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Suspending and Resuming Task in BDI Agents

Moderní teoretická informatika

25.11.2009

Outline

- Motivation
- The CAN language
- Reasons for suspension
- CAN syntax
- CAN semantics
- CAN + suspension
- Example of CAN expansion

Motivation

- Greater flexibility for agent developers to direct agent operation.
- Generic means for handling conflicts between tasks.

The CAN language

- High-level agent language (similar to AgentSpeak)
- Based on the **B**elief-**D**esire-**I**ntention agent model.
  - Belief base
  - Goals
  - Plans (Plan library)
- Declarative and procedural aspect of the goal
  - Goal(ϕ_s, P, ϕ_f)

Reasons for suspension

- Conflicts
  - Resource conflict
  - Effect conflict
- Positive interaction – two goals have a common step
- Invalid context
- No applicable plan
- Changing priorities
- Request from another agent

CAN - syntax

- An agent's behaviour is specified by a **plan library**, denoted by Π
- Π consists of a collection of plan clauses of the form

  $\mathbf{e : C \leftarrow P}$

  $C \rightarrow b \mid C \wedge C \mid C \vee C \mid \neg C \mid \exists x.C$

  $P \rightarrow a \mid +b \mid -b \mid ?C \mid !e \mid P;P \mid P \,||\, P \mid Goal(C,P,C)$

  $\mid P \triangleright P \mid (\mid \{ C : P, \ldots, C : P \} \mid) \mid \varepsilon$

CAN - semantics

- Operations:
  - $B \models C$ (?C)
  - $B \cup \{b\}$ (+b)
  - $B \setminus \{b\}$ (-b)
- Basic configuration: $\mathbf{S = \langle B,P \rangle}$
- Transition: $\mathbf{S_0 \rightarrow S_1}$ $\mathbf{(S_0 \rightarrow^* S_n)}$
- Derivation rule: $$\frac{\mathbf{S' \rightarrow S_r}}{\mathbf{S \rightarrow S'_r}}$$

CAN - semantics

$$\frac{\Delta = \{\psi_i\theta : P_i\theta \mid e' : \psi_i \leftarrow P_i \in \Pi \wedge \theta = \mathsf{mgu}(e, e')\}}{\langle \mathcal{B}, !e\rangle \longrightarrow \langle \mathcal{B}, (\!|\Delta|\!)\rangle} \; Event$$

$$\frac{\psi_i : P_i \in \Delta \quad \mathcal{B} \models \psi_i}{\langle \mathcal{B}, (\!|\Delta|\!)\rangle \longrightarrow \langle \mathcal{B}, P_i \triangleright (\!|\Delta \setminus \{\psi_i : P_i\}|\!)\rangle} \; Select$$

$$\frac{\langle \mathcal{B}, P_1\rangle \not\longrightarrow}{\langle \mathcal{B}, (P_1 \triangleright P_2)\rangle \longrightarrow \langle \mathcal{B}, P_2\rangle} \; \triangleright_{fail}$$

$$\frac{\langle \mathcal{B}, P_1\rangle \longrightarrow \langle \mathcal{B}', P_1'\rangle}{\langle \mathcal{B}, (P_1; P_2)\rangle \longrightarrow \langle \mathcal{B}', (P'; P_2)\rangle} \; Sequence$$

$$\frac{\langle \mathcal{B}, P_1\rangle \longrightarrow \langle \mathcal{B}', P'\rangle}{\langle \mathcal{B}, (P_1 \| P_2)\rangle \longrightarrow \langle \mathcal{B}', (P' \| P_2)\rangle} \; Parallel_1$$

$$\frac{\langle \mathcal{B}, P_2\rangle \longrightarrow \langle \mathcal{B}', P'\rangle}{\langle \mathcal{B}, (P_1 \| P_2)\rangle \longrightarrow \langle \mathcal{B}', (P' \| P_1)\rangle} \; Parallel_2$$

CAN - semantics

$$\frac{\mathcal{B} \models \phi_s}{\langle \mathcal{B}, \mathsf{Goal}(\phi_s, P, \phi_f) \rangle \longrightarrow \langle \mathcal{B}, true \rangle} \; \mathsf{G}_s$$

$$\frac{\mathcal{B} \models \phi_f}{\langle \mathcal{B}, \mathsf{Goal}(\phi_s, P, \phi_f) \rangle \longrightarrow \langle \mathcal{B}, fail \rangle} \; \mathsf{G}_f$$

$$\frac{P = \mathsf{Goal}(\phi_s, P', \phi_f) \quad P' \neq P_1 \rhd P_2 \quad \mathcal{B} \not\models \phi_s \vee \phi_f}{\langle \mathcal{B}, P \rangle \longrightarrow \langle \mathcal{B}, \mathsf{Goal}(\phi_s, P' \rhd P', \phi_f) \rangle} \; \mathsf{G}_I$$

$$\frac{P = P_1 \rhd P_2 \quad \mathcal{B} \not\models \phi_s \vee \phi_f \quad \langle \mathcal{B}, P_1 \rangle \longrightarrow \langle \mathcal{B}', P' \rangle}{\langle \mathcal{B}, \mathsf{Goal}(\phi_s, P, \phi_f) \rangle \longrightarrow \langle \mathcal{B}', \mathsf{Goal}(\phi_s, P' \rhd P_2, \phi_f) \rangle} \; \mathsf{G}_S$$

$$\frac{P = P_1 \rhd P_2 \quad \mathcal{B} \not\models \phi_s \vee \phi_f \quad P_1 \in \{true, fail\}}{\langle \mathcal{B}, \mathsf{Goal}(\phi_s, P, \phi_f) \rangle \longrightarrow \langle \mathcal{B}, \mathsf{Goal}(\phi_s, P_2 \rhd P_2, \phi_f) \rangle} \; \mathsf{G}_R$$

CAN + suspension, semantics

$$\frac{\mathcal{B} \not\models \phi}{\langle \mathcal{B}, (\phi{:}P) \rangle \longrightarrow \langle \mathcal{B}, (\phi{:}P) \rangle} \; :false$$

$$\frac{\Delta = \{\psi_i\theta : P_i\theta \mid e' : \psi_i \leftarrow P_i \in \Pi \wedge \theta = \mathsf{mgu}(e, e')\} \quad \mathcal{B} \models \phi}{\langle \mathcal{B}, \phi{:}!e \rangle \longrightarrow \langle \mathcal{B}, \phi{:}(\!|\Delta|\!) \rangle} \; :Event$$

$$\frac{\psi_i : P_i \in \Delta \quad \mathcal{B} \models \psi_i \quad \mathcal{B} \models \phi}{\langle \mathcal{B}, \phi{:}(\!|\Delta|\!) \rangle \longrightarrow \langle \mathcal{B}, P_i \triangleright \phi{:}(\!|\Delta \setminus \{\psi_i : P_i\}|\!) \rangle} \; :Select$$

$$\frac{P \neq !e \quad P \neq (\!|\Delta|\!) \quad \mathcal{B} \models \phi}{\langle \mathcal{B}, (\phi{:}P \rangle \longrightarrow \langle \mathcal{B}, P \rangle} \; :true$$

CAN + suspension, context

- Each task !e is tranlated to task !e(v)
  - *v* ... context (identity)
  - Context is a list if identifiers
    - Context of goal ..... *v* *(2)*
    - Context of sub-goal v … *n.v* *(32)*
    - Parent of n.v ..... *(n.v)* = v* *((32)* = 2)*
    - Root context ..... ⊥ *(2* = ⊥)*

CAN + suspension, new belief predicates

- New belief predicates
  - h_v
  - c_v
  - s_v
- New compound belief predicates
  - $H_v = h_v \vee (H_{v^*} \wedge \neg c_v)$
  - $A_v = \neg H_v \wedge \neg s_v$

CAN + suspension

- Program to suspend and resume *v:*
  $\boldsymbol{\pi(v, P^s, P^r)} = (h_v \vee (H_v \wedge s_{v*})) : P^s; +s_v; (\neg H_v \wedge \neg s_{v*}) : P^r; -s_v$

- Notation $\boldsymbol{while(P, q_v, \pi(v, P^s, P^r))}$ as an abbreviation for:
  $+q_v;((P; -q_v \triangleright -q_v; ?false) \,||\, Goal(\neg q_v, \pi(v, P^s, P^r), false))$

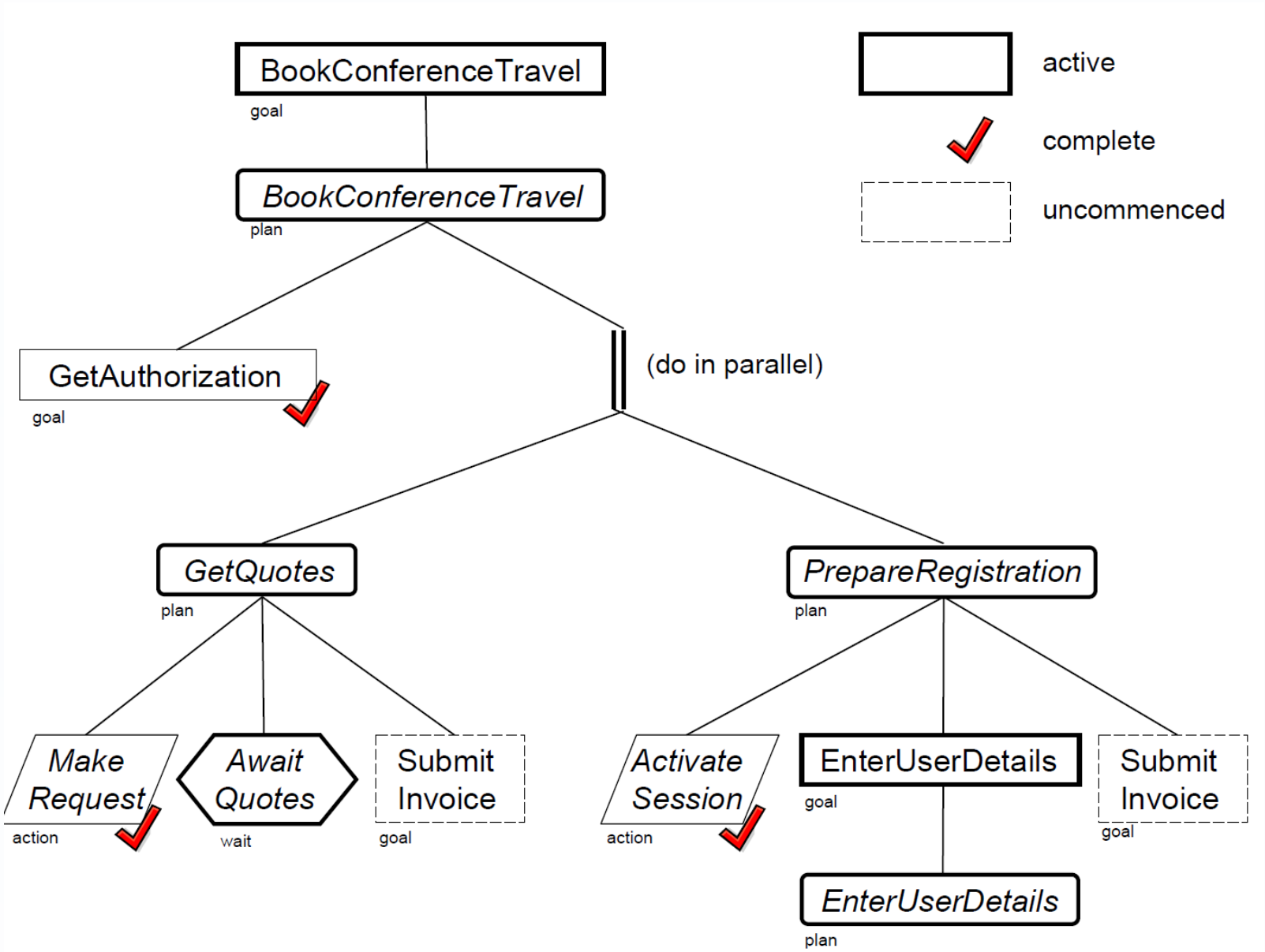
- Syntactic transformation of plan library
  - Plan clause of the form $\boldsymbol{e : c} \leftarrow \boldsymbol{P}$, suspend method $\boldsymbol{P^s}$, resume method $\boldsymbol{P^r}$ for e
  - $\boldsymbol{e}(v) : \boldsymbol{c} \leftarrow while(\mu_v(\boldsymbol{P}), q_v, \pi(v, \boldsymbol{P^s}, \boldsymbol{P^r}))$

CAN + suspension

$e(v) : c \leftarrow while(\ \boldsymbol{\mu_v(P)}\ ,\ q_v,\ \pi(v,\ P^s,\ P^r))$

$$\mu_v(nil) = nil$$
$$\mu_v(P_1; P_2) = \mu_v(P_1); \mu_v(P_2)$$
$$\mu_v(P_1 \triangleright P_2) = \mu_v(P_1) \triangleright \mu_v(P_2)$$
$$\mu_v((\!|\psi_1 : P_1, \ldots, \psi_n : P_n|\!)) = (\!|\psi_1 : \mu_v(P_1), \ldots, \psi_n : \mu_v(P_n)|\!)$$
$$\mu_v(P_1 \parallel P_2) = \mu_v(P_1) \parallel \mu_v(P_2)$$
$$\mu_v(\phi{:}P) = (a_v \wedge \phi){:}\mu_v(P)$$
$$\mu_v(\mathsf{Goal}(\phi_s, P, \phi_f)) = \mathsf{Goal}(a_v \wedge \phi_s, \mu_v(P), a_v \wedge \phi_f)$$
$$\mu_v(!e) = a_{n.v}{:}!e(n.v) \text{for the } n\text{-th sub-goal in the library}$$
$$\mu_v(act) = a_v{:}act$$
$$\mu_v(+b) = a_v{:}+b$$
$$\mu_v(-b) = a_v{:}-b$$

Example – plan body structure



CAN + suspension, transformation of plan library

BCT : true ← !GA; (!GQ || !PR)

$\Downarrow$

$BCT(v) : true \leftarrow while(P_v^{BCT}, q_v, (v, nil, nil))$ where

$P_v^{BCT} = a_{0.v} : !GA(0.v); (a_{1.v} : !GQ(1.v) \parallel a_{2.v} : !PR(2.v))$

GQ : true ← MR; AQ:nil; !SI

$\Downarrow$

$GQ(v) : while(P_v^{GQ}, q_v, (v, !IRS(v), !IRR(v)))$ where

$P_v^{GQ} = a_v : MR; (a_v \wedge AQ) : nil; a3.v:!SI\ (3.v)$

$PR : true \leftarrow AS; !EUD; !SI$

$\Downarrow$

$PR(v) : while(P_v^{PR}, q_v, (v, nil, !RS(v))$ where

$P_v^{PR} = a_v : AS; a_{4.v} : !EUD(4.v); a_{5.v} : !SI(5.v)$

CAN + suspension, example

1) a_0 : !BCT(0)

2) $P_0^{BCT} = a_{00}$: !GA(00); (a_{10} : !GQ(10) || a_{20} : !PR(20))

3) (a_{10} : !GQ(10) || a_{20} : !PR(20))

4) $P_{10}^{GQ} = a_{10}$: MR; (a_{10} ∧ AQ) : nil; a_{310} : !SI (310)

5) (a_{10} ∧ AQ) : nil; a_{310} : !SI (310)

6) $P_{20}^{PR} = a_{420}$: !EUD(420); a_{520} : !SI (520)

2. π(0, nil, nil) =

(h_0 ∨ (H_0 ∧ $s_\perp$)) : nil; $+s_0$; (¬H_0 ∧ ¬$s_\perp$) : nil; $-s_0$

4. π(10, nil, !IRS(10),!IRR(10)) =

(h_{10} ∨ (H_{10} ∧ s_0)): !IRS(10); $+s_{10}$; (¬H_{10} ∧ ¬s_0): !IRR(10); $-s_{10}$

6. π(20, nil, !RS(20)) =

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