Utilizing Permission Norms in BDI Practical Normative Reasoning

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Introduction

• Open Multiagent Systems

Heterogeneous
Autonomous
Self-Interested
Leave and join
Introduction

- Multiagent Systems

NORMS

- Dynamic
- Heterogeneous
- Autonomous
- Self-Interested
- Leave and join
Motivation

• Two major “choices” w.r.t. concrete implementations of normative agents
  – Regimentation (norms cannot be violated, i.e. hard constraints)
  – Enforcement (violations can occur, i.e. soft constraints)

• Enforcement makes runtime agent reasoning more complex
Motivation

• Much work on agent reasoning assume norms are:
  – Known in advance or agents are always aware of all norms
  – Ultimately decomposable into prohibitions/obligations
  – Thus, no room for uncertainty about normative state

• We use reasoning about permissions to account for uncertainty
  – Relation to work on norm identification (assumed to exist)
Motivation

• Sealing principle

“whatever is not prohibited is permitted”

Complete knowledge of agent about normative states
Motivation

• Incomplete knowledge $\rightarrow$ permission norm is significant
Background – Event Calculus

• Event Calculus
  – Framework in logic programming to represent and reason about actions and their consequences
  – Simple and widely used
    (usually implemented in Prolog)

• Jason
  – BDI-based programming language
## Event Calculus

<table>
<thead>
<tr>
<th>Predicate</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>happens(A,T)</td>
<td>Action A occurs at time T</td>
</tr>
<tr>
<td>holdsAt(F,T)</td>
<td>Fluent F is true at time T</td>
</tr>
<tr>
<td>terminate(A,F,T)</td>
<td>Occurrence of action A at time T will make fluent F false after time T</td>
</tr>
<tr>
<td>initiates(A,F,T)</td>
<td>Occurrence of action A at time T will make fluent F true after time T</td>
</tr>
<tr>
<td>clipped(T,F,Tn)</td>
<td>Fluent F is terminated between time T and Tn</td>
</tr>
<tr>
<td>&lt;, &gt;, &lt;=, &gt;=</td>
<td>Standard order relation for time</td>
</tr>
</tbody>
</table>
Event Calculus

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<tr>
<td>between(A,T1,T2)</td>
<td>Action A occurred after time T1 and before T2</td>
</tr>
<tr>
<td>initiatesAt(A,F,T1,T2)</td>
<td>The occurrence of action A at T1 will make fluent F true after T2, when T1≤ T2.</td>
</tr>
<tr>
<td>terminatesAt(A,F,T1,T2)</td>
<td>The occurrence of action A at time T1 makes fluent F false at time T2</td>
</tr>
</tbody>
</table>
Background - Jason

• BDI-based programming language
• Implementation of an extended version of the AgentSpeak(L) formalism/APL
  
  triggering_event : context
  <- body.

• Supports a subset of logic programming constructs from Prolog
Norm Representation

• We define a norm as a tuple
  \[ N = \langle D, C, Seq, S, R \rangle \]

  D: \( F, O \) or \( P \)

  C: Context
    \( \beta \): world state, defined via predicate holdsAt
    \( \alpha \): sequence of actions, defined via EC formula

Seq: sequence of action(s) that agents are forbidden to perform or obliged to perform

S: sanction

R: reward
Norm Representation

• Permission norm representation: 
  \[\text{initiatesAt}(\text{An}, p\text{Rew}(\text{Nid}), T_n, T_{n+1}) :- \]
  \[C, \text{happens}(A_1, T_1) \& \ldots \]
  \[\& \text{happens}(\text{An}, T_n) \& \]
  \[T_1 < T_2 < \ldots \& < T_n.\]

• Prohibition and Obligation norms represented in a similar way.
BDI agent normative reasoning

• In order to reason about plans in BDI agents, we define two key fluents
  – help(Plan) fluent will be true if executing Plan ends up with more rewards than punishments. That based on F and O norms.
  – safe(Plan) fluent will be true if executing Plan ends conforms with more permission norms
BDI agent normative reasoning

• Axioms:

EC1: clipped (T1, F, T4) :- happens(A, T2) & terminatesAt(A, F, T2,T3) & T1<T2 & T2≤T3 & T3<T4

EC3': holdsAt (F, T3) :- happens(A, T1) & initiatesAt(A, F, T1,T2) & T1≤ T2 & T2<T3 & not clipped (T2, F, T3)

Ax1: between(A,T1,T2) :- happens(A, T) & T1<T & T<T2

Ax2: terminatesAt(*,help(P),T1,T2):- happens(*,T1)

Ax3: terminatesAt(*,safe(P),T1,T2):- happens(*,T1)

Ax4: terminatesAt(*,fPun(I,S),T1,T2):- happens(*,T1)

Ax5: terminatesAt(*,oPun(I,S),T1,T2):- happens(*,T1)

Ax6: terminatesAt(*,oRew(I,R),T1,T2):- happens(*,T1)

Ax7: terminatesAt(*,pRew(I,R),T1,T2):- happens(*,T1)
BDI agent normative reasoning

• helpful-rule:
  
  \[
  \text{initiatesAt}(A, \text{help}(\text{Plan}_i), T1, T2):- \\
  \quad \text{findall}(V1, \text{holdsAt}(oRew(_, V1), T2+1), \text{Wins}) \\
  \quad \& \quad \text{findall}(V2, \text{holdsAt}(fPun(_, V2), T2+1), \text{Loses1}) \\
  \quad \& \quad \text{findall}(V3, \text{holdsAt}(oPun(_, V3), T2+1), \text{Loses2}) \\
  \quad \& \quad \text{goalpreference}(G, \text{Points}) \& \text{Points + sum(Wins)} - \text{sum(Loses1)} - \text{sum(Loses2)} > 0. 
  \]

• safe-rule:
  
  \[
  \text{initiatesAt}(A, \text{safe}(\text{Plan}_i), T1, T2):- \\
  \quad \text{findall}(V1, \text{holdsAt}(pRew(_, V1), T2+1), \text{Count}).
  \]
Experiments

• Environment (based on Gold miners in Jason):
  - Grid-like territory with gold and silver pieces scattered
  - Three agents; best-agent and best-safest-agent and monitor-agent
Experiments

• Goal: collect gold to the depot.

• Agents have same plans for achieving the goal:
  1- collect gold to the silver depot
  2- collect gold to the gold depot.
  3- collect gold to the gold depot and silver to gold depot.
  4- collect gold to the gold depot and collect another gold to the gold depot.
  5- collect gold to the gold depot and collect silver to silver depot.
Experiments - Norms

- All agents are aware of at least the following norms:
  - It is prohibited to drop gold in the silver depot if the gold depot is not full, the sanction value is 5
  - It is prohibited to carry more than one gold piece at the same time, the sanction value is 10
  - It is obligatory to collect silver immediately after collecting gold: the sanction value is 10, the reward for compliance is 10.

- The best-safest-agent is also aware that:
  - It is permitted to drop gold in gold depot
  - It is permitted to drop silver in silver depot

- Finally, the monitor agent knows, and enforces an unknown norm:
  - It is prohibited to drop silver in the gold depot if the silver depot is not full, the sanction value is 10.
Experiments

Fig. 3 Shows the average collected gold and silver pieces and the ultimate achievement utilities for best-agent and best-safest-agent.

Fig. 4 Shows the calculated/predicted utility for the best-safest-agent and best-agent.
Conclusion

• We developed a norm reasoning mechanism that uses permissions to account for uncertainty
• Using permission norms gives agents the ability to have preference over plans
  – plans containing actions that are known to be permitted are preferable over plans that contain actions whose normative status is unknown
Future work

• Perform further experiments to study the time efficiency of our practical normative reasoning mechanism.

• Compare our *best-safest-agent with other BDI norm aware agents in the literature*