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## APPLICATION OF METHODS FOR SOLVING THE SALESMAN PROBLEM FOR MODELING PRODUCTION PROCESSES

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The software of the solution of the salesman problem for the applied tasks is developed. As an area of application, the redistribution of cyclic production is chosen. The mission of a salesman is to find the most advantageous sequence of production of a range of products that pass through all these states once. To calculate the method of implicit selection with parallelization is applied. The developed interface, which allows you to work with a database of criteria and product range, choose interactive mode according to different criteria (and memorize) from the calculated sequences the most expedient. Also realized is the ability to track the process of the production itself and adjustments in dynamics (in the selected sequence), which is visualized in the form of diagrams..

**Key words:** CAD, training system, design method, design process, production processes.

## ЗАСТОСУВАННЯ МЕТОДІВ РОЗВ'ЯЗАННЯ ЗАДАЧІ КОМІВОЯЖЕРА ДЛЯ МОДЕЛЮВАННЯ ПРОЦЕСІВ ВИРОБНИЦТВА

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Розроблено програмне забезпечення для розв'язання задачі комівояжера для прикладних завдань. Як область застосування вибрано переналагодження виробництва циклічного характеру. Задача комівояжера полягає у пошуку найвигіднішої послідовності виробництва деякого асортименту продукції, що проходить через всі зазначені стани по одному разу. Для розрахунку застосовано метод неявного перебору з розпаралелюванням. Розроблено інтерфейс, який дає змогу працювати з базою критеріїв та асортименту продукції, вибирати в інтерактивному режимі за різними критеріями (та запам'ятовувати) із розрахованих послідовностей найдоцільнішу. Також реалізовано можливість відстежувати процес самого виробництва та переналагодження в динаміці (у вибраній послідовності), який візуалізується у вигляді діаграм.

**Ключові слова:** САПР, навчальна система, метод проектування, процес проектування, технологічні процеси.

### Introduction

The comparative simplicity of finding adequate solutions and the simple determination of the salesman's task is combined with the fact that the definition of a truly optimal path is a complex task.

Therefore, from the second half of the 20th century, the salesman's task is used not so much in practice, but is largely investigated theoretically as a model for the development of new algorithms for optimization. Based on the saleswoman's task, widely known modern discrete optimization techniques, such as the method of dividing the plane, the method of branches and boundaries, and various variants of heuristic algorithms, have been developed.

In practice, the task of traveling salesman in such a setting primarily concerns logistics, which is basically important in any business. For such tasks there is software, supplemented by convenient means of visualization.

The solution of this problem is also required in many other industries that have closed systems that are rigidly connected in time, such as: conveyor production, multioperational processing complexes, ship

and rail loading systems, cargo transportation on a closed route, calculation of air lines. Therefore, the salesman's task in our time is very relevant, because time, resources and finances are not limitless, and their rational and correct use is the key to success [1].

In addition, with the transition of humanity to the information society, there are extremely rapid transformational changes in generations of technologies, consumer standards, markets for the production and marketing of goods. Therefore, in modern conditions, when enterprises occupy a particular place in the economic labor market and are dynamic, non-stationary systems, the efficiency of their functioning is determined by the level of application of the methods of successful operation of the production itself, planning and analysis of its organization.

In order to implement such techniques, it is also possible to use the salesman problem solving software, which is oriented to the needs of a particular consumer. At the same time for each sphere of activity there are their peculiarities which must be taken into account and which impose restrictions on the statement of the task itself and on the means of visualization (user interface).

It is this approach that is implemented in this work on an example of industries that are cyclical and require redesign of production in the transition from one product to another.

### **Traveling Salesman Problem Methods and its Solution**

The mission of a salesman can be formulated as finding the most advantageous route that passes through specified points at least once. If it is required that the route passes through each point only once, then the solution is among the Hamiltonian cycles [2]. In the conditions of the task, the corresponding matrices of weights are also indicated, and the criterion of the profitability of the route (the cheapest, shortest, aggregate, etc.). The salesman's task can be represented as a model on the graph, that is, using vertices and edges between them.

You need to find the shortest route on this graph (Hamilton route), to which each vertex of the graph enters one time.

To guarantee the existence of a route and in order to simplify the task, it is assumed that the model graph of the problem is completely connected, that is, there is an edge between an arbitrary pair of vertices.

This can be achieved by inserting edges with the maximum weight (length, value, etc.) when there is no connection between the individual vertices. Such an edge will never get to the optimal route, if it exists, due to its long length.

Methods of solving the salesman problem can be divided into precise and heuristic. They can be combined. Exact methods are guaranteed to find the best way (if there is enough time). Heuristic methods find good solutions, which (in the general case) may be worse than optimal, but in a shorter time.

#### ***Exact methods***

If you calculate the length of all possible routes, you can find the exact solution of the salesman's task by choosing the route with the smallest length.

However, even for a small number of vertices, this problem is practically unsolvable. For a symmetric problem with  $n$  vertices, there are  $(n-1)! / 2$  possible routes, that is, there are 43 billion routes for 15 vertices.

Discrete optimization methods, in particular the branches and boundaries, allow finding optimal or approximate solutions for sufficiently large tasks.

#### ***Heuristic methods***

Heuristics can be used to speed up the search for acceptable routes, which, in general, do not guarantee the accuracy of the solutions found. Depending on whether heuristics calculate a new route, or trying to improve the already existing, heuristics are divided into constructive and iterative heuristics. In addition, dual heuristics are distinguished, and meta-evolutionists.

***Meta-heuristic methods*** combine the methods of locating local and global solutions in abstract strategies for heuristic optimization of tasks. Anthropogenic algorithm, genetic algorithms, or artificial neural networks (primarily the Hopfield network) use natural processes as a template. In principle, these methods can be found as rather qualitative solutions and are far removed from the optimal. The quality of the results and the length of the calculation depend on the definition and implementation of individual elements [3].

### Practical application of Traveling Salesman Problem

The software, which implements the salesman's problem in a certain area of application (re-regulation of production), is developed, taking into account its features.

The following features are provided for the user:

1. Calculation.
2. Tracking the process of creating products after the completion of the changeover.
3. Filling the information according to the criteria for the changeover.

Realized the possibility of calculating several sequences of switching, close to the best with the possibility of their evaluation according to various criteria. The choice of the required sequence is carried out by the user. This sequence is remembered and will continue to be used in the process of tracking production.

The software operates interactively; sold in the basic version (number of evaluation criteria unchanged), which is easy to adapt to the desired specifics.

Based on these requirements, a general scheme of software use is built

It all begins with the creation and filling of a range of product types (vertices of the graph), each of which is given a number (in the database) and it will remain the same in the future. Then you need to put in the database the value of the criteria for transitions (re-adjustments) from one type of product to another (ribs). Not all edges may be specified. Then they will be set to default value, or specified at calculation.

As a result of the calculation, a choice is made of the required sequence that is remembered.

Tracking of production (according to the selected sequence) will be carried out as production is at a specified date.

### Realization of the software system

Only Java [4] and C # [5] are cross-platform, which do not require the writing of programs separately for each platform. The C # language is more suitable for creating interfaces, which is the basis for implementation of the interactive mode of operation.

#### Work with the database

To use the program, you first need to specify an assortment of products at the enterprise, where you need to make adjustments, that is, switch from production of one type of product to another, whose production should begin sooner completion of the switching. You can set the range of products by clicking the "Base" button. To the left of the form is the table "Assortment" (Fig. 1).

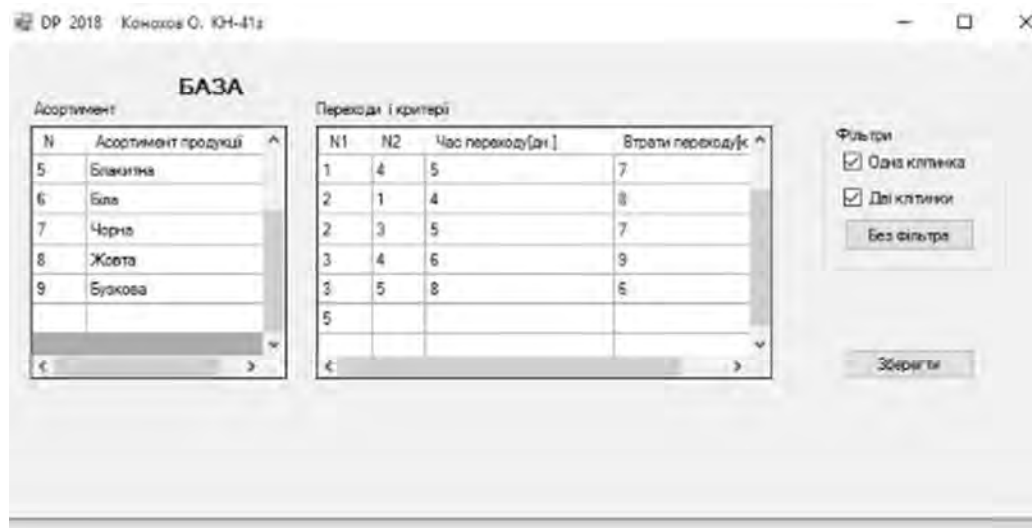


Fig. 1. Work with the database

Criteria for evaluating the changeover (switching from production of one product to another) are given in the table "Transitions and Criteria". The first column indicates the number of the type of product

from which you want to go, and in the second, the number of the type of product to which you want to go. The number of the product type corresponds to its number in the first table. The two other columns set the criteria values duration and cost).

In the general case, the quality of the value of the criteria may not be given, then either they are chosen by default or indicated immediately before the calculation begins.

For convenience, you can use the filter to search for the required assortment numbers in the “Transitions and Criteria” table. There are two types of filters for one cell (the vertex of the graph), or two (edges of the graph). In the first case, it is necessary to type in the free cell of the first or second column the necessary value, and in the second, to set the value in two columns. Next, click on the “Show” button.

To save the information, you must click the “Save” button. After that, the program saves all the necessary data, which can then be used for calculations.

If you want to remove any transition (edge of the graph), then you need to delete the necessary information in the appropriate cells.

Removing a type of product in the Assortment table results in the complete removal of the information from it from the “Transitions and Criteria” table.

### Settlement mode

Calculation is a work with sequences (Fig. 2).

On the form “Calculation” on the left is the table “Assortment from the database”, which contains an assortment of product types from the database. From this table you can use the buttons “>>” and “<<” to select the product range to be calculated. You can not change the contents of the table “Assortment from the database” (in this form).

After the set of the necessary assortment (in the “Selected range” table) it is possible for each type of product to indicate how much it is necessary to make it and the time required for the manufacture of this quantity of products of this type.

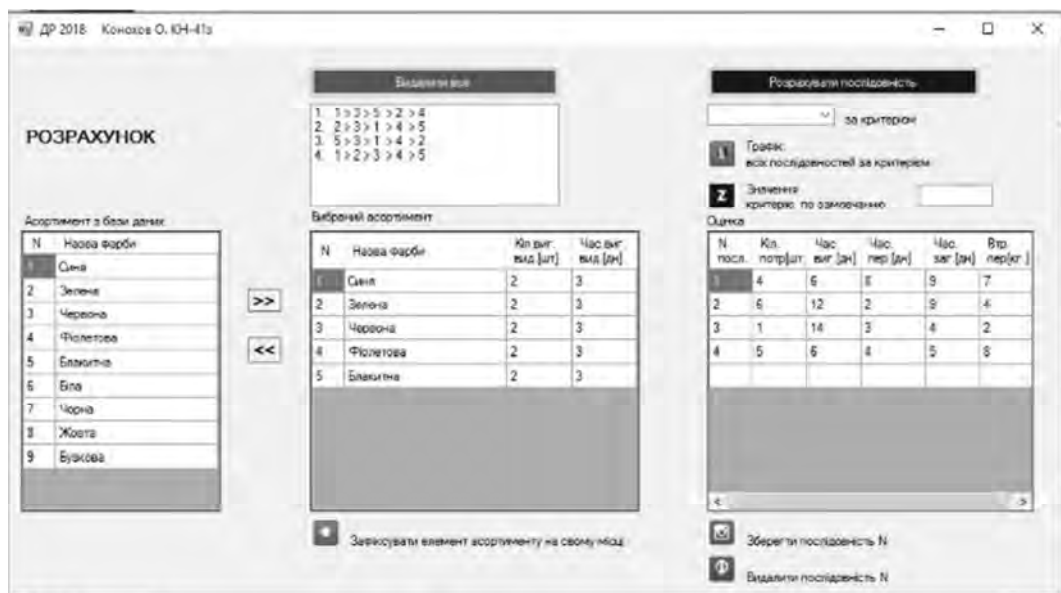


Fig. 2. Mode of settlement

The selected assortment creates a sequence that will be displayed in the list. In this case, the information from the table “Selected range” will be considered as a criterion for assessing but not transitions, and the process of production. In the “Score” table, you can see aggregate characteristics in sequence. You can also select the required criterion (including those that are available for referrals in the database) to display the graphs by clicking on the “Graph of all sequences by criterion” (Fig. 3).

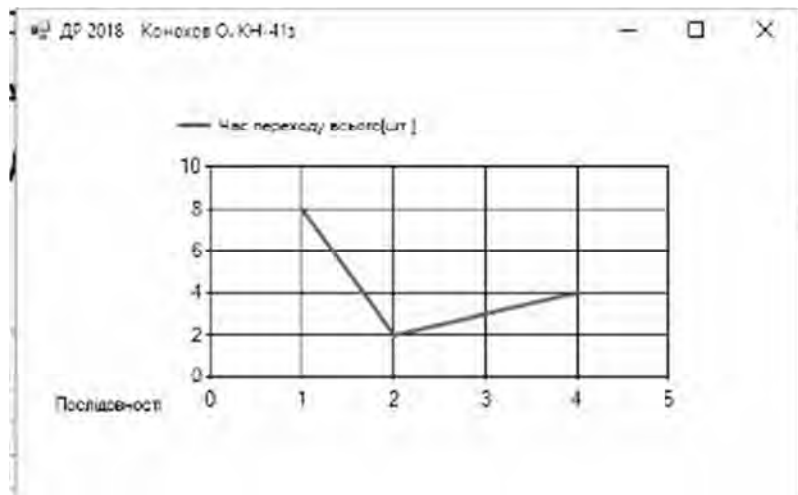


Fig. 3. Menu item. Graph of all sequences by criterion

You can, by clicking the “Calculate by criterion” button, to find three sequences that will have the best value. Now they can also be analyzed and displayed on the chart. If not all values of the criteria for the transitions (edges of the graph) are specified in the database, they can be set manually, otherwise they will be used by default.

In order to fix the item (s) of the assortment in its place, it is necessary to highlight the necessary element and to press the button “To fix the assortment item in its place” and then to execute the calculation.

If necessary, the sequence can be deleted, you need to select its number in the list and click on the “Delete sequence N” button.

Similarly, you can memorize the sequence to be able to track its execution.

Tracking mode

To monitor the implementation process – the production should click on the “Tracking” button (Fig. 4). The table will display information about the stored sequence.

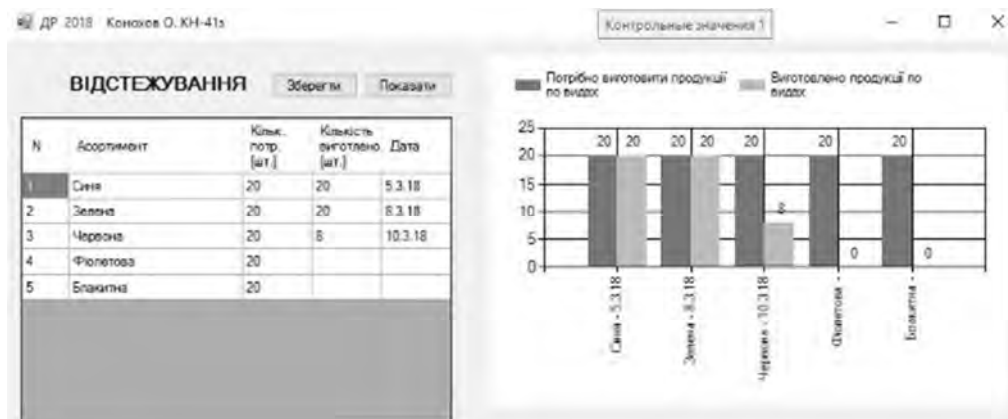


Fig. 4. Tracking item (implementation diagram)

The number of manufactured products at the appropriate date must be entered in the table in the production process, and then stored.

### Conclusions

The automated system, which performs the following functions, is developed and implemented: it provides an opportunity to study theoretical material, tests and adapts to specific technological processes. The results of the work have a theoretical and practical significance in the field of simulation of complex

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