Rational Agents: Prioritized Goals, Goal Dynamics, and Agent Programming Languages with Declarative Goals

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Motivation

• Agent theories (e.g. [Cohen & Levesque ‘90], [Rao & Georgeff ‘91]) model
  – the different mental attitudes of the agents (beliefs, goals, …) and the relationship between them
  – the relation between these and action
• Belief change
• But most agent theories do not account for
  – goals with different priorities
  – dynamics of goals
  – dependencies between goals and subgoals
• Modeling goals and preferences useful in many applications, e.g. e-commerce, etc.
Motivation

• Recently, much work on APLs with *declarative goals* (e.g. [Hindriks et al. ‘00]); essential for:
  – monitoring goal achievement and performing plan failure recovery
  – modeling rational behavior

• But most of these APLs do not
  – *provide a formal semantics for declarative goals or specify their dynamics*
  – *handle temporally extended goals and prioritized goals*
  – *require consistency between adopted declarative goals and plans*

• One reason for these deficiencies
  – underlying agent theory not expressive enough
Contributions

• Formalization of Prioritized Goals for Optimizing Agents
  – semantics of temporally extended prioritized goals
  – goal dynamics
• Formalization of Prioritized Goals for Committed Agents
• Account of Subgoals
• SR-APL: A Simple Rational APL with Prioritized Goals
  – operational semantics
  – rationality of SR-APL agents
Prioritized Goals: Semantics

- Situation Calculus [Reiter ‘01] + Knowledge [Scherl & Levesque ‘01]

- Thesis adds *infinite paths* in the situation calculus

- Prioritized Goals (p-goals) or Desires
  - not required to be consistent with agent’s knowledge or with each other
  - specified using a possible worlds account; “world = infinite path”
  - totally ordered – one p-goal per level – G relation

- Realistic P-Goals
  - p-goals that are compatible with what the agent knows – \( G_R \) relation
### Example: P-Goals and Realistic P-Goals

<table>
<thead>
<tr>
<th>level</th>
<th>poss?</th>
<th>Goals</th>
<th>Realistic Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>n&gt;2</td>
<td>✓</td>
<td>True</td>
<td>$G(n)$</td>
</tr>
<tr>
<td>2</td>
<td>✓</td>
<td>BeHappy</td>
<td>$G(2)$</td>
</tr>
<tr>
<td>1</td>
<td>✓</td>
<td>GetPhD</td>
<td>$G(1)$</td>
</tr>
<tr>
<td>0</td>
<td>✓</td>
<td>BeRich: highest priority</td>
<td>$G(0)$</td>
</tr>
</tbody>
</table>

$G_R(n)$ represents the realistic goals at each level.
Chosen Goals

- Chosen Goals (c-goals) or Intentions
  - defined in terms of realistic p-goal hierarchy
  - maximal set of highest priority goals that are consistent with each other and with agent’s knowledge

- p-goals can be *active* (i.e. chosen) or *inactive*

- Inactive p-goals can later become active
# Example: Chosen Goals

<table>
<thead>
<tr>
<th>level</th>
<th>poss?</th>
<th>active?</th>
<th>consistent?</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>1</td>
<td>✔</td>
<td>❌</td>
<td>✔</td>
</tr>
<tr>
<td>0</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

- **BeHappy**: BeHappy is chosen as the highest priority goal.
- **GetPhD**: GetPhD is chosen despite being active.
- **BeRich**: BeRich is also chosen.

The chosen goals are consistent with the level and possibility conditions.
Prioritized Goals: Dynamics

- **p-goals** change when
  - actions/event occurs and the agent's knowledge changes
  - $\text{adopt}(\varphi, n)$ and $\text{drop}(\varphi)$
- Specified by providing a Successor State Axiom for p-goals
- **c-goals** automatically updated when p-goals change
  - **idealized agent:** will drop an intended goal if an opportunity to commit to a higher priority but inconsistent goal arises (i.e. when an inactive goal becomes active)
Prioritized Goals: Properties

- Proven that has many intuitively justified properties
  - consistency of c-goals, realism
  - adopt/drop has desired effects
  - introspection of goals
  - persistence of p-goals/c-goals
Handling Subgoals

- Developed mechanism for modeling the dependencies between goals and subgoals
  - ensures that subgoals are dropped when supergoal becomes impossible or dropped
A Simple Rational APL (SR-APL)

• Developed modified version of our formalization of prioritized goals where agents are more committed to chosen goals

• Combines elements from
  – Belief-Desire-Intention APLs e.g. AgentSpeak [Rao ‘01]
  – and the situation calculus-based ConGolog APL [De Giacomo et al. ‘00]

• Based on our rich theory of prioritized goals for committed agents
  – grounded on a formal action theory (i.e. the situation calculus)
  – handles prioritized goals and their dynamics
  – formalizes the dependencies between subgoals and their parent goals

• Key advantages of SR-APL
  – maintains consistency between chosen declarative goals and plans
  – satisfies some key rationality requirements
Conclusion

- **Main contributions**
  - models of prioritized goals and intentions that handle temporally extended goals
  - account of goal dynamics
  - proven model has intuitive properties
  - see *(AAMAS 2010)*  Session 5.4 - Agent Reasoning
  - account of subgoal dynamics
  - see *(DALT 2009)*
  - Simple Rational APL (SR-APL)
  - proven that SR-APL satisfies key rationality postulates
  - see *(DALT 2010)*
Future Work

- Two frameworks for prioritized goals lie at the two extremes of the “resource-boundedness vs. tractability” spectrum – work on hybrid account of intention reconsideration
- Investigate restricted versions of SR-APL to improve efficiency/tractability
- Incorporate other types of temporally extended goals
Appendix : Goal Dynamics Example


BeHappy
GetPhD
BeRich

BeHappy
GetPhD
BeRich

goBankrupt