

#### 4.6. aHSDE vs. HS Variants on the CEC 2014 Benchmark

The following Tables S1–S6 belong to Section 4.6 “aHSDE vs. HS Variants on the CEC 2014 Benchmark” of the paper.

**Table S1.** Fitness of f10 for different parameters ( $PAR, F$ ).

| <b>PAR<br/>/F</b> | <b>0.1</b> | <b>0.2</b> | <b>0.3</b> | <b>0.4</b> | <b>0.5</b> | <b>0.6</b>      | <b>0.7</b> | <b>0.8</b> | <b>0.9</b> |
|-------------------|------------|------------|------------|------------|------------|-----------------|------------|------------|------------|
| 0.1               | 1.67E-01   | 1.61E-01   | 1.55E-01   | 1.50E-01   | 1.53E-01   | <b>1.42E-01</b> | 1.51E-01   | 1.46E-01   | 1.49E-01   |
| 0.2               | 1.61E-01   | 1.43E-01   | 1.45E-01   | 1.51E-01   | 1.66E-01   | 1.63E-01        | 1.65E-01   | 1.61E-01   | 1.77E-01   |
| 0.3               | 1.52E-01   | 1.53E-01   | 1.73E-01   | 1.84E-01   | 1.77E-01   | 1.87E-01        | 2.07E-01   | 2.16E-01   | 2.41E-01   |
| 0.4               | 1.78E-01   | 1.70E-01   | 1.89E-01   | 2.09E-01   | 2.96E-01   | 2.30E-01        | 3.24E-01   | 4.82E-01   | 1.38E+00   |
| 0.5               | 1.83E-01   | 1.74E-01   | 2.08E-01   | 2.40E-01   | 7.01E-01   | 1.62E+00        | 2.04E+00   | 4.37E+00   | 7.87E+00   |
| 0.6               | 1.91E-01   | 1.86E-01   | 2.64E-01   | 1.07E+00   | 5.33E+00   | 7.64E+00        | 9.33E+00   | 1.51E+01   | 2.45E+01   |
| 0.7               | 1.89E-01   | 2.09E-01   | 5.93E-01   | 8.48E+01   | 1.33E+02   | 9.68E+02        | 5.54E+02   | 2.85E+02   | 2.14E+02   |
| 0.8               | 1.91E-01   | 2.14E-01   | 1.63E+00   | 1.26E+03   | 4.03E+03   | 3.87E+03        | 3.97E+03   | 4.26E+03   | 4.35E+03   |
| 0.9               | 2.01E-01   | 2.21E-01   | 2.90E+00   | 3.45E+03   | 5.07E+03   | 5.36E+03        | 5.74E+03   | 5.77E+03   | 5.78E+03   |

**Table S2.** Fitness of f21 for different parameters ( $PAR, F$ ).

| <b>PAR<br/>/F</b> | <b>0.1</b> | <b>0.2</b> | <b>0.3</b>      | <b>0.4</b> | <b>0.5</b> | <b>0.6</b> | <b>0.7</b> | <b>0.8</b> | <b>0.9</b> |
|-------------------|------------|------------|-----------------|------------|------------|------------|------------|------------|------------|
| 0.1               | 5.36E+05   | 4.39E+05   | 8.66E+05        | 4.95E+05   | 5.14E+05   | 2.14E+05   | 2.34E+05   | 1.62E+05   | 1.50E+05   |
| 0.2               | 2.60E+05   | 2.09E+05   | 2.77E+05        | 8.67E+04   | 1.33E+05   | 7.85E+04   | 5.05E+04   | 5.48E+04   | 7.00E+04   |
| 0.3               | 1.78E+05   | 1.54E+05   | 9.82E+04        | 7.70E+04   | 4.05E+04   | 4.92E+04   | 3.26E+04   | 4.75E+04   | 4.04E+04   |
| 0.4               | 1.82E+05   | 1.07E+05   | 3.78E+04        | 4.41E+04   | 3.21E+04   | 3.87E+04   | 3.86E+04   | 4.99E+04   | 5.17E+04   |
| 0.5               | 1.38E+05   | 4.57E+04   | 1.94E+04        | 1.51E+04   | 1.48E+04   | 1.28E+04   | 1.68E+04   | 2.58E+04   | 2.57E+04   |
| 0.6               | 9.49E+04   | 1.12E+04   | 5.00E+02        | 8.89E+02   | 9.93E+02   | 1.65E+03   | 4.78E+03   | 6.62E+03   | 1.14E+04   |
| 0.7               | 6.45E+04   | 6.13E+03   | 2.66E+02        | 3.91E+02   | 9.90E+02   | 1.54E+03   | 2.75E+03   | 9.41E+03   | 1.67E+04   |
| 0.8               | 5.21E+04   | 9.10E+02   | 1.81E+02        | 3.62E+02   | 9.63E+02   | 1.39E+03   | 1.74E+03   | 2.62E+03   | 6.15E+03   |
| 0.9               | 4.26E+04   | 8.06E+02   | <b>8.89E+01</b> | 2.46E+02   | 8.76E+02   | 1.23E+03   | 1.54E+03   | 1.90E+03   | 2.45E+03   |

**Table S3.** Fitness of f28 for different parameters ( $PAR, F$ ).

| <b>PAR<br/>/F</b> | <b>0.1</b> | <b>0.2</b> | <b>0.3</b> | <b>0.4</b> | <b>0.5</b> | <b>0.6</b> | <b>0.7</b> | <b>0.8</b> | <b>0.9</b> |
|-------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| 0.1               | 1.35E+03   | 1.24E+03   | 1.11E+03   | 1.09E+03   | 9.84E+02   | 1.02E+03   | 9.80E+02   | 9.46E+02   | 9.58E+02   |
| 0.2               | 1.36E+03   | 1.14E+03   | 1.08E+03   | 9.60E+02   | 8.95E+02   | 9.00E+02   | 8.89E+02   | 8.77E+02   | 8.82E+02   |

|     |          |          |          |          |          |                 |          |          |          |
|-----|----------|----------|----------|----------|----------|-----------------|----------|----------|----------|
| 0.3 | 1.27E+03 | 1.09E+03 | 9.26E+02 | 8.92E+02 | 8.63E+02 | 8.55E+02        | 8.65E+02 | 8.43E+02 | 8.49E+02 |
| 0.4 | 1.25E+03 | 1.08E+03 | 8.83E+02 | 8.63E+02 | 8.43E+02 | 8.21E+02        | 8.26E+02 | 8.18E+02 | 8.30E+02 |
| 0.5 | 1.13E+03 | 1.01E+03 | 9.09E+02 | 8.53E+02 | 8.22E+02 | 8.16E+02        | 8.07E+02 | 7.98E+02 | 8.07E+02 |
| 0.6 | 1.21E+03 | 9.82E+02 | 8.69E+02 | 8.30E+02 | 8.12E+02 | 7.99E+02        | 7.99E+02 | 7.99E+02 | 8.05E+02 |
| 0.7 | 1.16E+03 | 9.65E+02 | 8.68E+02 | 8.12E+02 | 7.97E+02 | <b>7.86E+02</b> | 7.99E+02 | 8.04E+02 | 8.18E+02 |
| 0.8 | 1.12E+03 | 9.53E+02 | 8.71E+02 | 8.08E+02 | 7.95E+02 | 8.02E+02        | 8.16E+02 | 8.33E+02 | 8.83E+02 |
| 0.9 | 1.21E+03 | 9.82E+02 | 8.47E+02 | 8.06E+02 | 7.93E+02 | 8.04E+02        | 9.03E+02 | 9.50E+02 | 9.98E+02 |

**Table S4.** Performance comparison among five harmony search algorithms for f1–f30 (DIM = 10).

| Function | Item | HS              | IHS             | SGHS            | IGHS     | aHSDE           |
|----------|------|-----------------|-----------------|-----------------|----------|-----------------|
| f1       | Best | 4.43E+03        | 9.34E+03        | 6.63E+03        | 2.09E+04 | <b>1.52E-02</b> |
|          | Mean | 1.68E+05        | 7.75E+04        | 4.87E+05        | 7.28E+05 | <b>2.88E-01</b> |
|          | SD   | 3.01E+05        | 6.01E+04        | 5.57E+05        | 1.75E+06 | <b>2.57E-01</b> |
| f2       | Best | 6.55E-01        | 1.96E+01        | 1.07E+01        | 8.76E+05 | <b>1.35E-02</b> |
|          | Mean | 3.08E+03        | 3.84E+03        | 4.53E+03        | 1.81E+07 | <b>3.42E+00</b> |
|          | SD   | 3.41E+03        | 3.23E+03        | 4.42E+03        | 1.92E+07 | <b>4.92E+00</b> |
| f3       | Best | 3.29E+01        | 5.47E+00        | 2.20E+02        | 6.60E+01 | <b>1.41E-04</b> |
|          | Mean | 6.12E+03        | 4.42E+03        | 7.76E+03        | 4.92E+03 | <b>1.38E-02</b> |
|          | SD   | 6.31E+03        | 4.88E+03        | 6.52E+03        | 5.33E+03 | <b>1.50E-02</b> |
| f4       | Best | 1.81E-04        | 3.74E-04        | 1.01E-02        | 7.45E+00 | <b>3.13E-08</b> |
|          | Mean | 6.83E+00        | <b>1.80E+00</b> | 1.50E+01        | 3.97E+01 | 2.48E+01        |
|          | SD   | 1.27E+01        | <b>1.95E+00</b> | 2.46E+01        | 3.22E+01 | 1.56E+01        |
| f5       | Best | 2.81E+00        | 2.00E+01        | <b>3.03E-06</b> | 2.02E+01 | 2.00E+01        |
|          | Mean | 1.94E+01        | 2.00E+01        | <b>1.93E+01</b> | 2.04E+01 | 2.00E+01        |
|          | SD   | 3.14E+00        | <b>8.00E-04</b> | 3.65E+00        | 7.73E-02 | 1.30E-02        |
| f6       | Best | 1.44E+00        | 2.97E-03        | 2.76E-01        | 2.54E+00 | <b>2.90E-03</b> |
|          | Mean | 3.68E+00        | 3.13E+00        | 4.21E+00        | 4.65E+00 | <b>1.64E+00</b> |
|          | SD   | <b>1.19E+00</b> | 1.30E+00        | 1.62E+00        | 1.47E+00 | 1.76E+00        |
| f7       | Best | 7.14E-02        | 5.66E-02        | <b>9.86E-03</b> | 8.32E-01 | 9.86E-03        |
|          | Mean | 2.37E-01        | 1.70E-01        | 1.78E-01        | 1.45E+00 | <b>6.45E-02</b> |
|          | SD   | 1.42E-01        | 6.68E-02        | 9.59E-02        | 4.60E-01 | <b>3.27E-02</b> |
| f8       | Best | <b>0.00E+00</b> | <b>0.00E+00</b> | <b>0.00E+00</b> | 1.24E+00 | <b>0.00E+00</b> |
|          | Mean | <b>0.00E+00</b> | <b>0.00E+00</b> | <b>0.00E+00</b> | 6.81E+00 | <b>0.00E+00</b> |
|          | SD   | <b>0.00E+00</b> | <b>0.00E+00</b> | <b>0.00E+00</b> | 2.54E+00 | <b>0.00E+00</b> |
| f9       | Best | 3.98E+00        | <b>9.95E-01</b> | 6.96E+00        | 5.19E+00 | 3.98E+00        |
|          | Mean | 1.15E+01        | <b>1.11E+01</b> | 1.92E+01        | 1.43E+01 | 1.28E+01        |
|          | SD   | <b>4.27E+00</b> | 4.90E+00        | 6.25E+00        | 6.35E+00 | 6.08E+00        |
| f10      | Best | 1.72E-07        | 1.06E-07        | <b>0.00E+00</b> | 1.88E+00 | <b>0.00E+00</b> |
|          | Mean | <b>1.25E-02</b> | 6.83E-02        | 1.39E-01        | 7.08E+01 | 1.79E-01        |
|          | SD   | <b>3.02E-02</b> | 4.09E-02        | 8.51E-02        | 7.31E+01 | 1.01E-01        |
| f11      | Best | 2.52E+01        | <b>1.51E+01</b> | 1.62E+02        | 7.04E+01 | 1.13E+02        |
|          | Mean | <b>2.50E+02</b> | 2.57E+02        | 5.62E+02        | 4.61E+02 | 5.13E+02        |
|          | SD   | <b>1.16E+02</b> | 1.60E+02        | 2.58E+02        | 3.09E+02 | 2.81E+02        |
| f12      | Best | 2.80E-02        | 6.83E-03        | 2.50E-02        | 1.34E-01 | <b>5.80E-03</b> |
|          | Mean | 9.73E-02        | <b>7.57E-02</b> | 9.04E-02        | 7.06E-01 | 9.45E-02        |
|          | SD   | <b>4.28E-02</b> | 5.37E-02        | 6.79E-02        | 4.06E-01 | 9.08E-02        |
| f13      | Best | 1.09E-01        | 1.02E-01        | 1.09E-01        | 1.38E-01 | <b>1.83E-02</b> |
|          | Mean | 3.69E-01        | 3.59E-01        | 3.37E-01        | 3.69E-01 | <b>1.09E-01</b> |
|          | SD   | 1.46E-01        | 1.64E-01        | 1.80E-01        | 1.43E-01 | <b>4.66E-02</b> |
| f14      | Best | 9.92E-02        | <b>6.81E-02</b> | 1.26E-01        | 9.28E-02 | 9.56E-02        |

|     |      |                 |                 |                 |                 |                 |
|-----|------|-----------------|-----------------|-----------------|-----------------|-----------------|
|     | Mean | 3.37E-01        | 3.82E-01        | 3.77E-01        | 2.98E-01        | <b>2.30E-01</b> |
|     | SD   | 2.16E-01        | 2.46E-01        | 2.18E-01        | 1.70E-01        | <b>7.24E-02</b> |
|     | Best | 7.49E-01        | 5.49E-01        | 5.31E-01        | 1.75E+00        | <b>4.93E-01</b> |
| f15 | Mean | 2.34E+00        | 2.07E+00        | 1.90E+00        | 4.14E+00        | <b>8.14E-01</b> |
|     | SD   | 1.68E+00        | 1.54E+00        | 7.17E-01        | 1.87E+00        | <b>2.51E-01</b> |
|     | Best | 1.19E+00        | <b>3.44E-01</b> | 1.81E+00        | 1.54E+00        | 1.89E+00        |
| f16 | Mean | <b>2.23E+00</b> | 2.37E+00        | 2.73E+00        | 2.32E+00        | 2.69E+00        |
|     | SD   | 4.59E-01        | 5.30E-01        | 4.06E-01        | 4.20E-01        | <b>3.87E-01</b> |
|     | Best | 3.57E+03        | 7.28E+01        | 7.72E+02        | 3.26E+03        | <b>1.99E+00</b> |
| f17 | Mean | 3.43E+05        | 2.73E+04        | 3.41E+05        | 1.27E+05        | <b>4.35E+01</b> |
|     | SD   | 4.58E+05        | 4.30E+04        | 4.70E+05        | 9.36E+04        | <b>5.20E+01</b> |
|     | Best | 2.62E+00        | 1.83E+00        | 1.04E+01        | 4.24E+02        | <b>3.45E-01</b> |
| f18 | Mean | 1.37E+04        | 1.04E+04        | 1.55E+04        | 1.33E+04        | <b>4.27E+01</b> |
|     | SD   | 1.08E+04        | 1.10E+04        | 1.36E+04        | 1.52E+04        | <b>2.06E+02</b> |
|     | Best | 2.00E-01        | 5.78E-02        | 1.35E-01        | 5.24E-01        | <b>5.64E-02</b> |
| f19 | Mean | 9.14E-01        | 9.44E-01        | 1.71E+00        | 1.81E+00        | <b>8.22E-01</b> |
|     | SD   | 4.87E-01        | 4.33E-01        | 1.26E+00        | 9.93E-01        | <b>3.67E-01</b> |
|     | Best | 1.61E+01        | 1.82E+01        | 5.78E+01        | 1.82E+01        | <b>2.07E-01</b> |
| f20 | Mean | 4.32E+03        | 5.53E+03        | 9.60E+03        | 7.80E+03        | <b>2.64E+00</b> |
|     | SD   | 6.36E+03        | 8.66E+03        | 1.24E+04        | 7.79E+03        | <b>1.30E+00</b> |
|     | Best | 9.83E-01        | 7.76E-01        | 5.46E+02        | 1.99E+02        | <b>3.84E-02</b> |
| f21 | Mean | 1.67E+03        | 2.53E+03        | 7.53E+05        | 1.07E+05        | <b>8.53E+00</b> |
|     | SD   | 3.89E+03        | 3.94E+03        | 1.37E+06        | 2.42E+05        | <b>1.62E+01</b> |
|     | Best | 3.86E-01        | <b>1.82E-02</b> | 4.10E-02        | 6.17E+00        | 3.44E-02        |
| f22 | Mean | 1.35E+01        | <b>3.32E+00</b> | 4.92E+01        | 6.14E+01        | 4.14E+01        |
|     | SD   | 3.33E+01        | <b>6.89E+00</b> | 8.09E+01        | 6.21E+01        | 6.42E+01        |
|     | Best | 3.29E+02        | 3.29E+02        | <b>1.05E-05</b> | 2.00E+02        | 3.29E+02        |
| f23 | Mean | 3.29E+02        | 3.29E+02        | <b>3.11E+02</b> | 3.22E+02        | 3.29E+02        |
|     | SD   | <b>0.00E+00</b> | <b>0.00E+00</b> | 7.21E+01        | 3.33E+01        | <b>0.00E+00</b> |
|     | Best | 1.12E+02        | 1.09E+02        | 1.20E+02        | 1.15E+02        | <b>1.09E+02</b> |
| f24 | Mean | 1.26E+02        | 1.27E+02        | 1.43E+02        | 1.51E+02        | <b>1.22E+02</b> |
|     | SD   | 8.38E+00        | 9.69E+00        | 1.62E+01        | 2.94E+01        | <b>5.57E+00</b> |
|     | Best | 1.22E+02        | <b>1.21E+02</b> | 1.29E+02        | 1.26E+02        | 1.22E+02        |
| f25 | Mean | <b>1.75E+02</b> | 1.78E+02        | 1.87E+02        | 1.83E+02        | 1.96E+02        |
|     | SD   | 3.25E+01        | 3.11E+01        | 2.46E+01        | 2.77E+01        | <b>1.91E+01</b> |
|     | Best | <b>1.00E+02</b> | <b>1.00E+02</b> | <b>1.00E+02</b> | <b>1.00E+02</b> | <b>1.00E+02</b> |
| f26 | Mean | <b>1.00E+02</b> | <b>1.00E+02</b> | 1.14E+02        | 1.07E+02        | <b>1.00E+02</b> |
|     | SD   | 1.23E-01        | 1.25E-01        | 3.45E+01        | 2.53E+01        | <b>5.61E-02</b> |
|     | Best | 5.29E+00        | 8.60E+00        | 4.92E+00        | 4.50E+00        | <b>2.07E+00</b> |
| f27 | Mean | 3.63E+02        | 3.85E+02        | 3.98E+02        | <b>2.06E+02</b> | 2.99E+02        |
|     | SD   | 1.02E+02        | <b>7.63E+01</b> | 1.14E+02        | 2.01E+02        | 1.55E+02        |
|     | Best | 3.71E+02        | 3.56E+02        | <b>3.50E+02</b> | 3.63E+02        | 3.69E+02        |
| f28 | Mean | 4.65E+02        | 4.62E+02        | 6.05E+02        | 4.64E+02        | <b>4.05E+02</b> |
|     | SD   | 6.85E+01        | 6.91E+01        | 1.23E+02        | 9.70E+01        | <b>4.94E+01</b> |
|     | Best | 2.52E+02        | 2.11E+02        | 2.05E+02        | 2.50E+02        | <b>1.68E+02</b> |
| f29 | Mean | 9.94E+04        | 2.69E+02        | <b>2.09E+02</b> | 6.82E+02        | 1.15E+05        |
|     | SD   | 2.56E+05        | 7.61E+01        | <b>3.82E+00</b> | 2.76E+02        | 4.37E+05        |
|     | Best | 4.97E+02        | 4.33E+02        | <b>3.18E+02</b> | 5.05E+02        | 4.54E+02        |
| f30 | Mean | 8.28E+02        | 7.97E+02        | 7.08E+02        | 1.23E+03        | <b>5.37E+02</b> |
|     | SD   | 2.45E+02        | <b>1.83E+02</b> | 2.40E+02        | 4.15E+02        | 1.93E+02        |
|     | Best |                 |                 |                 |                 |                 |

**Table S5.** Performance comparison among five harmony search algorithms for f1–f30 (DIM = 50).

| Function | Item | HS       | IHS      | SGHS     | IGHS     | aHSDE           |
|----------|------|----------|----------|----------|----------|-----------------|
| f1       | Best | 1.02E+07 | 9.16E+06 | 2.45E+06 | 3.52E+08 | <b>6.90E+04</b> |
|          | Mean | 2.04E+07 | 1.86E+07 | 8.81E+06 | 4.97E+08 | <b>2.06E+05</b> |
|          | SD   | 8.10E+06 | 7.95E+06 | 5.73E+06 | 9.59E+07 | <b>9.12E+04</b> |

|     |      |                 |                 |                 |                 |                 |
|-----|------|-----------------|-----------------|-----------------|-----------------|-----------------|
| f2  | Best | 6.85E+06        | 8.72E+01        | 1.87E+02        | 2.83E+10        | <b>4.35E-01</b> |
|     | Mean | 1.55E+07        | 1.41E+04        | 5.78E+04        | 3.70E+10        | <b>5.77E+03</b> |
|     | SD   | 5.09E+06        | 2.87E+04        | 9.95E+04        | 4.22E+09        | <b>6.41E+03</b> |
| f3  | Best | 2.52E+03        | 5.91E+03        | 1.03E+04        | 5.44E+04        | <b>1.42E-01</b> |
|     | Mean | 1.01E+04        | 1.30E+04        | 2.93E+04        | 7.19E+04        | <b>1.25E+00</b> |
|     | SD   | 4.27E+03        | 5.60E+03        | 1.19E+04        | 1.00E+04        | <b>1.61E+00</b> |
| f4  | Best | 9.94E+01        | 5.19E+01        | 2.66E+01        | 4.00E+03        | <b>1.85E-01</b> |
|     | Mean | 1.64E+02        | 1.42E+02        | 9.85E+01        | 6.02E+03        | <b>4.43E+01</b> |
|     | SD   | 3.84E+01        | 3.92E+01        | 3.86E+01        | 1.07E+03        | <b>3.69E+01</b> |
| f5  | Best | <b>2.00E+01</b> | <b>2.00E+01</b> | <b>2.00E+01</b> | 2.10E+01        | <b>2.00E+01</b> |
|     | Mean | <b>2.00E+01</b> | <b>2.00E+01</b> | <b>2.00E+01</b> | 2.11E+01        | 2.01E+01        |
|     | SD   | <b>2.07E-04</b> | 4.44E-02        | 2.54E-02        | 3.38E-02        | 4.08E-02        |
| f6  | Best | 2.31E+01        | 1.69E+01        | 2.36E+01        | 5.41E+01        | <b>1.21E+01</b> |
|     | Mean | 2.90E+01        | 2.71E+01        | 3.31E+01        | 5.91E+01        | <b>2.02E+01</b> |
|     | SD   | 3.41E+00        | 4.30E+00        | 4.31E+00        | <b>2.65E+00</b> | 3.77E+00        |
| f7  | Best | 1.07E+00        | 3.39E-02        | <b>2.23E-08</b> | 2.55E+02        | 1.31E-06        |
|     | Mean | 1.17E+00        | 1.33E-01        | 1.43E-01        | 3.37E+02        | <b>2.14E-03</b> |
|     | SD   | 8.11E-02        | 7.79E-02        | 2.03E-01        | 3.85E+01        | <b>4.28E-03</b> |
| f8  | Best | 1.31E+00        | 8.55E-01        | <b>0.00E+00</b> | 3.97E+02        | 3.24E-08        |
|     | Mean | 2.78E+00        | 2.84E+00        | 2.52E-02        | 4.51E+02        | <b>7.41E-08</b> |
|     | SD   | 1.09E+00        | 1.33E+00        | 4.38E-02        | 2.56E+01        | <b>1.94E-08</b> |
| f9  | Best | 8.93E+01        | 1.01E+02        | 1.58E+02        | 4.87E+02        | <b>4.88E+01</b> |
|     | Mean | 1.38E+02        | 1.45E+02        | 2.46E+02        | 5.30E+02        | <b>7.89E+01</b> |
|     | SD   | 2.35E+01        | 3.31E+01        | 4.44E+01        | 2.25E+01        | <b>1.80E+01</b> |
| f10 | Best | 2.74E+00        | 2.70E+00        | 1.62E-01        | 9.13E+03        | <b>9.99E-02</b> |
|     | Mean | 7.87E+00        | 6.70E+00        | 4.32E-01        | 1.08E+04        | <b>1.94E-01</b> |
|     | SD   | 2.40E+00        | 2.46E+00        | 2.84E-01        | 6.93E+02        | <b>4.50E-02</b> |
| f11 | Best | <b>2.87E+03</b> | 3.00E+03        | 3.67E+03        | 1.25E+04        | 3.53E+03        |
|     | Mean | 4.21E+03        | <b>4.07E+03</b> | 4.94E+03        | 1.32E+04        | 4.71E+03        |
|     | SD   | 5.90E+02        | 6.90E+02        | 5.96E+02        | <b>3.35E+02</b> | 5.61E+02        |
| f12 | Best | 1.32E-01        | 4.95E-02        | 8.06E-02        | 3.01E+00        | <b>4.04E-02</b> |
|     | Mean | 2.45E-01        | 1.58E-01        | 1.28E-01        | 3.44E+00        | <b>9.57E-02</b> |
|     | SD   | 5.93E-02        | 6.86E-02        | <b>3.22E-02</b> | 2.10E-01        | 4.16E-02        |
| f13 | Best | 3.91E-01        | 4.41E-01        | 3.01E-01        | 3.01E+00        | <b>2.24E-01</b> |
|     | Mean | 6.37E-01        | 6.44E-01        | 5.92E-01        | 3.95E+00        | <b>3.31E-01</b> |
|     | SD   | 1.22E-01        | 1.07E-01        | 1.29E-01        | 2.79E-01        | <b>6.32E-02</b> |
| f14 | Best | 2.70E-01        | 2.66E-01        | 2.49E-01        | 6.78E+01        | <b>2.43E-01</b> |
|     | Mean | 5.24E-01        | 5.05E-01        | 4.42E-01        | 8.11E+01        | <b>3.30E-01</b> |
|     | SD   | 2.88E-01        | 2.22E-01        | 2.26E-01        | 7.92E+00        | <b>1.12E-01</b> |
| f15 | Best | 1.41E+01        | 1.39E+01        | 1.17E+01        | 2.74E+04        | <b>4.33E+00</b> |
|     | Mean | 3.23E+01        | 2.31E+01        | 1.83E+01        | 6.08E+04        | <b>8.09E+00</b> |
|     | SD   | 1.31E+01        | 5.78E+00        | 4.20E+00        | 2.18E+04        | <b>2.32E+00</b> |
| f16 | Best | 1.70E+01        | 1.61E+01        | 1.69E+01        | 2.11E+01        | <b>1.54E+01</b> |
|     | Mean | 1.83E+01        | 1.81E+01        | 1.83E+01        | 2.22E+01        | <b>1.78E+01</b> |
|     | SD   | 6.50E-01        | 7.11E-01        | 7.09E-01        | <b>3.83E-01</b> | 1.00E+00        |
| f17 | Best | 7.79E+05        | 1.76E+05        | 7.52E+05        | 5.23E+06        | <b>1.10E+03</b> |
|     | Mean | 3.55E+06        | 7.55E+05        | 2.73E+06        | 1.73E+07        | <b>2.66E+03</b> |
|     | SD   | 1.65E+06        | 3.85E+05        | 1.55E+06        | 8.41E+06        | <b>1.83E+03</b> |
| f18 | Best | 1.75E+02        | 6.96E+01        | 1.85E+02        | 4.05E+05        | <b>3.87E+01</b> |
|     | Mean | 1.71E+03        | 1.83E+03        | 7.08E+03        | 3.89E+06        | <b>8.88E+01</b> |
|     | SD   | 1.30E+03        | 1.44E+03        | 8.56E+03        | 3.57E+06        | <b>3.11E+01</b> |
| f19 | Best | 1.64E+01        | 1.37E+01        | 1.25E+01        | 8.35E+01        | <b>8.85E+00</b> |
|     | Mean | 5.59E+01        | 3.53E+01        | 3.09E+01        | 1.29E+02        | <b>1.16E+01</b> |
|     | SD   | 2.43E+01        | 2.60E+01        | 2.12E+01        | 2.40E+01        | <b>1.42E+00</b> |
| f20 | Best | 2.71E+03        | 1.49E+03        | 7.65E+03        | 6.19E+03        | <b>2.31E+01</b> |
|     | Mean | 8.85E+03        | 6.66E+03        | 5.51E+04        | 1.91E+04        | <b>4.07E+01</b> |
|     | SD   | 5.80E+03        | 4.41E+03        | 2.73E+04        | 7.24E+03        | <b>9.82E+00</b> |



|     |      |                 |          |                 |                 |                 |
|-----|------|-----------------|----------|-----------------|-----------------|-----------------|
| f21 | Best | 5.76E+05        | 8.70E+04 | 4.74E+05        | 1.04E+06        | <b>3.84E+02</b> |
|     | Mean | 3.21E+06        | 4.20E+05 | 3.36E+06        | 5.98E+06        | <b>8.35E+02</b> |
|     | SD   | 1.84E+06        | 2.35E+05 | 2.35E+06        | 3.37E+06        | <b>2.36E+02</b> |
| f22 | Best | 5.66E+02        | 3.30E+02 | 7.09E+02        | 1.57E+03        | <b>1.51E+02</b> |
|     | Mean | 1.14E+03        | 1.13E+03 | 1.58E+03        | 1.93E+03        | <b>8.30E+02</b> |
|     | SD   | 2.68E+02        | 2.78E+02 | 3.28E+02        | <b>1.72E+02</b> | 2.96E+02        |
| f23 | Best | 3.44E+02        | 3.40E+02 | <b>3.37E+02</b> | 4.25E+02        | 3.44E+02        |
|     | Mean | 3.45E+02        | 3.42E+02 | <b>3.39E+02</b> | 4.61E+02        | 3.44E+02        |
|     | SD   | 6.38E-01        | 1.05E+00 | 3.04E+00        | 2.17E+01        | <b>0.00E+00</b> |
| f24 | Best | 2.60E+02        | 2.58E+02 | 2.59E+02        | <b>2.00E+02</b> | 2.57E+02        |
|     | Mean | 2.68E+02        | 2.70E+02 | 2.70E+02        | <b>2.04E+02</b> | 2.69E+02        |
|     | SD   | <b>5.29E+00</b> | 7.32E+00 | 6.75E+00        | 2.17E+01        | 6.50E+00        |
| f25 | Best | 2.12E+02        | 2.11E+02 | 2.01E+02        | <b>2.00E+02</b> | 2.05E+02        |
|     | Mean | 2.16E+02        | 2.15E+02 | <b>2.03E+02</b> | 2.29E+02        | 2.07E+02        |
|     | SD   | 2.76E+00        | 2.41E+00 | 3.37E+00        | 3.68E+01        | <b>2.04E+00</b> |
| f26 | Best | 1.01E+02        | 1.01E+02 | 1.00E+02        | 1.04E+02        | <b>1.00E+02</b> |
|     | Mean | 1.85E+02        | 1.81E+02 | 1.84E+02        | 1.99E+02        | <b>1.00E+02</b> |
|     | SD   | 5.59E+01        | 5.80E+01 | 8.73E+01        | 2.63E+01        | <b>6.01E-02</b> |
| f27 | Best | 9.56E+02        | 9.49E+02 | <b>4.08E+02</b> | 1.81E+03        | 6.43E+02        |
|     | Mean | 1.11E+03        | 1.09E+03 | 1.23E+03        | 1.94E+03        | <b>8.76E+02</b> |
|     | SD   | 9.47E+01        | 8.46E+01 | 1.96E+02        | <b>6.28E+01</b> | 1.26E+02        |
| f28 | Best | 1.27E+03        | 1.28E+03 | 1.64E+03        | 2.62E+03        | <b>1.10E+03</b> |
|     | Mean | 1.72E+03        | 1.69E+03 | 3.10E+03        | 3.92E+03        | <b>1.28E+03</b> |
|     | SD   | 3.83E+02        | 2.79E+02 | 1.04E+03        | 8.61E+02        | <b>8.88E+01</b> |
| f29 | Best | 9.72E+02        | 1.26E+03 | <b>2.24E+02</b> | 4.39E+06        | 1.99E+03        |
|     | Mean | 2.25E+03        | 2.29E+03 | <b>3.11E+02</b> | 1.98E+07        | 2.35E+07        |
|     | SD   | 6.15E+02        | 7.17E+02 | <b>2.84E+02</b> | 1.07E+07        | 1.69E+07        |
| f30 | Best | 1.07E+04        | 3.83E+03 | <b>7.90E+02</b> | 1.14E+05        | 7.95E+03        |
|     | Mean | 2.08E+04        | 7.78E+03 | <b>1.57E+03</b> | 2.78E+05        | 8.93E+03        |
|     | SD   | 7.85E+03        | 2.88E+03 | <b>3.38E+02</b> | 1.07E+05        | 6.76E+02        |

**Table S6.** Performance comparison among five harmony search algorithms for f1–f30 (DIM = 100).

| Function | Item | HS       | IHS      | SGHS            | IGHS            | aHSDE           |
|----------|------|----------|----------|-----------------|-----------------|-----------------|
| f1       | Best | 1.12E+08 | 1.78E+08 | 9.99E+06        | 2.04E+09        | <b>1.17E+06</b> |
|          | Mean | 3.45E+08 | 3.50E+08 | 3.32E+07        | 2.69E+09        | <b>2.04E+06</b> |
|          | SD   | 9.17E+07 | 1.25E+08 | 3.54E+07        | 4.34E+08        | <b>4.80E+05</b> |
| f2       | Best | 5.41E+09 | 4.44E+09 | 3.99E+02        | 1.29E+11        | <b>5.86E+01</b> |
|          | Mean | 7.01E+09 | 7.14E+09 | 3.77E+05        | 1.45E+11        | <b>1.28E+04</b> |
|          | SD   | 8.85E+08 | 1.21E+09 | 7.83E+05        | 8.49E+09        | <b>1.26E+04</b> |
| f3       | Best | 2.53E+04 | 1.83E+04 | 8.38E+03        | 1.90E+05        | <b>4.52E+01</b> |
|          | Mean | 3.97E+04 | 3.81E+04 | 5.11E+04        | 2.24E+05        | <b>2.27E+02</b> |
|          | SD   | 1.17E+04 | 1.20E+04 | 2.05E+04        | 1.99E+04        | <b>1.73E+02</b> |
| f4       | Best | 7.58E+02 | 8.45E+02 | <b>9.53E+01</b> | 1.89E+04        | 1.22E+02        |
|          | Mean | 1.02E+03 | 1.03E+03 | <b>1.81E+02</b> | 2.63E+04        | 1.96E+02        |
|          | SD   | 1.66E+02 | 1.41E+02 | 5.90E+01        | 2.61E+03        | <b>4.11E+01</b> |
| f5       | Best | 2.09E+01 | 2.10E+01 | <b>2.00E+01</b> | 2.13E+01        | 2.00E+01        |
|          | Mean | 2.11E+01 | 2.12E+01 | <b>2.01E+01</b> | 2.13E+01        | 2.01E+01        |
|          | SD   | 9.08E-02 | 8.11E-02 | 6.77E-02        | <b>2.10E-02</b> | 5.77E-02        |
| f6       | Best | 7.35E+01 | 7.53E+01 | 6.84E+01        | 1.38E+02        | <b>3.75E+01</b> |
|          | Mean | 8.86E+01 | 8.69E+01 | 7.95E+01        | 1.45E+02        | <b>5.20E+01</b> |
|          | SD   | 6.13E+00 | 4.32E+00 | 5.71E+00        | <b>3.19E+00</b> | 7.90E+00        |
| f7       | Best | 4.69E+01 | 4.84E+01 | <b>7.30E-08</b> | 1.33E+03        | 2.81E-05        |
|          | Mean | 6.43E+01 | 6.70E+01 | 3.03E-01        | 1.50E+03        | <b>2.80E-03</b> |
|          | SD   | 8.88E+00 | 8.57E+00 | 3.76E-01        | 7.76E+01        | <b>7.04E-03</b> |
| f8       | Best | 1.43E+02 | 1.37E+02 | <b>9.64E-11</b> | 1.08E+03        | 1.69E-06        |
|          | Mean | 1.72E+02 | 1.63E+02 | 1.74E+00        | 1.16E+03        | <b>2.90E-06</b> |

|     |      |                 |                 |                 |                 |                 |
|-----|------|-----------------|-----------------|-----------------|-----------------|-----------------|
|     | SD   | 1.19E+01        | 1.07E+01        | 4.53E+00        | 3.91E+01        | <b>6.82E-07</b> |
| f9  | Best | 6.13E+02        | 5.76E+02        | 4.51E+02        | 1.16E+03        | <b>1.70E+02</b> |
|     | Mean | 7.04E+02        | 6.86E+02        | 6.09E+02        | 1.28E+03        | <b>2.24E+02</b> |
|     | SD   | 4.60E+01        | 5.61E+01        | 8.97E+01        | 4.07E+01        | <b>3.01E+01</b> |
| f10 | Best | 2.15E+03        | 1.66E+03        | 3.31E-01        | 2.40E+04        | <b>2.44E-01</b> |
|     | Mean | 2.65E+03        | 2.32E+03        | 3.62E+00        | 2.69E+04        | <b>3.77E-01</b> |
|     | SD   | 3.34E+02        | 3.26E+02        | 3.75E+00        | 1.10E+03        | <b>1.65E-01</b> |
| f11 | Best | 1.92E+04        | 1.74E+04        | 1.01E+04        | 2.94E+04        | <b>8.96E+03</b> |
|     | Mean | 2.25E+04        | 2.17E+04        | 1.25E+04        | 3.01E+04        | <b>1.17E+04</b> |
|     | SD   | 1.83E+03        | 2.15E+03        | 1.03E+03        | <b>4.44E+02</b> | 1.51E+03        |
| f12 | Best | 1.09E+00        | 9.14E-01        | <b>9.04E-02</b> | 3.51E+00        | 1.05E-01        |
|     | Mean | 1.72E+00        | 1.78E+00        | 1.92E-01        | 4.00E+00        | <b>1.90E-01</b> |
|     | SD   | 3.89E-01        | 4.81E-01        | 5.07E-02        | 2.24E-01        | <b>4.61E-02</b> |
| f13 | Best | 7.38E-01        | 7.15E-01        | 5.30E-01        | 6.10E+00        | <b>3.12E-01</b> |
|     | Mean | 9.31E-01        | 9.03E-01        | 6.39E-01        | 6.42E+00        | <b>4.18E-01</b> |
|     | SD   | 1.10E-01        | 8.51E-02        | 7.20E-02        | 1.31E-01        | <b>5.18E-02</b> |
| f14 | Best | 9.93E-01        | 1.08E+00        | <b>2.69E-01</b> | 3.81E+02        | 2.79E-01        |
|     | Mean | 1.04E+01        | 8.46E+00        | 4.22E-01        | 4.25E+02        | <b>3.14E-01</b> |
|     | SD   | 7.75E+00        | 7.12E+00        | 2.13E-01        | 2.78E+01        | <b>2.35E-02</b> |
| f15 | Best | 2.51E+02        | 2.46E+02        | 2.88E+01        | 9.88E+05        | <b>1.68E+01</b> |
|     | Mean | 6.18E+02        | 5.52E+02        | 5.61E+01        | 1.72E+06        | <b>2.15E+01</b> |
|     | SD   | 4.76E+02        | 2.22E+02        | 1.71E+01        | 7.11E+05        | <b>3.11E+00</b> |
| f16 | Best | 4.26E+01        | 4.23E+01        | 3.84E+01        | 4.55E+01        | <b>3.75E+01</b> |
|     | Mean | 4.44E+01        | 4.50E+01        | 4.06E+01        | 4.64E+01        | <b>3.97E+01</b> |
|     | SD   | 1.06E+00        | 1.07E+00        | 1.04E+00        | <b>2.73E-01</b> | 1.02E+00        |
| f17 | Best | 1.02E+07        | 3.79E+06        | 1.93E+06        | 9.96E+07        | <b>1.32E+04</b> |
|     | Mean | 2.24E+07        | 8.77E+06        | 8.15E+06        | 2.31E+08        | <b>7.72E+04</b> |
|     | SD   | 7.36E+06        | 3.00E+06        | 7.29E+06        | 4.66E+07        | <b>3.68E+04</b> |
| f18 | Best | 7.40E+02        | 4.79E+02        | 2.84E+02        | 1.80E+09        | <b>1.68E+02</b> |
|     | Mean | 3.85E+03        | 4.24E+03        | 4.20E+04        | 2.80E+09        | <b>2.27E+03</b> |
|     | SD   | 3.39E+03        | 4.31E+03        | 8.26E+04        | 7.01E+08        | <b>2.70E+03</b> |
| f19 | Best | 8.56E+01        | 7.40E+01        | <b>4.50E+01</b> | 7.89E+02        | 8.95E+01        |
|     | Mean | 1.67E+02        | 1.43E+02        | <b>8.43E+01</b> | 9.75E+02        | 9.54E+01        |
|     | SD   | 3.26E+01        | 4.23E+01        | 3.40E+01        | 1.30E+02        | <b>7.62E+00</b> |
| f20 | Best | 7.42E+03        | 8.50E+03        | 8.14E+04        | 8.22E+04        | <b>8.29E+01</b> |
|     | Mean | 1.65E+04        | 1.56E+04        | 1.69E+05        | 1.42E+05        | <b>2.73E+02</b> |
|     | SD   | 6.19E+03        | 5.23E+03        | 5.32E+04        | 3.80E+04        | <b>1.66E+02</b> |
| f21 | Best | 3.92E+06        | 1.68E+06        | 1.09E+06        | 3.99E+07        | <b>5.35E+03</b> |
|     | Mean | 9.91E+06        | 3.82E+06        | 5.25E+06        | 7.25E+07        | <b>2.28E+04</b> |
|     | SD   | 4.21E+06        | 1.30E+06        | 4.43E+06        | 2.13E+07        | <b>1.13E+04</b> |
| f22 | Best | 1.42E+03        | 9.42E+02        | 2.08E+03        | 4.68E+03        | <b>7.75E+02</b> |
|     | Mean | 2.48E+03        | 2.25E+03        | 3.19E+03        | 5.32E+03        | <b>1.64E+03</b> |
|     | SD   | 5.85E+02        | 5.33E+02        | 5.52E+02        | <b>3.42E+02</b> | 4.13E+02        |
| f23 | Best | 3.57E+02        | 3.55E+02        | <b>3.45E+02</b> | 8.01E+02        | 3.48E+02        |
|     | Mean | 3.62E+02        | 3.58E+02        | <b>3.47E+02</b> | 9.31E+02        | 3.48E+02        |
|     | SD   | 3.52E+00        | 2.30E+00        | 2.51E+00        | 7.60E+01        | <b>2.32E-04</b> |
| f24 | Best | 4.34E+02        | 4.37E+02        | 3.32E+02        | <b>2.00E+02</b> | 3.31E+02        |
|     | Mean | 4.51E+02        | 4.49E+02        | 3.56E+02        | 4.79E+02        | <b>3.54E+02</b> |
|     | SD   | 7.45E+00        | <b>6.32E+00</b> | 1.16E+01        | 1.88E+02        | 9.86E+00        |
| f25 | Best | 2.76E+02        | 2.71E+02        | 2.03E+02        | <b>2.00E+02</b> | 2.21E+02        |
|     | Mean | 2.96E+02        | 2.94E+02        | <b>2.16E+02</b> | 2.85E+02        | 2.35E+02        |
|     | SD   | <b>1.05E+01</b> | 1.20E+01        | 2.33E+01        | 1.34E+02        | 1.07E+01        |
| f26 | Best | 2.17E+02        | 1.01E+02        | 2.01E+02        | 2.00E+02        | <b>1.00E+02</b> |
|     | Mean | 2.26E+02        | 2.23E+02        | <b>2.02E+02</b> | 2.43E+02        | 2.28E+02        |
|     | SD   | 5.11E+00        | 2.37E+01        | <b>1.21E+00</b> | 4.42E+01        | 1.26E+02        |
| f27 | Best | 2.33E+03        | 2.20E+03        | 1.84E+03        | 3.97E+03        | <b>1.01E+03</b> |
|     | Mean | 2.54E+03        | 2.53E+03        | 2.34E+03        | 4.18E+03        | <b>1.41E+03</b> |

|     |      |          |                 |                 |                 |                 |
|-----|------|----------|-----------------|-----------------|-----------------|-----------------|
|     | SD   | 1.12E+02 | 1.45E+02        | 1.84E+02        | <b>7.07E+01</b> | 2.55E+02        |
| f28 | Best | 3.63E+03 | 3.78E+03        | 3.61E+03        | 1.27E+04        | <b>2.23E+03</b> |
|     | Mean | 5.06E+03 | 4.82E+03        | 6.11E+03        | 1.61E+04        | <b>2.56E+03</b> |
|     | SD   | 1.05E+03 | 7.16E+02        | 1.16E+03        | 1.73E+03        | <b>2.45E+02</b> |
| f29 | Best | 4.22E+04 | 2.81E+03        | <b>2.50E+02</b> | 4.31E+08        | 2.70E+03        |
|     | Mean | 1.43E+05 | 5.19E+03        | <b>1.34E+03</b> | 6.99E+08        | 7.21E+07        |
|     | SD   | 8.15E+04 | <b>1.22E+03</b> | 3.02E+03        | 1.53E+08        | 2.88E+07        |
| f30 | Best | 1.54E+05 | 1.44E+05        | <b>2.24E+03</b> | 1.61E+06        | 4.13E+03        |
|     | Mean | 3.44E+05 | 3.25E+05        | <b>4.13E+03</b> | 7.77E+06        | 5.73E+03        |
|     | SD   | 1.01E+05 | 1.22E+05        | 2.05E+03        | 3.72E+06        | <b>1.00E+03</b> |