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Application of Evolutionary Algorithms for Distribution of the Products in a Warehouse

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Abstract

The paper deals with an application of evolutionary algorithms for optimal distribution of products on a shelves of a warehouse of a store. There are three criteria: the rotation of products, distribution of groups of products side by side and simultaneous application of both criteria. In the latter case, the task is reduced to multicriteria optimisation. To solve the evolutionary algorithm was used.

Key Words: evolutionary algorithm, optimisation of distribution of products, multiobjective optimisation, warehouse

1. Introduction

Appropriate distribution of products on the shelves in the warehouse is an important element of the logistics, which is taken into account at the design stage of a warehouse. There are several rules in placement of each product. One of them is placing more frequently selling products closer to the exit of storage hall to sale section. It is also important that some groups of products are close to each other. A multi-criteria optimisation tasks including both criteria simultaneously: the frequency of releases and deployment of product groups together, can be used for solving the problem.

The task is to place the products on store shelves assuming that a number of products and a number of free places on the shelves is equal. This task can be reduced to the travelling salesman problem (TSP): a travelling salesman has to visit specified number of cities in such way to be in any city only once and travelling the shortest way. Any acceptable solution for the travelling salesman is a permutation of cities.

The origins of the TSP are in 1800s. The first example of this problem was routes through the cities of Germany and Switzerland in 1832. The TSP as a mathematical problem was formulated in 1930 by Karl Menger. The name travelling salesman problem origins from Hassler Whitney from Princeton University [15]. In 1950s and later there were developed algebraic methods like integer linear programming, cutting plane method and dynamic programming [2, 7, 9]. In 1972 R.M. Karp proved that the TSP is NP hard [8]. The exact solution are quite good for small problem size [1,14]. For bigger problems are used heuristic algorithms, which give solutions, which could not be proved to be optimal. They can solve very large problems with high probability that the solution is not far from optimal. Recently there are successfully applied artificial intelligence methods e.g. genetic end evolutionary algorithms [6, 10, 12], ant colony optimisation algorithms [4], simulated annealing [3], tabu search [5], the cross entropy method and nearest neighbour method in this research area.

2. Numerical Model

The task is to plan the distribution of the products on a warehouse store shelves. Figure 1 shows a diagram of empty places on the shelves. The best places are in the zone A. They are located closest to the exit of sales area. Placing on them products with the highest frequency of pick up will shorten the route to these products and thus employees would save much time and energy. Zone B is located further out of the sale area, and most far are shelving of area C. Zone D is closer to the exit, but empty spaces can be found on the top shelf. Table 2 presents the shelves ranking. The best places (zone A) were granted 3 points. 2 points were granted for places in the zone B. The worst place in zone C and D received 1 point.

Arranged items are divided into groups. It is desirable that the products of given group are close to each other. Table 1 lists 48 selected products, their frequency of releases per day is given and they are assigned to their respective groups.

Table 1 - Daily frequency of product rotations and the division of products into groups

Nr of product	Product	Frequency of pick ups per day	Nr of group of product	Nr of product	Product	Frequency of pick ups per day	Nr of group of product
1	Soap Arko Skin Care	120	1	25	Paper Towel Luxana	11	2
2	Sanitary Towel Bella Deo Nova	88	2	26	Bubble Bath Eva Natura	10	1
3	Sanitary Towel Always Duo	72	2	27	Shaver Wilkinson	9	9
4	Ambi Pur Flush	68	3	28	Shower Gel Johnsons&Johnsons	8	1
5	Toilet Paper Velvet	60	4	29	Shampoo Dave	8	8
6	Toilet Paper Regina	48	4	30	Toothpaste Elmex	7	6
7	Tissue Regina	42	5	31	Shaver Polsilver	7	9
8	Cream Nivea Soft	40	5	32	Pampers Jumbo Maxi	6	4
9	Toothpaste Blend-a-med.	32	6	33	Washing Powder Persil	6	10
10	Sanitary Towel Carefree	31	2	34	Tissue Luxana	5	5
11	Soap Luksja	30	1	35	Liquid Soap Luksja Fruity	5	1
12	Liquid Cleaner Pur for Dish	29	7	36	Balsam Dove	5	5
13	Liquid Cleaner for Glass	27	7	37	Air Refreshing Brise	4	3
14	Liquid Cleaner Tytan for Bathrooms	24	7	38	Shower Gel Palmolive Cashmere	4	1
15	Shampoo Shauma	21	8	39	Liquid Cleaner Pronto for Floor	3	7
16	Toothpaste Sensodyne	19	6	40	Stain Remover Ace	3	7
17	Sanitary Liquid Domestos	18	7	41	Bath Salt Apart	3	1
18	Rinse Liquid Silan	17	10	42	Shower Gel Adidas	2	1
19	Paper Towel Velvet XXL	16	2	43	Body Fluid Nutrisoft	2	5
20	Sanitary Towel Naturella	14	2	44	Toothpaste Dentix	2	6
21	Washing Powder Omo	14	10	45	Shaver Gillette	2	9
22	Cream Nivea Visage	13	5	46	Deodorant Rexona Deo	2	11
23	Cleaning Fluid Cif	13	7	47	Cream Garnier	2	5
24	Shampoo Nivea	12	8	48	Deodorant Adidas Action	1	11

Considering the task in the article, each product has to be placed on one of the designated locations. It can be many methods of positioning products on the shelves. Each allowed product placement is a permutation of the products setting on the shelves. The quality of each proposed solution is evaluated. The fitness function depends on the adopted optimisation criterion.

The solution task is a vector of natural numbers the following form:

$$m = < m_1 , m_2 , \dots , m_n > \quad (1)$$

where m_i – product number, which is placed on i-th shelf in the warehouse.

As a measure of the correctness of the distribution of products on shelves while meeting two criteria: frequency of releases and distribution the product groups together, it is assumed the function:

$$f = \frac{\alpha \sum_{i=1}^{n} \omega_{i_k} r_i}{z} \qquad (2)$$

where

n - number of places on the shelves. It is equal to the number of distributed products.

r_i – rank i-th place at the shelves,

ω_{ik} – frequency of releases of k-th product lying on the i-site

α - weighting factor, $\alpha \in (0,+\infty)$. It is possible to adjust the scale of importance between the two criteria. In the presented calculations $\alpha = 1$,

z – number of changes of product groups.

As it was mentioned above, place on a shelf has the higher rank if it is closer to sale area or it is easier accessible on the lower shelves. Products with a higher frequency of releases should be laid on shelves with a higher rank. This solution is convenient for servicemen, who can use shorter way to move products to sale area. The objective function described by formula (2) expresses such condition numerator of formula – if sum of product of shelf rank and product rotation frequency is higher, the distribution of products is better.

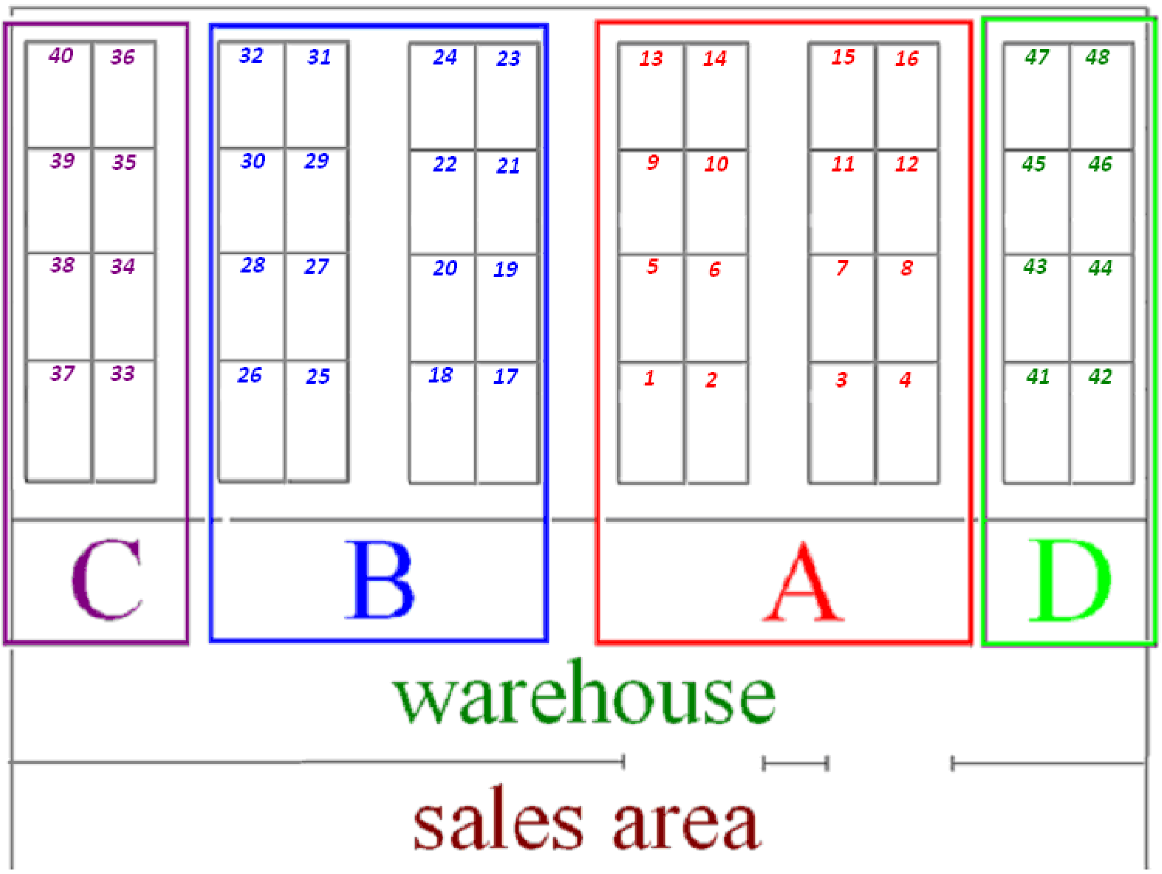

Figure 1 - The numbering of places on the shelves and warehouse division into zones

Vector (1) distribution of products on the shelves corresponds to the vector:

$$g = \langle g_1 , g_2 , \ldots , g_n \rangle \qquad (3)$$

where g_i – number of group of product, which is situated on the i-th place in the warehouse.

When all the products from the same group are close to each other, the sequence of numbers formed of successive coefficients of vector (3), groups of the same numbers should side by side. For k groups of products will be z = k-1 changes in sequence.

The criterion of distribution of products is limited only to the arrangement of groups of products together, the formula (2) can be written:

$$f = \frac{n}{z} \tag{4}$$

where the description is as above. As it can be seen the number of changes will be lower, the value of the objective function (4) will be higher.

In the article [11] calculations were carried out regarding only the criterion of frequency of releases of products and the ranks of places on a shelves. The objective function had the form [13]:

$$f = \sum_{i=1}^{n} \omega_{i_k} r_i \tag{5}$$

where the designation as above.

3. Calculation

Optimisation function (2) and (4) reduces itself to their maximisation. Problems were solved using evolutionary algorithms. Evolutionary algorithms belong to the methods of artificial intelligence. The evolutionary algorithm simulates evolution process. The genes in the chromosomes are optimisation parameters. Chromosomes are cloned, subjected to crossover and mutation processes in the course of the evolution. Each life cycle of the chromosomes ends in evaluation and selection. Usually better adapted chromosomes move to the next generation. This process is repeated specified number of cycles (length of life). Figure 2 shows the scheme of process the calculations.

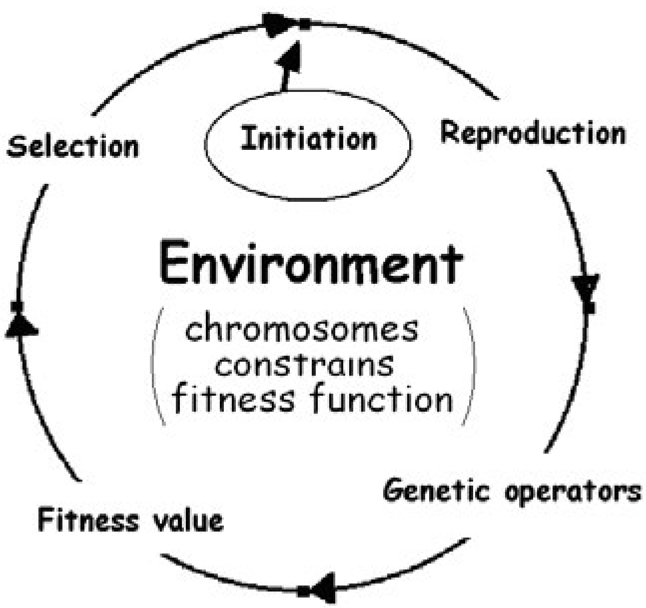

Figure 2 - The scheme of the calculation process

Environment is defined in the sense of mathematics by: variables of optimisation, imposed restrictions on it and the objective function. Vector variables of optimisation described by formula (1) is a chromosome that will be subjected to the action genetic operators in the process of evolution simulated by the algorithm.
There are used crossover operators: one-point crossover (figure 3) and two-point crossover and mutation operators: position based mutation (figure 4), order based mutation, adjacent two-job exchange mutation [10, 12]. The result of each of these operators is a permutation of products setting in the places assigned to them. That kind selection of crossovers and mutations operators ensures that the result of each operation is a feasible solution. These operators are used in the calculations with a given probability.

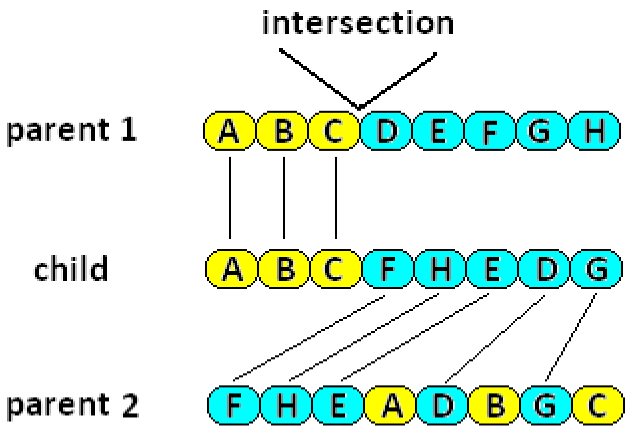

Figure 3 - One-point crossover

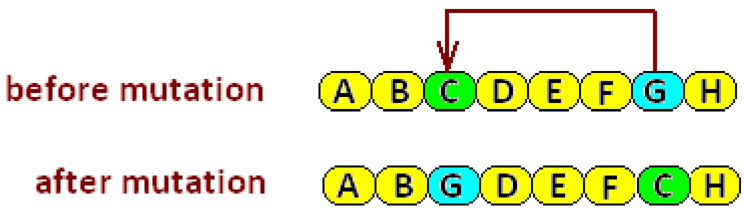

Figure 4 -Position based mutation

After each step of algorithm, new or modified chromosomes are evaluated. The fitness function is assigned for each solution. If its value is higher the solution fulfills criteria better. The functions (2) or (4) were assumed as the fitness functions in the presented calculations. Then the ranking selection is carried out, resulting in the best chromosomes move to the next generation. In addition, the exclusive selection is used, i.e. if the best chromosome of the previous generation is better than the worst chromosome in current generation, this worst is replaced by the best of the previous generation.

4. Results of Calculations

The calculations presented in the article focused on verifying the suitability of the proposed criterion to solve the problem formulated in the introduction. Applied algorithm has been tested previously in other examples. Therefore the calculations using criteria (2) and (4) were conducted without changes in population size and values of using probabilities of genetic operators. The table 4 containing the results of calculations for criterion 5 shows the results obtained in other research [11], where it was analysed the impact of the probabilities to use different operators on the values of the objective function. As it can be seen application of "adjacent two-job exchange mutation" increases significantly the value of the arithmetic mean of fitness function. It indicates that in the last generation the values of fitness function of all chromosomes were high.

Calculations for criteria 2 and 4 are a continuation of the previous calculations using this algorithm. The table 2 presents results of calculation using criterion (2). The table 3 presents results of calculation using criterion (4).

Table 2 – The results of calculations using criterion 2

Variant	Value of the fitness function	Best in the generation	Population	Length of the life	Probability of operators:				
					one-point crossover	two-point crossover	position based mutation	order based mutation	adjacent two-job exchange mutation
1	213,8333	2250235	100	2500000	0,8	0,8	0,3	0,3	0,3
2	214	2252097	100	2500000	0,8	0,8	0,3	0,3	0,3
3	213,1667	908457	100	2500000	0,8	0,8	0,3	0,3	0,3
4	211,75	1288626	100	2500000	0,8	0,8	0,3	0,3	0,3
5	197,8462	1158249	100	2500000	0,8	0,8	0,3	0,3	0,3

- the solution presented in figure 5

Figures 5, 6 and 7 show the distribution of products on the shelves according to the criteria appropriately to optimise the models (2), (4) and (5).

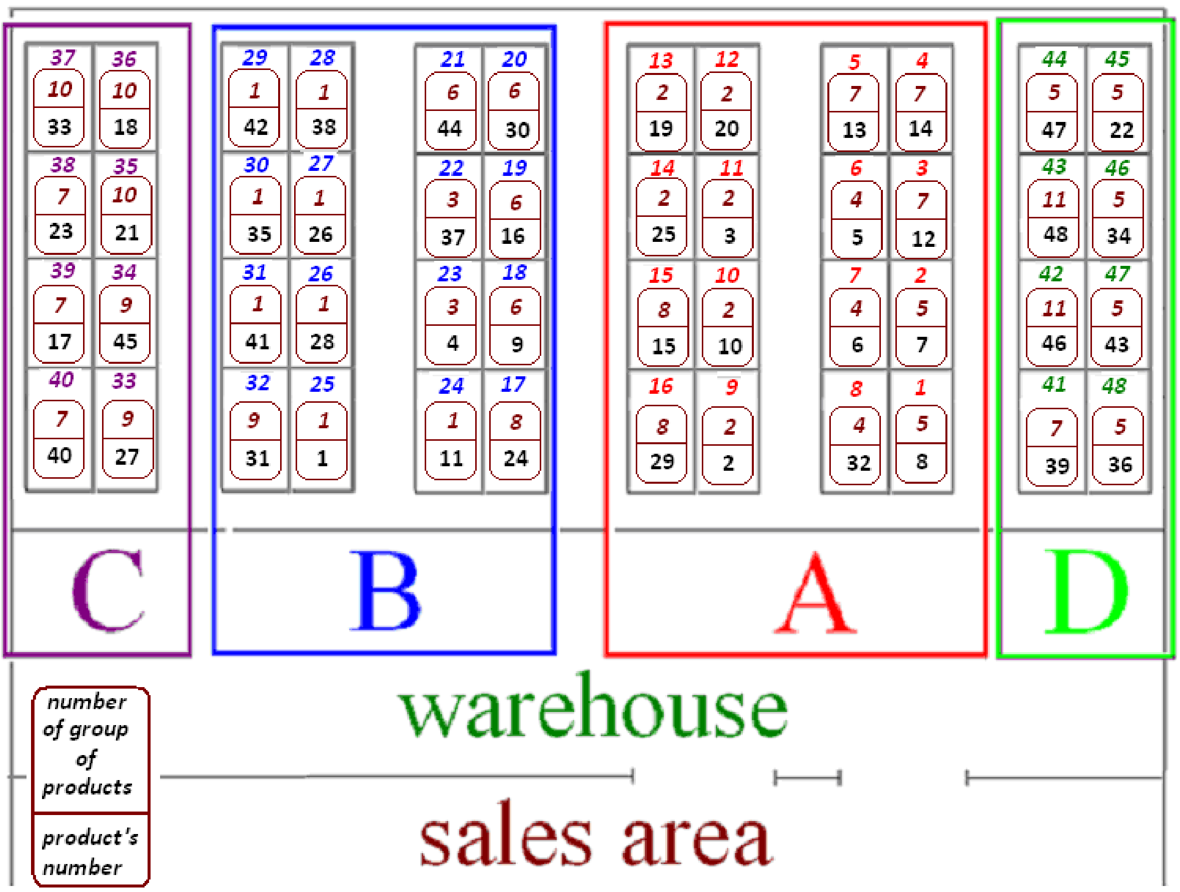

Figure 5 - Distribution of products on the shelves according to the optimization criterion (2)

As shown in Figure 5 and 6, the results of the optimisation carried out according to the criteria (4) and (5) fulfills them. Evaluation of results of multicriteria optimisation by criterion (2) is more difficult. For $\alpha = 1$ the frequency of rotation of the products has a greater impact on the results of optimisation than the criterion of grouping of the products.

Table 3 – The results of calculations using criterion 4

Variant	Value of the fitness function	Best in the generation	Population	Length of the life	Probability of operators:				
					one-point crossover	two-point crossover	position based mutation	order based mutation	adjacent two-job exchange mutation
1	4	742612	100	900000	0,8	0,8	0,3	0,3	0,3
2	4	813670	100	1200000	0,8	0,8	0,3	0,3	0,3
3	4,8	436214	100	1200000	0,8	0,8	0,3	0,3	0,3
4	4,363636	518522	100	1200000	0,8	0,8	0,3	0,3	0,3

- the solution presented in figure 6

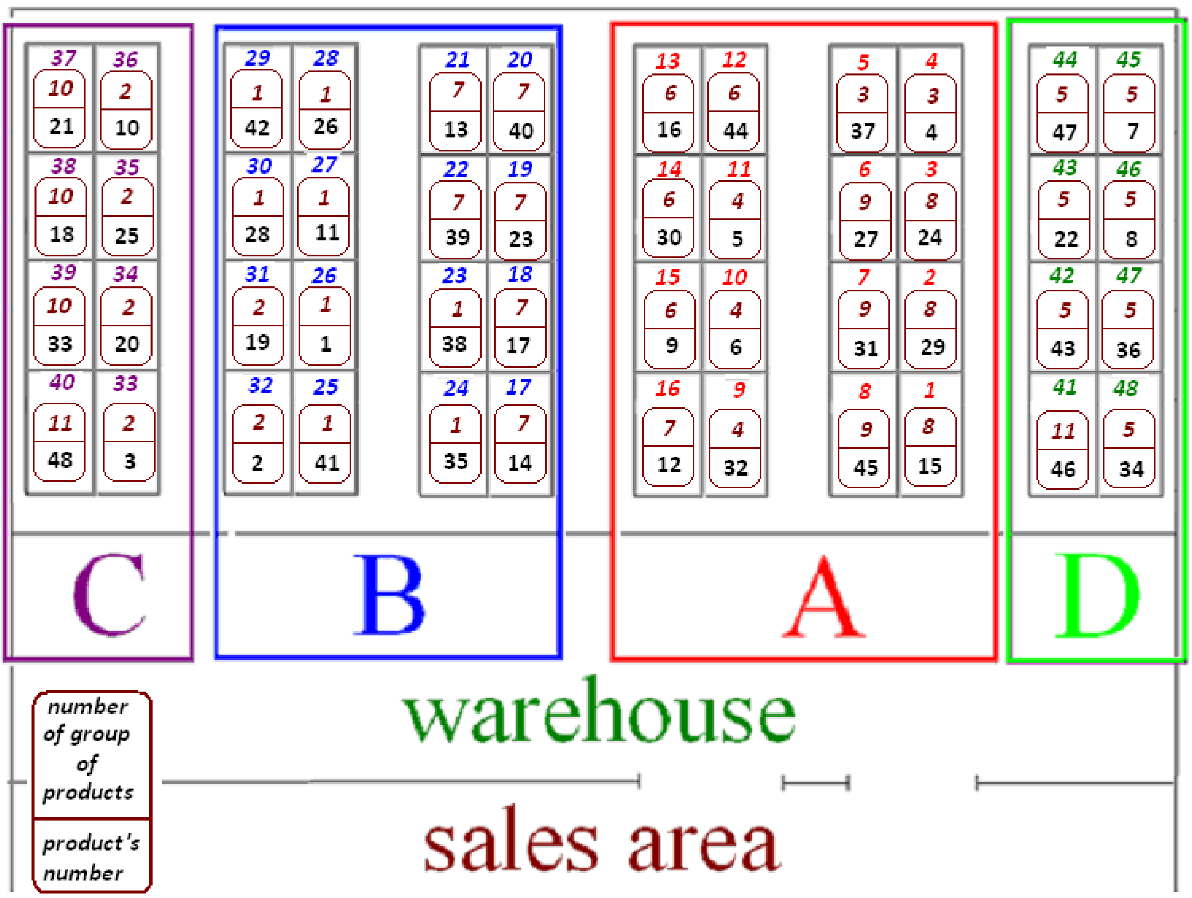

Figure 6 - Distribution of products on the shelves according to the optimization criterion (4)

Table 4 – The results of calculations using criterion 5

Variant	Value of the fitness function	Average value of the fitness function	Standard deviation of value of the fitness function	Best in the generation	Population	Length of the life	Probability of operators: one-point crossover	Probability of operators: two-point crossover	Probability of operators: position based mutation	Probability of operators: order based mutation	Probability of operators: adjacent two-job exchange mutation
2	2670	2503,95	74,55	9463	100	10000	0,8	0,8	0,2	0,2	0
6	2670	2517,84	93,94	8008	50	20000	0,5	0,5	0,8	0,8	0
8	2670	2664,7	7,13	416	100	10000	0,2	0,2	0,7	0,7	0,8
9	2670	2664,86	6,91	389	100	10000	0,5	0,5	0,5	0,5	0,5
10	2670	2663,92	7,52	868	100	10000	0,7	0,7	0,2	0,2	0,2
11	2670	2663,34	10,62	284	100	10000	0	0	0,7	0,7	0,8

- the solution presented in figure 7

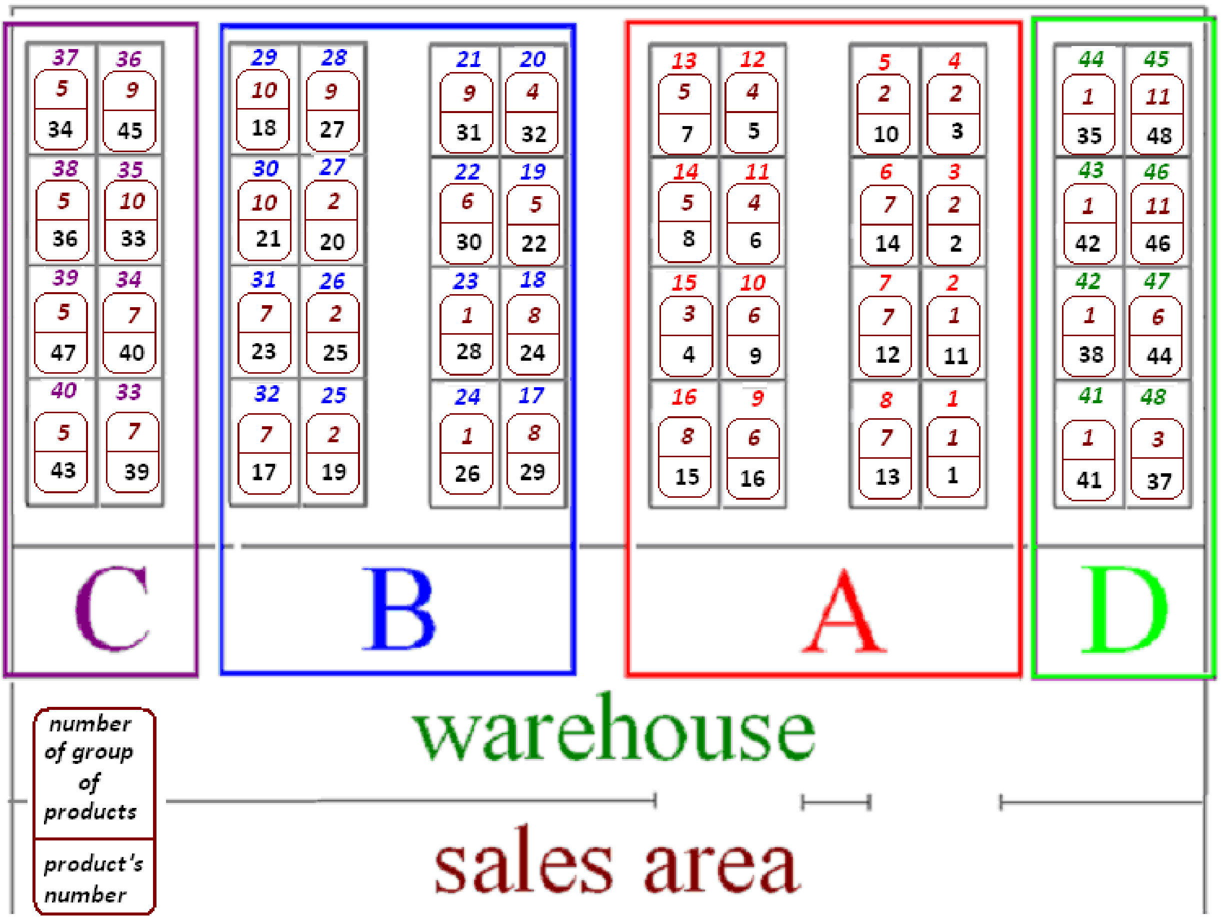

Figure 7 - Distribution of products on the shelves according to the optimisation criterion (5)

5. Conclusions

In the paper it is presented usage of evolutionary algorithms for the optimal distribution of products on the shelves of stockroom. There were compared the results obtained for three different optimization criteria: the criterion takes into account the size of the rotation of products, the criterion of grouping similar products side by side and taking into account criteria both of these conditions simultaneously. For the first two criteria, the results solution satisfies the requirements. In the case of multicriteria optimisation the assessment is difficult, but the results are also very good. Using evolutionary algorithms for multicriteria optimisation of products distribution on the shelves of warehouses including the frequency of rotation and arrangement of products groups together is effective. Efficiency of the calculations can be further improved by using more appropriate crossover operators for this task. It will be conducted in the future.

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