An Intelligent Optimization based Residual Negative Magnitude Shaping Scheme for Vibration Control Supplementary Material

Weiyi Yang, Shuai Li, *Senior Member, IEEE*, and Xin Luo, *Fellow, IEEE*

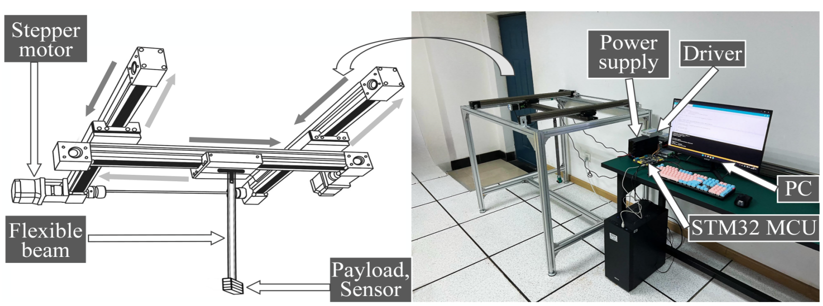
This supplementary file contains several figures and tables related to experimental setup, experimental results, and the pseudocode for DE-SPE and PSO-ISO.

I. Additional Tables

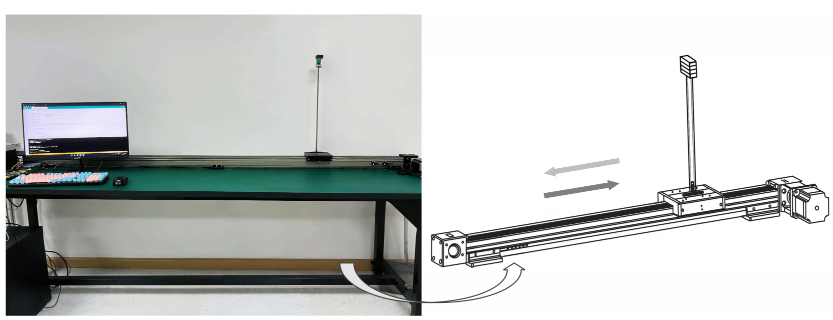
TABLE S.I
DETAILED CONFIGURATION OF DATA SOURCE DEVICES

Mark	D1	D2	D3	D4	D5	D6	D7	D8
Plant	VFB-1	VFB-2	LOC-1	LOC-2	VFB-3	VFB-4	LOC-3	LOC-4
Payload/kg	0.11	0.15	0.11	0.15	0.18	0.25	0.18	0.25
Length/m	0.30	0.30	0.50	0.50	0.30	0.30	0.50	0.50
Disturbance level/m·s^{-2}	–	–	–	–	1	1.5	1	1.5

II. Additional Figures

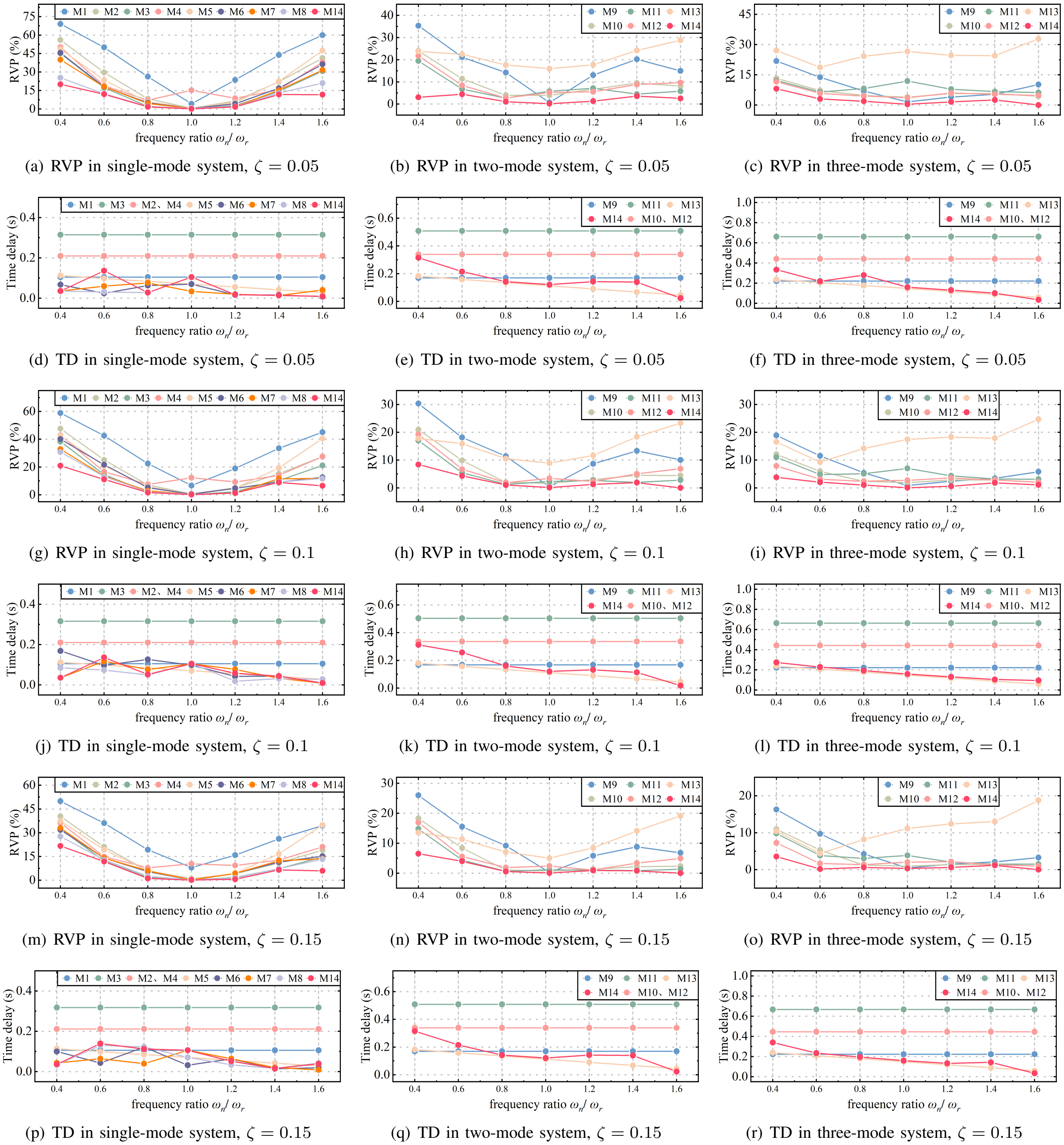


(a) Laboratory overhead crane



(b) Vertical flexible beam

Fig. S.1. The practical experimental setup.



(a) RVP in single-mode system, $\zeta = 0.05$ (b) RVP in two-mode system, $\zeta = 0.05$ (c) RVP in three-mode system, $\zeta = 0.05$

(d) TD in single-mode system, $\zeta = 0.05$ (e) TD in two-mode system, $\zeta = 0.05$ (f) TD in three-mode system, $\zeta = 0.05$

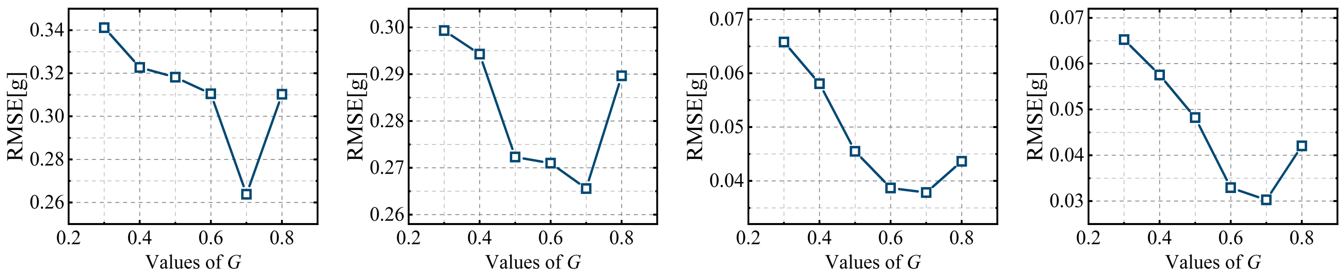
(g) RVP in single-mode system, $\zeta = 0.1$ (h) RVP in two-mode system, $\zeta = 0.1$ (i) RVP in three-mode system, $\zeta = 0.1$

(j) TD in single-mode system, $\zeta = 0.1$ (k) TD in two-mode system, $\zeta = 0.1$ (l) TD in three-mode system, $\zeta = 0.1$

(m) RVP in single-mode system, $\zeta = 0.15$ (n) RVP in two-mode system, $\zeta = 0.15$ (o) RVP in three-mode system, $\zeta = 0.15$

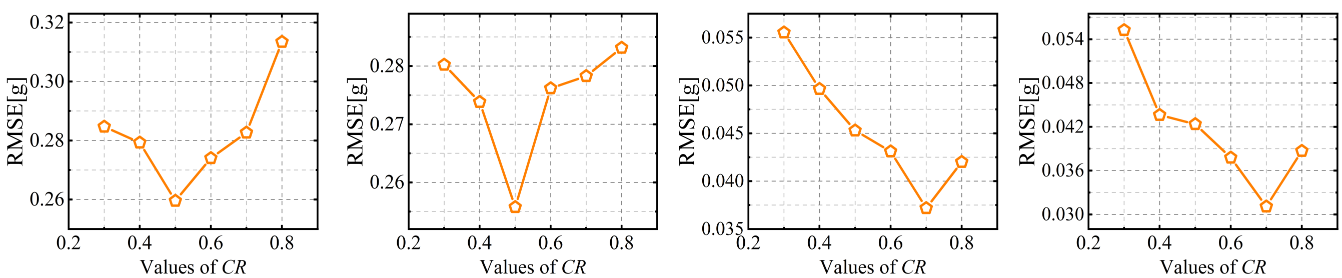
(p) TD in single-mode system, $\zeta = 0.15$ (q) TD in two-mode system, $\zeta = 0.15$ (r) TD in three-mode system, $\zeta = 0.15$

Fig. S.2. The The simulation experiment results. Note that M9 is the ZVD-based multimodal shaper, i.e.,ZV-ZV/ZV-ZV-ZV shaper, M10 is the ZVD-based multimodal shaper, i.e., ZVD-ZVD/ZVD-ZVD-ZVD shaper, M11 is the ZVD^2-based multimodal shaper, i.e., ZVD^2-ZVD^2/ZVD^2-ZVD^2-ZVD^2 shaper, M12 is the EI-based multimodal shaper, i.e., EI-EI/EI-EI-EI shaper and M13 is the NMe-based multimodal shaper, i.e., NMe-NMe/NMe-NMe-NMe shaper.



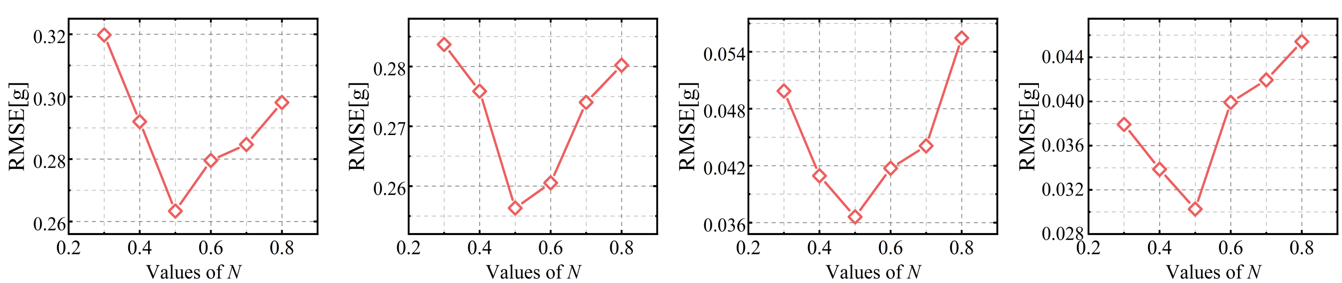
(a) RMSE on D1 (b) RMSE on D2 (c) RMSE on D3 (d) RMSE on D4

Fig. S.3. IRV model's estimation accuracy as G varies.



(a) RMSE on D1 (b) RMSE on D2 (c) RMSE on D3 (d) RMSE on D4

Fig. S.4. IRV model's estimation accuracy as CR varies.



(a) RMSE on D1 (b) RMSE on D2 (c) RMSE on D3 (d) RMSE on D4

Fig. S.5. IRV model's estimation accuracy as N varies.

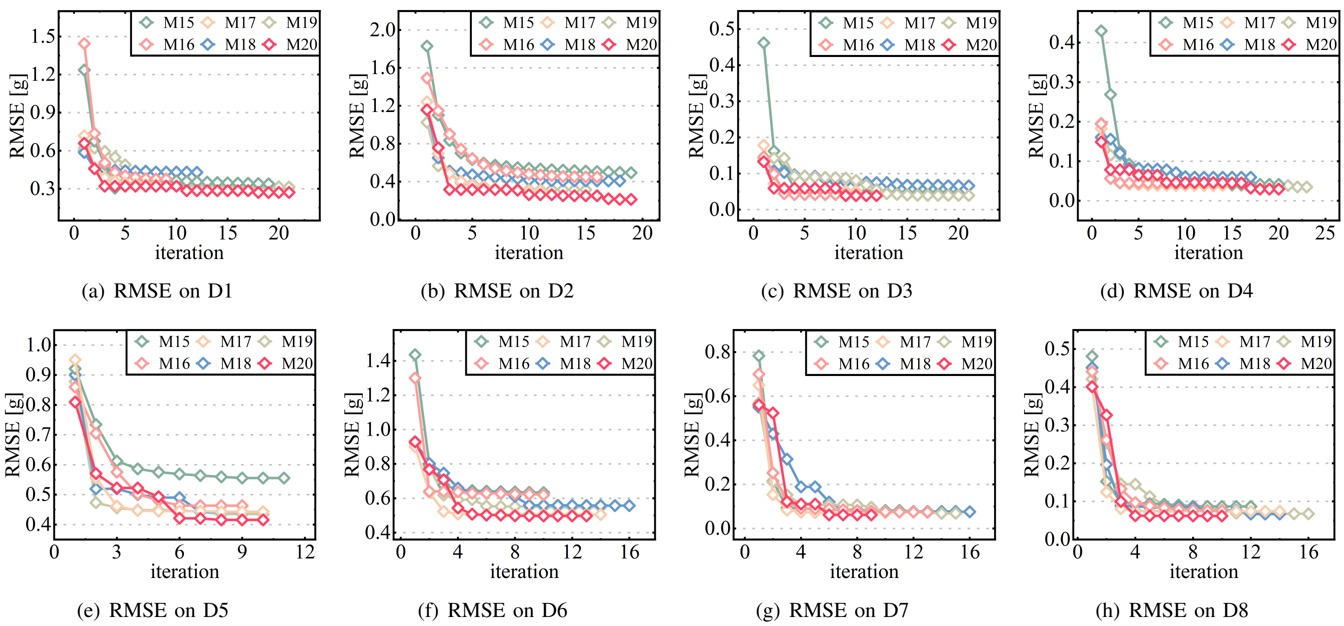
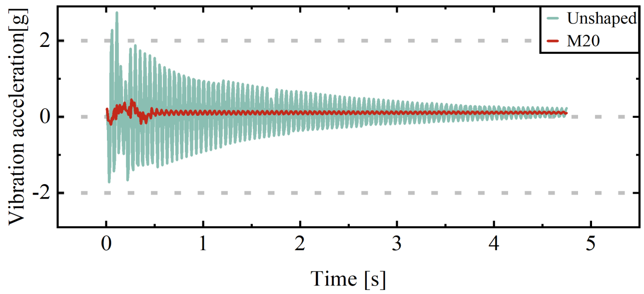
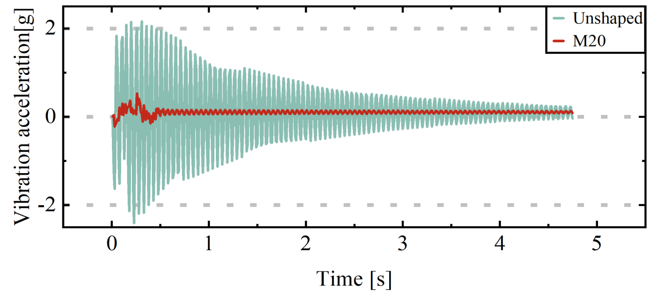


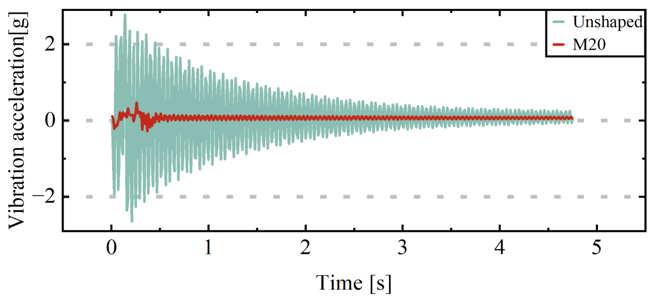
Fig. S.6. Comparison of training curves of M15-M20 on D1-D8 in RMSE



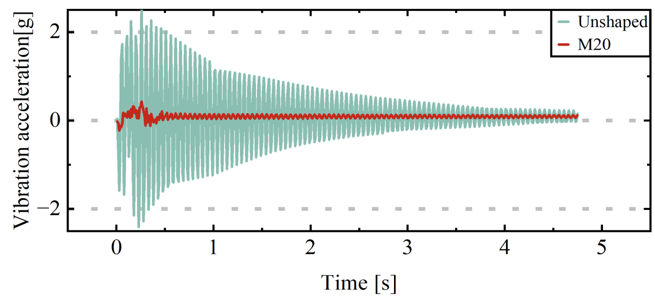
(a) Vibration acceleration on VFB-1



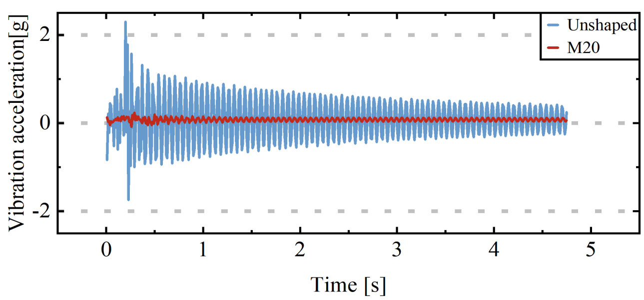
(b) Vibration acceleration on VFB-2



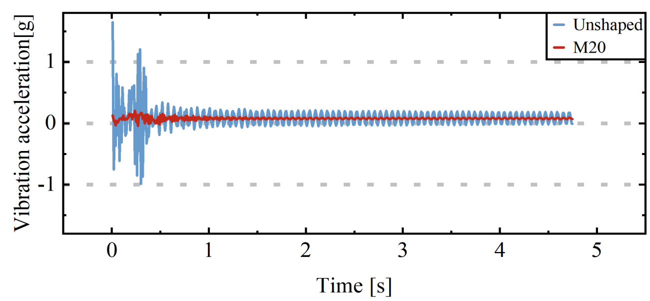
(c) Vibration acceleration on VFB-3



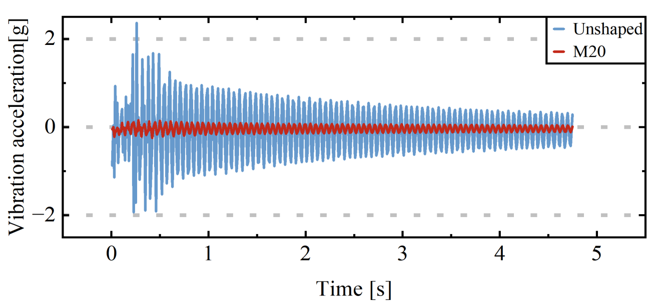
(d) Vibration acceleration on VFB-4



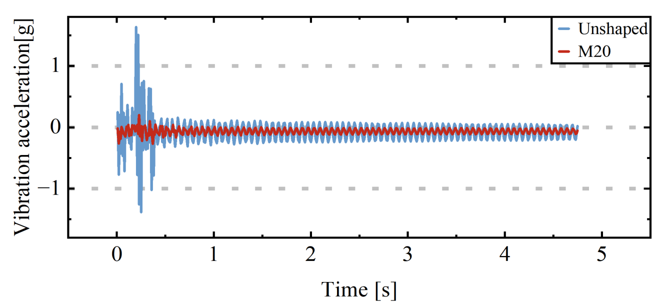
(e) Vibration acceleration on LOC-1



(f) Vibration acceleration on LOC-2



(g) Vibration acceleration on LOC-3



(h) Vibration acceleration on LOC-4

Fig. S.7. Comparison of actual vibration accelerations for VFB and LOC devices.

III. Additional Algorithm Pseudocode

<table>
<tr><th colspan="2">Algorithm I. DE-SPE</th></tr>
<tr><td colspan="2">Input: The actual vibration Y_n, initial system parameters $\mathbf{U}_a$</td></tr>
<tr><th>Operation</th><th>Cost</th></tr>
<tr><td>Initialize: $r_1, r_2, r_3, CR, G, i, j = 6$</td><td>$\Theta(1)$</td></tr>
<tr><td>Initialize: N: The number of population U</td><td>$\Theta(1)$</td></tr>
<tr><td>Initialize: d: The dimension of $\mathbf{U}_i$</td><td>$\Theta(1)$</td></tr>
<tr><td>Initialize: n: The iteration number</td><td>$\Theta(1)$</td></tr>
<tr><td>Initialize u_{ij} with (20)</td><td>$\Theta(\vert N\vert \times d)$</td></tr>
<tr><td>While not converge and $t \leq n$ do</td><td>$\times n$</td></tr>
<tr><td>| for $i = 1$ to $\vert N\vert$ do</td><td>$\times\vert N\vert$</td></tr>
<tr><td>| | Mutate $\mathbf{U}_i$ with (21)</td><td>$\Theta(\vert N\vert)$</td></tr>
<tr><td>| | Cross $\mathbf{M}_i$ with (22)</td><td>$\Theta(\vert N\vert \times d)$</td></tr>
<tr><td>| end for</td><td>-</td></tr>
<tr><td>| Greedy selection $\mathbf{U}_b$ via (23)</td><td>$\Theta(\vert N\vert)$</td></tr>
<tr><td>| $t = t + 1$</td><td>$\Theta(1)$</td></tr>
<tr><td colspan="2">Output: $\mathbf{U}_b$</td></tr>
</table>

<table>
<tr><th colspan="2">Algorithm II. PSO-ISO</th></tr>
<tr><td colspan="2">Input: $\mathbf{U}_b$</td></tr>
<tr><th>Operation</th><th>Cost</th></tr>
<tr><td>Initialize: $s_i, l_i, i, t = 1$</td><td>$\Theta(1)$</td></tr>
<tr><td>Initialize: D: The size of particles</td><td>$\Theta(1)$</td></tr>
<tr><td>Initialize: n: The iteration number</td><td>$\Theta(1)$</td></tr>
<tr><td>Set $p_{i,best} = s_i, g_{best} = \min\{p_{i,best}\}$</td><td>$\Theta(1)$</td></tr>
<tr><td>While not converge and $t \leq n$ do</td><td>$\times n$</td></tr>
<tr><td>| for $i = 1$ to $\vert D\vert$ do</td><td>$\times\vert D\vert$</td></tr>
<tr><td>| | Calculate s_i and l_i via (33) and (34)</td><td>$\Theta(1)$</td></tr>
<tr><td>| | Evaluate particle with the fitness function $\mathrm{H}(\cdot)$</td><td>$\Theta(1)$</td></tr>
<tr><td>| | if $\mathrm{H}(\mathbf{U}_b, l_i) < \mathrm{H}(\mathbf{U}_b, p_{i,best})$</td><td>$\Theta(1)$</td></tr>
<tr><td>| | | $p_{i,best} = l_i$</td><td>$\Theta(1)$</td></tr>
<tr><td>| | if $\mathrm{H}(\mathbf{U}_b, p_{i,best}) < \mathrm{H}(\mathbf{U}_b, g_{best})$</td><td>$\Theta(1)$</td></tr>
<tr><td>| | | $g_{best} = p_{i,best}$</td><td>$\Theta(1)$</td></tr>
<tr><td>| end for</td><td>-</td></tr>
<tr><td>| $t = t + 1$</td><td>$\Theta(1)$</td></tr>
<tr><td colspan="2">Output: g_{best}</td></tr>
</table>