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A new energy landscape paving heuristic for satellite module layouts

Key words: Three-dimensional packing, Energy landscape paving, Layout optimization, Performance constraints

Corresponding author: Juan Huang
E-mail: huangjuan4455@163.com
ORCID: http://orcid.org/0000-0003-2830-7699

Motivation

- The satellite module layout problem (SMLP) is not only an NP-hard problem in mathematics but also a complex engineering system problem in engineering.
- In recent years, although some layout design algorithms (Zhang *et al*., 2008; Wang and Teng, 2009; Teng *et al*., 2010) for solving SMLP have been proposed, their efficiency still needs to be improved.

Method

- We first converted the problem into an unconstrained optimization problem by the quasi-physical strategy and the penalty function method.
- To avoid the energy landscape paving (ELP) method becoming trapped in the narrow and deep valleys of the energy landscape, a new update mechanism was put forward for the histogram function in the ELP method.
- By incorporating the gradient method (GM) with local search and some heuristic layout updating strategies into the improved ELP method, a new global search method for SMLP, nELP, was proposed.

Major results (I)

- We tested two instances from Zhang *et al.* (2008). For the moment of inertia, overlap, centroid position error, and inertia angle error, the average and best results obtained by nELP were equal or superior to those obtained by algorithms in the literature.

Table 1 Comparison of the average and best performance indexes obtained by PPSO, QPGP, CCGA-CFG, DVGCCGA, and nELP for instance 1

Algorithm	Moment of inertia ($kg\cdot mm^2$)		Overlap (mm^2)		Centroid position error (mm)		Inertia angles error (rad)	
	Average	Best	Average	Best	Average	Best	Average	Best
PPSO	762.81	–	–	–	0.00	–	0.002	–
QPGP	773.58	758.33	18	0	0.13	0.000	0.000	0.000
CCGA-CFG	–	714.96	–	0	–	2.040	–	0.010
DVGCCGA	718.93	712.99	–	0	–	0.048	–	0.002
nELP	718.23	712.37	0	0	0.00	0.000	0.002	0.000

Major results (II)

Table 3 Comparison of the average and best performance indexes obtained by different methods in Zhang *et al.* (2008) and nELP for instance 2

Algorithm	Moment of inertia ($kg \cdot mm^2$)		Overlap (mm^2)		Centroid position error (mm)		Inertia angle error (rad)	
	Average	Best	Average	Best	Average	Best	Average	Best
Powell	843.72	844.17	73 426	47 786	0.44	5.26	0.018	0.048
GA	846.81	845.99	27 578	7846	0.36	1.61	0.045	0.709
PSO	846.40	847.27	49 675	24 391	0.40	1.25	0.081	0.708
GAPSO	844.40	843.88	9254	0	0.07	0.00	0.048	0.021
QPGP	844.10	843.88	3093	0	0.02	0.00	0.049	0.008
nELP	795.06	795.02	0	0	0.00	0.00	0.000	0.000

GA: genetic algorithm; PSO: particle swarm optimization; GAPSO: genetic algorithm/particle swarm optimization; QPGP: hybrid method based on soft computing techniques, integrating GAPSO and quasi-principal component analysis (QPCA); nELP: new energy landscape paving method. The moment of inertia is the sum of the moments of inertia in the x', y', and z' axes, i.e., $\boldsymbol{J}_{x'}(\boldsymbol{X})+\boldsymbol{J}_{y'}(\boldsymbol{X})+\boldsymbol{J}_{z'}(\boldsymbol{X})$. The centroid position error is the sum of the centroid errors in the x, y axes, i.e., $|x_c-x_e|+|y_c-y_e|$. The inertia angle error is the sum of the inertia angles in the x', y', and z' axes, i.e., $|\theta_{x'}(\boldsymbol{X})|+|\theta_{y'}(\boldsymbol{X})|+|\theta_{z'}(\boldsymbol{X})|$

Summary

- By incorporating the gradient method with local search into the improved ELP method, a new global search optimization method, nELP, is proposed for SMLP.
- Numerical results illustrate that the nELP algorithm is a promising method for SMLP.
- It is easy to see from the construction process of nELP that combining a stochastic algorithm, a local search method, and some heuristic strategies could be an effective way to design a high-performance algorithm in a certain field.