ISSN 1992-6502 (Print)
Vol. 17, no. 6 (59), pp. 101-102, 2013.

Vestnik UGATU

ISSN 2225-2789 (Online)
http://journal.ugatu.ac.ru

UDC 004.7

IMPROVEMENTS IN THE APLP[3D] FOR THREE-DIMENSIONAL PACKING PROBLEM OF CYLINDERS AND PARALLELEPIPEDS

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Submitted 2013, July 9

Abstract. The three-dimensional packing problem of cylinders and parallelepipeds into semi-infinite container is discussed in this paper. The focus of the paper is some improvement in the algorithm which was proposed in article [1].

Keywords: APLP-3D; three-dimensional packing problem; packing of cylinders and parallelepipeds.

1. INTRODUCTION

The three-dimensional Bin packing problem has many applications in various branches of human activity. Three-dimensional Bin Packing problem is NP-hard combinatorial optimization problem. There are only two articles about the packing of cylinders and parallelepipeds [1, 2]. In the first article author proposed the exact method. This method can't be used on the practice, because of a big amount of items it takes a lot of time. The second article is discussed a method on the base of (1+1)EA.

This paper consists of the three sections: introduction, problem statement, approach and conclusions.

2. PROBLEM STATEMENT

We formulate the statement of problem. Given: W is width of container, L is length of container, vector I_c=<r_i, h_{ci}> represents a collection of cylinders, vector I_p=<w_j, l_j, h_{pj}> represents a collection of parallelepipeds. Here r_i is the radius of the i-th cylinder, h_{ci} is the height of i-th cylinder, w_j is the width of j-th parallelepiped, l_j is the length of j-th parallelepiped, h_{pj} is the height of j-th parallelepiped, $i \in [0, N_c]$ is number of cylinders, $j \in [0, N_p]$, N_p is number of parallelepipeds.

We introduce Cartesian coordinate system centered in the far bottom left corner of the container (Fig. 1).

Solution of the problem is the set of elements <C, P>, where C=<x_{ci}, y_{ci}, z_{ci}> и P = <x_{pj}, y_{pj}, z_{pj}>, (x_{ci}, y_{ci}, z_{ci}) – coordinates of the center of the lower base of i-th cylinder, $i \in [0, N_c]$, (x_{pj}, y_{pj}, z_{pj}) – coordinates of lower left far corner of the parallelepiped, $j \in [0, N_p]$.

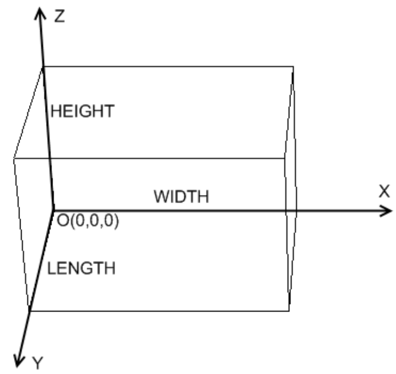

Fig. 1

Collection <C, P> is called acceptable packing, if the next conditions perform:

1) Orthogonality condition for parallelepipeds and cylinders.

2) Parallelepipeds don't overlap $j, s \in I_p$ $(s \neq j)$:

$$\begin{gathered}((x_{pj} \ge x_{ps} + w_s) \vee (x_{ps} \ge x_{pj} + w_j)) \vee \\ ((y_{pj} \ge y_{ps} + l_s) \vee (y_{ps} \ge y_{pj} + l_j)) \vee \\ ((z_{pj} \ge z_{ps} + h_{ps}) \vee (z_{ps} \ge z_{pj} + h_{pj})).\end{gathered} \tag{1}$$

3) Parallelepipeds don't go beyond container $(j \in I_p)$:

$$\begin{gathered}(x_{pj} \ge 0) \wedge (y_{pj} \ge 0) \wedge (z_{pj} \ge 0) \wedge \\ ((x_{pj} + w_j) \le W) \wedge ((y_{pj} + l_j) \le L).\end{gathered} \tag{2}$$

4) Cylinders don't go beyond pallets $(j \in I_c)$:

$$(x_{cj} \geq r_j) \wedge (y_{cj} \geq r_j) \wedge ((x_{cj} + r_j) \leq W) \wedge$$
$$((y_{cj} + r_j) \leq L) \wedge (z_{pj} \geq 0). \quad (3)$$

5) Cylinders and parallelepipeds don't overlap ($j \in I_p, j \in I_c$):

$$(x_{ci} + r_i \leq x_{pj}) \vee (x_{pj} + w_j \leq x_{ic} - r_i) \vee$$
$$(y_{pj} + l_j \leq y_{ci} - r_i) \vee (y_{ci} + r_i \leq y_{pj}) \quad (4)$$
$$\vee (z_{ci} + h_{ci} \leq z_{pj}) \vee (z_{pj} + h_{pj} \leq z_{cj}).$$

6) Cylinders don't overlap ($i,k \in I_c$):

$$((x_{ci} - x_{ck})^2 + (y_{ci} - y_{ck})^2 \geq (r_{ci} + r_{ck})^2) \vee$$
$$(z_{ci} + h_{ci} < z_{ck}) \vee (z_{ck} + h_{ck} < z_{ci}). \quad (5)$$

Need to find acceptable packing with minimal height H:

$$H = \max(\max(z_{ci} + h_{ci} \mid i = 1,\ldots,N_c),$$
$$\max(z_{pj} + h_{pj} \mid j = 1,\ldots,N_p)). \quad (6)$$

2. APPROACH

The approach on the base of (1+1)EA algorithm and ABLP^{3D} procedure was proposed in[1]. Here we propose some improvements in it.

Reduce the number of potential positions. After new item is added into container some positions can became unreachable. For example if first item in container is parallelepiped there is no sense to consider positions *1* and *2* (Fig. 2 two-dimensional case is presented) and compute new item coordinates for them.

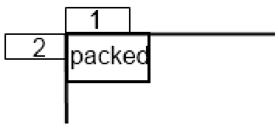

Fig. 2

There are several cases when we should eliminate some positions for the list of potential positions:

1) When added object has common faces with faces of container. We should remove one position from potential position list in this case (positions *1* in Fig. 3).

2) When we add new parallelepiped to a packed parallelepiped. We should remove two positions: one from the potential position list of already packed item and one from the potential position list of new packed item. (Positions *1* and 2 in Fig. 3).

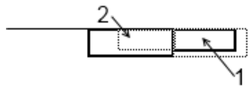

Fig. 3

3) When we add some parallelepiped into the corner of container, we should remove two positions (described above).

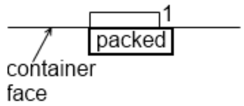

Fig. 3

4. CONCLUSION

Some simple improvements in the algorithm proposed in article. In some test cases, computation time was reduced sufficiently. Some complex test cases will be presented in next articles.

ACKNOWLEDGMENTS

This research has been partially supported by grants of the Russian Foundation of Basic Researches (RFBR) 12-07-00579.

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