SR-APL: A Model for a Programming Language for Rational BDI Agents with Prioritized Goals
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1. Introduction
- Recently, much work on BDI APLs with declarative goals
  e.g. (Dastani '08, Sarhadi & Padgham '16)
- Essential for:
  - monitoring goal achievement
  - performing plan failure recovery
  - modeling rational behavior
- However, to provide efficiency none
  - ensure consistency of adopted declarative goals & plans
- Also, few deal with:
  - prioritized goals
  - temporally extended goals
- Most use syntactic accounts of:
  - goal-subgoal dependency
  - goal dynamics

2. Need for Consistency Checking: A Motivating Example

3. Our Approach
- Develop model for a Simple Rational APL (SR-APL):
  - maintains consistency of chosen declarative goals & plans
  - bridges gap between rational agent theories and BDI APLs
- Combines elements from:
  - BDI APLs (e.g. AgentSpeak [Res '01])
  - the situation calculus-based ConGoleap APL [De Giacomo et al. '97]
- Based on theory of prioritized goals [KAL '10]:
  - grounded on a formal action theory (i.e. the situation calculus)
  - handles temporally extended goals & prioritized goals
  - formalizes goals and goal dynamics semantically
  - models dependencies between subgoals and their parent goals

4. Components of SR-APL
- Theory B specifying:
  - actions (preconditions & effects)
  - knowledge
  - both declarative (achievement) and procedural goals
- Planning Rule-Base T with rules of the form (\(\Phi : \Psi \rightarrow \alpha\)):
  - Plan language for:
    - primitive actions, wait/test actions, sequence of actions
    - special action for adopting subgoal \(\Phi\) relative to program \(\alpha\), adoptRT(\(\Phi, \alpha\))
  - Procedural intention base \(\Gamma\)

5. Operational Semantics
- Two-tier transition system:
  - program-level transitions \((T, D) \rightarrow (T', D')\) — as in ConGoleap
  - agent-level transitions \((\Gamma, \sigma) \Rightarrow (\Gamma', \sigma')\)

6. Why Procedural Goal-Base?
- How to model commitment to execute a plan \(\alpha\) next in theory \(D\)?
  - First attempt: agent has goal that \(\exists s. (\text{DoAL}(o, \text{now}, s))\)
    - too strong: does not allow concurrency/interleaving
  - Second attempt: has goal \(\exists s. (\text{DoAL}(o, \text{now}, s)) \rightarrow \sigma\)
    - execute \(\sigma\) possibly with any other actions
  - too weak: allows unnecessary actions/procrastination
- Our approach: use DoAL, but also define procedural intention base \(\Gamma\) — list of all plans agent is committed to
  - require actions the agent performs to come from \(\Gamma\)

7. Agent Transition Rules
- Rule \(\text{DoAL}\) for selecting and adopting a plan from \(\Gamma\):
  - if head of rule \(\Phi : \Psi \rightarrow \alpha\) matches with an unhandled intention
  - belief-condition \(\Psi\) of that rule also follows from agent’s knowledge
  - agent does not intend not to adopt the plan \(\text{DoAL}(o)\)
  - then can do transition by adopting \(\text{DoAL}(o)\) as a subgoal of \(\Phi\)

8. Weak Notion of Consistency
- In \(\text{AAW}\) and \(\text{aaw}\), only do partial consistency check:
  - require that agent does not intend not to adopt the plan \(\text{DoAL}(o)\)
  - but not that agent does not intend to adopt the plan \(\text{DoAL}(o)\)
- Plans might be abstract (include unexpanded subgoals)
  - Thus, currently non-executable without introducing additional actions
- Agent could get stuck due to wrong choice of plan interleaving, and may need to add actions to the plan
  - however agent will never perform actions that make other goals impossible

9. Rationality Properties
- Blocks World Eq. – in the absence of exogenous actions
  - \(\text{Do}\) is a complete trace relative to \(\text{Do}_{\text{aaw}}\)
  - \(\forall\) all complete traces \(\sigma_1 \vdash \cdots \vdash \sigma_n\) relative to \(\text{Do}_{\text{aaw}}\)
  - \(\text{Do}\) has no infinite traces relative to \(\text{Do}_{\text{aaw}}\)
- Consistency of knowledge & intentions:
  - holds for all configurations
    - \(D_{\text{al}} \vdash \langle \text{Know}(a, \Theta), \sigma \rangle \overrightarrow{\text{int}} \langle \text{Know}(a, \Theta), \sigma \rangle\)
- Consistency of declarative and procedural goals:
  - given complete trace \(\sigma_1 \vdash \cdots \vdash \sigma_n\) relative to theory \(B\) without exogenous actions
  - for all configurations \(\langle \text{Eg}(a, \Theta), \sigma \rangle\) in \(T, D\) if \(\sigma_n\) then
    - either \(D_{\text{al}} \vdash \text{DoAL}(a, \Theta, \sigma)\)
    - or there is a future configuration along the trace where consistency is restored
- Rationality of actions in a trace:
  - Given trace \(\sigma_1 \vdash \cdots \vdash \sigma_n\) relative to theory \(D\) without exogenous actions
  - for all \(i \leq \sigma_n\) and \(a, \Theta, \Theta', \Theta''\):
    - \(\text{Do}_{\text{al}} \vdash \langle \text{Know}(a, \Theta), \sigma_{i-1} \rangle \overrightarrow{\text{int}} \langle \text{Know}(a, \Theta), \sigma_i \rangle\)
    - \(D_{\text{al}} \vdash \langle \text{Know}(a, \Theta), \sigma_i \rangle \\overrightarrow{\text{int}} \langle \text{Know}(a, \Theta), \sigma_{i+1} \rangle\)
    - \(D_{\text{al}} \vdash \langle \text{Know}(a, \Theta), \sigma_{i+1} \rangle\)

10. Conclusion
- Proposed simple rational APL with declarative goals
- Proved some strong rationality principles
- Future work: investigate practical versions of SR-APL