Recognition of the Intention to Perform a Procedure: a Method Based on Probabilities

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ABSTRACT

A method to recognise agent's intentions is presented in a framework that combines the logic of Situation Calculus and Probability Theory. The method is restricted to contexts where the agent only performs procedures in a given library of procedures. To select the procedures that partially match the observations we consider the procedures that have the greatest estimated probability. This estimation is based on the application of Bayes' theorem and on specific heuristics.

Categories and Subject Descriptors

H.5 [**Information Interfaces and Presentation**]: Theory and methods

General Terms

Design, Theory

Keywords

Intention Recognition, Situation calculus, Probability Theory

1. INTRODUCTION

When two agents have to interact it is important for each agent to know the other agent's intentions because this knowledge allows to anticipate his future behavior.

In this paper a method is proposed to recognise what are the agent's intentions in the particular context of a pilot that interacts with an aircraft. The specificity of this context is that the pilot performs procedures that are very well defined in a handbook.

To define a method to recognise the pilot's intentions we have to find solutions to three independent problems: 1) to select a language to represent the procedures in formal terms, 2) to define a formal characterization of the procedures that match with the observations, 3) to define a method to select the procedures that have the "best" match and are assigned to the agent's intention.

In a previous work Demolombe and Hamon [2] have proposed solutions to problems 1 and 2 in the logical framework of the Situation Calculus. The contribution of this paper is to propose a solution to problem 3 in a framework that combines Situation Calculus [5] and Probability Theory and which is based on Bayes' theorem.

The original feature in our case is that the pilot's procedures may allow any other command in between a sequence of two prescribed commands and it may be specified that some commands are forbidden. To represent these procedures we have extended the GOLOG language (see [3] with the term σ and the constructor $/$. For instance, the procedure $\alpha = A; (\sigma/B); (C|D)$ specifies that the pilot must do A, and then any sequence of actions but B, and then C or D.

To characterise the fact that a sequence of performed actions "matches" a partial performance of a procedure, in the sense that this sequence **can be interpreted** as a partial performance of the procedure, we have defined the property $Doing(\alpha, s, s')$.

In informal terms [1] the property $Doing(\alpha, s, s')$ holds if the three following conditions are satisfied:

1. The agent has begun executing a part α' of α between s and s'.
2. The agent has not completely executed α between s and s'.
3. The actions performed between s and s' do not prevent the continuation of the execution of α.

2. INTENTION RECOGNITION

This section presents a method based on Probability Theory for choosing, between several procedures that satisfy the $Doing$ property, the one that can be assigned by the system to the agent's intention.

Let us define the following notations.

$P(\phi)$: probability that ϕ holds.

$Int(\alpha, s_i)$: in the situation s_i the agent has the intention to do α.

O_i: short hand to denote the fact that a_{j_i} is the action that has been observed at the observation number i.

$O_{1,i} \stackrel{\text{def}}{=} O_1 \wedge O_2 \wedge \ldots \wedge O_i \qquad O_{1,0} \stackrel{\text{def}}{=} true$

s_0: initial situation, $s_i = do(a_{j_i}, s_{i-1})$

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[1] A formal semantics of $Doing(\alpha, s, s')$ can be found in [2].

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$P(Int(\alpha, s_i)|O_{1,i})$: probability that in the situation s_i the agent has the intention to do α if the sequence of observations is $O_{1,i}$.

If we have: $\neg Doing(\alpha, s_0, s_i)$ the pilot is not doing α. It is assumed that the probability that he adopts the intention to do α is independent of $O_{1,i}$ and that this probability is known a priori. Then, we have:

(1) $P(Int(\alpha, s_i)|O_{1,i}) = \pi(\alpha)$

If we have: $Doing(\alpha, s_0, s_i)$, from Bayes' theorem we have:

(2) $P(Int(\alpha, s_i)|O_{1,i}) = \frac{P(O_{1,i})|Int(\alpha,s_i)) \times P(Int(\alpha,s_i))}{P(O_{1,i})}$

If it is assumed that we have: $Int(\alpha, s_i) \leftrightarrow Int(\alpha, s_{i-1})$, we have:

(3) $P(Int(\alpha, s_i)|O_{1,i}) = \frac{P(O_i|O_{1,i-1} \wedge Int(\alpha,s_{i-1}))}{P(O_i|O_{1,i-1})} \times P(Int(\alpha, s_{i-1})|O_{1,i-1})$

The formula (3) allows to regress the computation of $P(Int(\alpha, s_i)|O_{1,i})$ until a situation s_j where we have $\neg Doing(\alpha, s_0, s_j)$, provided we know a method to compute $P(O_i|O_{1,i-1} \wedge Int(\alpha, s_{i-1}))$ and $P(O_i|O_{1,i-1})$.

In a first approach it has been assumed that: $P(O_i|O_{1,i-1}) = P(O_i) = \frac{1}{N}$, where N is the total number of actions that the pilot can do.

The value of $P(O_i|O_{1,i-1} \wedge Int(\alpha, s_{i-1}))$ has been estimated by heuristics. These heuristics are based on the type of the observed action in O_i. In their definitions it is assumed that a procedure has been transformed into a set of procedures in "linear normal form". That is:

$\alpha = A_1; \Sigma_1; \ldots; A_k; \Sigma_k; A_{k+1}; \ldots; A_s$

where each A_k denotes an atomic action in A and Σ_k either is absent or denotes a term of the form $\sigma/(a_{i_1}|\ldots|a_{i_l})$ where each a_{i_j} is in the set of actions A that can be done by the pilot, and l may be equal to 0. We have considered the following types of actions.

A **prescribed** action, in a procedure definition, is an action that explicitly appears in the procedure and that is just preceded by an explicit action. For example, if α has the form: $\ldots; a; b; \ldots$ then this occurrence of b is a prescribed action in α. Notice that in a given procedure some occurrences of b may be prescribed actions and others not, like in $\alpha = c; \sigma; b; a; b$.

A **recommended** action, in a procedure definition, is an action that explicitly appears in the procedure and that is just preceded by a term of the form σ or σ/β. For example, if α has the form: $\ldots; \sigma; a; \ldots$ or $\ldots; \sigma/(b|c); a; \ldots$ then this occurrence of a is a recommended action in α.

An action is a **tolerated** action, in a procedure definition, if the procedure has the form: $\ldots; \sigma; a; \ldots$ and this action is in: $A - \{a\}$. For example, if $A = \{a, b, c, d, e\}$ and α has the form: $\ldots; \sigma; a; \ldots$, then the set of tolerated actions for this occurrence of σ is $\{b, c, d, e\}$.

An action is a **restricted tolerated** action, in a procedure definition, if the procedure has the form: $\ldots; \sigma/(a_{i_1}|\ldots|a_{i_l}); a; \ldots$ and this action is in $A - \{a_{i_1}, \ldots, a_{i_l}, a\}$. For example, if α has the form: $\ldots; \sigma/(b|d); a; \ldots$ the set of restricted tolerated actions for this occurrence of σ is $\{c, e\}$.

We have no room here to give the heuristics that have been used for each type of action. They can be found in [4].

3. CONCLUSION

We have presented a method for the recognition of intention that combines the logical framework of the Situation Calculus and the Probability Theory for the estimation of the uncertainty about intention assignment. This is the main difference with many other works in the field of plan recognition (see [1]).

The heursitics to estimate the probabilities are based on several assumptions that are not all listed here. In further works we shall investigate the possibility to drop some of these assumptions, in particular the assumption that: $P(O_i|O_{1,i-1}) = P(O_i)$.

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