Ant algorithms application for factory logistics with multiple waypoint routes

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Abstract. The research presented aims to propose a modelling complex for metal-processing enterprise logistics control. In this paper, the application with use of ant algorithms for multiple waypoint route optimization is described. Model equations and flowsheet are proposed along with preliminary experimental data.

1. Introduction

We proposed a model to solve the problem of optimizing the logistics processes of the metal-processing [1] enterprise. This model consists of two main parts: first is for calculating optimal cargo packing [2] for transport's cargo platform and second is for finding an optimal route for cargo delivery [3]. The model complex seeks to bring the system to an optimal state, so there is no need to repeat visits to the same points of a route during one trip and no need to unload and return materials from the cargo platform during transportation.

Today, logistics of the enterprise consists one courier and third-party transport companies, which are accessed through an office located separately from the production site and main warehouses. To achieve high efficiency of purchasing, production and stockpiling of materials and technical resources [4], as well as the distribution of finished product, it is necessary to determine optimal routes for cargo transportation by various contractors, both internal (courier) and external (third-party companies).

Object of study in this paper is courier of enterprise. His work is to transport products in the production process for revision. Revision of the most products is carried out on the additional production site of the enterprise, but often there is need for appeals to third-party subcontractors. In addition, the courier transports some standard parts and tools that necessary for production from trading warehouses to production sites.

The courier's work can be modelled and presented as one common task, including the transportation of products for revision and delivery of new parts in one departure with a minimum number of intermediate points and returns. The search for this problem's solution is carried out in the system using ant algorithms [5].

2. Theory

In real world, ants move along their colonies in search for food and produce a chemical called "pheromone". This substance attracts other ants, so that when food is found, ants follow the first ant to find it. As a result, most ants will prefer this route.

This behavior can be modeled in computational tasks. Initial results are processed and then, in the next iteration, positive decisions are added to good results and bad decisions are removed. This process continues until the best solution is found [6].

Ant algorithms simulate ant's behavior that related to their ability to quickly find the shortest path from an anthill to a food source and adapt to changing conditions, finding a new path. This process is usually modeled on a graph, the vertices of which are possible paths for ants to move. The vertices of the graph contain some level of pheromone, which ants leave as they pass through it. The path that most enriched with pheromone along the vertices of this graph will be the solution of the problem obtained using ant algorithms.

There is an important step in this process called "pheromone renewal". In each step, a positive rating will be added to all solutions, so good solutions will receive more pheromones than other routes, and then rate of good solutions will increase. This is how at the end of the iteration a better result will be found. However, these pheromones will not remain forever and they will gradually disappear. This evaporation process is a parameter in ant algorithms, which is called: "evaporation rate".

According to nature of route finding problem, that is very similar to ant movement, ant algorithms can be used to solve such problems.

The classic task for ant algorithms is to find the shortest path in the graph. This task represents typical problem of route finding. A route includes some nodes (i, j...) and edges. In a simple case of using ant algorithms, edge value corresponds to its length. Pheromones are defined for each edge as a specific value. Several routes are considered from the beginning to the end of the path and then being estimated. The best solutions attract more and more pheromones during the process of their updating, so at the end of an iteration the best route gets the greatest pheromone and is presented as the best solution. That's how the shortest path is found.

In this way, for convenient application of ant algorithms, we could reduce our task to finding an optimal path in a graph. In our case, the initial task is as follows: the courier needs to deliver part of the cargo from the main production site to an additional site, another part to the subcontractor and, in addition, collect a new set of parts and tools from any trading warehouse and bring it back to the main production site.

If the courier is not loaded to his maximum (but also not fully unloaded), possibility of loading with the necessary set of parts and tools is checked. This stage, as well as each cargo loading, is implemented using a separate software that was developed as part of our previous work. So, if there is a possibility, then in search for a path to choose the next vertex, warehouses are added, which are not initially taken into account until the courier is unloaded.

We will use a set of algorithms for finding a solution for the problem, which can be described by the following general equations:

$$p_{ij}^{k} = \begin{cases} \dfrac{\eta_{ij}^{\alpha} \cdot \tau_{ij}^{\beta}}{\sum_{l \in allowed_k} \eta_{il}^{\alpha} \cdot \tau_{il}^{\beta}}, j \in allowed_k; \\ 0 \end{cases} \quad (1)$$

This is the probability that k-th ant will move from vertex i to j, where: η is the "visibility" of vertex, that inversely proportional to distance; τ - "smell", which directly depends on the level of pheromone; l is a vertex of the graph; $allowed_k$ - a set of accessible points of the graph (this do not include already passed points, as well as points that are not available due to additional conditions like courier's overload); α, β are parameters that determine the significance of pheromone trace relative to distance (we take the values for these parameters equal to 1 by default).

$$\Delta\tau_{ij}^{k} = \begin{cases} \dfrac{Q}{L_k}, (i,j) \in T_k; \\ 0 \end{cases} \quad (2)$$

This formula is for calculating how much pheromone is should be left on the path, where: T is the path traveled by k-th ant; L is the path length; Q is the constant parameter that determines optimality of the path length.

$$\tau_{ij} \leftarrow (1-\rho) \cdot \tau_{ij} + \sum_{k=1}^{m} \Delta\tau_{ij}^{k} \quad (3)$$

Equation for pheromone update, where ρ is the evaporation rate, m number of ants.

3. Realization

3.1. Creating a model

Our task can be visualized as graph [7] on figure 1.

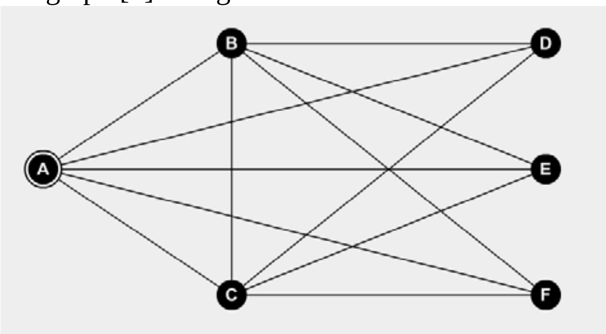

Figure 1. Graph for courier's transportation task: A - Main production site; B - Additional production site; C – Subcontractor; D - Warehouse 1; E - Warehouse 2; F - Warehouse 3.

The task can be described as set of subtasks that are: exit from the vertex A; necessarily pass through vertices B and C; necessarily pass through one of the vertices D, E, F; return to the vertex A.

Because of additional condition with a check on a possibility of loading courier’s cargo platform, the following scenarios are possible:

1. The courier is initially loaded to his maximum; the set of parts and tools cannot be loaded until the courier is completely unloaded;
2. The courier is initially loaded in a way that the set of parts and tools cannot be loaded until the courier is unloaded at the additional production site;
3. The courier is initially loaded in a way that the set of parts and tools cannot be loaded until the courier is unloaded at the subcontractor;
4. The courier is initially loaded in a way that the set of parts and tools cannot be loaded until the courier is unloaded at any place;
5. The courier is initially loaded in a way that the set of parts and tools can be loaded immediately.

Since the work of enterprise is carried out with different subcontractors, there were considered two examples for testing. The initial data for both of them is given in table 1.

Table 1. Initial data for two different subcontractors.

Path	Path length (Subcontractor 1)	Path length (Subcontractor 2)
1 – 2	9	9
1 – 3	12.5	16.5
1 – 4	16	16
1 – 5	22.5	22.5
1 – 6	26	26
2 – 3	6.5	14
2 – 4	23.5	23.5
2 – 5	14.5	14.5
2 – 6	17.5	17.5
3 – 4	26	18.5
3 – 5	19	21
3 – 6	16.5	20

There are results that gained using ant algorithms shown in table 2.

Table 2. Calculated results.

Subcontractor	Scenario	Optimal route	Route length
1	1	1-3-2-5-1	56
1	2, 4, 5	1-2-5-3-1	55
1	3, 4, 5	1-3-5-2-1	55
2	1, 2, 3, 4, 5	1-2-3-4-1	57.5
2	5	1-4-3-2-1	57.5

Operator's work in the system begins with an entry of data about the cargo for the courier. Previously mentioned program for cargo packing first determines loading of parts for revision, then calculates remaining space of cargo platform and determines space that necessary for loading the set of new parts and tools from a warehouse. After all calculations are finished, a scenario is chosen that determines the availability of paths for the courier. The operator writes in the distance to the subcontractor, and he also can add additional trading warehouses to the system. Then the system displays route that it have found.

The results that are shown in Table 2 can tell us the best options for path choosing for every scenario in terms of the length of the path, that are 56 and 55 km for situation with first subcontractor and 57,5 km for second. At this stage of work, the choice of the final route has to be assigned to the courier by the operator working with the data obtained as a result of calculations. In the future, it is possible to configure an automatic display of the best option without asking for confirmation by the operator.

3.2. Programming and potential updates

For model realization, we have built the system in a web application form. There are used PHP programming language and MySQL database for server part of the system and HTML5, CSS, javascript for visualization.

Parameters can be configured either manually by editing configuration files or through a graphical user interface in the application [8].

At this stage of development, our project is optimized for the needs of a particular enterprise. If it would be necessary to scale up for calculating more operations and increasing a degree of automation, than there will be needed some updates, which will be the subject for further research after completion of this prototype.

One of potential areas for future improvement may be a refinement for the system using multi-agent modeling [9-12]. The ant algorithm in a multi-agent model will work as follows: ants agents perform several iterations from the source to the final spot and provide results in a form of the traveled path and the pheromone left. The main agent monitors all the results and determines the best route. In this case, it is possible to realize the parallel operation of several agents in one iteration.

For the best visualization of results, possibility of adding connection with GIS will be considered [13]. With the help of GIS, you will be able to set addresses of subcontractors and trade warehouses to automatically calculate the distance, display received routes on the map, and also, depending on the functionality of the selected GIS, you may be able to get info about city traffic, road repairs and other additional parameters.

4. Conclusion

As a result of this work, main calculation formulas that used in ant algorithms were selected and adapted to the needs of the developed system, which describes a work of the metal-processing enterprise with multiple warehouse stores and subcontractors.

The described model allows to calculate optimal routes for the courier with specified criteria. Work has begun on a web application that includes described mathematical model. The application will implement an interface for the operator, containing a form for entering the initial data and visualizing the results of calculations.

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