

# Multi-Objective Optimization Model and Solution for Easily Broken Material Loading Based on Genetic Algorithms Under VMI

Du Yanwei\* and Liang Henggang

*School of Mechatronic Engineering, Xi'an Technological University, Xi'an 710032, P.R. China*

**Abstract:** The material loading operation plan by artificial preparation has been unable to meet the requirements of the timely delivery when the third party logistics enterprises are involved in vendor managed inventory strategy. According to the characteristics of the easily broken material the multi-objective optimization model was established. The objective functions of this model were the vehicle loading weight utilization rate and the volume utilization rate. The five constraints were introduced. The optimal solution of the model was obtained by genetic algorithm. The solving process was introduced including the pre processing coding, the individual coding, the fitness selection and the genetic operation. The genetic algorithm program was designed by using MATLAB genetic algorithm toolbox. The easily broken material boxes loading optimization of the VMI distribution center was as an example to verify the validity of the program. Thus a whole solution which contains the optimization model and the solution procedure was provided for the easily broken material loading.

**Keywords:** Vendor managed inventory, easily broken material, loading optimized model, genetic algorithm, MATLAB.

## 1. INTRODUCTION

Just in time production (JIT, also known as non stock production) is a kind of high quality, low consumption production mode, which contains the characteristics and advantages of single production and mass production in multi varieties and small batch mixed production. The inventory problems of raw materials, semi-finished products and finished products must be solved, in order to implement JIT production. The Vendor Managed Inventory (VMI) strategy is a new efficient inventory management thought. It embodies the thought of integrated management of supply chain and it adapts to the changing market requirements. A VMI HUB can be established in the vicinity of the manufacturing enterprises. In VMI HUB, dozens or even hundreds of suppliers which supply spare parts or raw materials for manufacturing enterprise are the third party logistics enterprise management object. In the process of implementing VMI, the material loading is one of the problems to be solved. The material loading should be high frequency, short time, with high quality and low cost [1, 2].

So the load and capacity of transport vehicles should be fully utilized, and advanced loading methods should be adopted to arrange the material assembled.

At present, the material loading plans are still compiled by artificial. With many years of experience in the cargo loading or presto wage operating post, the vehicle administrators make up different forms of goods to the whole vehicle, according to the material packing size, the truck container

volume and the sorting orders from the manufacturing enterprise. This distribution and transport method of goods is called the less-than-truck-load transport. Due to the complicated factors, a large amount of data, complex work, and the artificial preparation of loading way is time-consuming and requires a lot of manpower resources. And the loading efficiency is low, because of the inability to consider the truck types, volume, load, customer priority constraint.

At present the computer management system has yet to solve the optimization problem of less than carload material loading. Although there are some management systems, which adopts the method of combination of human and computer, provide the information required by computer, the loading plan is still used manual decision method. The quality level of loading plan is influenced by the human experience.

Some special materials are required frequently for manufacturing enterprises, such as the electric control boxes, lamps, glass products, ceramic products, precision guide, instrument, display etc. When this kind of material is in vehicle transportation, the following problems should be noted. The first is that the heavy objects cannot be placed on the material surface, so the packing box can not be stacked multilayer compaction. Second is that the packing boxes placement directions cannot be reversed.

The cargo loading and presto wage optimization problem can be abstracted as a single vehicle two-dimensional loading optimization model. In this model, the volume and the weight of the box constraints are considered, and the boxes are rectangular. The goods must be loaded into the box in the right angle direction, for every material box dimensions are different in length, width, height.

## 2. THE LOADING OPTIMIZATION METHOD

The material loading optimization research is an important branch of the Container Loading Problem (CLP) study. Research on this issue is very few in Chinese. Theoretical study is backward cause that the artificial management of the most transportation links in the logistics distribution center is backward. Therefore, both from a theoretical point of view, and from the practical application point of view, an effective solution for it is necessary to solve the material loading problem better, and to implement the loading strategy. There are many methods to solve material loading optimization model; in essence, these methods can be divided into two major categories of the exact algorithm and the heuristic algorithm [3]. The exact algorithm refers to the algorithm can get the optimal solution, such as the branch and bound method, the cut plane method, the network flow algorithm, the dynamic programming method, the integer programming method and so on. The computational complexity of exact algorithms is generally exponential growth, with the increase of the scale of the problem. So it is only suitable for solving small scale problems. Its application scope is very limited. The loading problem is a group of discrete optimization problem with strong application background. The material loading optimization models are mostly multi-objective, multi-constraint optimization models. So it is very difficult to get the optimal solution for the loading problems, and it is also very difficult to be accurately solved by mathematical model [4-8].

Genetic algorithm is a novel random search optimization method. It simulates the process of biological evolution. Because of the very strong robustness, it has been studied and widely used in combinatorial optimization field in recent years. It shows good performance and effect in the solution of many typical combinatorial optimization problems [9].

Application of genetic algorithm in solving the material loading problems, a variety of the loading schemes can be abstracted as implicit parallelism by proper loading scheme of coding and the evaluation function. Thus the time dimension disaster problem is overcome, and the genetic algorithm is proved to be an effective way to solve complex loading problem [10].

## 3. THE MULTI-OBJECTIVE OPTIMIZATION MODEL FOR EASILY BROKEN MATERIAL LOADING

### 3.1. Description of the Problem

As mentioned above the fragile material loading problem is also known as the monolayer material loading problem. Under some constraint conditions, the different requirements of customers of the material was loaded monolayer in vehicle reasonable, the premise is in no more than limited vehicles (weight, volume, compartment size), so that the vehicle weight and volume utilization rate reached the maximum [11].

Suppose there are  $n$  material boxes for loading in the VMI HUB distribution center. The material box weights are

$g_1, g_2, \dots, g_n$ , the volume of these material box are respectively  $v_1, v_2, \dots, v_n$ , the lengths are  $l_1, l_2, \dots, l_n$ , the widths are  $w_1, w_2, \dots, w_n$ , and they are the height of  $h_1, h_2, \dots, h_n$ . The truck Load capacity for loading material is  $G$ , the effective volume is  $V$ , and the length, the width, the height inside the truck compartment are respectively  $L, W, H$ . To meet the requirements in the truck the maximum load weight and the effective volume constraint, and to meet the car long, wide, high constraint condition, the loading material boxes' positions are be reasonably determined in the vehicle, so that the load volume and the effective utilization rate of freight car are the highest.

The loading problem is simplified and assumed for easy calculation, as follows:

1. Every material box for shipment is cuboids which size is smaller than the size of the carriage.
2. Every box is shipped from the VMI HUB to a same location.
3. There is only one van used to transport the material at the same time.
4. The material box is placed in any position of the vehicle in case cargo compartment but is not arbitrary rotation.

### 3.2. The Model

The mathematical model of the problem is established, according to the fragile material loading problem description. The objective function of the model is a maximization function:

$$\text{Max } z = \alpha \left( \sum_{i=1}^n x_i g_i / G \right) + \beta \left( \sum_{i=1}^n x_i l_i w_i h_i / V \right) \quad (1)$$

Where,

$\alpha$  is the coefficient of vehicle weight utilization rate;

$\beta$  is the coefficient of vehicle volume utilization rate;

They are given different values according to the characteristics of the material to be installed. In the fragile material loading problem, there are two kinds of materials, the first is the great density or heavy material, second is the avoid pressure or the brittle material. When the material is a large density of the material, the total weight of the material is mainly considered, then the maximum volume utilization rate. The total weight of goods does not exceed the rated vehicle total weight. In this case,  $\beta=1, \alpha=0$ . When the material is easily broken material,  $\beta=0, \alpha=1$ . When the material volume weight ratio are considered, the value of  $\alpha$  and  $\beta$  are determined in accordance with the requirements of the density ratio. In this paper,  $\alpha+\beta=1$ .

$x_i$  ( $i=1, 2, \dots, n$ ) is the 0-1 Variable, If the material box  $i$  is determined loading, then  $x_i=1$ , otherwise,  $x_i=0$ ;

$g_i$  ( $g=1, 2, \dots, n$ ) is the weight of the material box  $i$ ;

$l_i$  ( $i=1, 2, \dots, n$ ) is the length of the material box  $i$ ;

$w_i$  ( $i=1, 2, \dots, n$ ) is the width of the material box  $i$ ;

$h_i$  ( $i=1, 2, \dots, n$ ) is the height of the material box  $i$ ;

The truck Load capacity for loading material is  $G$ , the effective volume is  $V$ , and the length, the width, the height inside the truck compartment are respectively  $L, W, H$ .

The constraints include:

Direction constraint: flat or arbitrary rotation placement is not allowed;

1. The ordering constraint: the last loading material box was unloaded firstly, on the contrary, the first being loading material box was unloaded at last. This is known as first in last out.
2. The geometric constraints: the material box loading size shall not exceed the vehicle cargo compartment boundary limit;
3. The Weight constraints: the total weight of the material loading boxes shall not exceed the total weight capacity of the vehicle.
4. The center of gravity constraint: in the material after the loading, the total center of gravity should be located in the material within the allowed range, to ensure the safety of vehicle operation overall stability.

#### 4. OPTIMIZATION MODEL SOLUTION FOR EASILY BROKEN MATERIAL LOADING BASED ON GENETIC ALGORITHMS

##### 4.1. Pre Processing Coding

Before the individual coding, the pre specified on the code needs to be done as follows:

1. Material box number: the material filling boxes are numbered according to the sequence of natural number,  $i=1, 2, \dots, n$ .
2. Placement direction number: if the placed direction of material box  $i$  is  $l_i \parallel L, w_i \parallel W, h_i \parallel H$ , then the number is 1; if the placed direction of material box  $i$  is  $w_i \parallel L, l_i \parallel W, h_i \parallel H$ , then the number is 2.
3. The loading sequence number: the sequence of material box arrived at the station is in descending order of natural number sequence, and a material box the same station is the same number.

4. The box number: if the material box  $i$  is determined to loading, then the number is 1; otherwise, the number is zero.

##### 4.2. Individual Coding and Decoding

Because the material loading sequence is given according to the sequence of the material box arrived, the material box placed direction constraint is only considered. Each loading scheme corresponds to a string of symbols of individual which code length is  $2n$ .  $S_q^{gen} = (s_1, s_2, \dots, s_i, \dots, s_n, s_{n+1}, \dots, s_{n+i}, \dots, s_{2n})$  ( $q=1, 2, \dots, N$ , Where  $N$  is the size of the population), Gene  $s_1 \sim s_n$  are the loading number of the material box, its value is according to the code pretreatment results in the chapter 4.1. At the same time gene  $s_1 \sim s_n$  location sequence number 1, 2, ...,  $n$  is corresponding with the material box number; Gene  $s_{n+1} \sim s_{2n}$  is the placement direction number material, gene values are  $s_{n+i}=1$  or 2.

Individual decoding method:

1. The relationship between the  $s_i$  gene and the  $s_{n+i}$  gene is the corresponding, That is, the loading materials box  $i$  which is expressed by the gene  $s_i$  is loaded into the vehicle according to the placement direction said gene  $s_{n+i}$ ;
2. The values of gene  $s_i$  and gene  $s_{n+i}$  are decoded and analyzed according to the code pretreatment results in the chapter 4.1.

##### 4.3. The Fitness Selection

Fitness is a standard used to distinguish individual good or bad according to the objective function value, it is the driving force of the evolution process of the algorithm; it is also the only basis for natural selection. Fitness is not always negative. Fitness is considered that large value is good in any case. The loading scheme corresponding to the individual can be evaluated by the fitness.

In addition, the constraint conditions must be handled in the genetic algorithm, but at present there is no general method to deal with all kinds of constraint conditions. There are three methods can be chosen according to the specific problem, namely the search space limits method, the feasible solution transformation method and the penalty function method. The penalty function method is chosen in this paper.

The basic idea of this penalty function method is, when the fitness of the individual without corresponding feasible solution in the solution space is calculated, a penalty function is imposed, thus the individual fitness is reduced, so that

Table 1. The data of the material loading boxes.

The Material Box Number	$l_i$ (mm)	$w_i$ (mm)	$h_i$ (mm)	$g_i$ (kg)	The Loading Sequence
1	1570	960	1090	290	2
2	1080	1070	700	230	1
3	1560	600	990	260	3
4	1000	800	1400	280	5
5	1360	600	770	290	7
6	1520	900	790	150	2
7	1650	850	765	180	8
8	1080	750	850	180	5
9	1425	700	1100	240	4
10	1580	1070	665	180	6

the probability that the individual is genetic to the next generation is reduced.

Therefore, the individual in violation of the vehicle loading weight constraint and the space constraint should be punished accordingly in the computation of the fitness, and then the better individuals eligible have a greater chance of survival [12]. Therefore, the penalty function is constructed, as follows:

$$h_1(q) = \left( \sum_{i=1}^n x_i l_i w_i - LW \right) \quad (2)$$

$$h_2(q) = \sum_{i=1}^n x_i g_i - G \quad (3)$$

$$h_3(q) = \sum_{i=1}^n x_i v_i - V \quad (4)$$

The method to calculate the fitness of the individual  $S_q^{gen}$  in the gen generation is as follows:

$$f_{gen(q)} = z(q) - pen_{gen}(q) = z(q) - c_{gen} \left\{ \sum_{i=1}^3 \max[0, h_i(q)] \right\} \quad (5)$$

Where,  $pen_{gen}(q)$  is the material box loading penalty function; Formula (2) is the material box loading space penalty function; Formula (3) is the material box loading weight penalty function; Formula (4) is the material box loading volume of penalty function;  $c_{gen}$  is the penalty factor.

#### 4.4. The Genetic Operations Process

In the genetic algorithm, there are three genetic operations including the individual selection operation, the

crossover operation and the mutation operation. In the selection process, Nsel individuals was sampling replication using the random traversal method, namely Nsel individuals was chosen for the breeding probability, in accordance with the individual fitness in the current population. In the crossover process, the single point crossover method is adopted, that is, a cross point in individual code string is set randomly. Then, for each couples of the individuals in the current population, two individuals exchange partial chromosomes, according to cross a certain probability at their intersection. Thus, two new individuals are generated to return a new species after mating. The object of mating is orderly, namely the odd line is paired with its next even line. If the row number of the current population is odd, then, the last line is not to participate in the mating. Therefore, the population will be organized into the continuous pairs according to the mating requirements. At the same time, in order to maintain the diversity of population in genetic operation, avoiding the algorithm premature convergence and even can not find the global optimal solution; the individuals need to be taken in mutation operation. In the mutation process, the discrete mutation operator is adopted, i.e. each individual is mutated by specific probability.

#### 5. THE EXAMPLE AND THE RESULT ANALYSES

There are 10 kinds of brittle material boxes waiting for loading in the VMI distribution center of a manufacturing enterprise, the loading sequence, the length, the width, the height and the weight of the material boxes are shown in Table 1. The internal length, the width, the height and the maximum load weight of the vehicle cargo compartment are shown in Table 2. The material boxes are loaded into the vehicle cargo compartment in a rational way, and in order to the vehicle's capacity and volume are fully utilized.

Table 2. The main parameters of the vehicle carriage.

L(m)	W (m)	H(m)	G(t)
4.630	1.784	1.810	1.650

```

Editor - C:\MATLAB7\work\Knap_2D.m
File Edit Text Cell Tools Debug Desktop Window Help
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1  %-----
2  %                               Matlab                               %
3  %           NIND=20,
4  %           MAXGEN=100,
5  %           PRECI=20,
6  %           GGAP=0.9,
7  %           XOVR=0.95,
8  %           MUTR=0.01,
9  %-----
10 function []=Knap_2D
11 clear:
    
```

Fig. (1). The program interface diagram.

Chrom	<20x20 double>	double
Chrom0	<20x10 double>	double
Chrom2	<20x10 double>	double
Chrom1	<20x10 double>	double
FitnV	<20x1 double>	double
FitnVSel	<18x1 double>	double
G	16	double
GGAP	0.9	double
H	1.8	double

Fig. (2). The fitness function.

Many operators of genetic algorithm (such as selection, crossover, and mutation) are aimed at the so-called chromosomes. A chromosome is a vector, and it can be seen as a  $1 \times n$  matrix. Thus the operator is essentially some matrix operations. Genetic algorithm toolbox is a universal tool for solving genetic algorithm, using Matlab matrix functions. The genetic algorithm tool is written in M file command-line form function. It is a collection of programs to complete the most important function of the genetic algorithm. Application of Matlab genetic algorithm toolbox, the steps of Genetic algorithm to solve the model include the coding method, the initial population establishment, the operators choice, the crossover operator, the mutation operator, the evaluation function and the termination criterion etc [13]. There are four key parts of Matlab genetic algorithm toolbox: the coding mechanism, the fitness function, the genetic operator and the operation parameters. The genetic algorithm toolbox developed by the University of Sheffield in the UK is adopted in this paper; it provides a wide variety of useful functions for the user. Based on the genetic algorithm of fragile material

loading problem, the program is written using Matlab genetic algorithm toolbox, an example is given for solving.

The main variables in the program: the number of individuals is  $NIND=20$ ; the largest genetic algebra is  $MAXGEN=100$ ; each individual is represented using 20 bits, that is,  $PRECI=20$ ; the used generation gap is  $GGAP=0.9$ ; the crossover probability is  $XOVR=0.95$ ; the mutation probability  $MUTR=0.01$ .

A scheme is obtained by the Matlab program, that there are 6 materials boxes in 10 materials boxes are loaded into the vehicle carriage, respectively (1, 3, 4, 5, 6, 9). The specific load optimization results of the 6 kinds of materials boxes is shown in Table 6. The solving process is as follows: Open the matlab7.0 software; add the gatbx folder to the toolbox folder of the Matlab toolbox; open the Knap\_2D.m code procedures to enter the program interface, as shown in Fig. (1); Select a node, Click the run button; to choose the fitness function, as shown in Fig. (2); as shown in Table 3, the fitness is a maximum value of 0.51879; as shown in

Table 3. The fitness value.

	1	2	3
1	0.38968		
2	0.33456		
3	0.48884		
4	0.45178		
5	0.47871		
6	0.51879		
7	0.50726		
8	0.47731		
9	0.47762		
10	0.51879		
11	0.48081		
12	0.39352		
13	0.48279		
14	0.38378		
15	0.33718		
<b>16</b>	<b>0.51879</b>		
17	0.48279		
18	0.47731		
19	0.42494		
20	0.45178		

Table 4. The loading box number.

	1	2	3	4	5	6	7	8	9	10
1	1	0	1	1	0	0	1	1	1	0
2	1	0	1	1	0	0	0	0	0	0
3	0	1	1	1	1	0	1	0	0	0
4	1	0	0	1	0	1	1	1	1	1
5	1	0	0	0	1	1	0	0	1	1
6	1	0	0	1	1	0	0	0	0	0
7	1	0	1	0	1	1	0	1	1	0
8	0	0	0	1	1	0	0	1	0	1
9	1	0	1	0	1	1	0	1	1	0
10	0	1	1	0	0	0	0	0	1	0
11	1	0	1	1	0	0	1	1	1	0
12	1	0	1	1	0	0	1	1	1	0
13	0	0	1	1	0	1	1	0	0	0
14	0	0	0	1	1	1	0	1	1	1
15	1	0	1	0	1	1	0	1	1	0
<b>16</b>	<b>1</b>	<b>0</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>0</b>
17	1	0	1	1	0	1	0	0	1	0
18	1	1	1	1	0	1	1	0	0	0
19	0	1	0	1	1	1	0	1	1	1
20	1	1	1	1	0	1	1	0	0	0

Table 5. The loading mode number.

	11	12	13	14	15	16	17	18	19	20
1	1	1	1	1	2	1	2	2	2	1
1	1	1	1	2	2	2	1	2	1	2
2	2	2	2	2	2	2	1	1	1	1
1	2	2	2	1	2	2	2	1	1	2
1	2	2	2	2	2	2	2	2	1	1
1	1	1	1	1	2	2	2	1	2	1
1	1	1	1	1	2	1	2	2	2	1
1	1	1	1	1	2	1	2	2	2	1
2	1	1	1	1	2	1	2	2	2	1
1	1	1	1	1	2	1	2	2	2	1
2	1	1	1	1	2	1	2	2	2	1
1	1	1	1	1	2	1	2	2	2	1
2	2	2	2	2	2	2	1	1	1	1
2	2	2	2	1	1	1	2	2	1	1
2	2	1	2	2	2	2	1	1	2	2
<b>2</b>	<b>1</b>	<b>2</b>	<b>2</b>	<b>2</b>	<b>2</b>	<b>2</b>	<b>1</b>	<b>1</b>	<b>2</b>	<b>2</b>
1	2	2	2	1	1	1	2	2	1	2
2	2	2	2	1	1	1	2	1	2	2
2	1	2	1	1	2	1	1	1	1	1
2	1	2	1	1	2	1	1	1	1	2

Table 4 and Table 5, the optimal solution coding is (1, 0, 1, 1, 1, 1, 0, 0, 1, 0, 2, 1, 2, 2, 2, 2, 1, 1, 2, 2).

According to the decoding method in chapter 4.2, the material boxes loading number (1, 3, 4, 5, 6, 9); The loading method is ( $w_i \parallel L, l_i \parallel W, h_i \parallel H$ ;  $w_i \parallel L, l_i \parallel W, h_i \parallel H$ ;

$w_i \parallel L, l_i \parallel W, h_i \parallel H$ ;  $w_i \parallel L, l_i \parallel W, h_i \parallel H$ ;  $w_i \parallel L, l_i \parallel W, h_i \parallel H$ ). The loading simulation condition can be obtained by the loading optimization results from Table 6,

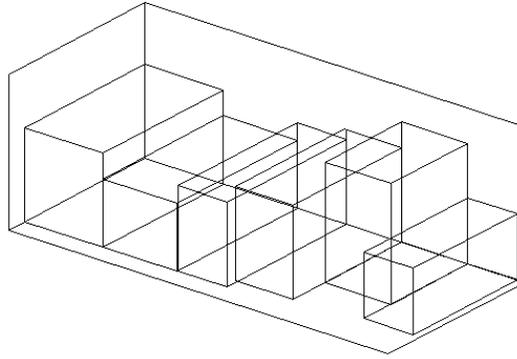


Fig. (3). The boxes loading simulate diagram for the easily broken materials.

Table 6. The loading optimization results.

The Loading Sequence	The Material Box Number	The Placement Direction
1	1	$w_i \parallel L, l_i \parallel W, h_i \parallel H$
2	6	$w_i \parallel L, l_i \parallel W, h_i \parallel H$
3	3	$w_i \parallel L, l_i \parallel W, h_i \parallel H$
4	9	$w_i \parallel L, l_i \parallel W, h_i \parallel H$
5	4	$w_i \parallel L, l_i \parallel W, h_i \parallel H$
6	5	$w_i \parallel L, l_i \parallel W, h_i \parallel H$

As shown in Fig. (3). From Table 6, the obtained results are the loading capacity utilization rate is  $1.51/1.65=91.5\%$  and the volume utilization rate is  $9.26/11.72=79.01\%$ .

## CONCLUSION

Genetic algorithm is applied in the fragile material loading optimization problem solving, and it is proved to be effective. Thus, a practical solution is provided for the third party logistics enterprises load the material boxes quickly and reasonably. However, the genetic algorithm performance depends on many aspects, including the encoding scheme, the decoding scheme, the various genetic operators selection, the crossover and mutation probability. Therefore, in view of the characteristics of different materials, these parameters are appropriately chosen, so much the better loading scheme can be obtained.

## CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

## ACKNOWLEDGEMENTS

The paper is supported by Education Department of Shaanxi Provincial Government Scientific Research Project (12JK0072).

## REFERENCES

- [1] R.D. Buzzell, and G. Ortmeier, "Channel partnerships streamline distribution", *Sloan Management Review*, vol. 36, no. 3, pp. 85-96, 1995.
- [2] J.B. Shah, "ST, HP, VMI program biting its stride", *Electronics Business News*, vol. 1309, pp. 42-43, 2002.
- [3] H.J. Gao, H.J. Li, R. Xie, and Z. Guo, "The practical heuristics of reasonable freight assembly", *Technology & Economy in Areas of Communication*, vol. 6, no. 1, pp. 59-61, 2004. (in Chinese)
- [4] C.S. Chen, S.M. Lee, and Q.S. Shen, "An analytical model for the container loading problem", *European Journal of Operational Research*, vol. 80, no. 1, pp. 68-76, 1995.
- [5] G. Scheithauer, and U. Sommerweib, "4-Block heuristic for the rectangle packing problem", *European Journal of Operational Research*, vol. 108, no. 3, pp. 509-526, 1998.
- [6] S. Bhattacharya, and R. Roy, "An exact depth-first algorithm for the pallet loading problem", *European Journal of Operational Research*, vol. 110, no. 3, pp. 610-625, 1998.
- [7] D. Pisinger, "Heuristics for the container loading problem", *European Journal of Operational Research*, vol. 141, no. 2, pp. 382-392, 2002.

- [8] M. Eley, "Solving container loading problem by block arrangement", *European Journal of Operational Research*, vol. 141, no. 2, pp. 393-409, 2002.
- [9] L. Bu, X. Yuan, Y. Pu, and J. Chang, "Optimization based on genetic algorithm for three-dimensional packing in a single container", *China Railway Science*, vol. 25, no. 4, pp. 108-111, 2004. (in Chinese)
- [10] G. Chen, X. Wang, Z. Zhuang, and D. Wang, *Genetic Algorithm and its Application*, Post and Telecom Press, Beijing, China, 1996, pp. 103-105. (in Chinese)
- [11] B. Lei, Y. Changzhong, and P. Yun, "Single three-dimensional loading genetic algorithm optimization problems", In: *Proceedings of Chinese Control and Decision Academic Annual Meeting, 2004*, pp. 394-397. (in Chinese)
- [12] X. Cioping, C. Liming, and L. Cao, *Genetic Algorithm: Theory, Application and Software Implementation*, Xi'an Jiaotong University Press, Xi'an, China, 2005, pp. 80-96. (in Chinese)
- [13] A. Zheng, *MATLAB Foundation Tutorial*, China Machine Press: Beijing, China, 2004, pp. 80-96. (in Chinese)

---

Received: September 16, 2014

Revised: December 23, 2014

Accepted: December 31, 2014

© Yanwei and Henggang; Licensee *Bentham Open*.

This is an open access article licensed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/3.0/>) which permits unrestricted, non-commercial use, distribution and reproduction in any medium, provided the work is properly cited.

RETRACTED ARTICLE