GENETIC AND MULTI-AGENT APPROACH TO CREATE SCHEDULE FOR AGRICULTURAL FIRMS

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Abstract

Search an optimal solution is often impossible for acceptable time. Determination a good solution in scheduling problem for the agricultural companies is an open task. This paper describes the intelligent system for creating schedule of agricultural equipment for doing farm works. We report a novel method for searching optimal scheduling of agricultural operations. The proposed approach is based on genetic algorithm and multi-agent systems and permits to find appropriate solution, which minimizes operation costs.

Introduction

Nowadays scheduling tasks are very actual and important. There is great amount of different tasks connected with effective using equipment and other resources, process coordination of different services. In spite of great number of research in this field the importance of it doesn’t decrease. Such tasks are rather difficult and need special methods to find solution in allowable time.

For solving the tasks, connected with scheduling, different heuristic methods are needful. There are a lot of artificial intelligence methods, which can be useful. As usual, developing intelligent systems, we deal with huge search space. Genetic algorithm can be used as heuristic search algorithm. They belong to the larger class of evolutionary algorithms, which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover.[1] Genetic Algorithms (GAs) are adaptive heuristic search algorithm premised on the evolutionary ideas of natural selection and genetic. The basic concept of GAs is designed to simulate processes in natural system necessary for evolution, specifically those that follow the principles first laid down by Charles Darwin of survival of the fittest. As such they represent an intelligent exploitation of a random search within a defined search space to solve a problem [2].

The next method, which is used in this paper, are a multi-agent systems (MAS). MAS is a system composed of multiple interacting intelligent agents within an environment. Multi-agent systems can be used to solve problems that are difficult or impossible for an individual agent or a monolithic system to solve. Intelligence may include some methodic, functional, procedural or algorithmic search, find and processing approach [3].

The main idea of the paper is to describe the intelligent system for making optimal schedule of using agricultural resources for farm works. The criteria of the optimality schedule is decreasing economical rate on the fuel, equipment repairing, salary and amortization. The task is to distribute aggregates, which consist of tractors and trails, to the farm works. This distribution must not contradict the rules, such as: all agricultural works must be done in time; a cycle (sequence) of farm works must be right (dependent operation must follow main operations); all agricultural equipment (aggregates and its parts: tractors, trails) must not be used simultaneously.

The paper is organized in a following way: the first section describes the task and the system for its solving. The second section is devoted to describing methods and algorithms of the problem solving. Section “3” is described the software and experimental results. The last section is concluded the paper.

1. Problem statement

Before talk about the system, it’s necessary to describe the task in more detail. The paper is devoted to description of system, solving the following task - to distribute aggregates, which consist of tractors and trails, to the farm works. So, the system must process next data:

1) There are a set of agricultural operations with its periods -range of dates. Some of them depend on others. Dependence means that if one agricultural operation depends on another, then in any day count of processed ha (hectares) on the field of main operation must not be less than processed ha of the dependent upon it.

2) There are agricultural resources - agricultural equipment for operations: machine-tractor aggregates, which consists of force resources (tractors, machines) and trails (planters, tups).

The problem is to create optimum schedule for farm works. Schedule means to allocate aggregates for farm operations in such a way, that all limitations would be observed. The limitations are:
• all farm work must be done during its dates ranges;
• main operations must not follow its dependent operations;
• any equipment (machines or trails) must not be used in more than one farm work in one day.

The optimality of schedule is meant to minimize the cost for the process of all farm works. The cost consists of fuel cost, amortization, equipment repair and workers’ salary.

Thus, the system must create optimal permissible schedule. As previously mentioned, the criteria of the optimality schedule is decreasing economical rate and a permissible schedule is meant all limitations to be observed.

The schedule can be represented by a time table. This time table depicts agricultural operations with its aggregates and periods. A cell of the table is a day of period of certain farm work, in which certain aggregate can be used. The cells can take one of two values: “1” (the aggregate is used for the farm work in this day) and “0” (the aggregate is not used for the farm work in this day). The count of these cells can be calculated by the formula (1):

\[ N = \sum_{i=1}^{n} Ag_i \times D_i \]  

(1)

where \( n \) – the count of agricultural operations (farm works), \( Ag_i \) – the count of aggregates for i operation; \( D_i \) – the count of days of period for i operation.

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Fig.1. Schedule. Time table

A permissible solution – is such schedule of using aggregates, which allows limitations to be observed. (Limitations are noted above). So, permissible solution is a sequence of cells values (“1” and “0”), which determines a schedule, which doesn’t contradict the rules-limitions.

The task solution or optimal schedule is one of the permissible solutions, which allows to minimize the cost of agricultural processing.

Solutions search space is a set of various (different) sequences of cells values: “0” or “1”.

Obviously, a count of permissible solutions is rather less than solutions search space. So it is needed to separate one more task (subtask) – searching of permissible solutions. Solving this task must be based on several rules, such as following:

a) All farm works must be done in time;
b) A dependent operation must follow its main operation.
c) Two aggregates can’t be used simultaneously for the same or different operations, if they include the same part (a tractor or a trail).
2. Solution algorithms description

2.1 Permissible schedule

A permissible solution is one of the schedules of aggregates, using for farm works, which can process agricultural circle correctly. It can be found with the help of multi-agent system. Multi-agent systems include cognitive agents whose the behavior tends to satisfy one or some objectives taking into account some constraints of facilities and their proper expertise.[5]

In this context each cell of time table is an agent. Its goal is to take value (“1” or “0”), which wouldn’t contradict the limitations. All agents have additional parameter – weight. The bigger this parameter the more probability, that the cell (agent) will take value “1”. The value “1” of neighbor agents also increases the probability of “1”-value. If an agent “switch on” (take the value “1”), other agents using the same parts of the aggregate in this day must be blocked (take the value “0”).

So, each agent can be in one of three states:
1) “Switched on” – the cell has value “1”. It means that the aggregate is used for the operation in this day.
2) “Waiting” – the cell has value “0”. It means that the aggregate is not used for the operation in this day, but it can be used if necessary.
3) “Blocked” – the cell has fixed value “0”. It means that the aggregate is not used for the operation in this day, and it can’t be used.

These states are illustrated on the figure 2.

Thus, agents calculate value of its cells, according to the rules (limitations). For the calculation they use information (signals) from other agents, current state of the schedule and their weights. Agents have different kinds of relation with other agents:
1) “A member” – the cells of one agricultural operation.
2) ”A neighbor” – neighboring cells in the row in time table.
3) “A rival” – the cells with aggregates, which contain the same parts and are used in the same day.

It’s difficultly to describe this heuristic algorithm of searching one of correct schedule by cells (agents) in the multi-agent system step by step, but it’s rather visually to depict it with the help of UML sequence diagram. It describes the communication protocol between agents, connected with different relationship. Data communications protocol is illustrated on the figure 3.
Thus, calculation of value of the sells is based on the data communication protocol and agents’ state graph. An agent processes signals from other agents and changes its state according to the states graph. When an agent changes its state it sends signals to other agents according to the protocol, after that these other agents receive and process the signals and go into new states or save previous state.

In a few word the basic logic of this subsystem (MAS) can be described in following way: agent with the most weights at first instance “try to switch on”. It means that such agents analyze:

- analyze, whether its farm operation has not processed completely yet, otherwise it doesn’t matter to switch on;
- analyze, if the one the integrated parts of the aggregate: tractor or trail is not used this day, otherwise it can’t be switched on, and etc.

If there is no factors, which disturb to use the aggregate to the farm work in the day (“to switch on” the cell), the agent takes the value “1”, turns into state “switched on” and sends several kind of signals: “switch on if not blocked” to the neighbors, signal “block” to rivals and signals to “members” that a part of work has been done. These signals mean, if the aggregate is used in the certain day for the farm work, it will be used in this operation with great probability in next day or in previous day. One more detail – if the aggregate is used in certain day, other aggregates, which contain the same part: tractor or can’t be used in this day, that’s why corresponding cells are blocked.

2.2 An optimal solution

The MAS is used for searching permissible solutions. As previously mentioned, the weights of cells influence on its values “1” or “0”. Different sequences of cell-weights can create different schedules. In order to find optimal schedule, we must generate different sequences of cell-weights then to converse them in permissible schedule with the help of MAS, calculate the costs of the schedules, and collect or chose the most inexpensive schedule. For this aim an adaptive heuristic search algorithm is needed.

A Genetic Algorithm (GA) is one of the possibilities, which take a logically centralised view on the problems as it is possible to have a number of solutions at the end, a centralised view is taken by choosing the best solution found so far [6].

Thus, genetic algorithm is used for searching optimal schedule among permissible solutions. **Individual** is a schedule. Fitness function is value of economic costs for the doing all farm works according to the schedule. The chromosome is a record - array of digits, which describe parameters of schedule-cells (their weights). Chromosome is illustrated on the figure 4.

![Fig. 4. Chromosome](image1)

It’s necessary to admit, that chromosome describes the precondition of schedule, but not schedule itself, because not only cells-weights influence on the probability of using certain aggregate on certain farm operation: “1”-value of the cell of timetable, but there are other factors, such as signals from other cells (agents). A schedule is created from its precondition or chromosome with the help of MAS (multi-agent system), and it is also heuristic algorithm. So there is a heuristic, not identical, connection between chromosome and individual.

![Fig. 5. Chromosome. Schedule](image2)

Apart from this feature, the genetic algorithm is common genetic algorithm and includes following steps:

1) **Initialization of chromosomes.** First of all it’s needed to generate population and calculate fitness-function of each individual. In this point several sequences of additional parameters of cells are initialized. Each sequence is transformed into permissible schedule with the help of multi-agent system, and then economic rate, which values fitness function, is calculated.

2) **Selection.** During each successive generation, a proportion of the existing population is selected to breed a new generation. 

3) **Reproduction.** The next step is to generate a second generation population of solutions from those selected through genetic operators: crossover and mutation. For each new solution to be produced, a pair of "parent" solutions is selected for breeding from the pool selected previously.

4) The algorithm goes on while fitness function stops change.
3. Experimental result

The system, described in this paper, is a part of large software system, which was designed to help agricultural firms to process its farm works effectively and to increase profitability of the resources. The system saves and process large amount of information about farm works, soil characteristics, parameters of aggregates power, user’s confidential data and etc. One of the main parts of this software complex is the schedule creature system. This system allows solve two main problems:

- to analyze, if amount of agricultural resources is enough to process the farm works, planned by the firm;
- to create schedule of more economic effective using of the available resources.

The system was tested for processing data for the small agricultural firm with standard set of operations of processing agricultural plants and population of machines. The system allowed to generate schedule for this firm and reduce economic rate on about 60% compared which the schedule, generated on the first population of genetic algorithm.

Conclusion

The solution of the task, which was described in this paper, is based on combination of two methods: genetic algorithm and multi-agent system. The main role of genetic algorithm is to direct solution searching to economic optimal schedule. Multi-agent system is used to find permissible schedule of using agricultural resources for the process farm works.

Bibliography