning

Refine + Zoom

- Examine system description ($\mathscr{D}_H$) at finer resolution ($\mathscr{D}_L$).
- Inherit knowledge; add knowledge fluents and actions.
- Automatically zoom to $\mathscr{D}_{LR}(T)$ relevant to $T = \langle \sigma_1, a^H, \sigma_2 \rangle$.
- Formal relationships between descriptions.

POMDP Construction

- $\mathscr{D}_{LR}(T)$ and statistics to construct Partially Observable Markov Decision Process (POMDP) tuple $\langle S^L, A^L, Z^L, T^L, O^L, R^L \rangle$.
- Add observed outcomes to $\mathscr{H}$ to be used by logician.

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Adapted Theory of Intentions

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Experimental Results: Sepeed and accuracy

Advantages of Methodology

Conclusions + Future Work

- **Conclusions:**

- **Future Work:**

That's all folks!