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Multi-objective layout optimization of a satellite module using the Wang-Landau sampling method with local search

Key words: Packing, Layout design, Satellite module, Wang-Landau algorithm

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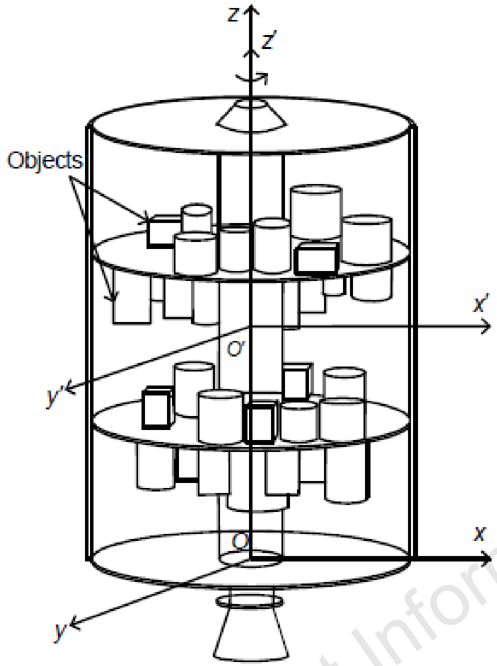
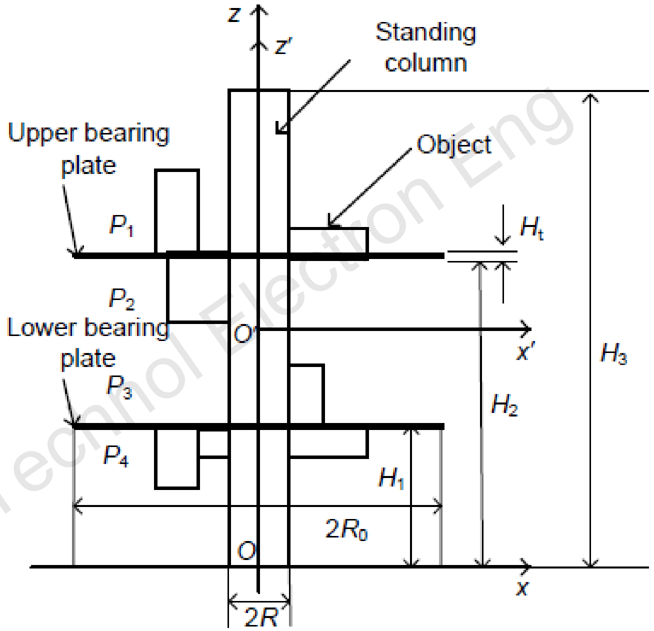
Introduction

- The layout design of a satellite module involves placing a certain number of objects, including various instruments and devices, in a particular satellite module, while satisfying various constraints with specific objectives.
- The layout design of satellite modules is considered to be NP-hard.
- Various approaches for the layout design of satellite modules are available in the literature.
- By combining the WL sampling algorithm, the LS method, and heuristic layout update strategies, a hybrid method called WL-LS has been presented in this paper.

Framework of our method (I)





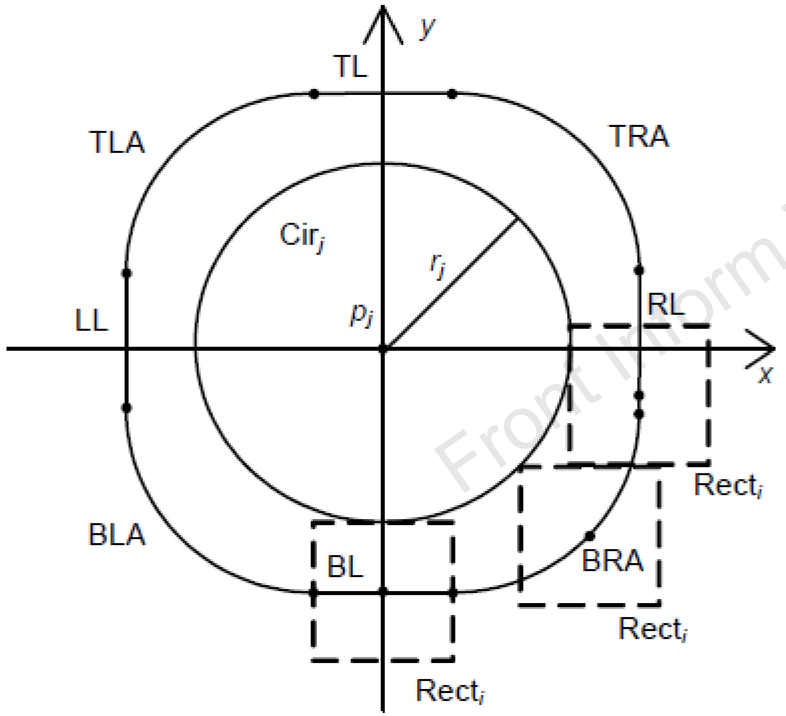
Convert the constrained optimization problem into an unconstrained optimization problem:

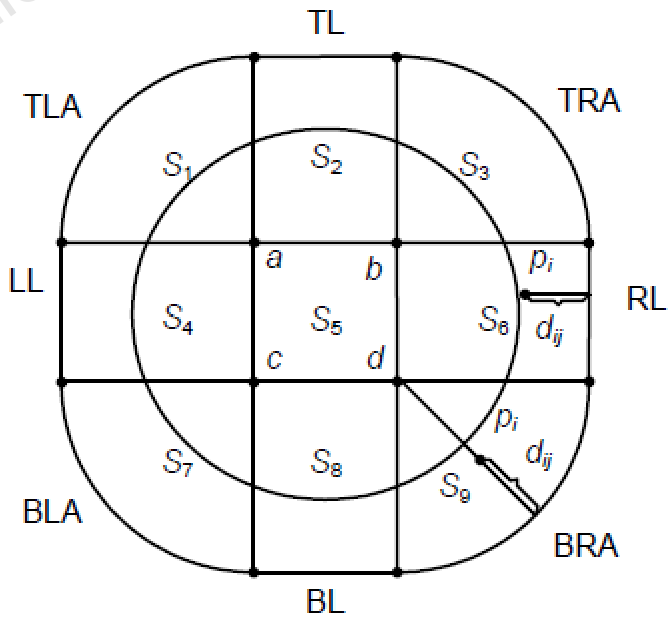
min $E(X)=\omega_1 f_2(X)+\omega_2 f_3(X)+\omega_3[g_2(X)+g_3(X)+g_4(X)]+\omega_4[g_5(X)+g_6(X)+g_7(X)]$

The smallest radii of the four surfaces are obtained by a dichotomous search. Then the largest of the four radii is considered to be the smallest radius of the satellite module.

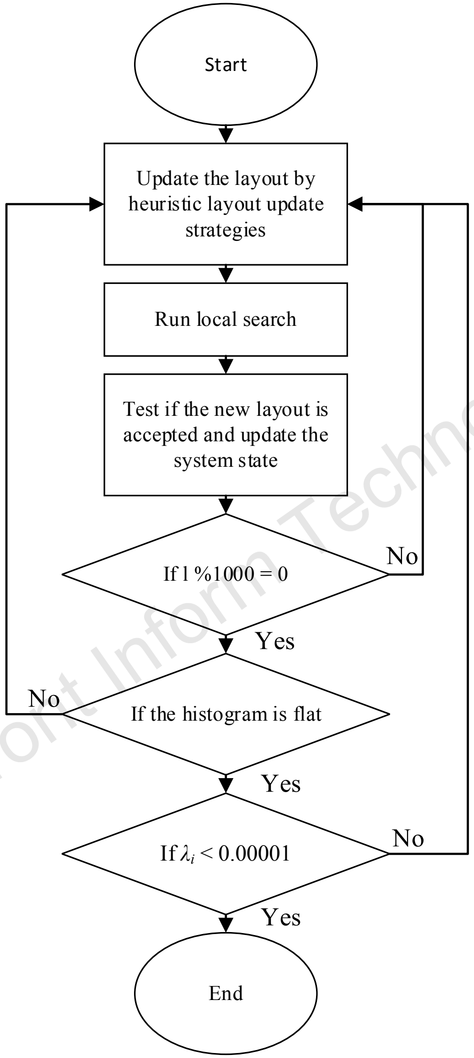
Framework of our method (II)

Adopt an approach based on a no-fit polygon to calculate the overlapping depth between a rectangle and a circle:





Framework of our method (III)



Description of WL-LS

Major results

We tested WL-LS with two instances. HAKD and HKF are the best methods in the literature. The experimental results are:

Table 1 Comparison of the best results by HAKD, WL, WL+GM, WL+HS, and WL-LS for instance 1

Algorithm	Overlapping area (mm^2)	Centroid position error (mm)	Inertia angle error (rad)	Inertia moment ($kg \cdot mm^2$)	Enveloping radius (mm)
HAKD	0	5.94e-2	2.00e-2	711.55	459.37
WL	0	1.03e-0	1.20e-1	710.96	465.05
WL+GM	0	6.09e-2	5.41e-3	695.34	459.17
WL+HS	0	9.77e-1	1.21e-1	708.31	462.48
WL-LS	0	4.21e-2	4.70e-3	693.07	457.76

Centroid position error is the sum of centroid errors in the x and y axes, i.e., $|x_c-x_e|+|y_c-y_e|$. Inertia angle error is the sum of inertia angles in the x', y', and z' axes, i.e., $|\theta_{x'}(X)|+|\theta_{y'}(X)|+|\theta_{z'}(X)|$. Inertia moment is the sum of inertia moments in the x', y', and z' axes, i.e., $J_{x'}(X)+J_{y'}(X)+J_{z'}(X)$

Table 4 Comparison of the best results by HKF, WL, WL+GM, WL+HS, and WL-LS for instance 2

Algorithm	Overlapping area (mm^2)	Centroid position error (mm)	Inertia angle error (rad)	Inertia moment ($kg \cdot mm^2$)	Enveloping radius (mm)
HKF	0	1.139e-0	1.46e-2	796.15	500.00
WL	0	3.60e-1	5.58e-1	802.13	487.05
WL+GM	0	3.59e-3	5.45e-3	797.01	478.50
WL+HS	0	3.60e-1	5.55e-1	800.69	483.49
WL-LS	0	3.40e-3	4.70e-3	795.59	475.11

Centroid position error is the sum of centroid errors in the x and y axes, i.e., $|x_c-x_e|+|y_c-y_e|$. Inertia angle error is the sum of inertia angles in the x', y', and z' axes, i.e., $|\theta_{x'}(X)|+|\theta_{y'}(X)|+|\theta_{z'}(X)|$. Inertia moment is the sum of inertia moments in the x', y', and z' axes, i.e., $J_{x'}(X)+J_{y'}(X)+J_{z'}(X)$