Introducing Relevance Awareness in BDI Agents

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Outline

Agents, Information and Resources

" What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate that attention efficiently among the overabundance of information sources that might consume it." [Simon, 1971]

Related Works

The notion of Relevance has been extensively investigated in several domains like AI, philosophy and cognitive sciences:

Causal relevance the concept of relevance coincides with the probabilistic concept of conditional dependence [Lakemeyer, 2004, Pearl, 1988]

- irrelevance is identified with conditional independence, and relevance is identified with the negation of irrelevance

Information Theory conceives relevance along a quantitative notion of informativeness (i.e., [Shannon, 1948])

- Google PageRank (almost) based on weighted analysis of incoming links of a web page

Cognitive Modeling

To envisage a computational model of relevance we are interested at investigating the particular relationships between cognitive reasoning and (active) perceptive processes:

Goal processing Relevance and trustworthiness of information sources are involved in rational goal selection (i.e., [Da Costa Pereira and Tettamanzi, 2008])

Information Filtering Perception of incoming input are ruled on the basis of their relevance (i.e., [Lorini and Piunti, 2007, Koster et al., 2008])

Goal Relevance Relevance is related to the subjective *appraisal* of a certain event, situation, object with respect to agent's actual goals and intentions (i.e., [Lazarus, 1991])

Outline

Cognitive Ingredients

Any given piece of information which affect goal processing has to be considered as *relevant*. So, relevance can be seen as relational notion:

- An information is relevant *in relation to* agent's ongoing **intentions**
- An information is relevant for (respect to) a given **goal** (and for a given agent)
- **Beliefs** supporting practical reasoning are relevant:
  - Means-end Beliefs regulating plan selection
  - Deliberation Beliefs regulating goal adoption

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BDI aware Agents

Agent's abstract model is defined by $\langle \Gamma, K, B, D, I, DG, PL, ACT \rangle$

BDI agent control loop

1. B:=B_0;
2. I:=I_0;
3. while (true) do
4. get new percept Γ;
5. B:=$bu(\Gamma, B)$;
6. D:=$options(B, I)$;
7. I:=$filter(B, D, I)$;
8. π:=$plan(B, I)$;
9. $execute(\pi)$;
10. end-while

BDI^{rel} agent control loop

1. B:=B_0;
2. I:=I_0;
3. while (true) do
4. get new percept Γ;
5. **if** $\mathbf{R}(I, \Gamma, B) > \Delta$ **then**
6. B:=$bu^*(\Gamma, B, I)$;
7. **end-if**
8. D:=$options(B, I)$;
9. I:=$filter(B, D, I)$;
10. π:=$plan(B, I)$;
11. $execute(\pi)$;
12. end-while

Table: Abstract interpreter of a normal BDI agent ([Rao and Georgeff, 1995]) and a BDI^{rel} agent

Relevance and Belief Update

BDI and BDI^{rel} differ in their belief update strategy:

- **standard BDI** agent updates his beliefs with no filter strategy
  - whether the perceived fact is relevant with respect to his intentions or not
- **BDI^{rel} agent** only if the agent perceives a fact and evaluates this as relevant with respect to what he intends to achieve
  - filters out all perceived facts that are irrelevant with respect to the current intentions.

Belief Update on Relevant Input

- If Γ is responsible for generating a degree of global relevance $R > \Delta$ (with $\Delta \in [0, 1]$), then BDI^{rel}:
  - triggers bu^* and adjusts his beliefs with the perceived data Γ
- The belief update function bu^* takes in input the set of intentions I, the belief configuration B and the percept Γ and returns an update belief configuration B$'$, that is:

$$bu^* : 2^{Inst} \times \text{BEL} \times 2^{\text{INT}} \mapsto \text{BEL}.$$

Relevance Function

Relevance of an input is defined with respect to agent's intentions (I):

$$\mathbf{R}(\mathrm{I},\Gamma,\mathrm{B}) = \max_{Y=y \in \mathrm{I}} r(Y{=}y,\Gamma,\mathrm{B}) \tag{1}$$

$$r(Y{=}y,\Gamma,\mathrm{B}) = \begin{cases} \Rightarrow \text{ If } \; Y \in \Gamma_{Var} : 1-\mathrm{B}(\Gamma(Y)) \\ \Rightarrow \text{ If } par(Y) \subseteq \Gamma_{Var} \text{ and } Y \notin \Gamma_{Var} : \\ \quad \|\mathrm{B}(Y{=}y) - P(Y{=}y \mid \{X_i{=}x \mid X_i \in par(Y) \text{ and } X_i{=}x \in \Gamma\})\| \\ \Rightarrow \text{ If } par(Y) \not\subseteq \Gamma_{Var} \text{ and } Y \notin \Gamma_{Var} : 0 \end{cases} \tag{2}$$

- if the percept is an intended variable, relevance is equal to the degree of unexpectedness of the related input
- if the percept is not an intended variable, but there are percepts which can be related to parents of intended variables, relevance is given by the discrepancy between the intendend fact Y and the Γ
- if there is no relation between intended variables and percept, relevance $= 0$

Outline

Experimental Scenario

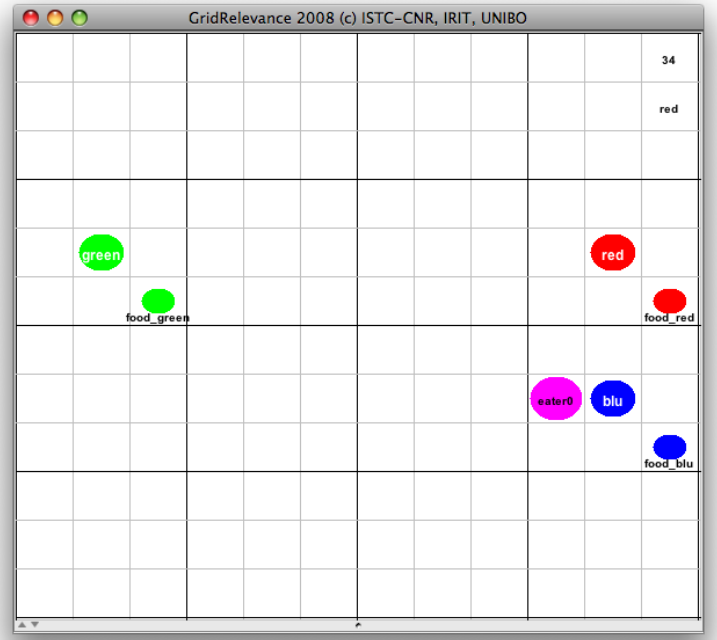

Figure: Three different season types (red, green, blu) are related to (tree,fruit) pairs of the same type. For each tree a related fruit is present in the same macro area of 3x3 cells. Environment dynamics is governed by a periodic function.

- The season changes after s_t rounds
- A tree change its position after δ season changes

Jason Implementation

```
+tick_time(X)
  [source("percept"),
  artifact("timer"),
  workspace("Relevance")]
  : actual_season(S)
  <- -+time(X);
     gridworld.perceptRel(S);
     !deliberateTarget.
```

```
+!deliberateTarget
  : actual_season(S) & food(S,X,Y)
  <- -+targetLoc(X,Y);
     !doAction.

+!deliberateTarget
   : actual_season(S) & not food(S,_,_)
   & tree(S,X,Y)
   <- -+targetLoc(X,Y);
      !doAction.

+!deliberateTarget <- !doAction.
```

- Jason code for BDI and BDI^{rel} is the same (relevance filtering is handled in a transparent fashion by the architecture)
- At each time step `gridworld.perceptRel` calls the belief update function: *bu* or bu^*
- Specialized versions of `jason.architecture.AgArch` and `jason.asSemantics.Agent` are used

Metrics

Agent's performance: computational load on operations of belief update

- *Goal.eff* represents the total amount of achieved goals during a trial (i.e., eaten fruits)
- *Cost.eff* is the total amount of update operations performed by an agent on his belief base
- *Cost.ratio* is agent's belief update cost divided by the total amount of achieved goals (*Cost.eff* / *Goal.eff*): indicates the cost the agent needs to spend for each achieved goal.

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Evaluation

	$\delta = 3$		$\delta = 2$		$\delta = 1$	
	BDI	BDI^{rel}	BDI	BDI^{rel}	BDI	BDI^{rel}
Goal.eff	42.375	42.375	38.185	37.625	33.937	33.875
Cost.eff	92.125	78.437	101.437	85.312	143.125	107.875
cost.ratio	2.381	2.012	2.882	2.252	4.379	3.214

Table: Amount of achieved goals and performed belief updates measured at the end of the experiment series for BDI and BDI^{rel} agents in environment with dynamism $\delta \in \{1, 2, 3\}$.

Slow Dynamic

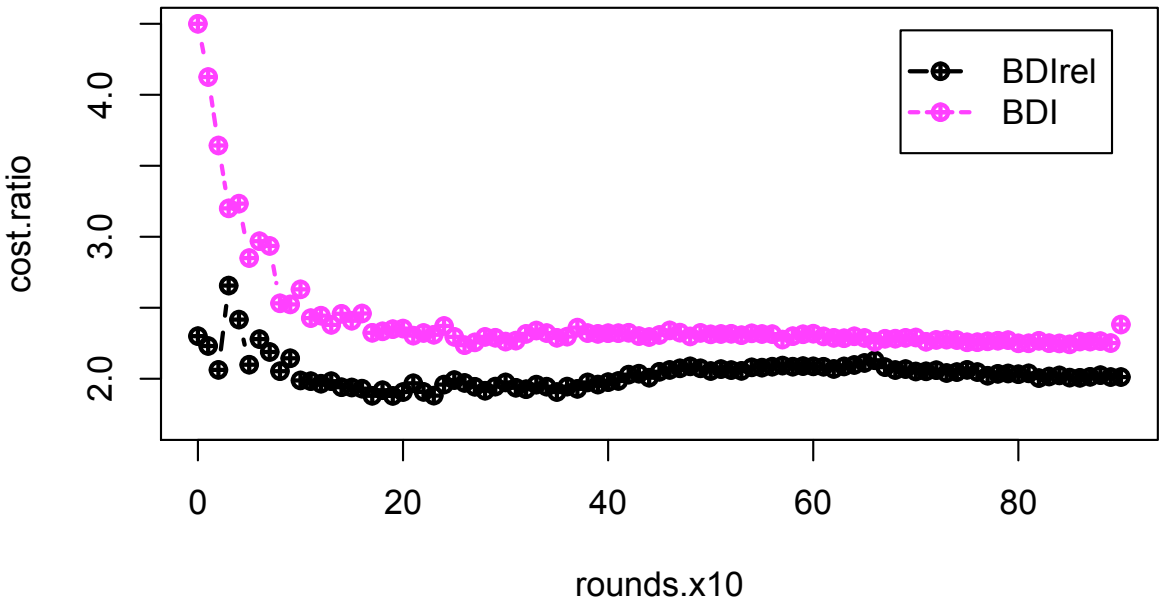

Figure: $\delta = 3$, three season before a tree change

Normal Dinamic

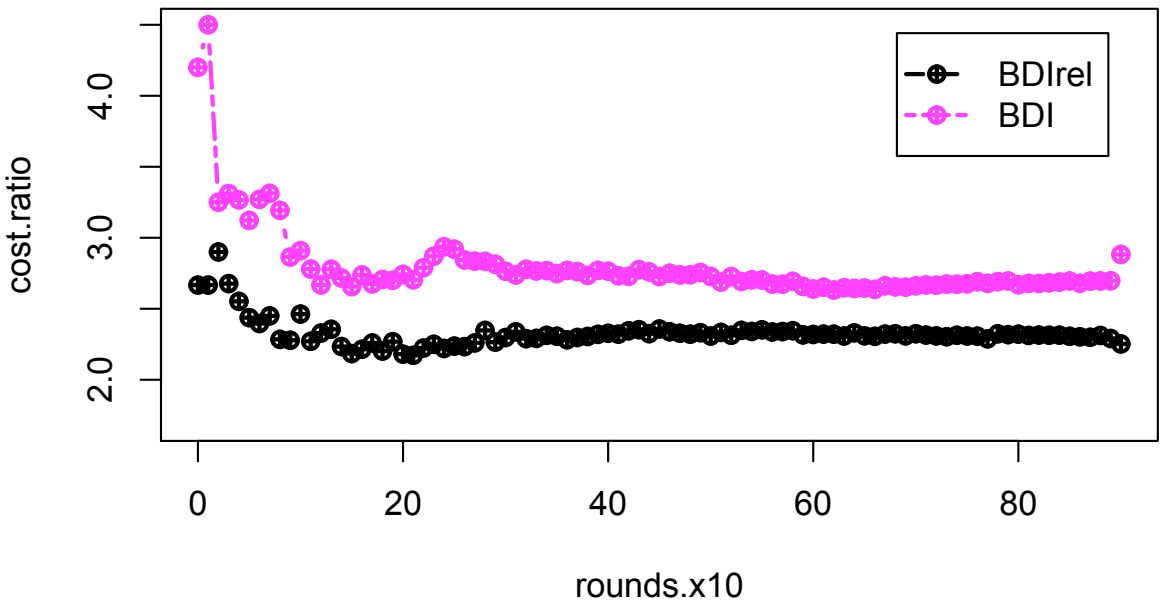

Figure: $\delta = 2$, two season before a tree change

Fast Dynamic

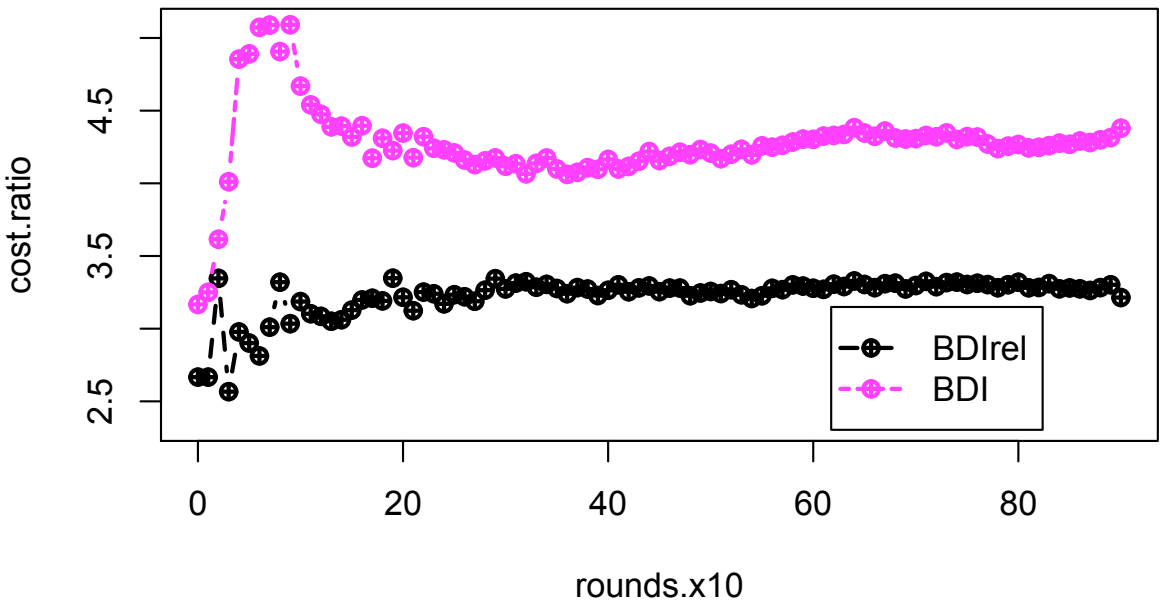

Figure: $\delta = 1$, one season before a tree change

Conclusion

Perception Filtering events coming from (open) working environment (vs. message passing and ACL)

Goal relevance Goals (and Intentions) as cognitive ingredients of Relevance

Programming Model Bridge the existing gap between computational models of perception/belief update and formal models of belief dynamic/epistemic reasoning

Results Relevant input as causal precursor and signals triggering belief changes ease computational load in resource-bounded agents

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