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The Quoting-Based Algorithm for Cooperative Decision Making in Production Systems

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Abstract

This paper discusses the task of cooperative decision making in distributed production systems. The quoting-based algorithm is presented which allows a production system to increase its capabilities basing on the rules borrowed from another production system. Originality of the obtained resultsis also discussed.

Keywords: artificial intelligence, production systems, inference engine, conflict resolution.

1 Introduction

Rapid advances in Internet technologies have opened new opportunities for enhancing traditional expert systems to distributed expert systems. The earlier success of rule-based expert systems employing more efficient inference engines pushed forward investigations of distributed production systems where multiple rule-based systems solve a common problem together. The basic idea is that a collection of production systems could be a model of group decision making, since single production system can represent logics of an individual human expert. Although researchers have offered a number of particular algorithms for cooperation between production systems, this research direction is still at the stage of formalization. Mostly the offered algorithms exploit such global ideas as data sharing [1], knowledge sharing, learning and quoting from external sources.

2 Production systems

Further we use the following restrictive assumptions about monotonic production systems [2]:
F_0 is an enumerated set of facts presented in working memory;
D is a set of potential goals;
P is a set of production rules like IF f_1 & ... & f_n THEN f;
E is an algorithm which task is to return just one proper rule on any step of inference.

Assumption. Rule interpreter is goal-driven; for a given potential goal d it either generates well-grounded inference (in the form of a chain of rules) supporting d or returns reject message informing it is impossible to draw the conclusion d. To search for an appropriate rule, the rule interpreter every time turns to the algorithm E.

Definition. The *h-rule* is any production rule like IF ... THEN h.

Definition. Given a set of production rules P and the goal d, we say that P_d is a *well-grounded inference for* d if P_d is minimal set of production rules which satisfy the following conditions:
(1) P_d contains just one d-rule;
(2) if P_d contains the rule IF f_1 & ... & f_n THEN f, then for every fact f_i either $f_i \in F_0$ or P_d contains just one f_i-rule.

Notice that the last definition is exhaustive: a given set of productions Q can be matching with the above conditions.

Now let us consider the algorithm E. If the fact h is selected as a hypothesis then rule interpreter turns to the algorithm E which returns either h-rule or reject message. If $E(h)$ is reject message, then rule interpreter starts with another hypothesis. If $E(h)$ is not reject message, then rule interpreter uses $E(h)$ for construction of inference.

In its operation, the algorithm E provides for that the same rules are not selected once again. At the very beginning all the rules are marked as executable; once selected rules are marked as non-executable.

In general, the algorithm E consists of two steps:

Step 1. To form the subset $P(h)$ which consists of all h-rules from the given set of production rules P.

Step 2. If $P(h) = \emptyset$ then to return reject message.
If $P(h) \neq \emptyset$ then to return the only rule from $P(h)$ on the basis of the predefined conflict resolution mechanism [3].

3 The quoting-based algorithm

Not to concentrate on minor aspects, hereinafter we will assume a certain level of similarity of the cooperating production systems, namely (1) rules of the production systems should be generated on the basis of the same syntax, (2) despite facts of the production systems may differ, the facts identical in meaning should have the same name, (3) the production systems should have at least one common goal.

Let us consider the two production systems: $S =< F_0, P, D, E >$ and $S_1 =< F_0, Q, D_1, E_1 >$. Suppose that for the same problem situation F_0 and for the same hypothesis d the system S returned reject message and the system S_1 generated a well-grounded inference Q_d. Backing to analogy with human collective decision making, imagine that the system S nevertheless tried to generate well-grounded inference P'_d referring to the respected opinion of the system S_1. In this case we say that the production system S "quoted" the system S_1.

Formally, the task of quoting for the production system S is
▷ to provide the well-grounded inference P_d for the goal d
▷ taking advantage of some of the rules of the another system S_1,
▷ with the post factum estimation of originality of the received results.

To solve the task of quoting we offer to upgrade the algorithm E of the production system S to the algorithm E^+, which explicitly uses the borrowed well-grounded inference:

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  if  E(h) is reject message   and  Q_d \ P contains the h-rule q
then  return the rule q        else  return E(h).
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Note, in the case $Q_d = \emptyset$ the algorithm E^+ turns into E. If $Q_d \neq \emptyset$ the production system $< F_0, P, D, E^+ >$ guarantees the well-grounded inference P' for the goal d, using the rules $P \cup Q_d$, where P'_d contains at least one rule from $Q_d \setminus P$.

The simplest formula for estimation of originality of the received result: $k = \| P'_d \setminus Q_d \| \;/\; \| P'_d \|$. In the worst case (full borrowing of knowledge): $P'_d = Q_d$ and $k = 0$. At best, but unattainable, case (no borrowing of knowledge): $k = 1$. The more sophisticated estimations can be calculated by using the measure of similarity of set Q_d and set P'_d [4].

4 Conclusion

We proposed a quoting-based algorithm which allows a production system to enhance its capabilities with the help of borrowing from another production system. In general case, the proposed algorithm does not guarantee the maximum originality for the generated inference P'_d. At the same time, realization of the algorithm requires minor changes the traditional backward chaining engine.

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