MULTIAGENT SYSTEM FOR DETERMINATION OF OPTIMAL HYBRID FOR SEEDING

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Abstract: Man expert determines suitable hybrid for seeding in four steps. General ES prototype is built in the same method, using agent-oriented approach. The knowledge base consists of several agents. Agents communicate using their language and update their internal beliefs, until solution is reached. General prototype is being used for creation ES prototype for determination of optimal maize hybrid for seeding.

Keywords: expert system prototype (ES), multiagent system (MAS), optimal variety, hybrid, seeding, maize.

1 Introduction

Expert system ([12], [8], [7]) prototype (ES), which is the subject of this work simulates thinking of an agricultural expert, which determines the most suitable variety or hybrid for seeding ([5]):

1. He collects all the essential data affecting the choice.
2. He roughly analyzes the given conditions (from 1.) and the characteristics of the individual varieties and hybrids. The varieties and hybrids are always in advance divided into groups (usually according to the length of vegetation period). As the result of analyzing, one group that competes further for selection of the optimal one, is obtained.
3. Only group of varieties and hybrids obtained in 2. are taken into consideration. Every variety and hybrid is optimal in certain conditions. In this step the expert compares the optimal conditions of each variety and hybrid to the given conditions for seeding.
4. Expert recommends seeding the variety or hybrid, which has the optimal conditions most fitting to the given conditions. In case that neither variety or hybrid was enough good in the given conditions, expert refers that to user, along with possible recommendation for seeding some other crop.

2 General Principles for Development of ES Prototype

A process of determination of optimal variety or hybrid for seeding is essentially similar for all agricultural crops. This fact enables to build general ES prototype that can be used for development of any ES specialized for some particular crop. The general prototype has been made as a multiagent system. It consists of several agents, and each agent is devoted to one part of the problem. The agents must cooperate during the problem solving, and this

cooperation is, like in real agency, achieved through communication. The organization of the general ES prototype is given in the Figure 1.

2.1 The System Architecture

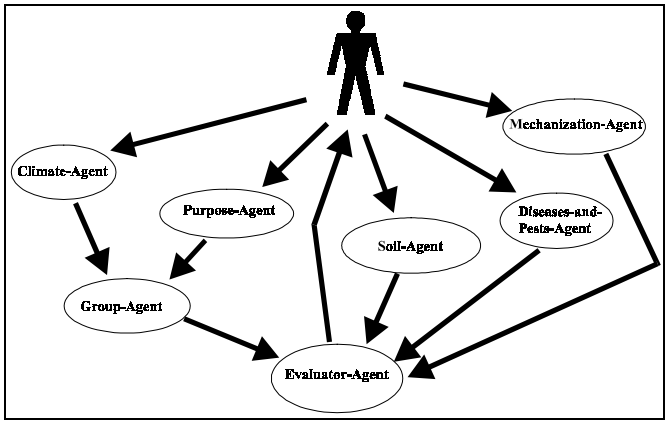

Figure 1.

There are many notions of an intelligent agent ([9], [3], [1]) today. We have chosen one that is most suited to the problem of determination of the optimal variety or hybrid.

In the ES prototype, beliefs of an agent consist of a set of propositions. Only propositions without logical operations are allowed. To every proposition, a certainty factor (CF) is attached. This is an integer between 0 (logical false) and 10 (logical true). This number may be unknown. At the beginning of the problem solving, every proposition has unknown CF. In case that CF of some proposition is required and it is unknown, it has to be determined. To determine CF, there is additional information attached to the proposition which enables the system to find appropriate CF. There are three types of hints, specified in advance by knowledge engineer, which define a way for CF determination: 1. ask some particular agent for the proposition's CF, 2. ask the user for the proposition's CF, 3. proposition's CF is equal to some given (possibly compound) proposition.

CF of any proposition can be evaluated using following formulas ([9]):

CF(NOT P) = 1 - CF(P); CF(P AND Q) = MIN{CF(P), CF(Q)}; CF(P OR Q) = MAX{CF(P), CF(Q)}

Beside it's beliefs, agent may contain capabilities to perform some actions as sending and receiving messages from another agent. Some agents communicate with user, so they have to be able to perform user-friendly communication with user of ES.

2.2 Agent Communication

There have been many propositions for an agent communication language in the MAS theory ([11], [9], [3]). The language, we have chosen, consists of two types of messages:

a) *request(from_agent, to_agent, proposition),* b) *inform(from_agent, to_agent, proposition, cf).*

The message *request*(A_1, A_2, *P)* is sent when agent A_1 is asking agent A_2 whether the proposition *P* is true. This message can be followed by message *inform*(A_2, A_1, *P, C)*.Inform message is a response to request message and means that agent A_2 informs (responses to) agent A_1 that the truth value of the proposition *P* is *C*.

2.3 The Agents in the ES Prototype

According to problem of determining of optimal hybrid for seeding, there are seven agents in the ES prototype.

- Climate-agent is concerned with weather conditions in the area where plant will be cultivated. CFs of this agent's propositions are mostly determined by asking a user. Such propositions could be:

dry_summer, rainy_spring, sum_of_received_temperature_between_1300_1400, possible_strong_winds.

There are also propositions whose CF can be inferred from other propositions. For instance: *possible_flood* has the same CF as a proposition *rainy_spring* OR *rainy_summer* OR *rainy_autumn* OR *lot_of_snow*.

- Purpose-agent contains important propositions describing purpose of the crop.
- Group-agent does not communicate with user. Its task is to determine an optimal group. It contains one proposition for each group: *group_1_is_optimal, ... group_m_is_optimal*.

CFs of these propositions should be determined on the base of information provided by other agents. If varieties-hybrids are grouped according to vegetation period, Climatic-agent and Purpose-agent should provide required information for determination of optimal

group. For example, a proposition *sum_of_received_temperatures_between_1500_1600* is placed in the Climatic-agent and another copy of it in the Group-agent. When Group-agent needs to know it's CF, it sends a message:
request(Group-agent, Climatic-agent, sum_of_received_temperature_between_1500_1600).

Climatic agent will ask the user about CF of this proposition. User can determine it as 9. After that, Climatic-agent will send a message:
inform(Climatic-agent, Group-agent, sum_of_received_temperatures_between_1500_1600, 9).

- Soil-agent is devoted to soil type information.
- Mechanization-agent is devoted to available mechanization and agricultural technology.
- Diseases and pests-agent concerns diseases and pests in the environment.
- Evaluator-agent is the agent that brings decision about optimal variety or hybrid for given conditions. If there are n possible recommendations then the agent mental space will includes following propositions: $solution\_is\_name_1,...,solution\_is\_name_n$

If solution $name_i$ belongs to group j, then CF of the proposition $solution\_is\_name_i$ will be determined as CF of the proposition *group_j_is_optimal* AND P_i. P_i is the compound proposition describing conditions in which $name_i$ is optimal solution to the problem.

The goal of the system is to evaluate CFs of these n propositions. After the Evaluator-agent has evaluated all these CFs, it performs an action. This action consists of finding the propositions with the highest CF.

The ES will always find optimal solution performing steps which man expert does.

At the beginning, system tries to determine CFs of its goal propositions. These propositions are: $solution\_is\_name_1,...,\ solution\_is\_name_n$. CF of the proposition $solution\_is\_name_i$ will be determined as the CF of the compound proposition *group_j_is_optimal* AND P_i (if $name_i$ belongs to group j). Determination of the CF of the proposition *group_j_is_optimal* involves message passing to the Group-agent. The Group-agent sends message to other agents, until the CF is found and received by the Evaluator-agent. Similar will happen next, while CF of P_i will be evaluating. P_i is a compound proposition. It consists of many propositions whose CFs will be requested from other agents. These propositions are connected with logical operations: NOT, OR and AND.

To prove why is the solution with the highest CF optimal one, it is enough to see that CF of the proposition P_i is directly proportional to the similarity between optimal conditions for solution $name_i$ (described by P_i) and the conditions given by user (described by user given CFs). Solution with the optimal conditions most similar to the given ones will become optimal solution.

The role of the first conjunct, *group_j_is_optimal*, is to forbid suggestion of any solution which is not from optimal group. If the group k is optimal then for all i $(1 \le i \le m, \quad i \ne k)$ CF of the proposition *group_i_is_optimal* will be 0. CF of the proposition *group_k_is_optimal* will be 10. Only solutions from the group k will be taken into consideration.

3 Determination of Optimal Maize Hybrid

The general ES has been used for the creation of the ES for determination of optimal maize hybrid for seeding from the group of 42 maize hybrids ([4]). Maize hybrids are divided into groups depending on ripening: very early, early, middle early, middle late, late, and very late.

For example, to determine the CF of the proposition *optimal_group_is_early*, system has to evaluate CF of the proposition:
(*sum_of_received_temperatures_between_2150_2300* AND *milky_waxy_maturity*) OR (*sum_of_received_temperatures_between_2175_2325* AND *complete_maturity*)

Group-agent will ask Climate-agent for the CF of the propositions about sum of received temperatures during vegetation period. Climate-agent will ask user for these CFs (if they are unknown).

Propositions about maturity are maintained by Purpose-agent. CF of these propositions will be inferred from the CF of the propositions about purpose of the yield. After its request, Group-agent will be informed about these CFs.

One of the goal propositions placed in the Evaluator-agent is: *solution_is_NSSC-370*. NSSC-370 is the early hybrid ([10]).

CF of this proposition will be equal to the CF of the proposition:
optimal_group_is_early AND ((*animal_feeding* AND *rolling_relief*) OR *extensive_growing_conditions*)

The *NSSC-370* will be recommended if the purpose of yield is animal feeding and relief at the farm is rolling or if there are extensive growing conditions.

4 Conclusion

A general model of the prototype ES was made for determination of the most suitable variety or hybrid for seeding in some real conditions. The prototype is made as multiagent system. This general model is being served for production of ES prototype for determination of optimal maize hybrid for seeding.

The system's performance has been compared with the performance of the system's rule-based predecessor [5] and similar systems ([2], [6]). There is no big improvement in the new system's performance, but advantages of the new approach has been notified in the system's building and modification. A human expert has also been satisfied with the new ES.

5 References

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