Dealing with Ambiguity in Plan Recognition under Time Constraints

Moser S. Fagundes, Felipe Meneguzzi, Rafael H. Bordini, Renata Vieira
Pontifical Catholic University of Rio Grande do Sul
Plan Recognition

- Broader Context: Plan, Activity and Intent Recognition

- Activity Recognition - deals with current (often low-level) actions

- Plan Recognition - deals with high-level complex goals

- Intent Recognition - deals with the relation between current plans and the plan library

- In this paper, we talk (mostly) about the latter two areas
Plan Recognition - Terminology

- Observation - input from the environment
- Plan Library (PL) - domain knowledge about the subject being observed, often represented as a directed (possibly cyclic) graph
- Plan Step - one node in the plan library graph
- Plan Hypothesis - a sequence of plan steps consistent with both the Plan Library and the Observations
Motivation for our Work

• Recognition often tied to **doing something** about recognized plans (or plan hypotheses)

  • Assistance (when observed subject is benign)
  
  • Countermeasures (when observed subject is adversarial)

• Responses usually not instantaneous

  • Observer agent needs to reason about plan hypotheses and time
Background: Symbolic Plan Recognition

- Symbolic Behavior Recognizer (SBR) by Avrahami-Zilberbrand and Kaminka
- Hybrid plan recognition approach
- Uses a decision tree (FDT) to map observations into plan-steps in the PL
- Allows quick response for plan-library membership queries
- Used for anomalous behavior identification
Recognizer Architecture

- We leverage SBR into an overall recognizer architecture, including:
  - Actual plan recognition
  - Interaction for disambiguation
  - Response to recognition
  - Estimation of recognition time
  - Assessing plan likelihood
Assessing Time to Recognize

• Assumption: observations are made at regular time intervals

• Basic approach, at every time step:
  • Collect observations and average times (CE Table)
  • Match observations to plan library nodes (via FDT)
  • Tag plan steps with time stamp and actual observation

• When only one hypothesis remains, update ERT Table using a reinforcement update: 
  \[ e[\text{“ert”}] \leftarrow (1 - \alpha(e[\text{“nupd”}]))e[\text{“ert”}] + \alpha(e[\text{“nupd”}]) \text{avg} \]
Assessing Time to Recognize

- ERT Table associates, for each “initial observation”, an average recognition time

- Example:
  - In a single episode observations "location(2,3)" mapped to “position” action in the PL averaged \textbf{15 time steps} before recognition
  - Over many episodes, this average resulted in an expected recognition time of \textbf{13.15 time steps}
Assessing Probability of Plan Selection

• In each recognition episode we keep track of:
  • the number of times a node in the plan library was updated with ERT; and, from this count
  • the number of times a node in the plan library was actually part of a successfully recognized plan

• This allows us to estimate how likely a hypothesis leads to a successful recognition using

\[
\text{maxChance}(t) = \max_{e \in CE(t, l)} \frac{e[nps]}{\sum_{e_i \in CE} e_i[nps]}
\]
Interaction Component

• The Interaction Component uses the probability and the estimated recognition time to:
  
  • compute the “value” of current plan recognition hypotheses
  
  • decide whether to disturb the observed subject or not;
  
  • Decision uses a combination of parameters and estimations made by our algorithm
Bringing it all Together

• Given the expected recognition time at a step $ert(t)$, a recognition deadline $\rho(t)$, a maximum chance for a successful hypothesis $maxChance(t)$ and a decision threshold $\phi$,

• The observer agent can decide whether to interrupt the user based on two criteria:

  • $ert(t) \leq \rho(t)$ - whether the expected time is lower than the deadline; and

  • $maxChance(t) \geq \phi$ - whether the maximum chance is greater than a threshold
Conclusions

• Our main contributions are:
  
  • A plan recognition algorithm and surrounding architecture that
    
    • Estimates time until a plan can be recognized in various contexts
    
    • Provides a probability estimation for plan recognition
    
    • Providing decision criteria on whether to interrupt a user to disambiguate multiple plan hypotheses
Future Work

• Take into account interleaved plan execution and lossy observations
• Evaluate the architecture with human-generated data
Questions?