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AN APPLICATION OF EVOLUTIONARY AND IMMUNE ALGORITHMS FOR THE OPTIMISATION OF PACKING A DIVERSIFIED SET OF PACKETS ON A PALLET

Key words

Evolutionary algorithm, immunology algorithm, optimisation, packages distributing, pallet.

Summary

This paper deals with an application of evolutionary and immune algorithms to load a diversified set of packages on a pallet in fully automated warehouses, where workers will be substituted by mobile robots. There are some problems in semi-automated warehouses, where new workers do not have enough experience to know how to distribute packages on pallet.

The aim of this work was to formulate the problem of loading a diversified set of packages on a pallet both in evolutionary and immune algorithms. The evolutionary algorithm is inspired by natural evolution. It searches for a solution in the evolution way. The artificial immune system is based on immunology principles. The adaptive immune system helps to recognise and respond to any microbe that has never attacked the body. The presented algorithm of the immune optimisation uses part of this immune system.

Introduction

Pallets are commonly used for the transport of goods. They are adjusted to transport facilities and normalised. There is an interesting problem concerning loading a diversified set of packages on a pallet. The packages have different dimensions and weights. They should be arranged within the limits of the pallet dimensions. The weight of the packages can not exceed the load-carrying ability of it. The height of the load is conditioned by transport facilities, and it is fixed for a particular solution. The heaviest packages should be put on the lower level of pallet, because their wrappers are more resistant and the load is more stable. Only experienced workers can pack them. Therefore, the automation of different packing packages on the pallet is important to help workers or substitute them by mobile robots.

The problem described above is not even known to be in NP, because of the complicated structure of packing. This problem has a lot of solutions from algebraic to artificial intelligence methods like *tabu* search or evolutionary and genetic algorithms [1–4]. There are pallet loading computer aided systems, which can solve such problems. They should be interactive and work in the real time. Therefore, solutions should satisfy this condition.

This paper describes an application of an evolutionary algorithm and an immune algorithm to distribute goods on a pallet. The problem of the optimisation of distributing the miscellaneous packages on the pallet is formulated. In the beginning, the evolutionary optimisation model is presented, then the immune algorithm implementation is described. This algorithm is acknowledged as faster and better than the evolutionary algorithms.

1. Mathematical model

The solved problem can formulated as follows:

A set of N packages { n_1 , n_2 , ... , n_N } should be distributed on a pallet. The volume of all packages cannot exceed volume of a cube: the palette area × the possible height of the load. An objective function is as follows:

$$f(V,h) = \alpha \sum_{i=k_1}^{N_k} V_i + \frac{\beta}{h_k} \tag{1}$$

where:

V_i – volume of the i-th package, which is loaded,

N_k – number of the loaded packages,

h_k – distance of the centre of gravity of all loaded packages from the pallet,

α, β – weight coefficients.

The optimal solution is obtained by maximising this function with respect to correct loading order of the packages. If the value of the objective function is higher then the order of the packages, it is better.

2. Evolutionary optimisation

The evolutionary algorithm is inspired by natural evolution. The algorithm of the evolutionary optimisation is presented in the Fig. 1. The evolutionary algorithm searches for the solution in the evolution way [5]. This algorithm has been described in details in [4].

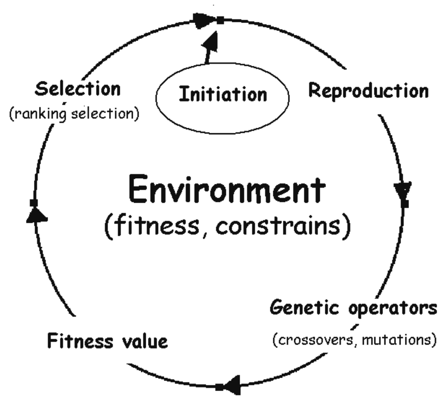

Fig. 1. An algorithm of evolutionary optimisation

Environment

The k-th chromosome from the population, which represents the possible solution is expressed in the form:

$$N_k = < n_{k1} , n_{k2} , \dots , n_{kn} > \tag{2}$$

where:

n_{ki} – i-th gene in the k-th chromosome. It is a label of the package, which was put in the i-th sequence.

The population is a set of chromosomes. They are all drawn by lot at first. They will evolve during all of the process of the artificial evolution.

Fitness function – the function (1).

The optimal solution is obtained by maximising the fitness function with respect to chromosome N_k (2).

Genetic operators

This evolutionary algorithm uses operators of a crossover (one-point crossover, two-point crossover) and of a mutation (position-based mutation, order-based mutation, and adjacent two-job exchange) described in [6]. Each result of genetic operators gives only one solution. In such a solution, every package has its own sequence of arrangement on the pallet. The genetic operators work with the assumed probabilities. Several of the tests were calculated in order to tune their proper running.

Selection

This evolutionary algorithm uses the operator of the proportional selection in order to select better solutions. An elitist model is used to remember the best solution [4].

3. Immune optimisation

The artificial immune system is based on immunology principles. An immune system consists of cells, molecules and organs, which recognise and destroy pathogens. There are two systems by which the body identifies foreign material: the innate immune system and the adaptive immune system. The innate immune system destroys pathogens at first contact. The adaptive immune system helps to recognise and respond any microbe that has never attacked the body.

The presented algorithm of the immune optimisation uses part of this immune system. The scheme of the calculation is presented in the Fig. 2. The algorithm has been described in detail in [7–9].

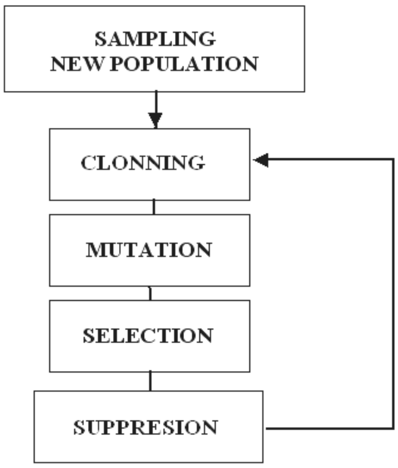

Fig. 2. The algorithm of the immune optimisation

There are the following:
Antigen – the function (1),
Antibody – best solution vector (2),
Mutation – this immune algorithm uses the adjacent two-job exchange mutation described in [6], and
Selection – this immune algorithm replace every chromosome by the best clone of it.

Suppression – the most similar chromosome is selected for every chromosome. The second-best is replaced by sampling.

4. Calculations

The solved problem was as follows: How do we locate 22 miscellaneous packages on pallet. In the Fig. 3, there are sketches of the packages. The packages can rotate only around their vertical axis. The dimensions and the weights of the packages are presented in Tab. 1.

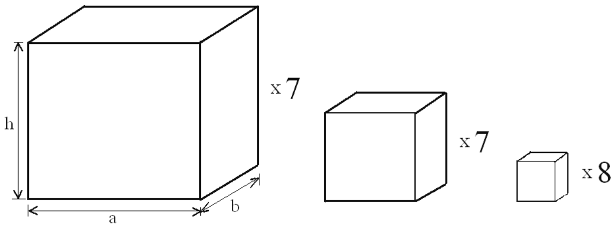

Fig. 3. The packages

Table 1. Dimensions and weights of the packages

Order number	Dimensions [mm]			Weight [kg]
	a	b	H	
1		600	800	100.00
2	400	600	800	100.00
3	400	600	800	100.00
4	400	600	800	80.00
5	400	600	800	50.00
6	400	600	800	50.00
7	400	600	800	50.00
8	200	300	400	20.00
9	200	300	400	20.00
10	200	300	400	20.00
11	200	300	400	20.00
12	200	300	400	20.00
13	200	300	400	20.00
14	200	300	400	10.00
15	100	150	200	2.00
16	100	150	200	2.00
17	100	150	200	2.00
18	100	150	200	2.00
19	100	150	200	1.00
20	100	150	200	0.5
21	100	150	200	0.5
22	100	150	200	0.5

The dimensions of the pallet: 800×1200 mm^2 (Fig. 4). The maximal height of the load: 1600 mm. Maximal load on pallet = 1000 kg.

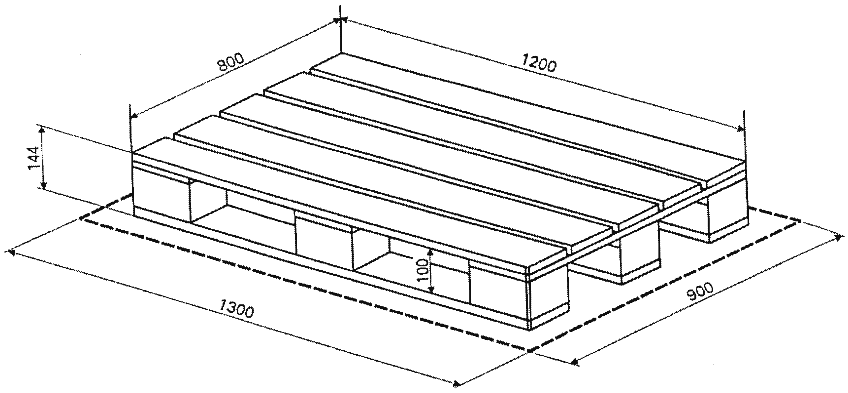

Fig. 4. The dimensions of pallet

The size of the chromosome population used in each evolutionary calculation was equal to 100. The length of the life was equal 5000.

The probabilities of the evolutionary operators were as follows:
For
one-point crossover = 0.8,
two-point crossover = 0.8,
position based mutation = 0.2,
order based mutation = 0.2,
adjacent two-job exchange = 0.2.

<u>The solution:</u>
Best in the generation 1027.
Value of the fitness function 2.064002.
Packages not loaded 0.
The obtained order of the packages:
{5 1 3 0 2 4 6 10 9 7 14 16 15 17 19 12 21 20 11 18 13 8}.

The solution is presented in Fig. 5. There are a lot of the correct solutions. The obtained solution fulfils all constraints. No packages exceed the dimensions of the pallet.

The results, which were obtained in [10], show that the probability of solving of the permutation problems are very high in comparison with probability of sampling solutions. But finding the solution was not easy. The solving consist of two parts: finding the best order of the packages, which is obtained on the evolutionary way, and arranging of the packages on the pallet.

This was done mechanically, like real packing. Thus, the fitness value depended on genetic operators and on the placing of the packages. In test version of this software, the packages were distributed in a fixed, 3- dimensional grid. It was not correct for real packages. Thus, the problem of package distributing is corrected.

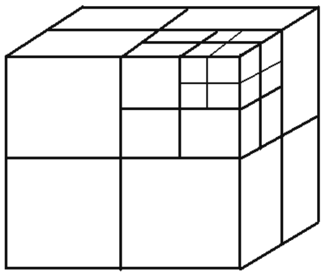

Fig. 5. The optimal distributing of the packages on the pallet

The size of the chromosome population used in the every immune computation was equal 25. The length of the life was equal 1000. The number of clones was 3.

The solution:
Best in the generation 261
Value of the fitness function 2.064002
Packages not loaded 0
The obtained order of the packages:
{0 4 6 12 11 10 7 8 5 2 9 13 14 15 16 18 17 19 21 20 1 3}.

The obtained solution fulfils all constrains. The packages do not exceed dimensions of the pallet.

Therefore, the immune algorithm is an efficient tool to solve difficult discrete optimisation problems. This implementation uses the mechanism of distributing the packages described above.

The size of population and the steps to the best solution were shorter in the immune algorithm. The immune algorithm uses less computer memory. The code is shorter. The immune algorithm has a fewer number of independent parameters of the calculation (like probabilities of genetic operators) than the evolutionary algorithm.

Conclusions

In this paper, the applications of the evolutionary and the immune algorithms for optimisation of the miscellaneous package distribution on the pallet were presented. The aim of this work was to formulate the problem of the arrangement of packages on palette both in evolutionary and immune algorithms. Some evolutionary solutions are already known. The immune algorithm is known as a better tool for optimisation than the evolutionary algorithm. The software implementing immune algorithm will be developed and improved for more complex problems.

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Zastosowanie algorytmów ewolucyjnych i immunologicznych do optymalizacji ułożenia różnorodnych pakunków na palecie

Słowa kluczowe

Algorytm ewolucyjny, algorytm immunologiczny, optymalizacja, układanie paczek, paleta.

Streszczenie

W niniejszym artykule przedstawiono zastosowanie algorytmu ewolucyjnego i algorytmu immunologicznego do optymalizacji załadunku palety różnorodnymi towarami. Automatyzacja załadunku jest potrzebna zarówno w całkowicie zautomatyzowanych magazynach, obsługiwanych przez mobilne roboty, jak i w częściowo zautomatyzowanych, ale z dużą fluktuacją zatrudnienia operatorów wózków widłowych, co powoduje zatrudnianie ciągle nowych, niedoświadczonych w pakowaniu palet pracowników.

W artykule zostało sformułowane zadanie optymalizacji. Zadanie należy do NP trudnych. Przedstawiono dwie metody rozwiązania: algorytmy ewolucyjne oraz algorytmy immunologiczne. Obie metody należą do metod sztucznej inteligencji. Pierwsza z nich poszukuje rozwiązania w sposób naśladujący naturalną ewolucję. W drugiej do znalezienia rozwiązania wykorzystuje się metody, w jaki żywy organizm identyfikuje przeciwciała.