A Formal Theory of Goal Abandonment for Intent Recognition for Elder Care

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Talk Outline

ï Requirements

ï Background on Probabilistic Hostile Agent Task Tracker (PHATT)

ï Recognizing plan goal abandonment

ï High Level Thesis: We need to be able to do high level inference of the goals/plans of an elder in order to be able to provide reasonable context dependent assistance to the elder and care giver. This requires that we confront some issues that have not previously been confronted in plan recognition.

ï Low Level Thesis: A formal model of recognizing plan/goal abandonment in plan recognition systems.

Previous takes on goal abandonment

ï Only worry about the current goal: Horvitz è98

ñ Just trying to assist with the single current goal

ï Assume that the agent only has one goal: Conati è97

ñ Fine in tutorial systems where their goal is to learn

ï Assume the agent will come back: Kautz and Allen è86

ñ Functionally assuming that no goals are abandoned

ï Rely on a cooperative agent for disambiguation: Lesh è01

ñ Fine if you can assume cooperative agents

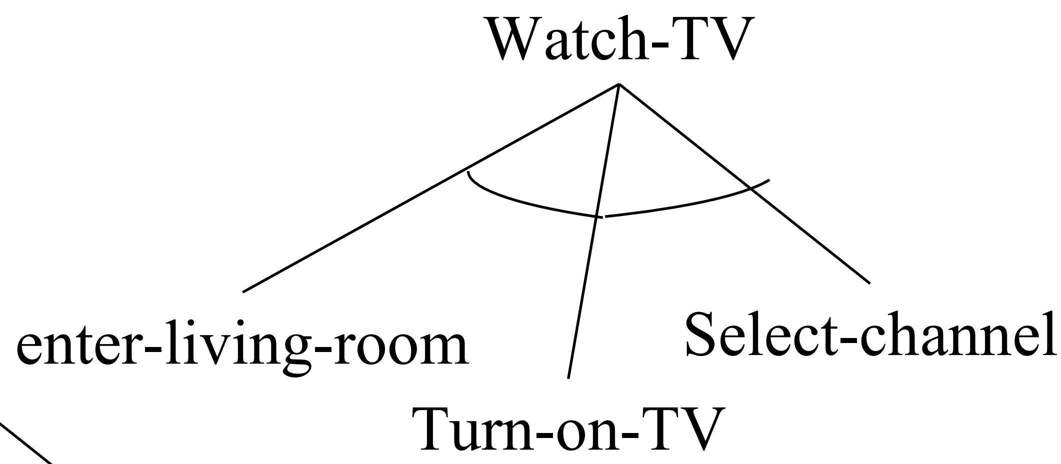
PHATT Background: plan library

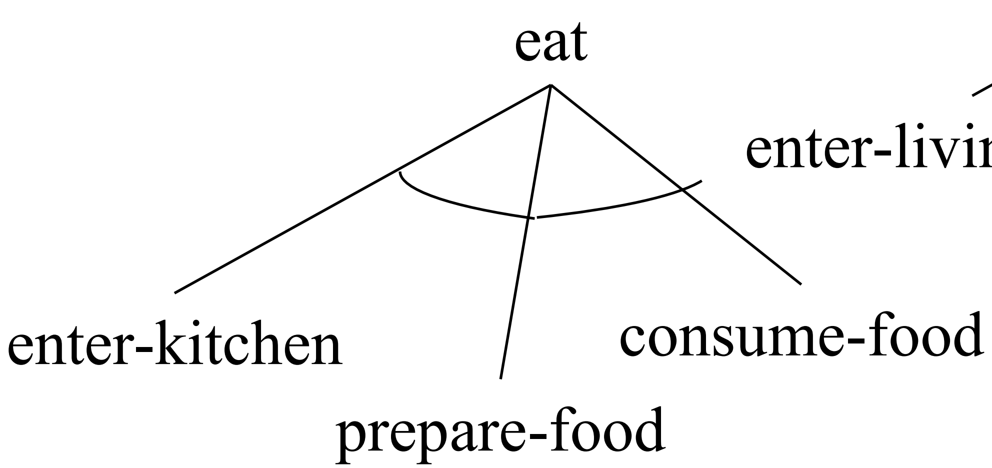
ï And/Or tree representation of the set of possible plans that could be used by the agent to be watched.

ï Distinguished nodes of the trees (most often the roots) represent the agentís possible goals,

ï Partial ordering constraints

ï Effects of select actions



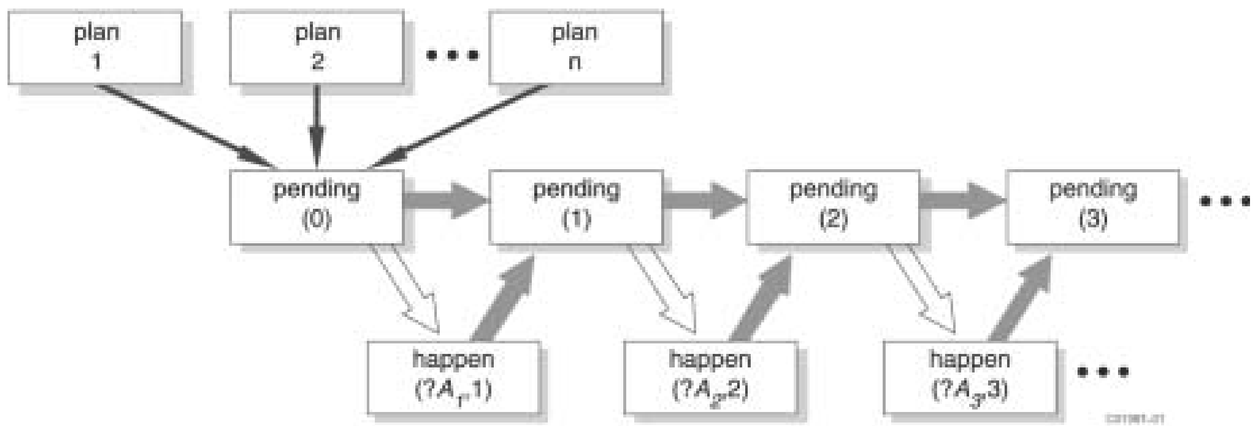


PHATT Background: Pending sets

ï Central Insight: the agents only execute actions that are consistent with their goals and are enabled by the previous actions they have performed.

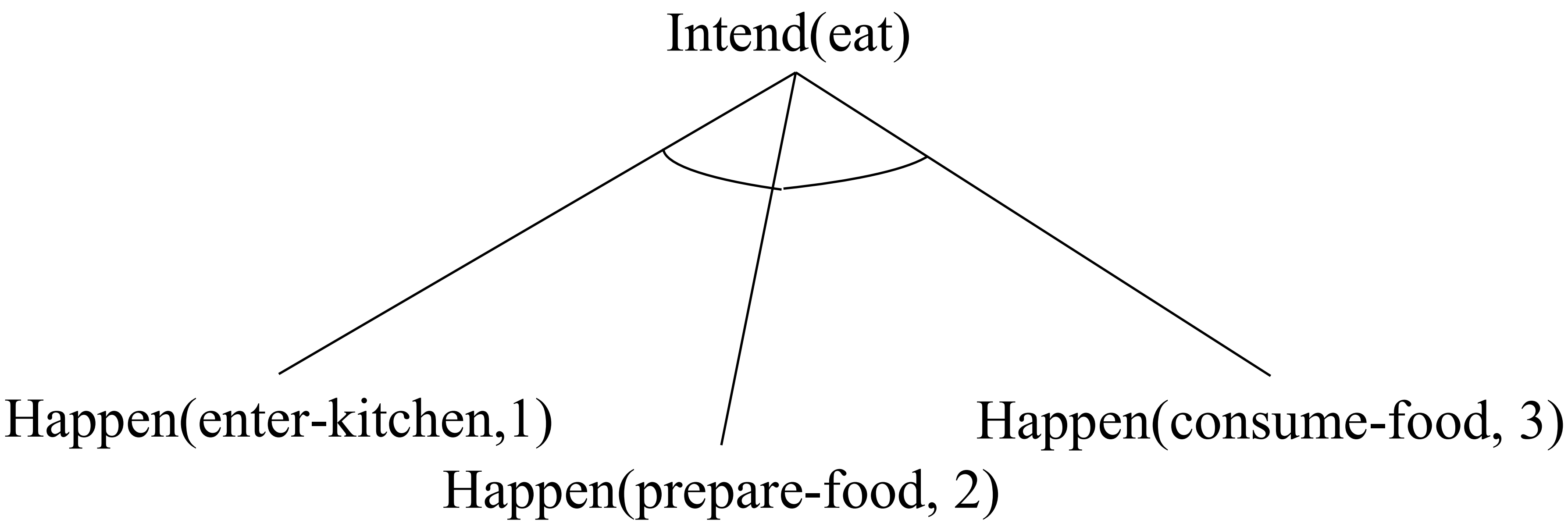
ï We define a ***pending set*** as the set of actions that are currently enabled by the agentís hypothesized goals and the actions the agent has taken.

ï If we know the goals of an agent, we can perform a probabilistic simulation of the actions of a goal directed agent.



PHATT Background: explanations

- Define: an ***Explanation*** for a set of observations as the substructure of the plan library with pending sets and hypothesized goals sufficient to explain the current set of observed actions.
- Example: observed **enter-kitchen, prepare-food, consume-food**



PHATT Background: algorithm intuition

ï To infer goals: given the set of observations we can build the complete, exclusive and exhaustive set of the explanations for the observed actions. Infering pending sets and resulting goals along the way.

ñ Probability note (POMDP)

ï Establish the probability of each of the explanations (P(Exp).)

ï The conditional probability of the goal given the observations is just the sum of those explanations that have the goal divided by the probability of the observations. (P(Goal | Observations))

PHATT Background: what probabilities?

- Not many that you have to know and they are easy to get
  - Prior probability of a given intention or
  - The conditional probability of the intention given a state of the world

- The other probabilities that we need we can compute:
  - The probability of choosing a given action from the pending set.
  - The probability of choosing a specific method
    (when you have a choice of plans.)

  - Our implementation assumes a uniform distribution for these
    (but this is not required)

$$\Pr(\exp) = \Pr(PS_0)\prod_{i=0}^{K}\left(1 / |PS_i| \right)$$

Midpoint summary

ï PHATT will handle:

ñ Hostile agents

ñ Cumulative effect of not seeing something

ñ Partial order plans

ñ Effect of world state on goals

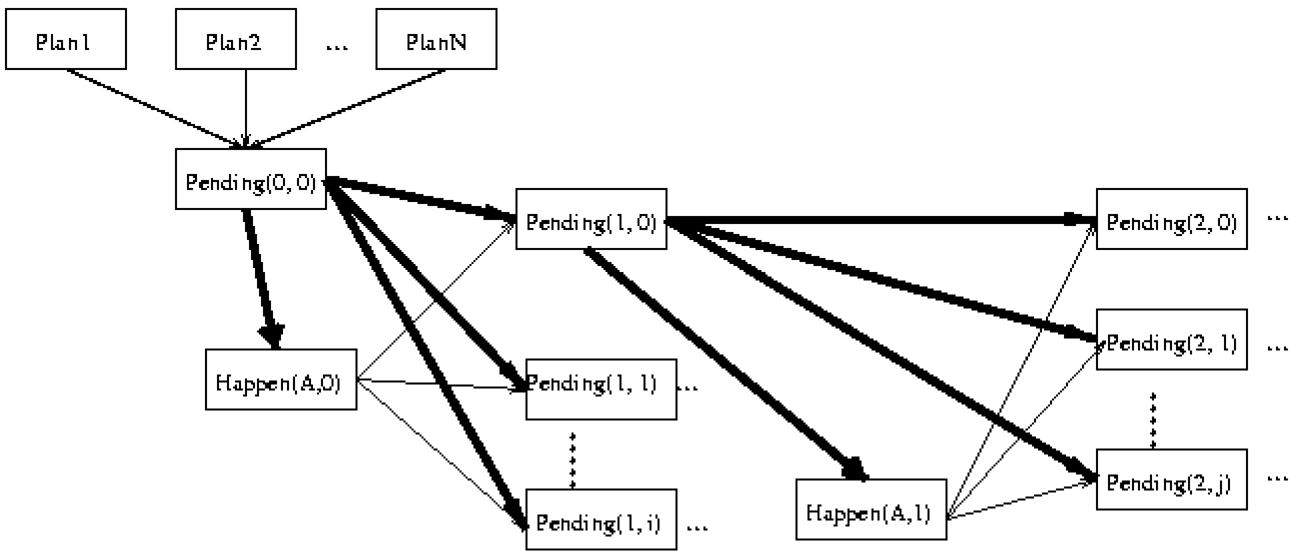
ñ Everloading of actions

ñ Multiple goal Vs. Single goal explanations

ï But we can also extend it model plan abandonment.

Solution: The exact solution

- Abandoning goals moves from a unique pending set to a tree of them.
- If we want to compute the exact probability that a given goal is abandoned the search space expands by 2^n at each time step.
  - Where n is the number of root goals the agent has
  - This reflects the fact that at any time step the agent can abandon any subset of their goals.



Solution: The exact solution

- We must add a term to reflect the abandonment of the goals to the probability of an explanation.

- Without abandonment:

$$\Pr(\exp) = \Pr(PS_0)\prod_{i=0}^{K}\left(1 / |PS_i| \right)$$

- With abandonment:

$$\Pr(\exp) = \Pr(PS_0)\prod_{i=0}^{K}\left(1 / |PS_i| \right)\Pr(PS_{i+1} \mid PS_i\ obs_i)$$

Solution: Why we canít do this

ï The expansion of the search space is a problem.

ï Even if we didnít mind the search space we need a probability distribution over the possible abandoned goals

- ñ canít assume that goal abandonment is independent of other goals
- ñ canít assume that goal abandonment is independent of situations

Approximating through model mismatch

ï Laskey ë91, Jensen ë90, Haberman ë76, and others have suggested that exceptionally low values for:

$$\Pr(\text{observations} \mid \text{model})$$

are an indication of a probabilistic model mismatch.

ï In our case, the mismatch we are looking for is the abandonment of the goal

ï Further we can look for something more specific than the probability of the whole observation stream to indicate the mismatch.

Solution for a single explanation

ï Intuition: If the agent abandons a goal, you wonít be seeing its actions.

ï Algorithm:

1. Compute the probability that nothing has contributed to a specific goal in this explanation. (ie. The probability that you still have the goal but have just naturally failed to execute any of the actions in the plan for it.)

$$\Pr(\mathrm{notcontrib}(q, s, t) \mid \mathrm{model}, \mathrm{obs}) = \prod_{i=s}^{t} 1 - \left(m_{q,i} / |\mathrm{PS}_i| \right)$$

Where $m_{q,i}$ is the number of actions that contribute to goal q at time I

2. If this drops below a user defined threshold assume the goal has been abandoned. Modify the explanation/model to abandon the goal and continue as before.

Estimating the probability

ï So having the used the model mismatch to find explanations that assume that a goal has been abandoned we can now estimate the probability of the goal being abandoned across all the explanations.

ï Divide the probability mass of those explanations where the goal is abandoned by the probability mass of all explanations of the observations.

$$\Pr(abandoned(g) \mid obs) \approx \frac{\sum_{e}^{Exp_{A(g)}} \Pr(e \mid obs)}{\sum_{e}^{Exp} \Pr(e \mid obs)}$$

Implementation

ï Just given the intuitions and the math (lots of bookkeeping and one or two subtle implementation points not covered here)

ï Currently implemented in Allegro Common Lisp

ï Reasonable runtimes achieved even with large numbers of observations and a reasonably high threshold (to encourage abandoning goals)

  ñ 2 goals, observations < 27, threshold = 0.24:

    Runtimes less than a second.