# Supplemental file of "Differential Evolution with Domain Transform"

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## TABLE CAPTIONS

**TABLE S18** PERFORMANCE COMPARISONS OF DTDEN WITH POPULAR NEAS ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH SLIGHT NOISE

**TABLE S19** PERFORMANCE COMPARISONS OF DTDEN WITH POPULAR NEAS ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH MODERATE NOISE

**TABLE S20** PERFORMANCE COMPARISONS OF DTDEN WITH POPULAR NEAS ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH SEVERE NOISE

TABLE S1 PERFORMANCE COMPARISONS OF DTDE WITH THE ORIGINAL SCSS-L-SHADE ON 30-D CEC2017 TEST FUNCTIONS

| | Original | | DTDE | | Original | | DTDE |
|---|---|---|---|---|---|---|---|
| | mean (std) | sig | mean (std) | | mean (std) | sig | mean (std) |
| F1 | 0.00E+00 (0.00E+00) | = | 0.00E+00 (0.00E+00) | F17 | 3.46E+01 (4.63E+00) | + | **1.92E+01 (7.76E+00)** |
| F3 | 0.00E+00 (0.00E+00) | = | 0.00E+00 (0.00E+00) | F18 | **2.08E+01 (5.43E-01)** | – | 2.69E+01 (3.52E+00) |
| F4 | 5.86E+01 (3.22E-14) | + | **5.86E+01 (1.61E-14)** | F19 | 5.08E+00 (1.61E+00) | = | 4.88E+00 (1.44E+00) |
| F5 | 6.86E+00 (1.92E+00) | + | **1.40E+00 (1.34E+00)** | F20 | 2.85E+01 (5.90E+00) | + | **1.60E+01 (9.59E+00)** |
| F6 | 6.71E-10 (4.79E-09) | = | 0.00E+00 (0.00E+00) | F21 | 2.08E+02 (1.65E+00) | + | **2.02E+02 (1.53E+00)** |
| F7 | 3.80E+01 (2.13E+00) | + | **3.40E+01 (1.09E+00)** | F22 | 1.00E+02 (6.39E-14) | = | 1.00E+02 (1.44E-14) |
| F8 | 7.18E+00 (1.73E+00) | + | **1.39E+00 (1.14E+00)** | F23 | 3.50E+02 (2.92E+00) | + | **3.47E+02 (3.15E+00)** |
| F9 | 0.00E+00 (0.00E+00) | = | 0.00E+00 (0.00E+00) | F24 | 4.26E+02 (1.89E+00) | + | **4.24E+02 (1.51E+00)** |
| F10 | 1.44E+03 (1.98E+02) | + | **5.82E+01 (8.94E+01)** | F25 | 3.87E+02 (1.46E-02) | = | 3.87E+02 (1.12E-02) |
| F11 | 2.26E+01 (2.72E+01) | = | 2.15E+01 (2.67E+01) | F26 | 9.34E+02 (3.52E+01) | + | **8.71E+02 (3.34E+01)** |
| F12 | 5.66E+02 (2.90E+02) | = | 6.21E+02 (2.32E+02) | F27 | 5.02E+02 (5.59E+00) | = | 5.01E+02 (6.37E+00) |
| F13 | 1.62E+01 (4.29E+00) | = | 1.61E+01 (6.17E+00) | F28 | 3.39E+02 (5.36E+01) | = | 3.34E+02 (5.10E+01) |
| F14 | **2.03E+01 (6.53E+00)** | – | 2.07E+01 (7.58E+00) | F29 | 4.38E+02 (1.46E+01) | + | **4.09E+02 (5.52E+00)** |
| F15 | **1.99E+00 (1.03E+00)** | – | 4.53E+00 (1.52E+00) | F30 | 1.99E+03 (5.15E+01) | = | 1.97E+03 (3.21E+01) |
| F16 | 4.40E+01 (4.78E+01) | + | **1.38E+01 (1.77E+00)** | | | | |
| **W/T/L** | **13**/13/3 | | | | | | |

TABLE S2 PERFORMANCE COMPARISONS OF DTDE WITH STATE-OF-THE-ART DES ON 30-D CEC2017 FUNCTIONS

| | EBL-SHADE | | | PaDE | | | EaDE | | | DTDE | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 |
| F3 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 |
| F4 | 5.86E+01 | 2.41E-14 | = | 5.00E+01 | 2.19E+01 | + | 5.86E+01 | 4.54E-13 | - | 5.86E+01 | 1.61E-14 |
| F5 | 6.24E+00 | 1.33E+00 | + | 8.85E+00 | 1.90E+00 | + | 3.87E+00 | 2.06E+00 | + | **1.40E+00** | **1.34E+00** |
| F6 | 4.03E-09 | 2.01E-08 | = | 2.68E-09 | 1.92E-08 | = | 7.08E-09 | 4.59E-08 | = | **0.00E+00** | **0.00E+00** |
| F7 | 3.71E+01 | 1.03E+00 | + | 3.86E+01 | 1.90E+00 | + | 3.64E+01 | 1.45E+00 | + | **3.40E+01** | **1.09E+00** |
| F8 | 6.72E+00 | 1.49E+00 | + | 8.74E+00 | 2.02E+00 | + | 4.38E+00 | 2.32E+00 | + | **1.39E+00** | **1.14E+00** |
| F9 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 |
| F10 | 1.45E+03 | 2.00E+02 | + | 1.48E+03 | 1.80E+02 | + | 1.32E+03 | 2.87E+02 | + | **5.82E+01** | **8.94E+01** |
| F11 | 2.41E+01 | 2.71E+01 | + | 1.30E+01 | 1.97E+01 | = | 2.26E+01 | 2.73E+01 | = | 2.15E+01 | 2.67E+01 |
| F12 | 8.97E+02 | 3.33E+02 | + | 1.04E+03 | 3.03E+02 | + | 6.06E+02 | 2.96E+02 | = | 6.21E+02 | 2.32E+02 |
| F13 | 1.48E+01 | 5.54E+00 | = | 1.52E+01 | 5.95E+00 | = | 1.66E+01 | 4.35E+00 | = | 1.61E+01 | 6.17E+00 |
| F14 | **1.89E+01** | **7.14E+00** | - | 2.21E+01 | 3.10E+00 | - | 2.01E+01 | 6.58E+00 | - | 2.07E+01 | 7.58E+00 |
| F15 | 2.34E+00 | 1.41E+00 | - | 2.84E+00 | 1.46E+00 | - | 2.29E+00 | 1.33E+00 | - | 4.53E+00 | 1.52E+00 |
| F16 | 3.79E+01 | 3.60E+01 | + | 1.02E+02 | 8.78E+01 | + | 3.10E+01 | 4.06E+01 | + | **1.38E+01** | **1.77E+00** |
| F17 | 3.17E+01 | 5.75E+00 | + | 3.09E+01 | 5.96E+00 | + | 3.29E+01 | 1.01E+01 | + | **1.92E+01** | **7.76E+00** |
| F18 | 2.09E+01 | 2.89E+00 | - | 2.21E+01 | 1.47E+00 | - | **2.04E+01** | **2.91E+00** | - | 2.69E+01 | 3.52E+00 |
| F19 | 5.07E+00 | 1.97E+00 | = | 4.79E+00 | 1.36E+00 | = | 5.26E+00 | 1.77E+00 | = | 4.88E+00 | 1.44E+00 |
| F20 | 3.22E+01 | 6.31E+00 | + | 4.06E+01 | 1.76E+01 | + | 3.00E+01 | 1.82E+01 | + | **1.60E+01** | **9.59E+00** |
| F21 | 2.06E+02 | 1.22E+00 | + | 2.08E+02 | 1.63E+00 | + | 2.06E+02 | 1.96E+00 | + | **2.02E+02** | **1.53E+00** |
| F22 | 1.00E+02 | 1.44E-14 | = | 1.00E+02 | 1.44E-14 | = | 1.00E+02 | 1.37E-13 | - | 1.00E+02 | 1.44E-14 |
| F23 | 3.49E+02 | 2.46E+00 | + | **3.46E+02** | **3.11E+00** | - | 3.49E+02 | 2.13E+00 | + | 3.47E+02 | 3.15E+00 |
| F24 | 4.25E+02 | 1.50E+00 | + | **4.21E+02** | **2.56E+00** | - | 4.26E+02 | 1.77E+00 | + | 4.24E+02 | 1.51E+00 |
| F25 | 3.87E+02 | 2.22E-02 | + | 3.87E+02 | 2.82E-02 | + | 3.87E+02 | 1.49E-02 | = | 3.87E+02 | 1.12E-02 |
| F26 | 9.04E+02 | 4.08E+01 | + | 8.79E+02 | 2.89E+01 | = | 9.25E+02 | 3.60E+01 | + | **8.71E+02** | **3.34E+01** |
| F27 | 5.01E+02 | 7.19E+00 | = | 5.07E+02 | 6.12E+00 | + | 5.02E+02 | 5.14E+00 | = | 5.01E+02 | 6.37E+00 |
| F28 | 3.20E+02 | 4.51E+01 | = | 3.30E+02 | 4.90E+01 | = | 3.30E+02 | 4.97E+01 | = | 3.34E+02 | 5.10E+01 |
| F29 | 4.30E+02 | 7.48E+00 | + | 4.35E+02 | 1.04E+01 | + | 4.33E+02 | 8.63E+00 | + | **4.09E+02** | **5.52E+00** |
| F30 | 1.98E+03 | 3.99E+01 | = | 2.05E+03 | 6.34E+01 | + | **1.97E+03** | **2.92E+01** | = | **1.97E+03** | **3.21E+01** |
| **W** | **15** | | | **14** | | | **12** | | | | |
| **T** | **11** | | | **10** | | | **12** | | | | |
| **L** | **3** | | | **5** | | | **5** | | | | |

| | L-SHADE_cnEpSin | | | jSO | | | L-SHADE-RSP | | | DTDE | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 |
| F3 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 |
| F4 | **4.21E+01** | **3.29E+00** | - | 5.87E+01 | 7.78E-01 | = | 5.86E+01 | 1.97E-14 | = | 5.86E+01 | 1.61E-14 |
| F5 | 1.18E+01 | 2.34E+00 | + | 8.70E+00 | 1.97E+00 | + | 7.27E+00 | 2.01E+00 | + | **1.40E+00** | **1.34E+00** |
| F6 | 6.04E-09 | 2.71E-08 | = | 1.07E-08 | 3.72E-08 | + | 1.14E-08 | 3.73E-08 | + | **0.00E+00** | **0.00E+00** |
| F7 | 4.31E+01 | 2.34E+00 | + | 3.82E+01 | 1.94E+00 | + | 3.84E+01 | 2.07E+00 | + | **3.40E+01** | **1.09E+00** |
| F8 | 1.35E+01 | 1.82E+00 | + | 9.07E+00 | 2.13E+00 | + | 6.80E+00 | 2.22E+00 | + | **1.39E+00** | **1.14E+00** |
| F9 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 |
| F10 | 1.39E+03 | 2.44E+02 | + | 1.51E+03 | 3.04E+02 | + | 1.57E+03 | 2.94E+02 | + | **5.82E+01** | **8.94E+01** |
| F11 | 1.00E+01 | 1.63E+01 | = | **5.15E+00** | **1.17E+01** | - | 6.43E+00 | 1.37E+01 | - | 2.15E+01 | 2.67E+01 |
| F12 | 3.96E+02 | 2.40E+02 | - | 1.83E+02 | 1.17E+02 | - | **1.39E+02** | **1.09E+02** | - | 6.21E+02 | 2.32E+02 |
| F13 | 1.97E+01 | 1.88E+01 | = | **1.37E+01** | **6.58E+00** | = | 1.80E+01 | 4.30E+00 | + | 1.61E+01 | 6.17E+00 |
| F14 | 2.15E+01 | 3.95E+00 | - | 2.21E+01 | 1.12E+00 | - | 2.17E+01 | 1.40E+00 | - | 2.07E+01 | 7.58E+00 |
| F15 | 3.15E+00 | 1.62E+00 | - | **1.05E+00** | **5.89E-01** | - | 1.11E+00 | 7.29E-01 | - | 4.53E+00 | 1.52E+00 |
| F16 | 3.16E+01 | 4.80E+01 | = | 9.12E+01 | 9.33E+01 | + | 2.09E+01 | 1.60E+01 | + | **1.38E+01** | **1.77E+00** |
| F17 | 2.77E+01 | 5.90E+00 | + | 3.40E+01 | 7.66E+00 | + | 3.44E+01 | 6.92E+00 | + | **1.92E+01** | **7.76E+00** |
| F18 | 2.11E+01 | 9.18E-01 | - | 2.08E+01 | 4.16E-01 | - | 2.08E+01 | 2.32E-01 | - | 2.69E+01 | 3.52E+00 |
| F19 | 5.82E+00 | 1.61E+00 | + | 3.88E+00 | 1.38E+00 | - | **3.59E+00** | **9.09E-01** | - | 4.88E+00 | 1.44E+00 |
| F20 | 3.07E+01 | 6.04E+00 | + | 2.90E+01 | 6.42E+00 | + | 3.20E+01 | 5.48E+00 | + | **1.60E+01** | **9.59E+00** |
| F21 | 2.13E+02 | 2.39E+00 | + | 2.10E+02 | 1.84E+00 | + | 2.07E+02 | 2.18E+00 | + | **2.02E+02** | **1.53E+00** |
| F22 | 1.00E+02 | 1.44E-14 | = | 1.00E+02 | 6.39E-14 | = | 1.00E+02 | 1.44E-14 | = | 1.00E+02 | 1.44E-14 |
| F23 | 3.55E+02 | 3.06E+00 | + | 3.50E+02 | 2.76E+00 | + | 3.51E+02 | 3.19E+00 | + | 3.47E+02 | 3.15E+00 |
| F24 | 4.29E+02 | 2.30E+00 | + | 4.26E+02 | 2.50E+00 | + | 4.27E+02 | 2.66E+00 | + | 4.24E+02 | 1.51E+00 |
| F25 | 3.87E+02 | 7.92E-03 | - | 3.87E+02 | 8.25E-03 | - | 3.87E+02 | 5.57E-03 | - | 3.87E+02 | 1.12E-02 |
| F26 | 9.46E+02 | 4.58E+01 | + | 9.29E+02 | 3.26E+01 | + | 9.42E+02 | 4.66E+01 | + | **8.71E+02** | **3.34E+01** |
| F27 | 5.03E+02 | 5.30E+00 | = | **4.97E+02** | **7.00E+00** | - | 4.98E+02 | 7.12E+00 | - | 5.01E+02 | 6.37E+00 |
| F28 | 3.21E+02 | 4.32E+01 | = | **3.04E+02** | **2.23E+01** | - | **3.04E+02** | **2.23E+01** | - | 3.34E+02 | 5.10E+01 |
| F29 | 4.34E+02 | 7.48E+00 | + | 4.33E+02 | 1.56E+01 | + | 4.41E+02 | 1.03E+01 | + | **4.09E+02** | **5.52E+00** |
| F30 | 1.99E+03 | 5.13E+01 | = | **1.97E+03** | **1.27E+01** | = | **1.97E+03** | **1.32E+01** | = | **1.97E+03** | **3.21E+01** |
| **W** | **12** | | | **13** | | | **14** | | | | |
| **T** | **11** | | | **7** | | | **6** | | | | |
| **L** | **6** | | | **9** | | | **9** | | | | |

TABLE S3 PERFORMANCE COMPARISONS OF DTDE WITH STATE-OF-THE-ART DES ON 50-D CEC2017 FUNCTIONS

| | EBL-SHADE | | | PaDE | | | EaDE | | | DTDE | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 |
| F3 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 |
| F4 | 7.82E+01 | 4.65E+01 | = | **3.22E+01** | **4.19E+01** | - | 6.98E+01 | 5.22E+01 | = | 6.07E+01 | 5.15E+01 |
| F5 | 1.21E+01 | 1.93E+00 | + | 1.77E+01 | 8.04E-01 | + | 7.92E+00 | 3.15E+00 | + | **1.50E+00** | **1.26E+00** |
| F6 | 2.60E-05 | 1.83E-04 | + | 4.26E-03 | 5.36E-03 | + | **2.41E-08** | **9.85E-08** | = | 1.14E-07 | 3.53E-07 |
| F7 | 6.27E+01 | 1.75E+00 | + | 6.63E+01 | 1.39E+00 | + | 6.11E+01 | 1.97E+00 | + | **5.65E+01** | **9.22E-01** |
| F8 | 1.26E+01 | 2.42E+00 | + | 1.79E+01 | 1.52E+00 | + | 8.28E+00 | 3.12E+00 | + | **1.54E+00** | **1.29E+00** |
| F9 | **0.00E+00** | **0.00E+00** | = | 1.76E-03 | 1.25E-02 | = | **0.00E+00** | **0.00E+00** | = | **0.00E+00** | **0.00E+00** |
| F10 | 3.16E+03 | 3.31E+02 | + | 2.92E+03 | 2.16E+02 | + | 3.01E+03 | 4.47E+02 | + | **1.61E+02** | **8.83E+01** |
| F11 | 4.44E+01 | 8.64E+00 | + | 6.24E+01 | 1.16E+01 | + | 3.27E+01 | 4.16E+00 | + | 3.01E+01 | 4.48E+00 |
| F12 | 2.15E+03 | 4.54E+02 | = | 2.53E+03 | 5.53E+02 | + | 2.01E+03 | 5.76E+02 | = | 2.06E+03 | 4.42E+02 |
| F13 | 5.41E+01 | 3.00E+01 | = | 6.11E+01 | 7.78E+00 | + | 4.53E+01 | 2.46E+01 | = | 5.39E+01 | 2.99E+01 |
| F14 | 2.75E+01 | 2.26E+00 | + | 3.41E+01 | 3.60E+00 | + | 2.61E+01 | 2.31E+00 | = | 2.47E+01 | 4.49E+00 |
| F15 | 3.37E+01 | 6.13E+00 | + | 4.03E+01 | 4.03E+00 | + | 2.80E+01 | 4.00E+00 | + | 2.62E+01 | 3.60E+00 |
| F16 | 3.28E+02 | 1.22E+02 | + | 3.07E+02 | 6.93E+01 | + | 3.59E+02 | 1.39E+02 | + | **1.44E+02** | **4.66E+01** |
| F17 | 2.43E+02 | 7.76E+01 | + | 2.45E+02 | 3.51E+01 | + | 2.88E+02 | 1.12E+02 | + | **4.93E+01** | **4.91E+01** |
| F18 | 3.31E+01 | 5.42E+00 | - | 4.10E+01 | 7.09E+00 | + | 2.73E+01 | 3.63E+00 | - | 3.65E+01 | 6.78E+00 |
| F19 | 1.86E+01 | 3.54E+00 | + | 5.13E+01 | 1.19E+01 | + | 1.61E+01 | 3.23E+00 | + | **9.41E+00** | **2.34E+00** |
| F20 | 1.51E+02 | 4.49E+01 | + | 1.22E+02 | 6.06E+01 | + | 1.94E+02 | 1.39E+02 | + | **2.32E+01** | **3.69E+00** |
| F21 | 2.12E+02 | 2.74E+00 | + | 2.16E+02 | 1.34E+00 | + | 2.09E+02 | 4.02E+00 | + | **2.02E+02** | **1.99E+00** |
| F22 | 2.18E+03 | 1.74E+03 | + | **1.00E+02** | **6.39E-14** | - | 2.69E+03 | 1.62E+03 | + | 2.97E+02 | 1.34E+02 |
| F23 | 4.27E+02 | 4.60E+00 | + | 4.34E+02 | 4.61E+00 | + | 4.28E+02 | 4.49E+00 | + | **4.19E+02** | **5.60E+00** |
| F24 | 5.05E+02 | 2.92E+00 | + | **4.98E+02** | **5.47E+00** | = | 5.06E+02 | 3.02E+00 | + | **4.98E+02** | **2.08E+00** |
| F25 | 4.91E+02 | 2.33E+01 | + | 5.16E+02 | 4.02E+01 | + | 4.82E+02 | 3.86E+00 | = | **4.81E+02** | **3.52E+00** |
| F26 | 1.11E+03 | 6.12E+01 | + | 1.18E+03 | 3.41E+01 | + | 1.14E+03 | 6.09E+01 | + | **9.84E+02** | **4.04E+01** |
| F27 | 5.27E+02 | 1.86E+01 | - | 5.26E+02 | 5.09E+00 | - | 5.26E+02 | 1.46E+01 | - | 5.34E+02 | 2.05E+01 |
| F28 | 4.81E+02 | 2.44E+01 | + | 5.00E+02 | 1.79E+01 | + | 4.66E+02 | 1.76E+01 | = | 4.65E+02 | 1.59E+01 |
| F29 | 3.53E+02 | 9.54E+00 | + | 3.45E+02 | 1.99E+01 | + | 3.61E+02 | 1.15E+01 | + | **3.00E+02** | **7.55E+00** |
| F30 | 6.30E+05 | 5.51E+04 | - | 6.50E+05 | 3.37E+04 | = | 6.50E+05 | 7.39E+04 | = | 6.58E+05 | 6.40E+04 |
| **W** | **20** | | | **21** | | | **16** | | | | |
| **T** | **6** | | | **5** | | | **11** | | | | |
| **L** | **3** | | | **3** | | | **2** | | | | |

| | L-SHADE_cnEpSin | | | jSO | | | L-SHADE-RSP | | | DTDE | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 |
| F3 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 |
| F4 | 4.57E+01 | 4.14E+01 | - | 5.01E+01 | 4.28E+01 | = | 5.30E+01 | 4.50E+01 | = | 6.07E+01 | 5.15E+01 |
| F5 | 2.54E+01 | 7.65E+00 | + | 1.66E+01 | 3.26E+00 | + | 1.22E+01 | 3.00E+00 | + | **1.50E+00** | **1.26E+00** |
| F6 | 6.69E-07 | 5.16E-07 | + | 5.93E-07 | 9.18E-07 | + | 1.36E-07 | 2.62E-07 | + | 1.14E-07 | 3.53E-07 |
| F7 | 7.70E+01 | 5.93E+00 | + | 6.58E+01 | 3.20E+00 | + | 6.65E+01 | 3.92E+00 | + | **5.65E+01** | **9.22E-01** |
| F8 | 2.51E+01 | 6.26E+00 | + | 1.66E+01 | 2.61E+00 | + | 1.26E+01 | 3.11E+00 | + | **1.54E+00** | **1.29E+00** |
| F9 | **0.00E+00** | **0.00E+00** | = | **0.00E+00** | **0.00E+00** | = | **0.00E+00** | **0.00E+00** | = | **0.00E+00** | **0.00E+00** |
| F10 | 3.21E+03 | 2.92E+02 | + | 3.21E+03 | 2.85E+02 | + | 3.46E+03 | 3.98E+02 | + | **1.61E+02** | **8.83E+01** |
| F11 | **2.19E+01** | **1.83E+00** | - | 2.85E+01 | 3.52E+00 | = | 2.49E+01 | 3.67E+00 | - | 3.01E+01 | 4.48E+00 |
| F12 | **1.22E+03** | **3.97E+02** | - | 1.78E+03 | 4.38E+02 | - | 1.54E+03 | 4.12E+02 | - | 2.06E+03 | 4.42E+02 |
| F13 | 6.50E+01 | 3.65E+01 | = | **3.25E+01** | **1.99E+01** | - | 3.78E+01 | 2.41E+01 | - | 5.39E+01 | 2.99E+01 |
| F14 | 2.65E+01 | 1.76E+00 | + | 2.51E+01 | 2.25E+00 | = | **2.32E+01** | **1.58E+00** | - | 2.47E+01 | 4.49E+00 |
| F15 | 2.59E+01 | 3.62E+00 | = | 2.35E+01 | 2.50E+00 | - | **2.14E+01** | **1.56E+00** | - | 2.62E+01 | 3.60E+00 |
| F16 | 2.86E+02 | 1.08E+02 | + | 4.47E+02 | 1.41E+02 | + | 3.35E+02 | 1.68E+02 | + | **1.44E+02** | **4.66E+01** |
| F17 | 2.26E+02 | 6.38E+01 | + | 2.63E+02 | 9.50E+01 | + | 2.25E+02 | 1.03E+02 | + | **4.93E+01** | **4.91E+01** |
| F18 | 2.46E+01 | 2.42E+00 | - | 2.43E+01 | 1.58E+00 | - | **2.27E+01** | **1.52E+00** | - | 3.65E+01 | 6.78E+00 |
| F19 | 1.72E+01 | 3.11E+00 | + | 1.34E+01 | 2.23E+00 | + | 1.03E+01 | 2.42E+00 | + | **9.41E+00** | **2.34E+00** |
| F20 | 1.15E+02 | 3.46E+01 | + | 1.49E+02 | 8.46E+01 | + | 1.41E+02 | 6.22E+01 | + | **2.32E+01** | **3.69E+00** |
| F21 | 2.28E+02 | 7.32E+00 | + | 2.18E+02 | 2.66E+00 | + | 2.14E+02 | 4.33E+00 | + | **2.02E+02** | **1.99E+00** |
| F22 | 1.36E+03 | 1.64E+03 | = | 2.14E+03 | 1.83E+03 | + | 2.22E+03 | 1.97E+03 | = | 2.97E+02 | 1.34E+02 |
| F23 | 4.39E+02 | 8.14E+00 | + | 4.31E+02 | 6.54E+00 | + | 4.33E+02 | 5.49E+00 | + | **4.19E+02** | **5.60E+00** |
| F24 | 5.13E+02 | 6.37E+00 | + | 5.07E+02 | 3.88E+00 | + | 5.08E+02 | 3.39E+00 | + | **4.98E+02** | **2.08E+00** |
| F25 | **4.81E+02** | **2.49E+00** | - | **4.81E+02** | **3.04E+00** | - | **4.81E+02** | **2.28E+00** | - | **4.81E+02** | **3.52E+00** |
| F26 | 1.22E+03 | 1.07E+02 | + | 1.13E+03 | 4.93E+01 | + | 1.13E+03 | 4.08E+01 | + | **9.84E+02** | **4.04E+01** |
| F27 | 5.27E+02 | 1.43E+01 | - | **5.09E+02** | **1.15E+01** | - | 5.12E+02 | 9.74E+00 | - | 5.34E+02 | 2.05E+01 |
| F28 | **4.59E+02** | **9.43E+00** | - | 4.60E+02 | 6.84E+00 | - | **4.59E+02** | **1.72E-13** | - | 4.65E+02 | 1.59E+01 |
| F29 | 3.52E+02 | 1.04E+01 | + | 3.64E+02 | 1.54E+01 | + | 3.64E+02 | 1.10E+01 | + | **3.00E+02** | **7.55E+00** |
| F30 | 6.50E+05 | 6.89E+04 | = | **6.07E+05** | **2.58E+04** | - | 6.13E+05 | 3.55E+04 | - | 6.58E+05 | 6.40E+04 |
| **W** | **15** | | | **15** | | | **14** | | | | |
| **T** | **7** | | | **6** | | | **5** | | | | |
| **L** | **7** | | | **8** | | | **10** | | | | |

TABLE S4 PERFORMANCE COMPARISONS OF DTDE WITH STATE-OF-THE-ART DES ON 100-D CEC2017 FUNCTIONS

| | EBL-SHADE | | | PaDE | | | EaDE | | | DTDE | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 |
| F3 | 2.09E-06 | 2.44E-06 | - | 7.60E-08 | 3.53E-08 | - | 1.18E-04 | 1.32E-04 | = | 1.33E-04 | 2.49E-04 |
| F4 | 1.61E+02 | 4.92E+01 | - | **1.19E+02** | **5.24E+01** | - | 1.96E+02 | 1.20E+01 | = | 2.01E+02 | 1.11E+01 |
| F5 | 4.01E+01 | 6.72E+00 | + | 4.06E+01 | 4.88E+00 | + | 2.45E+01 | 6.52E+00 | + | **2.11E+00** | **1.46E+00** |
| F6 | 9.31E-03 | 7.49E-03 | + | 7.95E-03 | 5.85E-04 | + | 1.97E-03 | 1.55E-03 | = | 1.52E-03 | 1.21E-03 |
| F7 | 1.40E+02 | 4.67E+00 | + | 1.39E+02 | 5.03E+00 | + | 1.29E+02 | 3.69E+00 | + | **1.11E+02** | **1.40E+00** |
| F8 | 4.17E+01 | 5.95E+00 | + | 4.27E+01 | 4.09E-01 | + | 2.18E+01 | 5.93E+00 | + | **2.01E+00** | **1.39E+00** |
| F9 | 8.71E-01 | 7.21E-01 | + | 6.00E-01 | 2.19E-01 | + | 8.48E-02 | 1.32E-01 | = | 9.56E-02 | 1.67E-01 |
| F10 | 1.03E+04 | 5.44E+02 | + | 1.03E+04 | 2.75E+02 | + | 9.22E+03 | 8.72E+02 | + | **4.03E+02** | **2.73E+02** |
| F11 | 4.16E+02 | 1.13E+02 | + | 5.71E+02 | 4.22E+01 | + | 1.63E+02 | 4.74E+01 | - | 1.95E+02 | 5.93E+01 |
| F12 | 2.13E+04 | 9.22E+03 | + | 1.74E+04 | 5.47E+03 | = | 1.82E+04 | 7.52E+03 | = | 1.83E+04 | 8.75E+03 |
| F13 | 2.44E+02 | 6.58E+01 | + | 3.70E+02 | 1.65E+02 | + | 1.74E+02 | 5.27E+01 | = | 1.58E+02 | 4.47E+01 |
| F14 | 2.25E+02 | 2.57E+01 | + | 2.75E+02 | 3.37E+01 | + | 8.70E+01 | 1.72E+01 | + | 6.52E+01 | 1.49E+01 |
| F15 | 2.57E+02 | 5.30E+01 | = | 2.27E+02 | 1.31E+01 | - | 2.51E+02 | 5.75E+01 | = | 2.56E+02 | 5.16E+01 |
| F16 | 1.53E+03 | 2.50E+02 | + | 1.53E+03 | 4.86E+02 | + | 1.52E+03 | 2.71E+02 | + | **2.00E+02** | **1.23E+02** |
| F17 | 1.09E+03 | 1.89E+02 | + | 1.15E+03 | 8.45E+01 | + | 1.04E+03 | 2.64E+02 | + | **8.87E+01** | **9.96E+01** |
| F18 | 2.40E+02 | 5.04E+01 | = | 2.26E+02 | 4.14E+01 | = | 2.16E+02 | 5.26E+01 | = | 2.30E+02 | 5.54E+01 |
| F19 | 1.69E+02 | 2.62E+01 | = | 1.72E+02 | 2.53E+01 | + | 1.69E+02 | 2.50E+01 | = | 1.62E+02 | 2.14E+01 |
| F20 | 1.54E+03 | 1.86E+02 | + | 1.32E+03 | 1.27E+02 | + | 1.41E+03 | 3.64E+02 | + | **1.80E+02** | **5.87E+01** |
| F21 | 2.57E+02 | 6.24E+00 | + | 2.64E+02 | 1.42E+00 | + | 2.49E+02 | 5.99E+00 | + | **2.22E+02** | **3.64E+00** |
| F22 | 1.13E+04 | 5.11E+02 | + | 1.10E+04 | 3.41E+02 | + | 1.02E+04 | 8.01E+02 | + | **1.06E+03** | **3.25E+02** |
| F23 | 5.71E+02 | 1.06E+01 | + | 6.07E+02 | 2.08E+01 | + | 5.64E+02 | 1.09E+01 | + | **5.37E+02** | **8.10E+00** |
| F24 | 9.04E+02 | 8.74E+00 | + | 9.28E+02 | 1.26E+01 | + | 9.04E+02 | 7.32E+00 | + | **8.84E+02** | **4.54E+00** |
| F25 | 7.41E+02 | 3.85E+01 | + | 7.64E+02 | 1.09E+01 | + | 7.41E+02 | 3.89E+01 | + | 7.27E+02 | 4.21E+01 |
| F26 | 3.24E+03 | 8.83E+01 | + | 3.36E+03 | 8.37E+01 | + | 3.25E+03 | 9.29E+01 | + | **3.05E+03** | **7.90E+01** |
| F27 | 6.14E+02 | 1.69E+01 | - | 6.46E+02 | 6.32E+00 | + | 6.19E+02 | 2.12E+01 | = | 6.26E+02 | 2.04E+01 |
| F28 | 5.36E+02 | 3.46E+01 | = | **5.06E+02** | **2.10E+01** | - | 5.29E+02 | 2.23E+01 | = | 5.28E+02 | 2.17E+01 |
| F29 | 1.12E+03 | 1.76E+02 | + | 1.09E+03 | 1.26E+02 | + | 1.24E+03 | 1.86E+02 | + | **8.13E+02** | **1.31E+02** |
| F30 | 2.36E+03 | 1.30E+02 | + | 2.41E+03 | 1.58E+02 | + | 2.34E+03 | 1.84E+02 | = | **2.30E+03** | **1.14E+02** |
| **W** | **21** | | | **22** | | | **15** | | | | |
| **T** | **5** | | | **3** | | | **13** | | | | |
| **L** | **3** | | | **4** | | | **1** | | | | |

| | L-SHADE_cnEpSin | | | jSO | | | L-SHADE-RSP | | | DTDE | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 |
| F3 | **0.00E+00** | **0.00E+00** | - | 2.08E-06 | 2.22E-06 | - | 2.03E-07 | 2.26E-07 | - | 1.33E-04 | 2.49E-04 |
| F4 | 2.01E+02 | 7.86E+00 | = | 1.96E+02 | 1.20E+01 | - | 2.01E+02 | 1.05E+01 | = | 2.01E+02 | 1.11E+01 |
| F5 | 5.63E+01 | 7.38E+00 | + | 4.18E+01 | 6.15E+00 | + | 3.07E+01 | 7.80E+00 | + | **2.11E+00** | **1.46E+00** |
| F6 | 6.50E-05 | 2.33E-05 | - | 3.25E-04 | 9.24E-04 | - | **5.01E-05** | **1.35E-04** | - | 1.52E-03 | 1.21E-03 |
| F7 | 1.62E+02 | 6.47E+00 | + | 1.41E+02 | 7.26E+00 | + | 1.37E+02 | 7.50E+00 | + | **1.11E+02** | **1.40E+00** |
| F8 | 5.46E+01 | 1.10E+01 | + | 4.31E+01 | 6.29E+00 | + | 3.03E+01 | 7.56E+00 | + | **2.01E+00** | **1.39E+00** |
| F9 | **0.00E+00** | **0.00E+00** | - | 2.30E-02 | 8.26E-02 | - | 1.76E-03 | 1.25E-02 | - | 9.56E-02 | 1.67E-01 |
| F10 | 1.04E+04 | 5.79E+02 | + | 9.80E+03 | 5.71E+02 | + | 1.06E+04 | 8.11E+02 | + | **4.03E+02** | **2.73E+02** |
| F11 | **5.67E+01** | **3.99E+01** | - | 1.13E+02 | 3.41E+01 | - | 7.98E+01 | 3.42E+01 | - | 1.95E+02 | 5.93E+01 |
| F12 | **4.45E+03** | **7.15E+02** | - | 1.90E+04 | 9.39E+03 | = | 1.23E+04 | 4.72E+03 | - | 1.83E+04 | 8.75E+03 |
| F13 | **1.15E+02** | **3.09E+01** | - | 1.59E+02 | 4.23E+01 | = | 1.28E+02 | 3.21E+01 | - | 1.58E+02 | 4.47E+01 |
| F14 | 5.21E+01 | 7.00E+00 | - | 6.36E+01 | 1.27E+01 | = | **4.29E+01** | **5.82E+00** | - | 6.52E+01 | 1.49E+01 |
| F15 | **8.38E+01** | **3.06E+01** | - | 1.66E+02 | 3.52E+01 | - | 1.19E+02 | 3.12E+01 | - | 2.56E+02 | 5.16E+01 |
| F16 | 1.20E+03 | 2.52E+02 | + | 1.87E+03 | 2.98E+02 | + | 1.60E+03 | 2.74E+02 | + | **2.00E+02** | **1.23E+02** |
| F17 | 8.59E+02 | 1.93E+02 | + | 1.25E+03 | 2.36E+02 | + | 1.16E+03 | 2.39E+02 | + | **8.87E+01** | **9.96E+01** |
| F18 | **7.38E+01** | **1.50E+01** | - | 1.95E+02 | 3.95E+01 | - | 1.49E+02 | 3.11E+01 | - | 2.30E+02 | 5.54E+01 |
| F19 | **5.59E+01** | **7.51E+00** | - | 1.08E+02 | 1.96E+01 | - | 6.35E+01 | 1.14E+01 | - | 1.62E+02 | 2.14E+01 |
| F20 | 1.15E+03 | 1.29E+02 | + | 1.40E+03 | 2.53E+02 | + | 1.31E+03 | 3.29E+02 | + | **1.80E+02** | **5.87E+01** |
| F21 | 2.78E+02 | 6.53E+00 | + | 2.62E+02 | 6.74E+00 | + | 2.51E+02 | 6.96E+00 | + | **2.22E+02** | **3.64E+00** |
| F22 | 1.06E+04 | 5.77E+02 | + | 1.06E+04 | 6.09E+02 | + | 1.12E+04 | 6.95E+02 | + | **1.06E+03** | **3.25E+02** |
| F23 | 5.95E+02 | 8.72E+00 | + | 5.68E+02 | 1.23E+01 | + | 5.65E+02 | 9.04E+00 | + | **5.37E+02** | **8.10E+00** |
| F24 | 9.18E+02 | 1.41E+01 | + | 9.01E+02 | 9.64E+00 | + | 9.00E+02 | 6.88E+00 | + | **8.84E+02** | **4.54E+00** |
| F25 | **6.85E+02** | **3.84E+01** | - | 7.28E+02 | 4.09E+01 | = | 7.19E+02 | 4.52E+01 | = | 7.27E+02 | 4.21E+01 |
| F26 | 3.09E+03 | 1.31E+02 | = | 3.21E+03 | 9.20E+01 | + | 3.16E+03 | 8.08E+01 | + | **3.05E+03** | **7.90E+01** |
| F27 | 5.86E+02 | 1.76E+01 | - | 5.84E+02 | 2.35E+01 | - | **5.82E+02** | **1.78E+01** | - | 6.26E+02 | 2.04E+01 |
| F28 | 5.14E+02 | 1.66E+01 | - | 5.25E+02 | 2.73E+01 | = | 5.20E+02 | 2.23E+01 | - | 5.28E+02 | 2.17E+01 |
| F29 | 1.11E+03 | 1.32E+02 | + | 1.29E+03 | 1.96E+02 | + | 1.23E+03 | 2.04E+02 | + | **8.13E+02** | **1.31E+02** |
| F30 | 2.40E+03 | 1.61E+02 | + | 2.32E+03 | 1.37E+02 | = | 2.35E+03 | 1.76E+02 | = | **2.30E+03** | **1.14E+02** |
| **W** | **13** | | | **13** | | | **13** | | | | |
| **T** | **3** | | | **7** | | | **4** | | | | |
| **L** | **13** | | | **9** | | | **12** | | | | |

TABLE S5 PERFORMANCE COMPARISONS OF DTDE-JSO AND DTDE-RSP WITH THE ORIGINAL ALGORITHMS ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS

| | 30-D | | | | | 50-D | | | | | 100-D | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SCSS-jSO | | | DTDE-jSO | | SCSS-jSO | | | DTDE-jSO | | SCSS-jSO | | | DTDE-jSO | |
| | mean | std | sig | mean | std | mean | std | sig | mean | std | mean | std | sig | mean | std |
| F1 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 |
| F3 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 1.80E-04 | 1.41E-04 | = | 1.85E-03 | 9.38E-03 |
| F4 | 5.86E+01 | 3.86E-14 | + | **5.86E+01** | **1.97E-14** | 6.06E+01 | 5.04E+01 | = | 5.62E+01 | 4.65E+01 | 1.97E+02 | 1.60E+01 | = | 2.01E+02 | 1.98E+01 |
| F5 | 7.65E+00 | 1.68E+00 | + | **8.39E-01** | **1.02E+00** | 1.55E+01 | 2.67E+00 | + | **1.42E+00** | **1.06E+00** | 3.31E+01 | 4.95E+00 | + | **2.11E+00** | **1.86E+00** |
| F6 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 1.56E-07 | 4.07E-07 | + | **3.76E-09** | **2.69E-08** | 3.90E-04 | 8.50E-04 | + | **1.74E-04** | **5.05E-04** |
| F7 | 3.87E+01 | 1.70E+00 | + | **3.32E+01** | **7.64E-01** | 6.67E+01 | 2.21E+00 | + | **5.60E+01** | **9.19E-01** | 1.36E+02 | 4.86E+00 | + | **1.11E+02** | **1.25E+00** |
| F8 | 8.64E+00 | 1.75E+00 | + | **7.22E-01** | **8.22E-01** | 1.44E+01 | 2.80E+00 | + | **1.50E+00** | **1.30E+00** | 3.14E+01 | 5.36E+00 | + | **2.46E+00** | **1.62E+00** |
| F9 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 1.23E-02 | 3.11E-02 | = | 1.77E-02 | 7.90E-02 |
| F10 | 1.42E+03 | 2.43E+02 | + | **9.07E+01** | **1.12E+02** | 2.97E+03 | 4.10E+02 | + | **1.83E+02** | **1.03E+02** | 9.03E+03 | 6.33E+02 | + | **6.48E+02** | **2.88E+02** |
| F11 | 7.80E+00 | 1.60E+01 | = | 1.47E+01 | 2.29E+01 | 2.75E+01 | 3.64E+00 | + | **2.48E+01** | **2.61E+00** | **9.28E+01** | **2.90E+01** | - | 1.58E+02 | 4.01E+01 |
| F12 | **1.74E+02** | **9.96E+01** | - | 2.83E+02 | 1.65E+02 | 1.72E+03 | 4.36E+02 | = | 1.74E+03 | 4.66E+02 | 1.86E+04 | 9.32E+03 | = | 1.95E+04 | 9.53E+03 |
| F13 | **1.69E+01** | **4.16E+00** | - | 1.89E+01 | 4.27E+00 | **4.04E+01** | **2.24E+01** | - | 6.38E+01 | 3.33E+01 | 1.28E+02 | 3.25E+01 | = | 1.19E+02 | 3.35E+01 |
| F14 | 2.01E+01 | 6.70E+00 | = | 1.90E+01 | 8.15E+00 | 2.58E+01 | 2.30E+00 | + | **2.36E+01** | **4.11E+00** | 5.20E+01 | 7.62E+00 | + | **3.51E+01** | **4.35E+00** |
| F15 | **2.05E+00** | **1.26E+00** | - | 5.75E+00 | 1.27E+00 | 2.29E+01 | 1.86E+00 | + | **2.17E+01** | **2.56E+00** | 1.57E+02 | 4.11E+01 | = | 1.47E+02 | 4.44E+01 |
| F16 | 4.94E+01 | 6.23E+01 | + | **1.40E+01** | **2.41E+00** | 3.56E+02 | 1.27E+02 | + | **1.71E+02** | **8.53E+01** | 1.61E+03 | 2.83E+02 | + | **2.94E+02** | **1.55E+02** |
| F17 | 3.14E+01 | 7.43E+00 | + | **2.11E+01** | **5.64E+00** | 2.57E+02 | 8.94E+01 | + | **8.10E+01** | **7.72E+01** | 1.08E+03 | 1.94E+02 | + | **9.69E+01** | **9.79E+01** |
| F18 | **1.99E+01** | **3.84E+00** | - | 2.77E+01 | 4.13E+00 | **2.45E+01** | **1.87E+00** | - | 3.16E+01 | 4.16E+00 | 2.05E+02 | 4.89E+01 | = | 2.04E+02 | 4.12E+01 |
| F19 | 5.44E+00 | 1.35E+00 | + | **3.93E+00** | **1.31E+00** | 1.42E+01 | 2.51E+00 | + | **6.70E+00** | **1.89E+00** | 7.56E+01 | 1.38E+01 | + | **5.59E+01** | **1.27E+01** |
| F20 | 2.42E+01 | 8.04E+00 | + | **2.64E+01** | **3.01E+01** | 1.18E+02 | 6.60E+01 | + | **2.40E+01** | **2.09E+00** | 1.25E+03 | 2.05E+02 | + | **1.96E+02** | **8.60E+01** |
| F21 | 2.09E+02 | 1.74E+00 | + | **2.02E+02** | **1.53E+00** | 2.15E+02 | 2.70E+00 | + | **2.02E+02** | **2.14E+00** | 2.57E+02 | 4.45E+00 | + | **2.25E+02** | **2.84E+00** |
| F22 | 1.00E+02 | 1.14E-13 | = | 1.00E+02 | 1.11E-13 | 1.24E+03 | 1.64E+03 | + | **3.12E+02** | **2.49E+02** | 9.94E+03 | 6.28E+02 | + | **1.34E+03** | **3.80E+02** |
| F23 | 3.50E+02 | 2.74E+00 | + | **3.47E+02** | **3.79E+00** | 4.30E+02 | 5.26E+00 | + | **4.19E+02** | **8.55E+00** | 5.64E+02 | 1.12E+01 | + | **5.34E+02** | **6.85E+00** |
| F24 | 4.27E+02 | 1.95E+00 | + | **4.24E+02** | **1.15E+00** | 5.08E+02 | 3.13E+00 | + | **5.00E+02** | **2.54E+00** | 9.06E+02 | 7.87E+00 | + | **8.80E+02** | **4.11E+00** |
| F25 | 3.87E+02 | 9.86E-03 | = | 3.87E+02 | 1.37E-02 | 4.82E+02 | 4.26E+00 | = | 4.81E+02 | 3.19E+00 | 7.36E+02 | 3.47E+01 | + | **7.24E+02** | **3.70E+01** |
| F26 | 9.33E+02 | 4.50E+01 | + | **8.50E+02** | **4.13E+01** | 1.13E+03 | 6.61E+01 | + | **9.42E+02** | **6.91E+01** | 3.30E+03 | 1.14E+02 | + | **2.87E+03** | **9.81E+01** |
| F27 | 4.99E+02 | 6.94E+00 | = | 4.99E+02 | 5.90E+00 | 5.17E+02 | 1.15E+01 | = | 5.20E+02 | 1.13E+01 | 5.99E+02 | 2.11E+01 | = | 5.94E+02 | 1.82E+01 |
| F28 | 3.19E+02 | 3.95E+01 | = | 3.18E+02 | 4.19E+01 | 4.62E+02 | 1.16E+01 | = | 4.63E+02 | 1.33E+01 | 5.28E+02 | 2.78E+01 | = | 5.27E+02 | 2.28E+01 |
| F29 | 4.28E+02 | 1.87E+01 | + | **4.13E+02** | **6.98E+00** | 3.51E+02 | 1.19E+01 | + | **3.07E+02** | **9.05E+00** | 1.18E+03 | 2.11E+02 | + | **8.30E+02** | **1.45E+02** |
| F30 | **1.97E+03** | **2.12E+01** | - | 1.98E+03 | 3.01E+01 | 6.14E+05 | 4.60E+04 | = | 6.16E+05 | 3.66E+04 | 2.31E+03 | 1.26E+02 | = | 2.30E+03 | 1.49E+02 |
| **W** | **14** | | | | | **18** | | | | | **17** | | | | |
| **T** | **10** | | | | | **9** | | | | | **11** | | | | |
| **L** | **5** | | | | | **2** | | | | | **1** | | | | |

| | 30-D | | | | | 50-D | | | | | 100-D | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SCSS-L-SHADE-RSP | | | DTDE-RSP | | SCSS-L-SHADE-RSP | | | DTDE-RSP | | SCSS-L-SHADE-RSP | | | DTDE-RSP | |
| | mean | std | sig | mean | std | mean | std | sig | mean | std | mean | std | sig | mean | std |
| F1 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 |
| F3 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 4.97E-05 | 5.56E-05 | = | 7.25E-05 | 9.20E-05 |
| F4 | 5.88E+01 | 1.09E+00 | = | 5.88E+01 | 1.09E+00 | 5.91E+01 | 4.57E+01 | = | 5.63E+01 | 4.49E+01 | 1.91E+02 | 2.30E+01 | = | 1.95E+02 | 1.70E+01 |
| F5 | 9.23E+00 | 3.10E+00 | + | **7.22E-01** | **8.92E-01** | 1.12E+01 | 3.62E+00 | + | **9.95E-01** | **9.33E-01** | 2.87E+01 | 5.86E+00 | + | **1.87E+00** | **1.27E+00** |
| F6 | 1.48E-08 | 5.31E-08 | = | 6.04E-09 | 2.71E-08 | 4.23E-08 | 8.60E-08 | + | **1.88E-09** | **9.40E-09** | 2.17E-04 | 6.72E-04 | + | **6.68E-05** | **3.33E-04** |
| F7 | 3.89E+01 | 2.51E+00 | + | **3.34E+01** | **8.60E-01** | 6.61E+01 | 2.87E+00 | + | **5.59E+01** | **8.35E-01** | 1.36E+02 | 6.77E+00 | + | **1.11E+02** | **1.30E+00** |
| F8 | 9.08E+00 | 2.79E+00 | + | **9.17E-01** | **7.92E-01** | 1.44E+01 | 3.43E+00 | + | **1.25E+00** | **1.19E+00** | 2.95E+01 | 6.17E+00 | + | **1.79E+00** | **1.32E+00** |
| F9 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | = | 3.51E-03 | 1.76E-02 |
| F10 | 1.53E+03 | 3.50E+02 | + | **4.97E+01** | **9.01E+01** | 3.36E+03 | 3.91E+02 | + | **1.66E+02** | **9.32E+01** | 1.03E+04 | 6.06E+02 | + | **4.29E+02** | **2.76E+02** |
| F11 | **8.90E+00** | **1.92E+01** | - | 1.30E+01 | 2.21E+01 | 2.42E+01 | 3.72E+00 | + | **2.33E+01** | **2.43E+00** | **6.12E+01** | **3.06E+01** | - | 1.27E+02 | 4.01E+01 |
| F12 | **1.22E+02** | **1.18E+02** | - | 1.45E+02 | 1.58E+02 | 1.50E+03 | 4.12E+02 | = | 1.51E+03 | 4.52E+02 | 1.47E+04 | 6.74E+03 | = | 1.59E+04 | 6.64E+03 |
| F13 | 1.98E+01 | 3.37E+00 | = | 1.92E+01 | 4.17E+00 | 3.75E+01 | 2.48E+01 | = | 4.61E+01 | 3.13E+01 | 1.04E+02 | 3.48E+01 | = | 1.00E+02 | 3.38E+01 |
| F14 | 2.14E+01 | 3.08E+00 | = | 1.99E+01 | 7.94E+00 | 2.46E+01 | 2.16E+00 | + | **2.19E+01** | **5.74E+00** | 4.15E+01 | 5.01E+00 | + | **2.83E+01** | **4.55E+00** |
| F15 | **2.59E+00** | **1.45E+00** | - | 4.19E+00 | 1.13E+00 | 2.11E+01 | 1.52E+00 | + | **1.91E+01** | **1.24E+00** | 1.07E+02 | 3.95E+01 | = | 1.14E+02 | 3.91E+01 |
| F16 | 2.19E+01 | 2.32E+01 | + | **1.67E+01** | **1.67E+01** | 2.90E+02 | 1.49E+02 | + | **1.82E+02** | **8.75E+01** | 1.17E+03 | 2.58E+02 | + | **2.53E+02** | **1.48E+02** |
| F17 | 3.42E+01 | 5.32E+00 | + | **1.98E+01** | **6.78E+00** | 2.11E+02 | 9.58E+01 | + | **1.04E+02** | **7.50E+01** | 1.00E+03 | 2.71E+02 | + | **9.37E+01** | **9.98E+01** |
| F18 | **2.05E+01** | **2.77E+00** | - | 2.74E+01 | 3.36E+00 | **2.26E+01** | **1.39E+00** | - | 3.21E+01 | 3.50E+00 | **1.50E+02** | **3.22E+01** | - | 1.70E+02 | 4.76E+01 |
| F19 | 4.27E+00 | 2.00E+00 | + | **3.20E+00** | **1.48E+00** | 1.22E+01 | 2.43E+00 | + | **5.82E+00** | **1.67E+00** | 5.87E+01 | 7.56E+00 | + | **3.50E+01** | **5.57E+00** |
| F20 | 3.21E+01 | 6.14E+00 | + | **1.66E+01** | **9.08E+00** | 1.06E+02 | 3.06E+01 | + | **2.33E+01** | **2.53E+00** | 1.31E+03 | 2.43E+02 | + | **1.79E+02** | **6.47E+01** |
| F21 | 2.10E+02 | 3.13E+00 | + | **2.02E+02** | **1.50E+00** | 2.17E+02 | 4.22E+00 | + | **2.03E+02** | **2.50E+00** | 2.43E+02 | 5.94E+00 | + | **2.23E+02** | **3.23E+00** |
| F22 | 1.00E+02 | 1.14E-13 | = | 1.00E+02 | 1.00E-13 | 1.29E+03 | 1.72E+03 | + | **2.57E+02** | **2.08E+02** | 1.06E+04 | 8.07E+02 | + | **9.91E+02** | **3.82E+02** |
| F23 | 3.55E+02 | 4.91E+00 | + | **3.48E+02** | **3.45E+00** | 4.28E+02 | 9.01E+00 | + | **4.19E+02** | **6.49E+00** | 5.61E+02 | 9.75E+00 | + | **5.36E+02** | **7.35E+00** |
| F24 | 4.29E+02 | 3.97E+00 | + | **4.23E+02** | **1.14E+00** | 5.14E+02 | 5.47E+00 | + | **5.00E+02** | **2.25E+00** | 8.91E+02 | 7.97E+00 | + | **8.84E+02** | **4.45E+00** |
| F25 | 3.87E+02 | 5.77E-03 | = | 3.87E+02 | 6.94E-03 | 4.87E+02 | 2.31E+01 | = | 4.86E+02 | 2.04E+01 | 7.37E+02 | 4.08E+01 | = | 7.37E+02 | 3.59E+01 |
| F26 | 9.49E+02 | 5.62E+01 | + | **8.27E+02** | **3.95E+01** | 1.16E+03 | 6.54E+01 | + | **9.14E+02** | **7.49E+01** | 3.21E+03 | 9.16E+01 | + | **2.83E+03** | **6.69E+01** |
| F27 | 4.99E+02 | 5.87E+00 | = | 4.99E+02 | 7.51E+00 | 5.12E+02 | 8.34E+00 | = | 5.11E+02 | 1.33E+01 | 5.89E+02 | 1.65E+01 | = | 5.86E+02 | 1.70E+01 |
| F28 | 3.12E+02 | 3.42E+01 | = | 3.21E+02 | 4.36E+01 | 4.58E+02 | 2.03E+01 | = | 4.58E+02 | 2.25E+01 | 5.21E+02 | 2.53E+01 | = | 5.19E+02 | 1.96E+01 |
| F29 | 4.46E+02 | 2.05E+01 | + | **4.11E+02** | **7.45E+00** | 3.73E+02 | 2.57E+01 | + | **3.01E+02** | **7.95E+00** | 1.14E+03 | 1.87E+02 | + | **7.66E+02** | **1.04E+02** |
| F30 | 1.97E+03 | 2.22E+01 | = | 1.97E+03 | 1.69E+01 | 6.14E+05 | 4.45E+04 | = | 6.23E+05 | 4.24E+04 | 2.32E+03 | 1.70E+02 | = | 2.31E+03 | 1.53E+02 |
| **W** | **13** | | | | | **18** | | | | | **16** | | | | |
| **T** | **12** | | | | | **10** | | | | | **11** | | | | |
| **L** | **4** | | | | | **1** | | | | | **2** | | | | |

TABLE S6 PERFORMANCE COMPARISONS OF DT-RSP WITH STATE-OF-THE-ART DES ON FOUR REAL-WORLD OPTIMIZATION PROBLEMS

| | jSO | | | EaDE | | | L-SHADE-RSP | | | SCSS-L-SHADE-RSP | | | DTDE-RSP | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| Parameter Estimation for Frequency Modulated (FM) Sound Waves | **3.39E-01** | **1.86E+00** | = | 7.22E-01 | 2.75E+00 | = | 1.02E+00 | 3.10E+00 | + | 6.77 E-01 | 2.57E+00 | = | 4.18E-01 | 2.28E+00 |
| Spread Spectrum Radar Polly phase Code Design | 1.06E+00 | 1.42E-01 | + | 1.04E+00 | 1.19E-01 | + | 1.07E+00 | 1.44E-01 | + | 1.08E+00 | 1.32-01 | + | **7.70E-01** | **1.55E-01** |
| Messenger: Spacecraft Trajectory Optimization Problem | 1.57E+01 | 8.13E-01 | = | 1.61E+01 | 6.66E-01 | + | 1.58E+01 | 6.82E-01 | + | 1.57E+01 | 7.95E-01 | + | **1.55E+01** | **5.38E-01** |
| Cassini 2: Spacecraft Trajectory Optimization Problem | 1.63E+01 | 2.32E+00 | + | **1.42E+01** | **2.67E+00** | - | 1.53E+01 | 2.55E+00 | = | 1.58E+01 | 2.26E+00 | = | 1.58E+01 | 2.69E+00 |
| **W** | **2** | | | **2** | | | **3** | | | **2** | | | | |
| **T** | **2** | | | **1** | | | **1** | | | **2** | | | | |
| **L** | **0** | | | **1** | | | **0** | | | **0** | | | | |

TABLE S7 PERFORMANCE COMPARISONS OF DTDE WITH THE VARIANTS ON 30-D CEC2017 FUNCTIONS

| | Variant-L | | | Variant-R | | | Variant-DTo | | | DTDE | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 5.50E+10 | 6.75E+09 | + | **0.00E+00** | **0.00E+00** | = | 1.98E+03 | 1.69E+03 | + | **0.00E+00** | **0.00E+00** |
| F3 | 9.51E+04 | 1.09E+04 | + | 5.86E+04 | 1.38E+04 | + | 7.36E+04 | 1.04E+04 | + | **0.00E+00** | **0.00E+00** |
| F4 | 1.02E+03 | 2.72E+02 | + | **5.86E+01** | **2.90E-14** | + | 8.75E+01 | 5.52E+00 | + | **5.86E+01** | **1.61E-14** |
| F5 | 4.33E+02 | 2.29E+01 | + | 1.46E+02 | 1.14E+01 | + | **4.68E-01** | **7.27E-01** | - | 1.40E+00 | 1.34E+00 |
| F6 | 8.81E+01 | 4.52E+00 | + | 1.06E-07 | 7.44E-07 | + | **0.00E+00** | **0.00E+00** | = | **0.00E+00** | **0.00E+00** |
| F7 | 1.39E+03 | 1.05E+02 | + | 1.76E+02 | 1.07E+01 | + | **3.33E+01** | **8.32E-01** | - | 3.40E+01 | 1.09E+00 |
| F8 | 3.89E+02 | 1.93E+01 | + | 1.43E+02 | 1.16E+01 | + | **8.78E-01** | **9.04E-01** | - | 1.39E+00 | 1.14E+00 |
| F9 | 1.19E+04 | 2.70E+03 | + | **0.00E+00** | **0.00E+00** | = | **0.00E+00** | **0.00E+00** | = | **0.00E+00** | **0.00E+00** |
| F10 | 7.30E+03 | 2.66E+02 | + | 6.54E+03 | 4.67E+02 | + | **4.80E+01** | **8.31E+01** | = | 5.82E+01 | 8.94E+01 |
| F11 | 4.54E+03 | 1.13E+03 | + | 7.08E+02 | 5.16E+02 | + | 2.32E+01 | 2.59E+01 | + | **2.15E+01** | **2.67E+01** |
| F12 | 1.14E+09 | 1.63E+09 | + | **5.88E+02** | **2.87E+02** | = | 1.14E+04 | 4.04E+03 | + | 6.21E+02 | 2.32E+02 |
| F13 | 1.01E+08 | 3.69E+07 | + | 6.38E+01 | 2.02E+01 | + | 8.31E+03 | 3.74E+03 | + | **1.61E+01** | **6.17E+00** |
| F14 | 2.33E+05 | 1.41E+05 | + | 5.21E+03 | 1.04E+04 | + | 2.38E+03 | 2.47E+03 | + | **2.07E+01** | **7.58E+00** |
| F15 | 7.43E+06 | 8.02E+06 | + | 2.87E+01 | 2.46E+01 | + | 7.33E+02 | 1.09E+03 | + | **4.53E+00** | **1.52E+00** |
| F16 | 2.08E+03 | 2.99E+02 | + | 1.05E+03 | 2.83E+02 | + | **1.17E+01** | **3.68E+00** | - | 1.38E+01 | 1.77E+00 |
| F17 | 1.16E+03 | 1.49E+02 | + | 4.47E+02 | 1.11E+02 | + | **1.77E+01** | **8.13E+00** | - | 1.92E+01 | 7.76E+00 |
| F18 | 1.84E+06 | 1.07E+06 | + | 2.66E+04 | 7.21E+04 | + | 9.71E+04 | 5.14E+04 | + | **2.69E+01** | **3.52E+00** |
| F19 | 9.34E+06 | 6.10E+06 | + | 2.28E+01 | 5.86E+00 | + | 3.02E+03 | 1.89E+03 | + | **4.88E+00** | **1.44E+00** |
| F20 | 8.17E+02 | 9.03E+01 | + | 3.60E+02 | 9.86E+01 | + | 3.79E+01 | 4.61E+01 | = | **1.60E+01** | **9.59E+00** |
| F21 | 5.68E+02 | 2.62E+01 | + | 3.37E+02 | 1.48E+01 | + | **2.01E+02** | **1.08E+00** | - | 2.02E+02 | 1.53E+00 |
| F22 | 5.33E+03 | 6.43E+02 | + | 3.84E+02 | 9.71E+02 | + | **1.00E+02** | **1.44E-14** | = | **1.00E+02** | **1.44E-14** |
| F23 | 8.44E+02 | 8.71E+01 | + | 4.93E+02 | 1.17E+01 | + | **3.46E+02** | **3.24E+00** | = | 3.47E+02 | 3.15E+00 |
| F24 | 1.17E+03 | 9.42E+01 | + | 5.72E+02 | 1.94E+01 | + | **4.23E+02** | **1.11E+00** | - | 4.24E+02 | 1.51E+00 |
| F25 | 8.20E+02 | 7.78E+01 | + | **3.87E+02** | **1.43E-02** | = | **3.87E+02** | **7.21E-02** | + | **3.87E+02** | **1.12E-02** |
| F26 | 5.09E+03 | 4.47E+02 | + | 2.23E+03 | 1.32E+02 | + | **7.90E+02** | **5.95E+01** | - | 8.71E+02 | 3.34E+01 |
| F27 | 8.95E+02 | 1.19E+02 | + | 5.02E+02 | 6.39E+00 | = | 5.05E+02 | 4.28E+00 | + | **5.01E+02** | **6.37E+00** |
| F28 | 1.22E+03 | 1.80E+02 | + | **3.29E+02** | **5.01E+01** | = | 3.79E+02 | 3.57E+01 | + | 3.34E+02 | 5.10E+01 |
| F29 | 2.64E+03 | 2.93E+02 | + | 1.43E+03 | 3.52E+02 | + | 4.11E+02 | 7.56E+00 | = | **4.09E+02** | **5.52E+00** |
| F30 | 1.24E+07 | 6.61E+06 | + | 1.98E+03 | 5.15E+01 | = | 2.82E+03 | 3.49E+02 | + | **1.97E+03** | **3.21E+01** |
| **W** | **29** | | | **22** | | | **14** | | | | |
| **T** | **0** | | | **7** | | | **7** | | | | |
| **L** | **0** | | | **0** | | | **8** | | | | |

TABLE S8 PERFORMANCE COMPARISONS OF DTDEN WITH THE BASELINE ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH SLIGHT NOISE

| | 30-D | | | | | 50-D | | | | | 100-D | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Original | | | DTDEn | | Original | | | DTDEn | | Original | | | DTDEn | |
| | mean | std | sig | mean | std | mean | std | sig | mean | std | mean | std | sig | mean | std |
| F1 | 1.40E+03 | 1.70E+03 | = | 1.55E+03 | 1.61E+03 | **2.41E+03** | **1.76E+03** | - | 3.72E+03 | 2.16E+03 | 4.24E+03 | 2.47E+03 | + | **3.16E+03** | **2.18E+03** |
| F3 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 7.20E-09 | 3.35E-08 | = | 4.81E-09 | 1.26E-08 | **4.03E+02** | **3.15E+02** | - | 7.20E+02 | 5.09E+02 |
| F4 | 9.15E+01 | 1.95E+00 | = | 9.14E+01 | 2.34E+00 | 2.05E+02 | 3.70E+01 | = | 2.03E+02 | 3.77E+01 | 2.94E+02 | 2.22E+01 | + | **2.86E+02** | **1.56E+01** |
| F5 | 5.42E+01 | 1.77E+01 | + | **2.70E+00** | **1.67E+00** | 2.07E+02 | 3.06E+01 | + | **6.05E+00** | **2.79E+00** | 6.56E+02 | 2.72E+01 | + | **2.23E+01** | **5.92E+00** |
| F6 | 1.03E-07 | 3.95E-07 | + | **9.50E-09** | **3.70E-08** | 2.98E-06 | 4.31E-06 | + | **5.74E-08** | **1.66E-07** | 8.76E-03 | 7.38E-03 | + | **2.55E-03** | **2.25E-03** |
| F7 | 1.03E+02 | 1.77E+01 | + | **3.57E+01** | **1.38E+00** | 2.84E+02 | 2.52E+01 | + | **6.15E+01** | **1.82E+00** | 7.90E+02 | 3.24E+01 | + | **1.46E+02** | **9.02E+00** |
| F8 | 5.22E+01 | 1.56E+01 | + | **2.68E+00** | **1.78E+00** | 2.03E+02 | 2.46E+01 | + | **5.69E+00** | **2.24E+00** | 6.57E+02 | 2.65E+01 | + | **2.29E+01** | **7.23E+00** |
| F9 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 9.17E-02 | 1.45E-01 | = | 6.04E-02 | 1.24E-01 |
| F10 | 4.76E+03 | 7.81E+02 | + | **1.74E+02** | **1.78E+02** | 1.22E+04 | 8.78E+02 | + | **4.46E+02** | **3.29E+02** | 2.97E+04 | 5.79E+02 | + | **3.72E+03** | **1.90E+03** |
| F11 | 3.95E+01 | 3.30E+01 | + | **2.53E+01** | **2.85E+01** | 5.95E+01 | 1.60E+01 | + | **2.97E+01** | **2.96E+00** | 5.71E+02 | 1.20E+02 | + | **3.96E+02** | **7.71E+01** |
| F12 | 6.42E+02 | 2.82E+02 | = | 6.15E+02 | 2.88E+02 | 1.02E+04 | 7.43E+03 | = | 1.03E+04 | 9.92E+03 | 6.03E+05 | 4.28E+05 | = | 6.68E+05 | 3.72E+05 |
| F13 | 3.36E+01 | 2.29E+01 | + | **2.16E+01** | **9.89E+00** | 1.81E+02 | 4.72E+01 | + | **1.03E+02** | **3.75E+01** | 6.20E+03 | 2.54E+03 | + | **5.05E+03** | **1.30E+03** |
| F14 | 2.52E+01 | 2.03E+00 | = | 2.55E+01 | 3.46E+00 | 3.90E+01 | 8.96E+00 | + | **2.80E+01** | **2.62E+00** | 2.21E+02 | 5.94E+01 | + | **7.61E+01** | **2.01E+01** |
| F15 | 7.61E+00 | 1.40E+00 | = | 7.77E+00 | 1.29E+00 | 4.54E+01 | 1.07E+01 | + | **2.82E+01** | **5.17E+00** | 5.60E+02 | 9.35E+01 | + | **5.09E+02** | **7.40E+01** |
| F16 | 3.11E+02 | 1.71E+02 | + | **1.48E+01** | **1.77E+00** | 1.33E+03 | 2.33E+02 | + | **1.61E+02** | **9.25E+01** | 5.12E+03 | 6.02E+02 | + | **3.66E+02** | **1.80E+02** |
| F17 | 1.12E+02 | 2.05E+01 | + | **2.17E+01** | **5.96E+00** | 7.79E+02 | 1.71E+02 | + | **8.44E+01** | **7.92E+01** | 2.94E+03 | 3.60E+02 | + | **9.48E+01** | **9.40E+01** |
| F18 | **2.34E+01** | **1.39E+00** | - | 2.89E+01 | 2.71E+00 | **3.96E+01** | **6.90E+00** | - | 4.53E+01 | 1.01E+01 | 4.11E+02 | 6.37E+01 | = | 4.10E+02 | 7.21E+01 |
| F19 | 8.90E+00 | 2.81E+00 | + | **5.58E+00** | **1.64E+00** | 2.62E+01 | 4.59E+00 | + | **1.11E+01** | **2.56E+00** | 1.92E+02 | 2.80E+01 | + | **1.71E+02** | **2.94E+01** |
| F20 | 1.22E+02 | 3.15E+01 | + | **2.10E+01** | **4.05E+00** | 8.10E+02 | 2.07E+02 | + | **2.98E+01** | **3.14E+01** | 3.64E+03 | 4.32E+02 | + | **1.92E+02** | **7.08E+01** |
| F21 | 3.15E+02 | 1.38E+01 | + | **2.10E+02** | **2.51E+00** | 4.73E+02 | 2.56E+01 | + | **2.17E+02** | **6.83E+00** | 9.34E+02 | 3.62E+01 | + | **2.73E+02** | **2.64E+01** |
| F22 | 1.14E+02 | 2.14E+00 | + | **1.12E+02** | **2.68E+00** | 1.16E+04 | 3.02E+03 | + | **7.29E+02** | **8.19E+02** | 3.09E+04 | 6.10E+02 | + | **5.10E+03** | **2.32E+03** |
| F23 | 4.95E+02 | 2.08E+01 | + | **3.57E+02** | **7.93E+00** | 7.28E+02 | 2.31E+01 | + | **4.46E+02** | **1.52E+01** | 1.30E+03 | 4.77E+01 | + | **6.06E+02** | **4.33E+01** |
| F24 | 5.71E+02 | 1.86E+01 | + | **4.31E+02** | **4.71E+00** | 8.06E+02 | 2.41E+01 | + | **5.21E+02** | **1.20E+01** | 1.66E+03 | 4.12E+01 | + | **9.91E+02** | **5.36E+01** |
| F25 | 3.96E+02 | 6.68E+00 | = | 3.96E+02 | 4.92E+00 | 5.59E+02 | 9.28E+00 | = | 5.59E+02 | 5.67E+00 | 1.02E+03 | 4.56E+01 | + | **9.83E+02** | **3.86E+01** |
| F26 | 1.87E+03 | 1.72E+02 | + | **8.71E+02** | **5.58E+01** | 3.38E+03 | 2.39E+02 | + | **9.85E+02** | **7.69E+01** | 1.01E+04 | 2.96E+02 | + | **3.09E+03** | **1.60E+02** |
| F27 | 5.41E+02 | 8.74E+00 | + | **5.29E+02** | **7.65E+00** | 6.12E+02 | 4.11E+01 | + | **5.81E+02** | **3.77E+01** | 7.29E+02 | 3.15E+01 | + | **7.05E+02** | **2.25E+01** |
| F28 | 4.54E+02 | 1.81E+01 | = | 4.58E+02 | 1.47E+01 | 5.24E+02 | 2.53E+01 | = | 5.16E+02 | 2.26E+01 | 7.29E+02 | 3.87E+01 | + | **7.11E+02** | **3.10E+01** |
| F29 | 6.06E+02 | 2.60E+01 | + | **4.27E+02** | **7.25E+00** | 7.41E+02 | 7.52E+01 | + | **3.24E+02** | **9.85E+00** | 3.44E+03 | 3.54E+02 | + | **9.98E+02** | **1.93E+02** |
| F30 | **2.20E+03** | **1.11E+02** | - | 2.24E+03 | 1.03E+02 | 7.33E+05 | 8.99E+04 | = | 7.40E+05 | 8.15E+04 | 7.78E+03 | 1.92E+03 | + | **6.81E+03** | **1.52E+03** |
| **W** | **18** | | | | | **20** | | | | | **25** | | | | |
| **T** | **9** | | | | | **7** | | | | | **3** | | | | |
| **L** | **2** | | | | | **2** | | | | | **1** | | | | |

TABLE S9 PERFORMANCE COMPARISONS OF DTDEN WITH THE BASELINE ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH MODERATE NOISE

| | 30-D | | | | | 50-D | | | | | 100-D | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Original | | | DTDEn | | Original | | | DTDEn | | Original | | | DTDEn | |
| | mean | std | sig | mean | std | mean | std | sig | mean | std | mean | std | sig | mean | std |
| F1 | 3.08E+03 | 3.87E+03 | = | 2.37E+03 | 2.37E+03 | 9.17E+07 | 3.13E+08 | = | 2.08E+06 | 3.83E+06 | 5.44E+09 | 9.40E+09 | + | **7.90E+08** | **2.68E+09** |
| F3 | **6.12E-01** | **3.36E+00** | - | 4.92E+00 | 1.51E+01 | **1.62E+03** | **1.87E+03** | - | 4.58E+03 | 3.58E+03 | **5.38E+04** | **2.39E+04** | - | 8.88E+04 | 2.07E+04 |
| F4 | 1.19E+02 | 1.46E+01 | + | **1.12E+02** | **9.05E+00** | 2.89E+02 | 3.34E+01 | + | **2.66E+02** | **1.49E+01** | 5.59E+02 | 1.06E+02 | + | **4.84E+02** | **7.20E+01** |
| F5 | 2.11E+02 | 2.63E+01 | + | **4.81E+01** | **3.78E+01** | 4.42E+02 | 5.39E+01 | + | **1.91E+02** | **6.72E+01** | 1.09E+03 | 1.40E+02 | + | **8.24E+02** | **9.52E+01** |
| F6 | 1.80E+01 | 1.17E+01 | + | **1.26E-01** | **3.44E-01** | 3.58E+01 | 1.55E+01 | + | **1.18E+00** | **1.64E+00** | 6.27E+01 | 2.37E+01 | + | **9.42E+00** | **6.96E+00** |
| F7 | 2.51E+02 | 3.56E+01 | + | **1.32E+02** | **4.24E+01** | 4.84E+02 | 8.04E+01 | + | **3.61E+02** | **7.30E+01** | 1.26E+03 | 2.39E+02 | + | **1.07E+03** | **1.41E+02** |
| F8 | 2.11E+02 | 2.60E+01 | + | **4.93E+01** | **4.23E+01** | 4.63E+02 | 7.17E+01 | + | **2.00E+02** | **6.15E+01** | 1.14E+03 | 2.01E+02 | + | **7.98E+02** | **1.03E+02** |
| F9 | 1.30E-01 | 2.51E-01 | + | **7.81E-02** | **1.65E-01** | 3.56E+01 | 1.35E+02 | = | 4.13E+00 | 4.94E+00 | 6.93E+03 | 1.64E+04 | + | **2.02E+02** | **5.85E+02** |
| F10 | 7.11E+03 | 2.61E+02 | + | **4.20E+03** | **1.24E+03** | 1.34E+04 | 2.82E+02 | + | **9.69E+03** | **1.71E+03** | 3.01E+04 | 4.43E+02 | + | **2.78E+04** | **1.67E+03** |
| F11 | 1.30E+02 | 3.34E+01 | + | **7.87E+01** | **2.64E+01** | 2.63E+02 | 5.07E+01 | + | **1.49E+02** | **6.48E+01** | **1.59E+03** | **1.97E+02** | - | 1.93E+03 | 2.10E+02 |
| F12 | 7.24E+03 | 5.42E+03 | = | 6.78E+03 | 5.27E+03 | 1.88E+06 | 1.20E+06 | = | 1.98E+06 | 1.15E+06 | 2.00E+08 | 1.54E+08 | + | **7.75E+07** | **4.75E+07** |
| F13 | 1.92E+02 | 8.95E+01 | = | 2.13E+02 | 1.01E+02 | 5.81E+03 | 2.27E+03 | + | **4.46E+03** | **1.99E+03** | 2.82E+04 | 3.86E+03 | + | **2.57E+04** | **4.11E+03** |
| F14 | 7.11E+01 | 1.11E+01 | + | **6.34E+01** | **1.77E+01** | 1.78E+02 | 2.52E+01 | = | 1.61E+02 | 4.24E+01 | **5.45E+02** | **5.77E+01** | - | 5.92E+02 | 5.64E+01 |
| F15 | 6.10E+01 | 2.28E+01 | = | 5.30E+01 | 2.24E+01 | 4.33E+02 | 1.23E+02 | + | **3.20E+02** | **1.39E+02** | 8.95E+03 | 4.47E+03 | + | **3.83E+03** | **1.77E+03** |
| F16 | 1.45E+03 | 2.15E+02 | + | **3.33E+02** | **2.85E+02** | 3.16E+03 | 2.52E+02 | + | **7.38E+02** | **2.74E+02** | 8.52E+03 | 5.01E+02 | + | **3.47E+03** | **1.34E+03** |
| F17 | 2.76E+02 | 9.47E+01 | + | **5.15E+01** | **5.08E+01** | 1.75E+03 | 1.70E+02 | + | **4.91E+02** | **2.70E+02** | 4.81E+03 | 2.93E+02 | + | **1.61E+03** | **8.32E+02** |
| F18 | **5.74E+01** | **1.63E+01** | - | 6.92E+01 | 1.43E+01 | **3.46E+02** | **1.03E+02** | - | 3.96E+02 | 7.70E+01 | **7.68E+03** | **8.10E+03** | - | 1.14E+04 | 8.23E+03 |
| F19 | 2.97E+01 | 6.02E+00 | + | **1.85E+01** | **5.92E+00** | 9.35E+01 | 1.63E+01 | + | **4.61E+01** | **1.77E+01** | 1.27E+03 | 1.41E+03 | + | **5.40E+02** | **2.57E+02** |
| F20 | 5.14E+02 | 1.54E+02 | + | **1.37E+02** | **1.15E+02** | 1.70E+03 | 1.74E+02 | + | **2.77E+02** | **2.38E+02** | 5.17E+03 | 1.87E+02 | + | **1.89E+03** | **7.67E+02** |
| F21 | 4.31E+02 | 2.36E+01 | + | **3.31E+02** | **3.43E+01** | 6.59E+02 | 4.68E+01 | + | **4.89E+02** | **4.85E+01** | 1.36E+03 | 1.64E+02 | + | **1.11E+03** | **8.41E+01** |
| F22 | 4.74E+02 | 9.65E+02 | + | **1.39E+02** | **1.84E+01** | 1.36E+04 | 4.04E+02 | + | **4.91E+03** | **5.12E+03** | 3.12E+04 | 4.79E+02 | + | **2.58E+04** | **9.36E+03** |
| F23 | 5.84E+02 | 2.60E+01 | + | **5.06E+02** | **3.52E+01** | 9.32E+02 | 4.94E+01 | + | **7.83E+02** | **5.25E+01** | 1.77E+03 | 1.33E+02 | + | **1.49E+03** | **1.17E+02** |
| F24 | 6.40E+02 | 2.35E+01 | + | **5.78E+02** | **3.24E+01** | 9.52E+02 | 3.91E+01 | + | **8.63E+02** | **6.10E+01** | 2.12E+03 | 1.38E+02 | + | **1.95E+03** | **1.26E+02** |
| F25 | 4.44E+02 | 2.13E+01 | = | 4.37E+02 | 1.39E+01 | 6.64E+02 | 4.44E+01 | + | **6.43E+02** | **3.30E+01** | 1.46E+03 | 2.27E+02 | + | **1.31E+03** | **1.11E+02** |
| F26 | 3.34E+03 | 3.48E+02 | + | **1.79E+03** | **4.57E+02** | 5.63E+03 | 5.04E+02 | + | **3.61E+03** | **7.12E+02** | 1.45E+04 | 1.45E+03 | + | **1.26E+04** | **1.33E+03** |
| F27 | 5.96E+02 | 1.96E+01 | = | 5.97E+02 | 1.60E+01 | 9.12E+02 | 8.85E+01 | = | 8.83E+02 | 6.23E+01 | 1.29E+03 | 2.91E+02 | + | **1.14E+03** | **1.33E+02** |
| F28 | 5.46E+02 | 4.56E+01 | = | 5.30E+02 | 2.50E+01 | 7.98E+02 | 3.63E+02 | + | **6.63E+02** | **6.42E+01** | 3.13E+03 | 3.05E+03 | + | **1.46E+03** | **4.68E+02** |
| F29 | 1.03E+03 | 1.34E+02 | + | **5.77E+02** | **7.92E+01** | 1.86E+03 | 2.66E+02 | + | **6.49E+02** | **2.21E+02** | 6.14E+03 | 5.35E+02 | + | **2.92E+03** | **6.83E+02** |
| F30 | **3.85E+03** | **7.53E+02** | - | 4.40E+03 | 1.07E+03 | 2.18E+06 | 1.13E+06 | = | 1.94E+06 | 4.58E+05 | 4.86E+05 | 2.91E+05 | + | **2.05E+05** | **9.38E+04** |
| **W** | **19** | | | | | **21** | | | | | **25** | | | | |
| **T** | **7** | | | | | **6** | | | | | **0** | | | | |
| **L** | **3** | | | | | **2** | | | | | **4** | | | | |

TABLE S10 PERFORMANCE COMPARISONS OF DTDEN WITH THE BASELINE ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH SEVERE NOISE

| | 30-D | | | | | 50-D | | | | | 100-D | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Original | | | DTDEn | | Original | | | DTDEn | | Original | | | DTDEn | |
| | mean | std | sig | mean | std | mean | std | sig | mean | std | mean | std | sig | mean | std |
| F1 | 2.93E+09 | 4.79E+09 | + | **2.63E+03** | **2.10E+03** | 2.15E+10 | 2.25E+10 | + | **3.06E+04** | **2.97E+04** | 8.79E+10 | 6.35E+10 | + | **4.52E+07** | **1.35E+07** |
| F3 | **5.53E+03** | **5.88E+03** | - | 7.11E+04 | 1.05E+04 | **3.44E+04** | **1.58E+04** | - | 1.50E+05 | 1.63E+04 | **1.62E+05** | **3.88E+04** | - | 3.47E+05 | 2.26E+04 |
| F4 | 1.78E+02 | 3.35E+01 | + | **1.44E+02** | **1.08E+01** | 5.97E+02 | 3.54E+02 | + | **2.61E+02** | **1.07E+01** | 2.48E+03 | 3.02E+03 | + | **5.72E+02** | **2.39E+01** |
| F5 | 2.61E+02 | 2.99E+01 | + | **9.79E+01** | **2.95E+01** | 5.55E+02 | 5.65E+01 | + | **3.16E+02** | **4.32E+01** | 1.33E+03 | 1.23E+02 | + | **9.13E+02** | **2.98E+01** |
| F6 | 4.58E+01 | 8.68E+00 | + | **2.59E-01** | **1.21E-01** | 6.63E+01 | 9.11E+00 | + | **1.92E+00** | **5.19E-01** | 8.86E+01 | 1.13E+01 | + | **1.36E+01** | **1.92E+00** |
| F7 | 4.08E+02 | 1.32E+02 | + | **1.85E+02** | **2.61E+01** | 1.00E+03 | 4.11E+02 | + | **4.24E+02** | **2.58E+01** | 2.78E+03 | 9.86E+02 | + | **1.14E+03** | **3.53E+01** |
| F8 | 2.57E+02 | 2.48E+01 | + | **9.77E+01** | **3.00E+01** | 5.53E+02 | 5.63E+01 | + | **3.16E+02** | **4.13E+01** | 1.41E+03 | 1.18E+02 | + | **9.11E+02** | **3.43E+01** |
| F9 | 7.77E+02 | 1.20E+03 | + | **1.93E-02** | **4.63E-02** | 6.43E+03 | 6.54E+03 | + | **6.09E-01** | **2.28E-01** | 4.53E+04 | 2.36E+04 | + | **1.91E+01** | **6.49E+00** |
| F10 | 7.09E+03 | 3.35E+02 | + | **5.33E+03** | **8.35E+02** | 1.33E+04 | 2.98E+02 | + | **1.18E+04** | **7.52E+02** | 3.00E+04 | 5.05E+02 | + | **2.88E+04** | **6.22E+02** |
| F11 | **2.37E+02** | **6.05E+01** | - | 2.52E+03 | 1.33E+03 | **5.19E+02** | **1.71E+02** | - | 7.58E+03 | 2.79E+03 | **6.45E+03** | **5.69E+03** | - | 1.05E+05 | 1.87E+04 |
| F12 | 2.73E+07 | 7.77E+07 | + | **7.69E+05** | **4.07E+05** | 5.99E+08 | 1.08E+09 | + | **3.27E+06** | **1.31E+06** | 1.37E+10 | 1.32E+10 | + | **3.20E+07** | **9.55E+06** |
| F13 | **2.65E+04** | **1.34E+05** | - | 9.11E+03 | 4.61E+03 | 1.74E+07 | 1.06E+08 | + | **1.85E+03** | **1.07E+03** | 7.18E+08 | 1.16E+09 | + | **6.94E+03** | **1.22E+03** |
| F14 | **1.24E+02** | **2.19E+01** | - | 2.66E+05 | 1.46E+05 | **3.41E+02** | **7.22E+01** | - | 3.43E+05 | 2.18E+05 | **1.96E+05** | **7.27E+05** | - | 2.00E+06 | 4.00E+05 |
| F15 | 3.21E+02 | 1.77E+02 | = | 9.45E+02 | 1.24E+03 | 6.38E+05 | 4.45E+06 | + | **2.03E+03** | **1.08E+03** | 1.13E+08 | 4.22E+08 | + | **1.04E+03** | **3.49E+02** |
| F16 | 1.70E+03 | 1.49E+02 | + | **4.91E+02** | **2.73E+02** | 3.45E+03 | 2.27E+02 | + | **9.49E+02** | **2.91E+02** | 9.52E+03 | 7.01E+02 | + | **5.16E+03** | **1.10E+03** |
| F17 | 5.81E+02 | 1.11E+02 | + | **7.38E+01** | **6.80E+01** | 2.03E+03 | 1.71E+02 | + | **7.23E+02** | **3.03E+02** | 5.09E+03 | 2.68E+02 | + | **2.86E+03** | **8.25E+02** |
| F18 | **6.41E+02** | **1.78E+03** | - | 4.80E+05 | 3.86E+05 | **1.52E+04** | **1.95E+04** | - | 1.87E+06 | 5.68E+05 | **2.48E+05** | **2.40E+05** | - | 1.80E+06 | 3.82E+05 |
| F19 | **6.75E+01** | **2.51E+01** | - | 3.04E+03 | 2.21E+03 | **5.70E+03** | **2.08E+04** | - | 1.36E+04 | 2.75E+03 | 9.58E+07 | 3.80E+08 | + | **9.33E+02** | **5.21E+02** |
| F20 | 6.71E+02 | 8.91E+01 | + | **2.49E+02** | **9.86E+01** | 1.79E+03 | 1.41E+02 | + | **2.88E+02** | **1.43E+02** | 5.21E+03 | 2.02E+02 | + | **3.08E+03** | **7.93E+02** |
| F21 | 4.56E+02 | 1.75E+01 | + | **3.66E+02** | **1.78E+01** | 7.37E+02 | 4.12E+01 | + | **5.49E+02** | **2.69E+01** | 1.64E+03 | 1.37E+02 | + | **1.15E+03** | **3.35E+01** |
| F22 | 1.86E+03 | 1.18E+03 | + | **1.38E+02** | **4.49E+00** | 1.36E+04 | 3.40E+02 | + | **1.03E+03** | **2.73E+03** | 3.14E+04 | 4.29E+02 | + | **1.28E+04** | **1.30E+04** |
| F23 | 6.16E+02 | 2.62E+01 | + | **5.38E+02** | **2.21E+01** | 1.05E+03 | 7.94E+01 | + | **8.25E+02** | **2.81E+01** | 2.07E+03 | 2.36E+02 | + | **1.56E+03** | **4.83E+01** |
| F24 | 6.73E+02 | 2.36E+01 | + | **6.00E+02** | **2.11E+01** | 1.05E+03 | 6.84E+01 | + | **8.70E+02** | **2.67E+01** | 2.84E+03 | 5.19E+02 | + | **1.92E+03** | **4.21E+01** |
| F25 | 5.14E+02 | 5.05E+01 | + | **4.47E+02** | **1.38E+01** | 1.08E+03 | 5.79E+02 | + | **6.65E+02** | **1.54E+01** | 4.07E+03 | 2.58E+03 | + | **1.33E+03** | **4.73E+01** |
| F26 | 3.98E+03 | 3.46E+02 | + | **2.44E+03** | **2.99E+02** | 7.08E+03 | 8.00E+02 | + | **4.54E+03** | **3.76E+02** | 2.10E+04 | 3.98E+03 | + | **1.36E+04** | **5.90E+02** |
| F27 | 6.45E+02 | 4.24E+01 | + | **6.17E+02** | **1.53E+01** | 1.25E+03 | 2.14E+02 | + | **9.50E+02** | **3.95E+01** | 2.42E+03 | 5.53E+02 | + | **1.19E+03** | **5.43E+01** |
| F28 | 7.25E+02 | 1.53E+02 | + | **5.42E+02** | **1.95E+01** | 2.92E+03 | 1.22E+03 | + | **8.38E+02** | **7.18E+01** | 1.31E+04 | 4.66E+03 | + | **1.51E+03** | **1.62E+02** |
| F29 | 1.32E+03 | 1.36E+02 | + | **7.13E+02** | **1.32E+02** | 2.48E+03 | 2.56E+02 | + | **8.57E+02** | **2.38E+02** | 7.05E+03 | 5.18E+02 | + | **3.66E+03** | **6.71E+02** |
| F30 | 3.13E+04 | 6.18E+04 | + | **7.62E+03** | **3.44E+03** | 6.94E+07 | 5.46E+07 | + | **2.03E+06** | **2.08E+05** | 4.34E+08 | 1.09E+09 | + | **5.88E+04** | **2.35E+04** |
| **W** | **22** | | | | | **24** | | | | | **25** | | | | |
| **T** | **1** | | | | | **0** | | | | | **0** | | | | |
| **L** | **6** | | | | | **5** | | | | | **4** | | | | |

TABLE S11 PERFORMANCE COMPARISONS OF DT WITH THE BASELINE ON 30-D CEC2017 FUNCTIONS WITH SLIGHT AND MODERATE NOISE

| | Slight | | | | | Moderate | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Original | | | DT_slight | | Original | | | DT_moderate | |
| | mean | std | sig | mean | std | mean | std | sig | mean | std |
| F1 | 1.40E+03 | 1.70E+03 | - | 1.97E+03 | 1.18E+03 | 3.08E+03 | 3.87E+03 | = | 2.09E+03 | 1.74E+03 |
| F3 | 0.00E+00 | 0.00E+00 | - | 7.15E+04 | 9.29E+03 | 6.12E-01 | 3.36E+00 | - | 7.43E+04 | 1.16E+04 |
| F4 | 9.15E+01 | 1.95E+00 | - | 9.83E+01 | 1.05E+01 | 1.19E+02 | 1.46E+01 | = | 1.19E+02 | 7.44E+00 |
| F5 | 5.42E+01 | 1.77E+01 | + | 1.47E+00 | 1.14E+00 | 2.11E+02 | 2.63E+01 | + | 1.40E+01 | 3.41E+00 |
| F6 | 1.03E-07 | 3.95E-07 | + | 0.00E+00 | 0.00E+00 | 1.80E+01 | 1.17E+01 | + | 2.81E-04 | 1.69E-04 |
| F7 | 1.03E+02 | 1.77E+01 | + | 3.42E+01 | 8.39E-01 | 2.51E+02 | 3.56E+01 | + | 6.27E+01 | 1.14E+01 |
| F8 | 5.22E+01 | 1.56E+01 | + | 1.24E+00 | 1.05E+00 | 2.11E+02 | 2.60E+01 | + | 1.51E+01 | 4.18E+00 |
| F9 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 1.30E-01 | 2.51E-01 | + | 0.00E+00 | 0.00E+00 |
| F10 | 4.76E+03 | 7.81E+02 | + | 1.36E+02 | 1.55E+02 | 7.11E+03 | 2.61E+02 | + | 1.88E+03 | 7.34E+02 |
| F11 | 3.95E+01 | 3.30E+01 | = | 3.75E+01 | 3.37E+01 | 1.30E+02 | 3.34E+01 | - | 1.54E+03 | 1.00E+03 |
| F12 | 6.42E+02 | 2.82E+02 | - | 1.05E+05 | 5.99E+04 | 7.24E+03 | 5.42E+03 | - | 3.79E+05 | 2.52E+05 |
| F13 | 3.36E+01 | 2.29E+01 | - | 8.74E+03 | 3.50E+03 | 1.92E+02 | 8.95E+01 | - | 7.54E+03 | 3.64E+03 |
| F14 | 2.52E+01 | 2.03E+00 | - | 6.50E+03 | 7.41E+03 | 7.11E+01 | 1.11E+01 | - | 6.80E+04 | 4.96E+04 |
| F15 | 7.61E+00 | 1.40E+00 | - | 6.14E+02 | 9.54E+02 | 6.10E+01 | 2.28E+01 | - | 9.47E+02 | 7.81E+02 |
| F16 | 3.11E+02 | 1.71E+02 | + | 1.74E+01 | 3.12E+01 | 1.45E+03 | 2.15E+02 | + | 8.05E+01 | 1.24E+02 |
| F17 | 1.12E+02 | 2.05E+01 | + | 2.14E+01 | 5.10E+00 | 2.76E+02 | 9.47E+01 | + | 2.88E+01 | 2.96E+00 |
| F18 | 2.34E+01 | 1.39E+00 | - | 3.29E+05 | 2.05E+05 | 5.74E+01 | 1.63E+01 | - | 3.22E+05 | 2.06E+05 |
| F19 | 8.90E+00 | 2.81E+00 | - | 3.62E+03 | 2.08E+03 | 2.97E+01 | 6.02E+00 | - | 3.55E+03 | 2.42E+03 |
| F20 | 1.22E+02 | 3.15E+01 | + | 4.98E+01 | 6.19E+01 | 5.14E+02 | 1.54E+02 | + | 1.38E+02 | 7.40E+01 |
| F21 | 3.15E+02 | 1.38E+01 | + | 2.05E+02 | 1.95E+00 | 4.31E+02 | 2.36E+01 | + | 2.69E+02 | 2.25E+01 |
| F22 | 1.14E+02 | 2.14E+00 | + | 1.04E+02 | 2.16E+00 | 4.74E+02 | 9.65E+02 | + | 1.21E+02 | 1.78E+00 |
| F23 | 4.95E+02 | 2.08E+01 | + | 3.49E+02 | 3.63E+00 | 5.84E+02 | 2.60E+01 | + | 4.39E+02 | 2.38E+01 |
| F24 | 5.71E+02 | 1.86E+01 | + | 4.26E+02 | 2.42E+00 | 6.40E+02 | 2.35E+01 | + | 5.23E+02 | 2.41E+01 |
| F25 | 3.96E+02 | 6.68E+00 | + | 3.93E+02 | 2.04E+00 | 4.44E+02 | 2.13E+01 | + | 4.22E+02 | 8.28E+00 |
| F26 | 1.87E+03 | 1.72E+02 | + | 7.91E+02 | 8.15E+01 | 3.34E+03 | 3.48E+02 | + | 1.08E+03 | 9.96E+01 |
| F27 | 5.41E+02 | 8.74E+00 | + | 5.23E+02 | 7.57E+00 | 5.96E+02 | 1.96E+01 | + | 5.76E+02 | 1.32E+01 |
| F28 | 4.54E+02 | 1.81E+01 | - | 4.65E+02 | 1.38E+01 | 5.46E+02 | 4.56E+01 | + | 5.02E+02 | 1.09E+01 |
| F29 | 6.06E+02 | 2.60E+01 | + | 4.30E+02 | 9.17E+00 | 1.03E+03 | 1.34E+02 | + | 5.28E+02 | 6.68E+01 |
| F30 | 2.20E+03 | 1.11E+02 | - | 3.36E+03 | 4.02E+02 | 3.85E+03 | 7.53E+02 | - | 4.13E+03 | 6.66E+02 |
| **W** | **16** | | | | | **18** | | | | |
| **T** | **2** | | | | | **2** | | | | |
| **L** | **11** | | | | | **9** | | | | |

TABLE S12 PERFORMANCE COMPARISONS OF DTDEN WITH THE RESAMPLING METHOD ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH SLIGHT NOISE

| | 30-D | | | | | 50-D | | | | | 100-D | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Resampling | | | DTDEn | | Resampling | | | DTDEn | | Resampling | | | DTDEn | |
| | mean | std | sig | mean | std | mean | std | sig | mean | std | mean | std | sig | mean | std |
| F1 | 1.10E+03 | 1.22E+03 | = | 1.55E+03 | 1.61E+03 | 3.52E+03 | 2.07E+03 | = | 3.72E+03 | 2.16E+03 | 4.59E+03 | 2.82E+03 | + | **3.16E+03** | **2.18E+03** |
| F3 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 4.99E-02 | 1.20E-01 | + | **4.81E-09** | **1.26E-08** | 3.78E+03 | 1.47E+03 | + | **7.20E+02** | **5.09E+02** |
| F4 | 9.14E+01 | 1.63E+00 | = | 9.14E+01 | 2.34E+00 | 2.06E+02 | 3.39E+01 | = | 2.03E+02 | 3.77E+01 | 2.91E+02 | 1.81E+01 | = | 2.86E+02 | 1.56E+01 |
| F5 | 5.58E+01 | 1.48E+01 | + | **2.70E+00** | **1.67E+00** | 1.96E+02 | 3.21E+01 | + | **6.05E+00** | **2.79E+00** | 6.38E+02 | 3.01E+01 | + | **2.23E+01** | **5.92E+00** |
| F6 | 5.18E-06 | 8.51E-06 | + | **9.50E-09** | **3.70E-08** | 6.84E-05 | 3.12E-04 | + | **5.74E-08** | **1.66E-07** | 9.81E-03 | 6.94E-03 | + | **2.55E-03** | **2.25E-03** |
| F7 | 1.01E+02 | 1.52E+01 | + | **3.57E+01** | **1.38E+00** | 2.66E+02 | 2.94E+01 | + | **6.15E+01** | **1.82E+00** | 7.53E+02 | 3.58E+01 | + | **1.46E+02** | **9.02E+00** |
| F8 | 4.93E+01 | 1.31E+01 | + | **2.68E+00** | **1.78E+00** | 1.95E+02 | 2.23E+01 | + | **5.69E+00** | **2.24E+00** | 6.43E+02 | 3.00E+01 | + | **2.29E+01** | **7.23E+00** |
| F9 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | = | 0.00E+00 | 0.00E+00 | 2.31E-01 | 2.56E-01 | + | **6.04E-02** | **1.24E-01** |
| F10 | 4.68E+03 | 7.63E+02 | + | **1.74E+02** | **1.78E+02** | 1.13E+04 | 1.12E+03 | + | **4.46E+02** | **3.29E+02** | 2.93E+04 | 9.36E+02 | + | **3.72E+03** | **1.90E+03** |
| F11 | 3.06E+01 | 3.17E+01 | + | **2.53E+01** | **2.85E+01** | 6.03E+01 | 1.59E+01 | + | **2.97E+01** | **2.96E+00** | 6.52E+02 | 1.45E+02 | + | **3.96E+02** | **7.71E+01** |
| F12 | 9.02E+02 | 3.59E+02 | + | **6.15E+02** | **2.88E+02** | 1.37E+04 | 9.80E+03 | + | **1.03E+04** | **9.92E+03** | 7.95E+05 | 4.69E+05 | = | 6.68E+05 | 3.72E+05 |
| F13 | 4.16E+01 | 2.04E+01 | + | **2.16E+01** | **9.89E+00** | 2.24E+02 | 4.68E+01 | + | **1.03E+02** | **3.75E+01** | 6.91E+03 | 1.82E+03 | + | **5.05E+03** | **1.30E+03** |
| F14 | 2.76E+01 | 2.61E+00 | + | **2.55E+01** | **3.46E+00** | 4.64E+01 | 1.16E+01 | + | **2.80E+01** | **2.62E+00** | 2.16E+02 | 5.67E+01 | + | **7.61E+01** | **2.01E+01** |
| F15 | 1.01E+01 | 2.58E+00 | + | **7.77E+00** | **1.29E+00** | 6.17E+01 | 1.53E+01 | + | **2.82E+01** | **5.17E+00** | 6.09E+02 | 1.05E+02 | + | **5.09E+02** | **7.40E+01** |
| F16 | 3.31E+02 | 1.61E+02 | + | **1.48E+01** | **1.77E+00** | 1.32E+03 | 2.65E+02 | + | **1.61E+02** | **9.25E+01** | 4.84E+03 | 4.23E+02 | + | **3.66E+02** | **1.80E+02** |
| F17 | 1.16E+02 | 2.39E+01 | + | **2.17E+01** | **5.96E+00** | 8.55E+02 | 2.02E+02 | + | **8.44E+01** | **7.92E+01** | 2.99E+03 | 3.91E+02 | + | **9.48E+01** | **9.40E+01** |
| F18 | **2.52E+01** | **2.04E+00** | - | 2.89E+01 | 2.71E+00 | 5.47E+01 | 1.51E+01 | + | **4.53E+01** | **1.01E+01** | 4.45E+02 | 7.02E+01 | = | 4.10E+02 | 7.21E+01 |
| F19 | 1.17E+01 | 2.56E+00 | + | **5.58E+00** | **1.64E+00** | 3.02E+01 | 4.90E+00 | + | **1.11E+01** | **2.56E+00** | 2.01E+02 | 2.73E+01 | + | **1.71E+02** | **2.94E+01** |
| F20 | 1.37E+02 | 5.06E+01 | + | **2.10E+01** | **4.05E+00** | 8.45E+02 | 1.63E+02 | + | **2.98E+01** | **3.14E+01** | 3.64E+03 | 3.71E+02 | + | **1.92E+02** | **7.08E+01** |
| F21 | 3.10E+02 | 1.39E+01 | + | **2.10E+02** | **2.51E+00** | 4.49E+02 | 2.29E+01 | + | **2.17E+02** | **6.83E+00** | 8.95E+02 | 3.75E+01 | + | **2.73E+02** | **2.64E+01** |
| F22 | 1.13E+02 | 1.95E+00 | + | **1.12E+02** | **2.68E+00** | 1.11E+04 | 2.92E+03 | + | **7.29E+02** | **8.19E+02** | 3.05E+04 | 9.67E+02 | + | **5.10E+03** | **2.32E+03** |
| F23 | 4.82E+02 | 1.72E+01 | + | **3.57E+02** | **7.93E+00** | 7.11E+02 | 2.25E+01 | + | **4.46E+02** | **1.52E+01** | 1.26E+03 | 3.99E+01 | + | **6.06E+02** | **4.33E+01** |
| F24 | 5.65E+02 | 1.61E+01 | + | **4.31E+02** | **4.71E+00** | 7.89E+02 | 2.35E+01 | + | **5.21E+02** | **1.20E+01** | 1.64E+03 | 4.06E+01 | + | **9.91E+02** | **5.36E+01** |
| F25 | **3.93E+02** | **3.84E+00** | - | 3.96E+02 | 4.92E+00 | 5.58E+02 | 8.24E+00 | = | 5.59E+02 | 5.67E+00 | 1.00E+03 | 4.73E+01 | + | **9.83E+02** | **3.86E+01** |
| F26 | 1.80E+03 | 1.66E+02 | + | **8.71E+02** | **5.58E+01** | 3.34E+03 | 1.91E+02 | + | **9.85E+02** | **7.69E+01** | 9.82E+03 | 3.05E+02 | + | **3.09E+03** | **1.60E+02** |
| F27 | 5.38E+02 | 7.31E+00 | + | **5.29E+02** | **7.65E+00** | 5.98E+02 | 3.84E+01 | + | **5.81E+02** | **3.77E+01** | 7.26E+02 | 2.57E+01 | + | **7.05E+02** | **2.25E+01** |
| F28 | **4.51E+02** | **1.50E+01** | - | 4.58E+02 | 1.47E+01 | 5.24E+02 | 2.23E+01 | = | 5.16E+02 | 2.26E+01 | 7.25E+02 | 3.26E+01 | + | **7.11E+02** | **3.10E+01** |
| F29 | 6.03E+02 | 3.09E+01 | + | **4.27E+02** | **7.25E+00** | 7.25E+02 | 8.17E+01 | + | **3.24E+02** | **9.85E+00** | 3.39E+03 | 3.63E+02 | + | **9.98E+02** | **1.93E+02** |
| F30 | 2.22E+03 | 1.40E+02 | = | 2.24E+03 | 1.03E+02 | 7.59E+05 | 1.17E+05 | = | 7.40E+05 | 8.15E+04 | 8.93E+03 | 2.34E+03 | + | **6.81E+03** | **1.52E+03** |
| **W** | **21** | | | | | **23** | | | | | **26** | | | | |
| **T** | **5** | | | | | **6** | | | | | **3** | | | | |
| **L** | **3** | | | | | **0** | | | | | **0** | | | | |

TABLE S13 PERFORMANCE COMPARISONS OF DTDEN WITH THE RESAMPLING METHOD ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH MODERATE NOISE

| | 30-D | | | | | 50-D | | | | | 100-D | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Resampling | | | DTDEn | | Resampling | | | DTDEn | | Resampling | | | DTDEn | |
| | mean | std | sig | mean | std | mean | std | sig | mean | std | mean | std | sig | mean | std |
| F1 | 1.75E+03 | 1.35E+03 | = | 2.37E+03 | 2.37E+03 | **2.00E+05** | **1.06E+06** | - | 2.08E+06 | 3.83E+06 | 2.39E+09 | 6.35E+09 | + | **7.90E+08** | **2.68E+09** |
| F3 | **2.28E-01** | **4.17E-01** | - | 4.92E+00 | 1.51E+01 | **1.57E+03** | **1.29E+03** | - | 4.58E+03 | 3.58E+03 | **4.88E+04** | **1.60E+04** | - | 8.88E+04 | 2.07E+04 |
| F4 | 1.12E+02 | 1.17E+01 | = | 1.12E+02 | 9.05E+00 | 2.71E+02 | 2.65E+01 | = | 2.66E+02 | 1.49E+01 | 4.62E+02 | 7.00E+01 | = | 4.84E+02 | 7.20E+01 |
| F5 | 2.07E+02 | 2.62E+01 | + | **4.81E+01** | **3.78E+01** | 4.40E+02 | 6.27E+01 | + | **1.91E+02** | **6.72E+01** | 1.09E+03 | 1.79E+02 | + | **8.24E+02** | **9.52E+01** |
| F6 | 1.05E+01 | 9.26E+00 | + | **1.26E-01** | **3.44E-01** | 2.41E+01 | 1.70E+01 | + | **1.18E+00** | **1.64E+00** | 6.17E+01 | 2.21E+01 | + | **9.42E+00** | **6.96E+00** |
| F7 | 2.35E+02 | 3.01E+01 | + | **1.32E+02** | **4.24E+01** | 4.61E+02 | 4.17E+01 | + | **3.61E+02** | **7.30E+01** | 1.13E+03 | 1.49E+02 | + | **1.07E+03** | **1.41E+02** |
| F8 | 2.11E+02 | 2.75E+01 | + | **4.93E+01** | **4.23E+01** | 4.46E+02 | 6.90E+01 | + | **2.00E+02** | **6.15E+01** | 1.07E+03 | 1.79E+02 | + | **7.98E+02** | **1.03E+02** |
| F9 | 4.62E-02 | 1.15E-01 | = | 7.81E-02 | 1.65E-01 | **1.45E+00** | **2.03E+00** | - | 4.13E+00 | 4.94E+00 | 4.62E+02 | 8.79E+02 | + | **2.02E+02** | **5.85E+02** |
| F10 | 7.31E+03 | 3.37E+02 | + | **4.20E+03** | **1.24E+03** | 1.36E+04 | 3.19E+02 | + | **9.69E+03** | **1.71E+03** | 3.04E+04 | 4.92E+02 | + | **2.78E+04** | **1.67E+03** |
| F11 | 1.25E+02 | 3.45E+01 | + | **7.87E+01** | **2.64E+01** | 2.43E+02 | 4.61E+01 | + | **1.49E+02** | **6.48E+01** | **1.57E+03** | **2.34E+02** | - | 1.93E+03 | 2.10E+02 |
| F12 | **6.28E+03** | **6.86E+03** | - | 6.78E+03 | 5.27E+03 | **1.28E+06** | **9.93E+05** | - | 1.98E+06 | 1.15E+06 | 7.68E+07 | 7.08E+07 | = | 7.75E+07 | 4.75E+07 |
| F13 | 2.51E+02 | 2.77E+02 | = | 2.13E+02 | 1.01E+02 | 5.51E+03 | 2.39E+03 | = | 4.46E+03 | 1.99E+03 | 2.61E+04 | 3.70E+03 | = | 2.57E+04 | 4.11E+03 |
| F14 | 6.69E+01 | 1.17E+01 | = | 6.34E+01 | 1.77E+01 | 1.69E+02 | 2.48E+01 | = | 1.61E+02 | 4.24E+01 | **5.53E+02** | **4.40E+01** | - | 5.92E+02 | 5.64E+01 |
| F15 | 4.95E+01 | 1.43E+01 | = | 5.30E+01 | 2.24E+01 | 4.36E+02 | 1.05E+02 | + | **3.20E+02** | **1.39E+02** | 5.48E+03 | 2.93E+03 | + | **3.83E+03** | **1.77E+03** |
| F16 | 1.42E+03 | 3.17E+02 | + | **3.33E+02** | **2.85E+02** | 3.12E+03 | 3.20E+02 | + | **7.38E+02** | **2.74E+02** | 8.45E+03 | 5.01E+02 | + | **3.47E+03** | **1.34E+03** |
| F17 | 2.46E+02 | 9.53E+01 | + | **5.15E+01** | **5.08E+01** | 1.71E+03 | 2.80E+02 | + | **4.91E+02** | **2.70E+02** | 4.90E+03 | 2.72E+02 | + | **1.61E+03** | **8.32E+02** |
| F18 | **6.13E+01** | **2.31E+01** | - | 6.92E+01 | 1.43E+01 | **3.33E+02** | **1.06E+02** | - | 3.96E+02 | 7.70E+01 | **4.29E+03** | **4.71E+03** | - | 1.14E+04 | 8.23E+03 |
| F19 | 2.73E+01 | 4.62E+00 | + | **1.85E+01** | **5.92E+00** | 8.74E+01 | 1.47E+01 | + | **4.61E+01** | **1.77E+01** | 5.62E+02 | 2.74E+02 | = | 5.40E+02 | 2.57E+02 |
| F20 | 5.00E+02 | 1.54E+02 | + | **1.37E+02** | **1.15E+02** | 1.83E+03 | 1.83E+02 | + | **2.77E+02** | **2.38E+02** | 5.31E+03 | 2.48E+02 | + | **1.89E+03** | **7.67E+02** |
| F21 | 4.33E+02 | 1.99E+01 | + | **3.31E+02** | **3.43E+01** | 6.60E+02 | 6.04E+01 | + | **4.89E+02** | **4.85E+01** | 1.35E+03 | 1.96E+02 | + | **1.11E+03** | **8.41E+01** |
| F22 | 2.55E+02 | 6.50E+02 | + | **1.39E+02** | **1.84E+01** | 1.39E+04 | 3.54E+02 | + | **4.91E+03** | **5.12E+03** | 3.17E+04 | 5.11E+02 | + | **2.58E+04** | **9.36E+03** |
| F23 | 5.81E+02 | 2.17E+01 | + | **5.06E+02** | **3.52E+01** | 9.11E+02 | 5.00E+01 | + | **7.83E+02** | **5.25E+01** | 1.72E+03 | 1.28E+02 | + | **1.49E+03** | **1.17E+02** |
| F24 | 6.42E+02 | 1.49E+01 | + | **5.78E+02** | **3.24E+01** | 9.43E+02 | 3.58E+01 | + | **8.63E+02** | **6.10E+01** | 2.06E+03 | 1.32E+02 | + | **1.95E+03** | **1.26E+02** |
| F25 | 4.42E+02 | 2.20E+01 | = | 4.37E+02 | 1.39E+01 | 6.48E+02 | 4.03E+01 | = | 6.43E+02 | 3.30E+01 | 1.44E+03 | 3.05E+02 | + | **1.31E+03** | **1.11E+02** |
| F26 | 3.17E+03 | 3.00E+02 | + | **1.79E+03** | **4.57E+02** | 5.37E+03 | 4.94E+02 | + | **3.61E+03** | **7.12E+02** | 1.41E+04 | 1.08E+03 | + | **1.26E+04** | **1.33E+03** |
| F27 | **5.92E+02** | **1.89E+01** | - | 5.97E+02 | 1.60E+01 | 8.75E+02 | 7.91E+01 | = | 8.83E+02 | 6.23E+01 | 1.18E+03 | 2.76E+02 | = | 1.14E+03 | 1.33E+02 |
| F28 | 5.31E+02 | 2.45E+01 | = | 5.30E+02 | 2.50E+01 | 6.61E+02 | 5.45E+01 | = | 6.63E+02 | 6.42E+01 | 1.95E+03 | 1.76E+03 | = | 1.46E+03 | 4.68E+02 |
| F29 | 9.65E+02 | 1.48E+02 | + | **5.77E+02** | **7.92E+01** | 1.88E+03 | 3.22E+02 | + | **6.49E+02** | **2.21E+02** | 6.31E+03 | 5.80E+02 | + | **2.92E+03** | **6.83E+02** |
| F30 | **3.81E+03** | **8.85E+02** | - | 4.40E+03 | 1.07E+03 | **1.76E+06** | **5.83E+05** | - | 1.94E+06 | 4.58E+05 | 2.85E+05 | 1.49E+05 | + | **2.05E+05** | **9.38E+04** |
| **W** | **16** | | | | | **17** | | | | | **19** | | | | |
| **T** | **8** | | | | | **6** | | | | | **6** | | | | |
| **L** | **5** | | | | | **6** | | | | | **4** | | | | |

TABLE S14 PERFORMANCE COMPARISONS OF DTDEN WITH THE RESAMPLING METHOD ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH SEVERE NOISE

| | 30-D | | | | | 50-D | | | | | 100-D | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Resampling | | | DTDEn | | Resampling | | | DTDEn | | Resampling | | | DTDEn | |
| | mean | std | sig | mean | std | mean | std | sig | mean | std | mean | std | sig | mean | std |
| F1 | 1.93E+09 | 4.54E+09 | + | **2.63E+03** | **2.10E+03** | 1.26E+10 | 1.54E+10 | + | **3.06E+04** | **2.97E+04** | 1.24E+11 | 7.66E+10 | + | **4.52E+07** | **1.35E+07** |
| F3 | **3.37E+03** | **3.22E+03** | - | 7.11E+04 | 1.05E+04 | **2.85E+04** | **1.36E+04** | - | 1.50E+05 | 1.63E+04 | **1.59E+05** | **4.04E+04** | - | 3.47E+05 | 2.26E+04 |
| F4 | 1.60E+02 | 3.74E+01 | + | **1.44E+02** | **1.08E+01** | 4.31E+02 | 1.19E+02 | + | **2.61E+02** | **1.07E+01** | 2.75E+03 | 7.75E+03 | + | **5.72E+02** | **2.39E+01** |
| F5 | 2.89E+02 | 2.72E+01 | + | **9.79E+01** | **2.95E+01** | 6.15E+02 | 4.80E+01 | + | **3.16E+02** | **4.32E+01** | 1.60E+03 | 1.05E+02 | + | **9.13E+02** | **2.98E+01** |
| F6 | 5.15E+01 | 1.07E+01 | + | **2.59E-01** | **1.21E-01** | 8.01E+01 | 6.96E+00 | + | **1.92E+00** | **5.19E-01** | 1.07E+02 | 6.03E+00 | + | **1.36E+01** | **1.92E+00** |
| F7 | 3.70E+02 | 9.47E+01 | + | **1.85E+02** | **2.61E+01** | 1.06E+03 | 4.65E+02 | + | **4.24E+02** | **2.58E+01** | 2.83E+03 | 1.01E+03 | + | **1.14E+03** | **3.53E+01** |
| F8 | 2.91E+02 | 2.24E+01 | + | **9.77E+01** | **3.00E+01** | 6.18E+02 | 5.69E+01 | + | **3.16E+02** | **4.13E+01** | 1.62E+03 | 1.18E+02 | + | **9.11E+02** | **3.43E+01** |
| F9 | 6.55E+02 | 1.11E+03 | + | **1.93E-02** | **4.63E-02** | 4.52E+03 | 5.38E+03 | + | **6.09E-01** | **2.28E-01** | 5.00E+04 | 2.76E+04 | + | **1.91E+01** | **6.49E+00** |
| F10 | 7.31E+03 | 2.41E+02 | + | **5.33E+03** | **8.35E+02** | 1.36E+04 | 3.24E+02 | + | **1.18E+04** | **7.52E+02** | 3.05E+04 | 5.07E+02 | + | **2.88E+04** | **6.22E+02** |
| F11 | **2.18E+02** | **5.54E+01** | - | 2.52E+03 | 1.33E+03 | **4.89E+02** | **4.25E+02** | - | 7.58E+03 | 2.79E+03 | **5.15E+03** | **6.27E+03** | - | 1.05E+05 | 1.87E+04 |
| F12 | 4.36E+06 | 1.24E+07 | = | 7.69E+05 | 4.07E+05 | 1.06E+08 | 3.56E+08 | + | **3.27E+06** | **1.31E+06** | 1.06E+10 | 2.12E+10 | + | **3.20E+07** | **9.55E+06** |
| F13 | **5.77E+03** | **7.35E+03** | - | 9.11E+03 | 4.61E+03 | 3.48E+05 | 2.03E+06 | + | **1.85E+03** | **1.07E+03** | 2.77E+08 | 9.07E+08 | + | **6.94E+03** | **1.22E+03** |
| F14 | **1.13E+02** | **2.26E+01** | - | 2.66E+05 | 1.46E+05 | **2.93E+02** | **4.48E+01** | - | 3.43E+05 | 2.18E+05 | **1.91E+04** | **3.93E+04** | - | 2.00E+06 | 4.00E+05 |
| F15 | **2.85E+02** | **1.06E+02** | - | 9.45E+02 | 1.24E+03 | 2.57E+03 | 2.65E+03 | = | 2.03E+03 | 1.08E+03 | 1.49E+06 | 6.84E+06 | + | **1.04E+03** | **3.49E+02** |
| F16 | 1.78E+03 | 1.76E+02 | + | **4.91E+02** | **2.73E+02** | 3.69E+03 | 3.08E+02 | + | **9.49E+02** | **2.91E+02** | 9.46E+03 | 5.38E+02 | + | **5.16E+03** | **1.10E+03** |
| F17 | 5.84E+02 | 1.05E+02 | + | **7.38E+01** | **6.80E+01** | 2.01E+03 | 2.00E+02 | + | **7.23E+02** | **3.03E+02** | 5.17E+03 | 3.00E+02 | + | **2.86E+03** | **8.25E+02** |
| F18 | **2.16E+02** | **6.86E+01** | - | 4.80E+05 | 3.86E+05 | **4.84E+03** | **7.35E+03** | - | 1.87E+06 | 5.68E+05 | **1.01E+05** | **5.16E+04** | - | 1.80E+06 | 3.82E+05 |
| F19 | **6.48E+01** | **2.02E+01** | - | 3.04E+03 | 2.21E+03 | **1.02E+04** | **5.79E+04** | - | 1.36E+04 | 2.75E+03 | 3.40E+06 | 1.35E+07 | + | **9.33E+02** | **5.21E+02** |
| F20 | 7.59E+02 | 1.16E+02 | + | **2.49E+02** | **9.86E+01** | 1.94E+03 | 1.16E+02 | + | **2.88E+02** | **1.43E+02** | 5.40E+03 | 1.82E+02 | + | **3.08E+03** | **7.93E+02** |
| F21 | 4.74E+02 | 2.11E+01 | + | **3.66E+02** | **1.78E+01** | 7.96E+02 | 3.99E+01 | + | **5.49E+02** | **2.69E+01** | 1.77E+03 | 1.57E+02 | + | **1.15E+03** | **3.35E+01** |
| F22 | 2.68E+03 | 1.49E+03 | + | **1.38E+02** | **4.49E+00** | 1.41E+04 | 2.91E+02 | + | **1.03E+03** | **2.73E+03** | 3.16E+04 | 6.12E+02 | + | **1.28E+04** | **1.30E+04** |
| F23 | 6.36E+02 | 4.18E+01 | + | **5.38E+02** | **2.21E+01** | 1.07E+03 | 8.37E+01 | + | **8.25E+02** | **2.81E+01** | 2.11E+03 | 2.25E+02 | + | **1.56E+03** | **4.83E+01** |
| F24 | 6.81E+02 | 3.61E+01 | + | **6.00E+02** | **2.11E+01** | 1.09E+03 | 1.00E+02 | + | **8.70E+02** | **2.67E+01** | 2.97E+03 | 7.04E+02 | + | **1.92E+03** | **4.21E+01** |
| F25 | 4.94E+02 | 4.20E+01 | + | **4.47E+02** | **1.38E+01** | 9.06E+02 | 2.64E+02 | + | **6.65E+02** | **1.54E+01** | 3.56E+03 | 2.37E+03 | + | **1.33E+03** | **4.73E+01** |
| F26 | 3.94E+03 | 3.33E+02 | + | **2.44E+03** | **2.99E+02** | 6.81E+03 | 6.59E+02 | + | **4.54E+03** | **3.76E+02** | 1.97E+04 | 4.61E+03 | + | **1.36E+04** | **5.90E+02** |
| F27 | 6.36E+02 | 3.37E+01 | + | **6.17E+02** | **1.53E+01** | 1.21E+03 | 1.94E+02 | + | **9.50E+02** | **3.95E+01** | 2.37E+03 | 6.70E+02 | + | **1.19E+03** | **5.43E+01** |
| F28 | 6.92E+02 | 2.56E+02 | + | **5.42E+02** | **1.95E+01** | 2.17E+03 | 1.17E+03 | + | **8.38E+02** | **7.18E+01** | 1.26E+04 | 5.59E+03 | + | **1.51E+03** | **1.62E+02** |
| F29 | 1.32E+03 | 1.51E+02 | + | **7.13E+02** | **1.32E+02** | 2.41E+03 | 2.80E+02 | + | **8.57E+02** | **2.38E+02** | 7.05E+03 | 5.82E+02 | + | **3.66E+03** | **6.71E+02** |
| F30 | 1.16E+04 | 1.02E+04 | + | **7.62E+03** | **3.44E+03** | 2.98E+07 | 3.89E+07 | + | **2.03E+06** | **2.08E+05** | 2.66E+08 | 1.10E+09 | + | **5.88E+04** | **2.35E+04** |
| **W** | **21** | | | | | **23** | | | | | **25** | | | | |
| **T** | **1** | | | | | **1** | | | | | **0** | | | | |
| **L** | **7** | | | | | **5** | | | | | **4** | | | | |

TABLE S15 PERFORMANCE COMPARISONS OF DTDEN WITH STATE-OF-THE-ART DES ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH SLIGHT NOISE

| | 30-D | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | EaDE | | | jSO | | | L-SHADE-RSP | | | DTDEn | |
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 1.40E+03 | 1.70E+03 | = | **0.00E+00** | **0.00E+00** | - | **0.00E+00** | **0.00E+00** | - | 1.55E+03 | 1.61E+03 |
| F3 | **0.00E+00** | **0.00E+00** | = | **0.00E+00** | **0.00E+00** | = | **0.00E+00** | **0.00E+00** | = | **0.00E+00** | **0.00E+00** |
| F4 | 9.11E+01 | 1.24E+00 | = | 9.11E+01 | 1.38E+00 | = | **9.05E+01** | **1.14E+00** | - | 9.14E+01 | 2.34E+00 |
| F5 | 3.04E+01 | 1.63E+01 | + | 6.12E+01 | 3.24E+01 | + | 6.78E+01 | 2.98E+01 | + | **2.70E+00** | **1.67E+00** |
| F6 | 8.75E-08 | 3.62E-07 | + | 6.17E-07 | 9.42E-07 | + | 2.27E-07 | 5.80E-07 | + | **9.50E-09** | **3.70E-08** |
| F7 | 7.73E+01 | 2.26E+01 | + | 1.20E+02 | 2.21E+01 | + | 1.29E+02 | 1.90E+01 | + | **3.57E+01** | **1.38E+00** |
| F8 | 2.62E+01 | 1.49E+01 | + | 5.38E+01 | 2.83E+01 | + | 6.64E+01 | 2.64E+01 | + | **2.68E+00** | **1.78E+00** |
| F9 | **0.00E+00** | **0.00E+00** | = | **0.00E+00** | **0.00E+00** | = | **0.00E+00** | **0.00E+00** | = | **0.00E+00** | **0.00E+00** |
| F10 | 4.92E+03 | 1.30E+03 | + | 5.95E+03 | 5.61E+02 | + | 6.17E+03 | 5.91E+02 | + | **1.74E+02** | **1.78E+02** |
| F11 | 3.53E+01 | 3.26E+01 | + | **9.35E+00** | **1.38E+01** | = | 1.49E+01 | 2.19E+01 | = | 2.53E+01 | 2.85E+01 |
| F12 | 5.53E+02 | 2.63E+02 | = | 2.06E+02 | 1.32E+02 | - | **1.73E+02** | **1.12E+02** | - | 6.15E+02 | 2.88E+02 |
| F13 | 3.31E+01 | 1.21E+01 | + | 2.96E+01 | 1.33E+01 | + | 3.25E+01 | 7.58E+00 | + | **2.16E+01** | **9.89E+00** |
| F14 | 2.61E+01 | 3.51E+00 | = | 2.64E+01 | 2.81E+00 | = | 2.60E+01 | 2.77E+00 | = | **2.55E+01** | **3.46E+00** |
| F15 | 7.54E+00 | 1.56E+00 | = | 6.64E+00 | 1.25E+00 | - | **5.99E+00** | **7.83E-01** | - | 7.77E+00 | 1.29E+00 |
| F16 | 2.39E+02 | 1.83E+02 | + | 1.87E+02 | 1.66E+02 | + | 8.90E+01 | 8.75E+01 | + | **1.48E+01** | **1.77E+00** |
| F17 | 6.90E+01 | 2.06E+01 | + | 9.59E+01 | 1.66E+01 | + | 9.13E+01 | 1.38E+01 | + | **2.17E+01** | **5.96E+00** |
| F18 | 2.28E+01 | 1.12E+00 | - | **2.12E+01** | **8.28E-01** | - | 2.17E+01 | 4.40E-01 | - | 2.89E+01 | 2.71E+00 |
| F19 | 1.09E+01 | 2.96E+00 | + | 9.53E+00 | 2.98E+00 | + | 7.47E+00 | 2.63E+00 | + | **5.58E+00** | **1.64E+00** |
| F20 | 6.92E+01 | 4.76E+01 | + | 9.02E+01 | 2.07E+01 | + | 7.40E+01 | 2.14E+01 | + | **2.10E+01** | **4.05E+00** |
| F21 | 3.00E+02 | 2.44E+01 | + | 3.29E+02 | 1.38E+01 | + | 3.24E+02 | 1.56E+01 | + | **2.10E+02** | **2.51E+00** |
| F22 | 1.14E+02 | 2.05E+00 | + | 1.14E+02 | 1.86E+00 | + | 1.15E+02 | 3.00E+00 | + | **1.12E+02** | **2.68E+00** |
| F23 | 4.88E+02 | 2.46E+01 | + | 5.00E+02 | 1.49E+01 | + | 5.04E+02 | 1.72E+01 | + | **3.57E+02** | **7.93E+00** |
| F24 | 5.76E+02 | 2.23E+01 | + | 5.78E+02 | 1.73E+01 | + | 5.79E+02 | 1.37E+01 | + | **4.31E+02** | **4.71E+00** |
| F25 | 3.96E+02 | 5.77E+00 | = | 3.97E+02 | 4.96E+00 | + | **3.94E+02** | **2.34E+00** | = | 3.96E+02 | 4.92E+00 |
| F26 | 1.57E+03 | 3.16E+02 | + | 1.82E+03 | 2.81E+02 | + | 1.87E+03 | 1.90E+02 | + | **8.71E+02** | **5.58E+01** |
| F27 | 5.40E+02 | 8.50E+00 | + | 5.49E+02 | 9.74E+00 | + | 5.43E+02 | 6.85E+00 | + | **5.29E+02** | **7.65E+00** |
| F28 | 4.52E+02 | 1.57E+01 | - | 4.57E+02 | 1.75E+01 | = | **4.51E+02** | **1.48E+01** | - | 4.58E+02 | 1.47E+01 |
| F29 | 5.71E+02 | 2.93E+01 | + | 6.38E+02 | 3.64E+01 | + | 5.95E+02 | 3.38E+01 | + | **4.27E+02** | **7.25E+00** |
| F30 | **2.15E+03** | **8.41E+01** | - | 2.18E+03 | 7.29E+01 | - | **2.15E+03** | **8.24E+01** | - | 2.24E+03 | 1.03E+02 |
| **W** | **18** | | | **18** | | | **17** | | | | |
| **T** | **8** | | | **6** | | | **5** | | | | |
| **L** | **3** | | | **5** | | | **7** | | | | |

TABLE S15 (CONTINUED) PERFORMANCE COMPARISONS OF DTDEN WITH STATE-OF-THE-ART DES ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH SLIGHT NOISE

50-D

| | EaDE | | | jSO | | | L-SHADE-RSP | | | DTDEn | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 2.98E+03 | 1.65E+03 | = | 2.92E+03 | 2.38E+03 | - | **2.68E+03** | **2.67E+03** | - | 3.72E+03 | 2.16E+03 |
| F3 | **7.05E-10** | **3.53E-09** | - | 1.41E-06 | 5.15E-06 | + | 1.34E-08 | 3.69E-08 | = | 4.81E-09 | 1.26E-08 |
| F4 | 2.02E+02 | 3.87E+01 | = | **1.65E+02** | **4.42E+01** | - | 1.74E+02 | 4.49E+01 | - | 2.03E+02 | 3.77E+01 |
| F5 | 1.64E+02 | 4.84E+01 | + | 2.31E+02 | 3.20E+01 | + | 2.38E+02 | 3.43E+01 | + | **6.05E+00** | **2.79E+00** |
| F6 | 5.53E-05 | 3.83E-04 | + | 1.48E-05 | 1.45E-05 | + | 6.38E-06 | 5.46E-06 | + | **5.74E-08** | **1.66E-07** |
| F7 | 2.56E+02 | 4.10E+01 | + | 3.00E+02 | 2.38E+01 | + | 3.05E+02 | 2.06E+01 | + | **6.15E+01** | **1.82E+00** |
| F8 | 1.71E+02 | 5.66E+01 | + | 2.38E+02 | 2.51E+01 | + | 2.39E+02 | 2.80E+01 | + | **5.69E+00** | **2.24E+00** |
| F9 | **0.00E+00** | **0.00E+00** | = | **0.00E+00** | **0.00E+00** | = | **0.00E+00** | **0.00E+00** | = | **0.00E+00** | **0.00E+00** |
| F10 | 1.20E+04 | 1.11E+03 | + | 1.25E+04 | 6.17E+02 | + | 1.24E+04 | 6.64E+02 | + | **4.46E+02** | **3.29E+02** |
| F11 | 5.21E+01 | 1.41E+01 | + | 5.26E+01 | 1.05E+01 | + | 4.40E+01 | 8.96E+00 | + | **2.97E+01** | **2.96E+00** |
| F12 | 8.83E+03 | 6.42E+03 | = | 2.97E+03 | 1.58E+03 | - | **2.16E+03** | **5.47E+02** | - | 1.03E+04 | 9.92E+03 |
| F13 | 1.91E+02 | 3.56E+01 | + | 1.62E+02 | 4.27E+01 | + | 1.55E+02 | 5.43E+01 | + | **1.03E+02** | **3.75E+01** |
| F14 | 4.43E+01 | 1.22E+01 | + | 4.23E+01 | 1.06E+01 | + | 4.17E+01 | 1.06E+01 | + | **2.80E+01** | **2.62E+00** |
| F15 | 4.59E+01 | 1.25E+01 | + | 3.51E+01 | 6.45E+00 | + | **2.81E+01** | **4.69E+00** | = | 2.82E+01 | 5.17E+00 |
| F16 | 1.01E+03 | 3.47E+02 | + | 1.10E+03 | 3.07E+02 | + | 9.86E+02 | 3.55E+02 | + | **1.61E+02** | **9.25E+01** |
| F17 | 5.69E+02 | 2.32E+02 | + | 6.71E+02 | 2.28E+02 | + | 6.53E+02 | 2.06E+02 | + | **8.44E+01** | **7.92E+01** |
| F18 | 4.09E+01 | 8.98E+00 | - | 3.05E+01 | 4.65E+00 | - | **2.58E+01** | **2.23E+00** | - | 4.53E+01 | 1.01E+01 |
| F19 | 2.84E+01 | 4.15E+00 | + | 2.43E+01 | 5.06E+00 | + | 1.95E+01 | 4.09E+00 | + | **1.11E+01** | **2.56E+00** |
| F20 | 5.04E+02 | 2.89E+02 | + | 5.09E+02 | 2.01E+02 | + | 4.98E+02 | 1.88E+02 | + | **2.98E+01** | **3.14E+01** |
| F21 | 4.54E+02 | 3.50E+01 | + | 4.83E+02 | 2.64E+01 | + | 4.87E+02 | 1.78E+01 | + | **2.17E+02** | **6.83E+00** |
| F22 | 1.12E+04 | 3.84E+03 | + | 9.53E+03 | 5.55E+03 | + | 1.01E+04 | 5.33E+03 | + | **7.29E+02** | **8.19E+02** |
| F23 | 7.22E+02 | 4.10E+01 | + | 7.36E+02 | 3.05E+01 | + | 7.49E+02 | 2.91E+01 | + | **4.46E+02** | **1.52E+01** |
| F24 | 8.10E+02 | 3.18E+01 | + | 8.09E+02 | 2.80E+01 | + | 8.18E+02 | 2.26E+01 | + | **5.21E+02** | **1.20E+01** |
| F25 | 5.62E+02 | 1.26E+01 | = | 5.66E+02 | 1.12E+01 | + | **5.58E+02** | **1.05E+01** | = | 5.59E+02 | 5.67E+00 |
| F26 | 3.13E+03 | 6.50E+02 | + | 3.47E+03 | 2.50E+02 | + | 3.49E+03 | 3.10E+02 | + | **9.85E+02** | **7.69E+01** |
| F27 | 6.19E+02 | 4.64E+01 | + | 6.36E+02 | 5.41E+01 | + | 6.15E+02 | 4.47E+01 | + | **5.81E+02** | **3.77E+01** |
| F28 | 5.24E+02 | 2.38E+01 | = | 5.18E+02 | 2.37E+01 | = | **5.12E+02** | **1.91E+01** | = | 5.16E+02 | 2.26E+01 |
| F29 | 6.45E+02 | 7.42E+01 | + | 7.55E+02 | 8.94E+01 | + | 7.11E+02 | 6.76E+01 | + | **3.24E+02** | **9.85E+00** |
| F30 | 7.50E+05 | 1.27E+05 | = | 7.37E+05 | 7.00E+04 | = | **6.86E+05** | **5.10E+04** | - | 7.40E+05 | 8.15E+04 |
| **W** | **20** | | | **22** | | | **19** | | | | |
| **T** | **7** | | | **3** | | | **5** | | | | |
| **L** | **2** | | | **4** | | | **5** | | | | |

TABLE S15 (CONTINUED) PERFORMANCE COMPARISONS OF DTDEN WITH STATE-OF-THE-ART DES ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH SLIGHT NOISE

100-D

| | EaDE | | | jSO | | | L-SHADE-RSP | | | DTDEn | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 4.38E+03 | 3.23E+03 | = | 5.07E+03 | 4.12E+03 | + | 4.80E+03 | 4.16E+03 | = | **3.16E+03** | **2.18E+03** |
| F3 | 3.69E+02 | 2.82E+02 | - | 1.45E+03 | 9.66E+02 | + | **9.91E+01** | **1.18E+02** | - | 7.20E+02 | 5.09E+02 |
| F4 | 2.94E+02 | 1.88E+01 | + | 3.07E+02 | 1.98E+01 | + | **2.86E+02** | **1.14E+01** | = | **2.86E+02** | **1.56E+01** |
| F5 | 6.24E+02 | 9.83E+01 | + | 6.85E+02 | 3.31E+01 | + | 6.71E+02 | 2.92E+01 | + | **2.23E+01** | **5.92E+00** |
| F6 | 6.72E-03 | 5.30E-03 | + | 2.82E-02 | 2.57E-02 | + | 6.23E-03 | 6.41E-03 | + | **2.55E-03** | **2.25E-03** |
| F7 | 7.66E+02 | 5.75E+01 | + | 7.93E+02 | 2.89E+01 | + | 7.88E+02 | 4.10E+01 | + | **1.46E+02** | **9.02E+00** |
| F8 | 6.29E+02 | 5.65E+01 | + | 6.89E+02 | 3.04E+01 | + | 6.75E+02 | 3.23E+01 | + | **2.29E+01** | **7.23E+00** |
| F9 | 6.98E-02 | 1.38E-01 | = | 6.94E-02 | 1.56E-01 | = | **0.00E+00** | **0.00E+00** | - | 6.04E-02 | 1.24E-01 |
| F10 | 2.97E+04 | 5.79E+02 | + | 2.98E+04 | 4.64E+02 | + | 2.96E+04 | 5.58E+02 | + | **3.72E+03** | **1.90E+03** |
| F11 | 5.80E+02 | 1.63E+02 | + | 5.24E+02 | 1.27E+02 | + | 4.02E+02 | 1.14E+02 | = | **3.96E+02** | **7.71E+01** |
| F12 | 6.61E+05 | 4.31E+05 | = | 3.20E+05 | 1.55E+05 | - | **2.20E+05** | **1.14E+05** | - | 6.68E+05 | 3.72E+05 |
| F13 | 6.05E+03 | 1.54E+03 | + | 3.72E+03 | 1.04E+03 | - | **2.26E+03** | **1.16E+03** | - | 5.05E+03 | 1.30E+03 |
| F14 | 2.11E+02 | 7.51E+01 | + | 1.96E+02 | 5.84E+01 | + | 1.21E+02 | 4.81E+01 | + | **7.61E+01** | **2.01E+01** |
| F15 | 5.54E+02 | 9.17E+01 | + | 4.94E+02 | 6.33E+01 | = | **4.14E+02** | **7.20E+01** | - | 5.09E+02 | 7.40E+01 |
| F16 | 4.78E+03 | 5.50E+02 | + | 5.39E+03 | 5.57E+02 | + | 5.16E+03 | 5.42E+02 | + | **3.66E+02** | **1.80E+02** |
| F17 | 2.60E+03 | 4.80E+02 | + | 2.92E+03 | 4.09E+02 | + | 2.79E+03 | 4.41E+02 | + | **9.48E+01** | **9.40E+01** |
| F18 | 4.23E+02 | 6.32E+01 | = | 3.57E+02 | 5.01E+01 | - | **3.22E+02** | **5.00E+01** | - | 4.10E+02 | 7.21E+01 |
| F19 | 1.91E+02 | 2.79E+01 | + | 1.39E+02 | 2.19E+01 | - | **1.04E+02** | **2.01E+01** | - | 1.71E+02 | 2.94E+01 |
| F20 | 3.22E+03 | 5.54E+02 | + | 3.29E+03 | 3.58E+02 | + | 3.20E+03 | 3.79E+02 | + | **1.92E+02** | **7.08E+01** |
| F21 | 9.10E+02 | 5.53E+01 | + | 9.60E+02 | 4.43E+01 | + | 9.38E+02 | 3.77E+01 | + | **2.73E+02** | **2.64E+01** |
| F22 | 3.07E+04 | 7.47E+02 | + | 3.07E+04 | 5.19E+02 | + | 3.07E+04 | 6.02E+02 | + | **5.10E+03** | **2.32E+03** |
| F23 | 1.25E+03 | 1.17E+02 | + | 1.34E+03 | 5.31E+01 | + | 1.32E+03 | 5.85E+01 | + | **6.06E+02** | **4.33E+01** |
| F24 | 1.66E+03 | 4.50E+01 | + | 1.69E+03 | 7.06E+01 | + | 1.68E+03 | 5.21E+01 | + | **9.91E+02** | **5.36E+01** |
| F25 | 1.00E+03 | 5.30E+01 | = | 1.03E+03 | 5.04E+01 | + | **9.80E+02** | **6.33E+01** | = | 9.83E+02 | 3.86E+01 |
| F26 | 9.93E+03 | 8.90E+02 | + | 1.01E+04 | 4.80E+02 | + | 1.01E+04 | 3.72E+02 | + | **3.09E+03** | **1.60E+02** |
| F27 | 7.32E+02 | 2.91E+01 | + | 7.56E+02 | 3.81E+01 | + | 7.21E+02 | 3.23E+01 | + | **7.05E+02** | **2.25E+01** |
| F28 | 7.36E+02 | 3.19E+01 | + | 7.51E+02 | 4.66E+01 | + | **7.11E+02** | **4.10E+01** | = | **7.11E+02** | **3.10E+01** |
| F29 | 3.24E+03 | 5.48E+02 | + | 3.67E+03 | 4.23E+02 | + | 3.55E+03 | 3.92E+02 | + | **9.98E+02** | **1.93E+02** |
| F30 | 7.94E+03 | 2.05E+03 | + | 5.46E+03 | 1.14E+03 | - | **4.70E+03** | **5.48E+02** | - | 6.81E+03 | 1.52E+03 |
| **W** | **23** | | | **22** | | | **16** | | | | |
| **T** | **5** | | | **2** | | | **5** | | | | |
| **L** | **1** | | | **5** | | | **8** | | | | |

TABLE S16 PERFORMANCE COMPARISONS OF DTDEN WITH STATE-OF-THE-ART DES ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH MODERATE NOISE

30-D

| | EaDE | | | jSO | | | L-SHADE-RSP | | | DTDEn | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | **1.90E+03** | **2.08E+03** | = | 1.88E+04 | 9.47E+04 | = | 2.15E+03 | 1.72E+03 | = | 2.37E+03 | 2.37E+03 |
| F3 | 4.89E-01 | 2.02E+00 | - | 1.53E+01 | 4.27E+01 | = | **3.41E-01** | **2.09E+00** | - | 4.92E+00 | 1.51E+01 |
| F4 | 1.19E+02 | 1.38E+01 | + | 1.28E+02 | 2.02E+01 | + | 1.19E+02 | 1.30E+01 | + | **1.12E+02** | **9.05E+00** |
| F5 | 2.11E+02 | 2.74E+01 | + | 2.13E+02 | 2.54E+01 | + | 2.09E+02 | 2.15E+01 | + | **4.81E+01** | **3.78E+01** |
| F6 | 1.19E+01 | 1.23E+01 | + | 1.35E+01 | 8.80E+00 | + | 1.14E+01 | 9.94E+00 | + | **1.26E-01** | **3.44E-01** |
| F7 | 2.42E+02 | 2.80E+01 | + | 2.44E+02 | 3.17E+01 | + | 2.37E+02 | 2.80E+01 | + | **1.32E+02** | **4.24E+01** |
| F8 | 2.01E+02 | 2.22E+01 | + | 2.12E+02 | 2.38E+01 | + | 2.02E+02 | 1.99E+01 | + | **4.93E+01** | **4.23E+01** |
| F9 | 1.37E-01 | 2.97E-01 | = | 1.75E+00 | 1.17E+01 | + | 7.96E-02 | 1.69E-01 | = | **7.81E-02** | **1.65E-01** |
| F10 | 7.14E+03 | 2.38E+02 | + | 7.05E+03 | 2.76E+02 | + | 7.11E+03 | 2.51E+02 | + | **4.20E+03** | **1.24E+03** |
| F11 | 1.37E+02 | 3.56E+01 | + | 1.39E+02 | 3.12E+01 | + | 1.36E+02 | 2.03E+01 | + | **7.87E+01** | **2.64E+01** |
| F12 | **6.22E+03** | **3.72E+03** | = | 8.51E+03 | 6.10E+03 | + | 6.59E+03 | 5.08E+03 | = | 6.78E+03 | 5.27E+03 |
| F13 | 1.94E+02 | 1.17E+02 | = | 2.13E+02 | 1.56E+02 | = | **1.44E+02** | **5.36E+01** | - | 2.13E+02 | 1.01E+02 |
| F14 | 7.30E+01 | 1.17E+01 | + | 7.29E+01 | 1.21E+01 | + | 6.92E+01 | 1.07E+01 | = | **6.34E+01** | **1.77E+01** |
| F15 | 6.09E+01 | 2.72E+01 | = | 5.23E+01 | 2.16E+01 | = | **4.92E+01** | **2.29E+01** | = | 5.30E+01 | 2.24E+01 |
| F16 | 1.47E+03 | 2.52E+02 | + | 1.47E+03 | 1.82E+02 | + | 1.41E+03 | 2.05E+02 | + | **3.33E+02** | **2.85E+02** |
| F17 | 2.87E+02 | 1.39E+02 | + | 3.14E+02 | 1.07E+02 | + | 2.97E+02 | 1.14E+02 | + | **5.15E+01** | **5.08E+01** |
| F18 | 6.54E+01 | 2.68E+01 | - | 5.32E+01 | 1.56E+01 | - | **4.75E+01** | **1.47E+01** | - | 6.92E+01 | 1.43E+01 |
| F19 | 3.01E+01 | 4.87E+00 | + | 2.82E+01 | 4.24E+00 | + | 2.93E+01 | 4.29E+00 | + | **1.85E+01** | **5.92E+00** |
| F20 | 5.11E+02 | 1.61E+02 | + | 5.69E+02 | 1.44E+02 | + | 5.26E+02 | 1.19E+02 | + | **1.37E+02** | **1.15E+02** |
| F21 | 4.23E+02 | 1.89E+01 | + | 4.14E+02 | 2.01E+01 | + | 4.06E+02 | 1.49E+01 | + | **3.31E+02** | **3.43E+01** |
| F22 | 1.63E+02 | 5.29E+01 | + | 2.97E+02 | 7.09E+02 | + | 1.54E+02 | 6.31E+01 | = | **1.39E+02** | **1.84E+01** |
| F23 | 5.85E+02 | 1.88E+01 | + | 5.86E+02 | 2.25E+01 | + | 5.67E+02 | 2.32E+01 | + | **5.06E+02** | **3.52E+01** |
| F24 | 6.41E+02 | 1.77E+01 | + | 6.43E+02 | 2.23E+01 | + | 6.22E+02 | 1.81E+01 | + | **5.78E+02** | **3.24E+01** |
| F25 | 4.46E+02 | 2.70E+01 | = | 4.53E+02 | 2.20E+01 | + | 4.48E+02 | 2.02E+01 | + | **4.37E+02** | **1.39E+01** |
| F26 | 3.25E+03 | 2.68E+02 | + | 3.30E+03 | 2.30E+02 | + | 3.20E+03 | 2.36E+02 | + | **1.79E+03** | **4.57E+02** |
| F27 | 6.00E+02 | 2.29E+01 | = | 6.16E+02 | 2.45E+01 | + | **5.85E+02** | **1.49E+01** | - | 5.97E+02 | 1.60E+01 |
| F28 | 5.38E+02 | 2.37E+01 | = | 5.44E+02 | 3.40E+01 | = | 5.46E+02 | 3.23E+01 | + | **5.30E+02** | **2.50E+01** |
| F29 | 1.05E+03 | 1.44E+02 | + | 1.10E+03 | 1.27E+02 | + | 1.03E+03 | 9.26E+01 | + | **5.77E+02** | **7.92E+01** |
| F30 | 3.76E+03 | 8.84E+02 | - | 3.92E+03 | 7.53E+02 | - | **3.67E+03** | **7.51E+02** | - | 4.40E+03 | 1.07E+03 |
| **W** | **18** | | | **22** | | | **18** | | | | |
| **T** | **8** | | | **5** | | | **6** | | | | |
| **L** | **3** | | | **2** | | | **5** | | | | |

TABLE S16 (CONTINUED) PERFORMANCE COMPARISONS OF DTDEN WITH STATE-OF-THE-ART DES ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH MODERATE NOISE

50-D

| | EaDE | | | jSO | | | L-SHADE-RSP | | | DTDEn | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | **2.06E+06** | **5.99E+06** | - | 2.46E+08 | 1.18E+09 | + | 9.70E+07 | 4.18E+08 | - | 2.08E+06 | 3.83E+06 |
| F3 | 1.31E+03 | 1.74E+03 | - | 5.34E+03 | 5.57E+03 | = | **6.46E+02** | **7.92E+02** | - | 4.58E+03 | 3.58E+03 |
| F4 | 2.94E+02 | 4.05E+01 | + | 3.14E+02 | 4.51E+01 | + | 2.89E+02 | 3.49E+01 | + | **2.66E+02** | **1.49E+01** |
| F5 | 4.33E+02 | 4.83E+01 | + | 4.38E+02 | 4.58E+01 | + | 4.21E+02 | 4.53E+01 | + | **1.91E+02** | **6.72E+01** |
| F6 | 2.38E+01 | 1.46E+01 | + | 3.53E+01 | 1.62E+01 | + | 2.67E+01 | 1.78E+01 | + | **1.18E+00** | **1.64E+00** |
| F7 | 4.86E+02 | 1.20E+02 | + | 4.93E+02 | 1.14E+02 | + | 4.94E+02 | 1.11E+02 | + | **3.61E+02** | **7.30E+01** |
| F8 | 4.22E+02 | 5.23E+01 | + | 4.44E+02 | 5.08E+01 | + | 4.30E+02 | 5.08E+01 | + | **2.00E+02** | **6.15E+01** |
| F9 | 5.42E+00 | 1.52E+01 | = | 1.31E+02 | 7.30E+02 | + | 3.22E+01 | 2.10E+02 | = | **4.13E+00** | **4.94E+00** |
| F10 | 1.34E+04 | 3.19E+02 | + | 1.33E+04 | 3.84E+02 | + | 1.33E+04 | 3.26E+02 | + | **9.69E+03** | **1.71E+03** |
| F11 | 2.66E+02 | 5.79E+01 | + | 2.71E+02 | 4.98E+01 | + | 2.37E+02 | 4.64E+01 | + | **1.49E+02** | **6.48E+01** |
| F12 | 1.83E+06 | 1.16E+06 | = | 2.16E+06 | 9.27E+05 | = | **1.73E+06** | **1.07E+06** | = | 1.98E+06 | 1.15E+06 |
| F13 | 5.31E+03 | 2.08E+03 | = | 7.53E+03 | 2.91E+03 | + | 5.42E+03 | 2.64E+03 | = | **4.46E+03** | **1.99E+03** |
| F14 | 1.72E+02 | 2.44E+01 | = | 1.71E+02 | 2.86E+01 | = | **1.58E+02** | **2.70E+01** | = | 1.61E+02 | 4.24E+01 |
| F15 | 4.31E+02 | 9.24E+01 | + | 4.45E+02 | 1.14E+02 | + | 3.96E+02 | 1.19E+02 | + | **3.20E+02** | **1.39E+02** |
| F16 | 3.15E+03 | 2.94E+02 | + | 3.07E+03 | 2.60E+02 | + | 2.99E+03 | 2.42E+02 | + | **7.38E+02** | **2.74E+02** |
| F17 | 1.77E+03 | 1.58E+02 | + | 1.78E+03 | 1.92E+02 | + | 1.81E+03 | 1.89E+02 | + | **4.91E+02** | **2.70E+02** |
| F18 | 3.13E+02 | 9.30E+01 | - | 3.40E+02 | 9.52E+01 | - | **2.87E+02** | **6.74E+01** | - | 3.96E+02 | 7.70E+01 |
| F19 | 8.92E+01 | 1.58E+01 | + | 8.84E+01 | 1.38E+01 | + | 8.08E+01 | 1.31E+01 | + | **4.61E+01** | **1.77E+01** |
| F20 | 1.71E+03 | 1.51E+02 | + | 1.68E+03 | 1.48E+02 | + | 1.64E+03 | 1.53E+02 | + | **2.77E+02** | **2.38E+02** |
| F21 | 6.51E+02 | 4.83E+01 | + | 6.60E+02 | 4.53E+01 | + | 6.30E+02 | 3.94E+01 | + | **4.89E+02** | **4.85E+01** |
| F22 | 1.37E+04 | 3.20E+02 | + | 1.36E+04 | 3.99E+02 | + | 1.34E+04 | 4.59E+02 | + | **4.91E+03** | **5.12E+03** |
| F23 | 9.33E+02 | 6.17E+01 | + | 9.41E+02 | 4.44E+01 | + | 8.92E+02 | 4.51E+01 | + | **7.83E+02** | **5.25E+01** |
| F24 | 9.62E+02 | 5.59E+01 | + | 9.85E+02 | 5.37E+01 | + | 9.18E+02 | 3.14E+01 | + | **8.63E+02** | **6.10E+01** |
| F25 | 6.72E+02 | 4.02E+01 | + | 6.84E+02 | 4.37E+01 | + | 6.73E+02 | 4.03E+01 | + | **6.43E+02** | **3.30E+01** |
| F26 | 5.62E+03 | 5.11E+02 | + | 5.72E+03 | 6.48E+02 | + | 5.41E+03 | 4.08E+02 | + | **3.61E+03** | **7.12E+02** |
| F27 | 9.14E+02 | 1.06E+02 | = | 1.04E+03 | 1.34E+02 | + | 9.02E+02 | 8.93E+01 | = | **8.83E+02** | **6.23E+01** |
| F28 | 7.59E+02 | 2.50E+02 | + | 8.49E+02 | 4.33E+02 | + | 6.80E+02 | 6.41E+01 | = | **6.63E+02** | **6.42E+01** |
| F29 | 1.93E+03 | 2.38E+02 | + | 2.10E+03 | 2.54E+02 | + | 1.96E+03 | 2.85E+02 | + | **6.49E+02** | **2.21E+02** |
| F30 | 2.22E+06 | 2.06E+06 | = | 2.77E+06 | 1.13E+06 | + | **1.86E+06** | **1.03E+06** | - | 1.94E+06 | 4.58E+05 |
| **W** | **20** | | | **25** | | | **19** | | | | |
| **T** | **6** | | | **3** | | | **6** | | | | |
| **L** | **3** | | | **1** | | | **4** | | | | |

TABLE S16 (CONTINUED) PERFORMANCE COMPARISONS OF DTDEN WITH STATE-OF-THE-ART DES ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH MODERATE NOISE

100-D

| | EaDE | | | jSO | | | L-SHADE-RSP | | | DTDEn | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 7.20E+09 | 2.32E+10 | + | 1.33E+10 | 1.75E+10 | + | 4.44E+09 | 1.17E+10 | + | **7.90E+08** | **2.68E+09** |
| F3 | 5.88E+04 | 3.37E+04 | - | 8.44E+04 | 2.99E+04 | = | **5.35E+04** | **2.96E+04** | - | 8.88E+04 | 2.07E+04 |
| F4 | 5.65E+02 | 1.25E+02 | + | 7.97E+02 | 5.69E+02 | + | 5.55E+02 | 8.83E+01 | + | **4.84E+02** | **7.20E+01** |
| F5 | 1.12E+03 | 1.87E+02 | + | 1.10E+03 | 1.12E+02 | + | 1.02E+03 | 8.57E+01 | + | **8.24E+02** | **9.52E+01** |
| F6 | 5.29E+01 | 2.12E+01 | + | 6.65E+01 | 1.26E+01 | + | 4.99E+01 | 1.59E+01 | + | **9.42E+00** | **6.96E+00** |
| F7 | 1.18E+03 | 3.60E+02 | + | 1.36E+03 | 3.37E+02 | + | 1.24E+03 | 2.76E+02 | + | **1.07E+03** | **1.41E+02** |
| F8 | 1.07E+03 | 1.92E+02 | + | 1.11E+03 | 1.26E+02 | + | 1.05E+03 | 1.15E+02 | + | **7.98E+02** | **1.03E+02** |
| F9 | 4.64E+03 | 1.40E+04 | + | 6.14E+03 | 6.85E+03 | + | 1.68E+03 | 2.72E+03 | + | **2.02E+02** | **5.85E+02** |
| F10 | 3.00E+04 | 4.78E+02 | + | 2.98E+04 | 5.47E+02 | + | 2.97E+04 | 5.79E+02 | + | **2.78E+04** | **1.67E+03** |
| F11 | 1.61E+03 | 2.54E+02 | - | 1.83E+03 | 2.87E+02 | - | **1.56E+03** | **2.00E+02** | - | 1.93E+03 | 2.10E+02 |
| F12 | 2.18E+08 | 2.39E+08 | + | 3.39E+08 | 3.38E+08 | + | 1.86E+08 | 1.39E+08 | + | **7.75E+07** | **4.75E+07** |
| F13 | 2.78E+04 | 4.27E+03 | + | 2.89E+04 | 4.45E+03 | + | 2.87E+04 | 4.43E+03 | + | **2.57E+04** | **4.11E+03** |
| F14 | 5.59E+02 | 5.17E+01 | - | **5.00E+02** | **5.11E+01** | - | 5.01E+02 | 4.21E+01 | - | 5.92E+02 | 5.64E+01 |
| F15 | 7.94E+03 | 3.63E+03 | + | 1.28E+04 | 4.15E+03 | + | 8.87E+03 | 4.85E+03 | + | **3.83E+03** | **1.77E+03** |
| F16 | 8.38E+03 | 5.78E+02 | + | 8.35E+03 | 4.09E+02 | + | 8.23E+03 | 4.52E+02 | + | **3.47E+03** | **1.34E+03** |
| F17 | 4.68E+03 | 3.10E+02 | + | 4.89E+03 | 2.71E+02 | + | 4.84E+03 | 2.76E+02 | + | **1.61E+03** | **8.32E+02** |
| F18 | 1.04E+04 | 8.95E+03 | = | 1.36E+04 | 9.63E+03 | = | **8.92E+03** | **7.59E+03** | - | 1.14E+04 | 8.23E+03 |
| F19 | 7.47E+02 | 4.45E+02 | + | 3.97E+03 | 5.95E+03 | + | 8.95E+02 | 7.11E+02 | + | **5.40E+02** | **2.57E+02** |
| F20 | 5.06E+03 | 2.42E+02 | + | 4.96E+03 | 2.17E+02 | + | 4.97E+03 | 2.35E+02 | + | **1.89E+03** | **7.67E+02** |
| F21 | 1.34E+03 | 1.43E+02 | + | 1.41E+03 | 1.21E+02 | + | 1.30E+03 | 9.42E+01 | + | **1.11E+03** | **8.41E+01** |
| F22 | 3.12E+04 | 4.72E+02 | + | 3.11E+04 | 5.18E+02 | + | 3.11E+04 | 4.38E+02 | + | **2.58E+04** | **9.36E+03** |
| F23 | 1.75E+03 | 1.38E+02 | + | 1.86E+03 | 1.35E+02 | + | 1.71E+03 | 1.33E+02 | + | **1.49E+03** | **1.17E+02** |
| F24 | 2.13E+03 | 1.53E+02 | + | 2.38E+03 | 2.53E+02 | + | 2.04E+03 | 1.01E+02 | + | 1.95E+03 | 1.26E+02 |
| F25 | 1.46E+03 | 2.91E+02 | + | 1.78E+03 | 3.93E+02 | + | 1.51E+03 | 3.02E+02 | + | **1.31E+03** | **1.11E+02** |
| F26 | 1.46E+04 | 1.48E+03 | + | 1.57E+04 | 2.39E+03 | + | 1.39E+04 | 8.31E+02 | + | **1.26E+04** | **1.33E+03** |
| F27 | 1.26E+03 | 2.40E+02 | + | 1.75E+03 | 4.46E+02 | + | 1.33E+03 | 1.95E+02 | + | **1.14E+03** | **1.33E+02** |
| F28 | 2.92E+03 | 2.19E+03 | + | 3.81E+03 | 2.35E+03 | + | 2.53E+03 | 2.08E+03 | + | **1.46E+03** | **4.68E+02** |
| F29 | 6.12E+03 | 4.72E+02 | + | 6.57E+03 | 5.08E+02 | + | 6.14E+03 | 4.63E+02 | + | **2.92E+03** | **6.83E+02** |
| F30 | 6.24E+05 | 7.31E+05 | + | 9.06E+05 | 9.49E+05 | + | 3.71E+05 | 2.38E+05 | + | **2.05E+05** | **9.38E+04** |
| **W** | **25** | | | **25** | | | **25** | | | | |
| **T** | **1** | | | **2** | | | **0** | | | | |
| **L** | **3** | | | **2** | | | **4** | | | | |

TABLE S17 PERFORMANCE COMPARISONS OF DTDEN WITH STATE-OF-THE-ART DES ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH SEVERE NOISE

30-D

| | EaDE | | | jSO | | | L-SHADE-RSP | | | DTDEn | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 1.04E+09 | 1.58E+09 | + | 1.94E+09 | 2.94E+09 | + | 1.12E+09 | 1.77E+09 | + | **2.63E+03** | **2.10E+03** |
| F3 | 4.61E+03 | 5.42E+03 | - | 5.87E+03 | 3.86E+03 | - | **3.69E+03** | **5.25E+03** | - | 7.11E+04 | 1.05E+04 |
| F4 | 1.79E+02 | 4.13E+01 | + | 2.03E+02 | 5.98E+01 | + | 1.78E+02 | 4.56E+01 | + | **1.44E+02** | **1.08E+01** |
| F5 | 2.56E+02 | 2.90E+01 | + | 2.55E+02 | 2.69E+01 | + | 2.27E+02 | 1.82E+01 | + | **9.79E+01** | **2.95E+01** |
| F6 | 3.95E+01 | 1.07E+01 | + | 4.09E+01 | 8.60E+00 | + | 3.61E+01 | 1.09E+01 | + | **2.59E-01** | **1.21E-01** |
| F7 | 3.88E+02 | 1.45E+02 | + | 3.81E+02 | 7.21E+01 | + | 3.43E+02 | 6.26E+01 | + | **1.85E+02** | **2.61E+01** |
| F8 | 2.54E+02 | 2.69E+01 | + | 2.34E+02 | 2.00E+01 | + | 2.25E+02 | 1.83E+01 | + | **9.77E+01** | **3.00E+01** |
| F9 | 5.97E+02 | 1.15E+03 | + | 8.52E+02 | 1.01E+03 | + | 5.26E+02 | 8.98E+02 | + | **1.93E-02** | **4.63E-02** |
| F10 | 7.17E+03 | 2.96E+02 | + | 7.16E+03 | 2.67E+02 | + | 7.14E+03 | 2.42E+02 | + | **5.33E+03** | **8.35E+02** |
| F11 | 2.38E+02 | 6.01E+01 | - | 2.42E+02 | 6.18E+01 | - | **2.14E+02** | **4.85E+01** | - | 2.52E+03 | 1.33E+03 |
| F12 | 7.56E+06 | 1.93E+07 | + | 5.78E+07 | 2.18E+08 | + | 1.41E+07 | 5.47E+07 | = | **7.69E+05** | **4.07E+05** |
| F13 | 1.72E+04 | 4.77E+04 | = | **7.99E+03** | **5.11E+03** | = | 3.93E+04 | 2.10E+05 | - | 9.11E+03 | 4.61E+03 |
| F14 | 1.19E+02 | 2.65E+01 | - | **1.09E+02** | **2.22E+01** | - | **1.09E+02** | **2.42E+01** | - | 2.66E+05 | 1.46E+05 |
| F15 | 3.10E+02 | 1.25E+02 | = | 2.82E+02 | 1.20E+02 | - | **2.44E+02** | **1.09E+02** | - | 9.45E+02 | 1.24E+03 |
| F16 | 1.70E+03 | 1.79E+02 | + | 1.61E+03 | 1.81E+02 | + | 1.55E+03 | 1.82E+02 | + | **4.91E+02** | **2.73E+02** |
| F17 | 5.44E+02 | 1.09E+02 | + | 5.26E+02 | 9.16E+01 | + | 4.93E+02 | 7.93E+01 | + | **7.38E+01** | **6.80E+01** |
| F18 | 6.43E+02 | 1.36E+03 | - | 2.84E+02 | 4.10E+02 | - | **2.12E+02** | **8.94E+01** | - | 4.80E+05 | 3.86E+05 |
| F19 | 6.84E+01 | 2.69E+01 | - | **6.02E+01** | **1.80E+01** | - | 6.26E+01 | 1.86E+01 | - | 3.04E+03 | 2.21E+03 |
| F20 | 6.60E+02 | 9.51E+01 | + | 6.40E+02 | 9.61E+01 | + | 6.35E+02 | 8.80E+01 | + | **2.49E+02** | **9.86E+01** |
| F21 | 4.49E+02 | 2.49E+01 | + | 4.38E+02 | 2.16E+01 | + | 4.23E+02 | 1.81E+01 | + | **3.66E+02** | **1.78E+01** |
| F22 | 1.13E+03 | 1.18E+03 | + | 1.14E+03 | 8.29E+02 | + | 7.16E+02 | 5.24E+02 | + | **1.38E+02** | **4.49E+00** |
| F23 | 6.24E+02 | 3.56E+01 | + | 6.27E+02 | 3.79E+01 | + | 5.94E+02 | 2.78E+01 | + | **5.38E+02** | **2.21E+01** |
| F24 | 6.67E+02 | 2.74E+01 | + | 6.75E+02 | 3.02E+01 | + | 6.55E+02 | 3.42E+01 | + | **6.00E+02** | **2.11E+01** |
| F25 | 5.34E+02 | 9.02E+01 | + | 5.39E+02 | 6.16E+01 | + | 5.17E+02 | 4.63E+01 | + | **4.47E+02** | **1.38E+01** |
| F26 | 3.86E+03 | 4.08E+02 | + | 3.89E+03 | 4.14E+02 | + | 3.60E+03 | 3.94E+02 | + | **2.44E+03** | **2.99E+02** |
| F27 | 6.39E+02 | 3.45E+01 | + | 6.58E+02 | 3.64E+01 | + | **6.14E+02** | **2.54E+01** | = | 6.17E+02 | 1.53E+01 |
| F28 | 6.84E+02 | 1.29E+02 | + | 7.50E+02 | 1.78E+02 | + | 6.99E+02 | 1.10E+02 | + | **5.42E+02** | **1.95E+01** |
| F29 | 1.30E+03 | 1.40E+02 | + | 1.34E+03 | 1.75E+02 | + | 1.21E+03 | 1.51E+02 | + | **7.13E+02** | **1.32E+02** |
| F30 | 2.50E+04 | 4.43E+04 | + | 3.21E+04 | 6.61E+04 | + | 1.60E+04 | 1.36E+04 | + | **7.62E+03** | **3.44E+03** |
| **W** | **22** | | | **22** | | | **20** | | | | |
| **T** | **2** | | | **1** | | | **2** | | | | |
| **L** | **5** | | | **6** | | | **7** | | | | |

TABLE S17 (CONTINUED) PERFORMANCE COMPARISONS OF DTDEN WITH STATE-OF-THE-ART DES ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH SEVERE NOISE

50-D

| | EaDE | | | jSO | | | L-SHADE-RSP | | | DTDEn | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 8.67E+09 | 1.07E+10 | + | 1.49E+10 | 1.36E+10 | + | 6.93E+09 | 6.57E+09 | + | **3.06E+04** | **2.97E+04** |
| F3 | 2.99E+04 | 1.36E+04 | - | 4.21E+04 | 1.74E+04 | - | **2.58E+04** | **1.32E+04** | - | 1.50E+05 | 1.63E+04 |
| F4 | 4.90E+02 | 1.67E+02 | + | 6.64E+02 | 2.72E+02 | + | 4.90E+02 | 1.86E+02 | + | **2.61E+02** | **1.07E+01** |
| F5 | 5.31E+02 | 6.94E+01 | + | 5.04E+02 | 5.08E+01 | + | 4.64E+02 | 3.98E+01 | + | **3.16E+02** | **4.32E+01** |
| F6 | 6.19E+01 | 1.43E+01 | + | 6.04E+01 | 1.10E+01 | + | 5.07E+01 | 1.38E+01 | + | **1.92E+00** | **5.19E-01** |
| F7 | 7.88E+02 | 3.29E+02 | + | 8.17E+02 | 2.22E+02 | + | 7.22E+02 | 1.87E+02 | + | **4.24E+02** | **2.58E+01** |
| F8 | 5.27E+02 | 4.98E+01 | + | 5.11E+02 | 5.14E+01 | + | 4.76E+02 | 5.28E+01 | + | **3.16E+02** | **4.13E+01** |
| F9 | 4.05E+03 | 4.13E+03 | + | 6.07E+03 | 5.69E+03 | + | 4.73E+03 | 5.74E+03 | + | **6.09E-01** | **2.28E-01** |
| F10 | 1.32E+04 | 3.72E+02 | + | 1.33E+04 | 3.02E+02 | + | 1.33E+04 | 3.88E+02 | + | **1.18E+04** | **7.52E+02** |
| F11 | 5.17E+02 | 1.35E+02 | - | 4.66E+02 | 1.13E+02 | - | **4.48E+02** | **1.13E+02** | - | 7.58E+03 | 2.79E+03 |
| F12 | 2.54E+08 | 5.95E+08 | + | 6.25E+08 | 1.21E+09 | + | 1.59E+08 | 2.68E+08 | + | **3.27E+06** | **1.31E+06** |
| F13 | 8.32E+06 | 4.95E+07 | + | 7.03E+07 | 4.94E+08 | + | 2.68E+07 | 1.28E+08 | + | **1.85E+03** | **1.07E+03** |
| F14 | 3.23E+02 | 6.53E+01 | - | **2.82E+02** | **3.80E+01** | - | 2.86E+02 | 5.38E+01 | - | 3.43E+05 | 2.18E+05 |
| F15 | 1.18E+04 | 2.55E+04 | + | 3.69E+03 | 4.23E+03 | + | 3.30E+03 | 3.05E+03 | = | **2.03E+03** | **1.08E+03** |
| F16 | 3.50E+03 | 2.68E+02 | + | 3.32E+03 | 2.42E+02 | + | 3.26E+03 | 2.31E+02 | + | **9.49E+02** | **2.91E+02** |
| F17 | 1.99E+03 | 1.53E+02 | + | 1.92E+03 | 1.91E+02 | + | 1.92E+03 | 1.82E+02 | + | **7.23E+02** | **3.03E+02** |
| F18 | 1.14E+04 | 9.77E+03 | - | 9.43E+03 | 8.66E+03 | - | **7.45E+03** | **9.33E+03** | - | 1.87E+06 | 5.68E+05 |
| F19 | 1.99E+04 | 8.33E+04 | - | 5.08E+03 | 8.12E+03 | - | **2.89E+03** | **8.76E+03** | - | 1.36E+04 | 2.75E+03 |
| F20 | 1.76E+03 | 1.65E+02 | + | 1.73E+03 | 1.76E+02 | + | 1.68E+03 | 1.29E+02 | + | **2.88E+02** | **1.43E+02** |
| F21 | 7.42E+02 | 4.20E+01 | + | 6.97E+02 | 4.05E+01 | + | 6.66E+02 | 4.55E+01 | + | **5.49E+02** | **2.69E+01** |
| F22 | 1.36E+04 | 4.38E+02 | + | 1.35E+04 | 4.79E+02 | + | 1.33E+04 | 6.21E+02 | + | **1.03E+03** | **2.73E+03** |
| F23 | 1.05E+03 | 8.02E+01 | + | 1.06E+03 | 6.81E+01 | + | 9.93E+02 | 9.87E+01 | + | **8.25E+02** | **2.81E+01** |
| F24 | 1.05E+03 | 7.12E+01 | + | 1.11E+03 | 1.11E+02 | + | 9.99E+02 | 6.56E+01 | + | **8.70E+02** | **2.67E+01** |
| F25 | 1.08E+03 | 4.83E+02 | + | 1.29E+03 | 6.92E+02 | + | 1.01E+03 | 4.01E+02 | + | **6.65E+02** | **1.54E+01** |
| F26 | 7.00E+03 | 8.84E+02 | + | 6.96E+03 | 6.70E+02 | + | 6.30E+03 | 6.95E+02 | + | **4.54E+03** | **3.76E+02** |
| F27 | 1.32E+03 | 2.18E+02 | + | 1.36E+03 | 1.93E+02 | + | 1.14E+03 | 1.22E+02 | + | **9.50E+02** | **3.95E+01** |
| F28 | 2.83E+03 | 1.06E+03 | + | 2.52E+03 | 1.11E+03 | + | 2.06E+03 | 9.94E+02 | + | **8.38E+02** | **7.18E+01** |
| F29 | 2.51E+03 | 3.52E+02 | + | 2.54E+03 | 2.69E+02 | + | 2.38E+03 | 2.78E+02 | + | **8.57E+02** | **2.38E+02** |
| F30 | 5.08E+07 | 4.31E+07 | + | 6.16E+07 | 5.91E+07 | + | 4.23E+07 | 3.48E+07 | + | **2.03E+06** | **2.08E+05** |
| **W** | **24** | | | **24** | | | **23** | | | | |
| **T** | **0** | | | **0** | | | **1** | | | | |
| **L** | **5** | | | **5** | | | **5** | | | | |

TABLE S17 (CONTINUED) PERFORMANCE COMPARISONS OF DTDEN WITH STATE-OF-THE-ART DES ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH SEVERE NOISE

100-D

| | EaDE | | | jSO | | | L-SHADE-RSP | | | DTDEn | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 9.09E+10 | 6.36E+10 | + | 9.59E+10 | 4.44E+10 | + | 6.35E+10 | 4.24E+10 | + | **4.52E+07** | **1.35E+07** |
| F3 | 1.54E+05 | 4.12E+04 | - | 1.77E+05 | 3.81E+04 | - | **1.45E+05** | **3.95E+04** | - | 3.47E+05 | 2.26E+04 |
| F4 | 2.26E+03 | 2.32E+03 | + | 4.00E+03 | 5.14E+03 | + | 1.49E+03 | 1.23E+03 | + | **5.72E+02** | **2.39E+01** |
| F5 | 1.31E+03 | 1.47E+02 | + | 1.26E+03 | 8.63E+01 | + | 1.19E+03 | 1.36E+02 | + | **9.13E+02** | **2.98E+01** |
| F6 | 8.34E+01 | 1.51E+01 | + | 8.12E+01 | 9.04E+00 | + | 7.42E+01 | 1.34E+01 | + | **1.36E+01** | **1.92E+00** |
| F7 | 2.21E+03 | 8.22E+02 | + | 2.26E+03 | 5.61E+02 | + | 1.86E+03 | 5.29E+02 | + | **1.14E+03** | **3.53E+01** |
| F8 | 1.35E+03 | 1.43E+02 | + | 1.27E+03 | 1.07E+02 | + | 1.19E+03 | 1.16E+02 | + | **9.11E+02** | **3.43E+01** |
| F9 | 3.19E+04 | 2.26E+04 | + | 3.65E+04 | 1.52E+04 | + | 2.66E+04 | 1.77E+04 | + | **1.91E+01** | **6.49E+00** |
| F10 | 3.01E+04 | 3.88E+02 | + | 3.00E+04 | 5.05E+02 | + | 2.98E+04 | 5.59E+02 | + | **2.88E+04** | **6.22E+02** |
| F11 | **6.97E+03** | **6.85E+03** | - | 1.24E+04 | 9.94E+03 | - | 7.52E+03 | 1.11E+04 | - | 1.05E+05 | 1.87E+04 |
| F12 | 1.06E+10 | 1.62E+10 | + | 1.35E+10 | 1.08E+10 | + | 6.48E+09 | 9.77E+09 | + | **3.20E+07** | **9.55E+06** |
| F13 | 3.19E+08 | 8.94E+08 | + | 3.68E+08 | 7.73E+08 | + | 2.24E+08 | 4.69E+08 | + | **6.94E+03** | **1.22E+03** |
| F14 | 1.55E+05 | 3.16E+05 | - | 1.25E+05 | 2.56E+05 | - | **1.10E+05** | **3.60E+05** | - | 2.00E+06 | 4.00E+05 |
| F15 | 1.93E+07 | 1.16E+08 | + | 1.82E+07 | 7.80E+07 | + | 3.86E+07 | 2.06E+08 | + | **1.04E+03** | **3.49E+02** |
| F16 | 9.34E+03 | 6.39E+02 | + | 9.14E+03 | 6.18E+02 | + | 8.76E+03 | 6.84E+02 | + | **5.16E+03** | **1.10E+03** |
| F17 | 5.01E+03 | 2.89E+02 | + | 5.11E+03 | 2.71E+02 | + | 5.13E+03 | 2.51E+02 | + | **2.86E+03** | **8.25E+02** |
| F18 | 2.54E+05 | 2.95E+05 | - | 1.50E+05 | 9.60E+04 | - | **1.24E+05** | **8.89E+04** | - | 1.80E+06 | 3.82E+05 |
| F19 | 3.33E+07 | 1.54E+08 | + | 3.15E+07 | 1.75E+08 | + | 1.16E+08 | 4.38E+08 | + | **9.33E+02** | **5.21E+02** |
| F20 | 5.13E+03 | 2.25E+02 | + | 5.02E+03 | 2.21E+02 | + | 4.99E+03 | 1.74E+02 | + | **3.08E+03** | **7.93E+02** |
| F21 | 1.61E+03 | 1.62E+02 | + | 1.59E+03 | 1.13E+02 | + | 1.47E+03 | 1.44E+02 | + | **1.15E+03** | **3.35E+01** |
| F22 | 3.14E+04 | 4.58E+02 | + | 3.13E+04 | 4.68E+02 | + | 3.11E+04 | 4.42E+02 | + | **1.28E+04** | **1.30E+04** |
| F23 | 2.03E+03 | 1.74E+02 | + | 2.19E+03 | 1.67E+02 | + | 1.92E+03 | 1.89E+02 | + | **1.56E+03** | **4.83E+01** |
| F24 | 2.85E+03 | 4.27E+02 | + | 3.19E+03 | 4.28E+02 | + | 2.43E+03 | 2.71E+02 | + | **1.92E+03** | **4.21E+01** |
| F25 | 4.26E+03 | 2.88E+03 | + | 5.15E+03 | 2.53E+03 | + | 3.75E+03 | 1.71E+03 | + | **1.33E+03** | **4.73E+01** |
| F26 | 2.08E+04 | 4.52E+03 | + | 2.21E+04 | 3.33E+03 | + | 1.81E+04 | 3.04E+03 | + | **1.36E+04** | **5.90E+02** |
| F27 | 2.63E+03 | 6.30E+02 | + | 2.83E+03 | 5.75E+02 | + | 2.13E+03 | 4.46E+02 | + | **1.19E+03** | **5.43E+01** |
| F28 | 1.40E+04 | 4.94E+03 | + | 1.27E+04 | 4.04E+03 | + | 1.05E+04 | 3.22E+03 | + | **1.51E+03** | **1.62E+02** |
| F29 | 6.90E+03 | 5.96E+02 | + | 7.43E+03 | 6.51E+02 | + | 7.12E+03 | 6.29E+02 | + | **3.66E+03** | **6.71E+02** |
| F30 | 1.79E+08 | 4.05E+08 | + | 2.98E+08 | 5.32E+08 | + | 2.95E+08 | 6.21E+08 | + | **5.88E+04** | **2.35E+04** |
| **W** | **25** | | | **25** | | | **25** | | | | |
| **T** | **0** | | | **0** | | | **0** | | | | |
| **L** | **4** | | | **4** | | | **4** | | | | |

TABLE S18 PERFORMANCE COMPARISONS OF DTDEN WITH POPULAR NEAS ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH SLIGHT NOISE

30-D

| | ODE | | | MUDE | | | IPOP-UH-CMA-ES | | | BBPSO_CJ | | | DEPSO | | | DTDEn | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | **9.42E+01** | **6.14E+02** | - | 2.88E+10 | 3.79E+10 | + | 6.36E+05 | 7.29E+05 | + | 4.92E+05 | 1.39E+06 | + | 1.89E+03 | 2.27E+03 | = | 1.55E+03 | 1.61E+03 |
| F3 | 7.82E+02 | 2.43E+02 | + | 1.27E+03 | 3.20E+03 | + | 5.28E+04 | 1.44E+04 | + | 2.43E+04 | 1.34E+04 | + | 5.37E+02 | 4.39E+02 | + | **0.00E+00** | **0.00E+00** |
| F4 | 9.67E+01 | 6.60E+00 | + | 1.55E+02 | 1.36E+01 | + | 8.74E+02 | 3.78E+03 | + | 2.62E+02 | 5.78E+01 | + | 1.98E+02 | 2.61E+01 | + | **9.14E+01** | **2.34E+00** |
| F5 | 1.98E+02 | 7.46E+00 | + | 4.40E+02 | 3.28E+01 | + | 2.88E+02 | 1.23E+02 | + | 3.40E+02 | 5.45E+01 | + | 3.18E+02 | 2.54E+01 | + | **2.70E+00** | **1.67E+00** |
| F6 | 2.80E-04 | 1.24E-04 | + | 1.08E+02 | 6.07E+00 | + | 7.25E+01 | 2.47E+01 | + | 1.20E+02 | 1.89E+01 | + | 1.23E+02 | 2.60E+00 | + | **9.50E-09** | **3.70E-08** |
| F7 | 2.30E+02 | 1.28E+01 | + | 7.82E+02 | 4.95E+01 | + | 3.25E+02 | 2.50E+02 | + | 4.39E+02 | 7.39E+01 | + | 3.40E+02 | 4.00E+01 | + | **3.57E+01** | **1.38E+00** |
| F8 | 1.89E+02 | 1.39E+01 | + | 3.60E+02 | 3.18E+01 | + | 2.30E+02 | 1.00E+02 | + | 3.91E+02 | 6.06E+01 | + | 3.71E+02 | 1.70E+01 | + | **2.68E+00** | **1.78E+00** |
| F9 | **0.00E+00** | **0.00E+00** | = | 5.39E+03 | 3.32E+02 | + | 2.33E+01 | 3.21E+01 | + | 8.68E+02 | 6.55E+02 | + | 9.01E+01 | 3.53E+01 | + | **0.00E+00** | **0.00E+00** |
| F10 | 6.99E+03 | 3.07E+02 | + | 4.68E+03 | 3.00E+02 | + | 2.50E+03 | 2.46E+03 | + | 6.56E+03 | 1.25E+03 | + | 8.15E+03 | 6.19E+02 | + | **1.74E+02** | **1.78E+02** |
| F11 | 7.27E+01 | 2.61E+01 | + | 2.13E+02 | 2.51E+01 | + | 1.06E+04 | 7.16E+03 | + | 4.76E+02 | 1.29E+02 | + | 3.42E+02 | 8.37E+01 | + | **2.53E+01** | **2.85E+01** |
| F12 | 8.28E+03 | 4.68E+03 | + | 7.33E+09 | 1.20E+10 | + | 7.13E+04 | 4.92E+05 | + | 3.80E+06 | 3.49E+06 | + | 1.03E+05 | 2.26E+04 | + | **6.15E+02** | **2.88E+02** |
| F13 | 8.93E+01 | 9.49E+00 | + | 7.72E+08 | 5.51E+09 | + | 2.37E+03 | 1.31E+03 | + | 3.19E+05 | 9.01E+05 | + | 9.82E+03 | 4.76E+03 | + | **2.16E+01** | **9.89E+00** |
| F14 | 6.60E+01 | 6.68E+00 | + | 1.55E+02 | 1.94E+01 | + | 4.88E+03 | 1.76E+04 | + | 8.57E+04 | 2.06E+05 | + | 2.22E+04 | 7.24E+03 | + | **2.55E+01** | **3.46E+00** |
| F15 | 4.71E+01 | 5.63E+00 | + | 2.17E+02 | 4.32E+01 | + | 1.29E+08 | 5.26E+08 | + | 1.15E+05 | 3.06E+05 | + | 9.84E+03 | 2.67E+03 | + | **7.77E+00** | **1.29E+00** |
| F16 | 1.25E+03 | 1.85E+02 | + | 1.28E+03 | 2.35E+02 | + | 1.38E+03 | 1.27E+03 | + | 1.23E+03 | 3.01E+02 | + | 1.95E+03 | 2.70E+02 | + | **1.48E+01** | **1.77E+00** |
| F17 | 1.05E+02 | 6.45E+01 | + | 3.55E+02 | 9.27E+01 | + | 1.14E+03 | 7.32E+02 | + | 5.46E+02 | 2.07E+02 | + | 3.50E+02 | 1.31E+02 | + | **2.17E+01** | **5.96E+00** |
| F18 | 4.38E+01 | 3.97E+00 | + | 4.27E+03 | 5.22E+03 | + | 2.28E+03 | 5.03E+03 | + | 3.03E+05 | 2.43E+05 | + | 2.35E+05 | 2.13E+04 | + | **2.89E+01** | **2.71E+00** |
| F19 | 2.56E+01 | 6.57E+00 | + | 1.79E+02 | 5.01E+02 | + | 3.07E+08 | 7.25E+08 | + | 1.02E+05 | 3.23E+05 | + | 5.08E+03 | 4.42E+03 | + | **5.58E+00** | **1.64E+00** |
| F20 | 6.45E+01 | 5.36E+01 | + | 1.03E+03 | 2.17E+02 | + | 8.54E+02 | 3.24E+02 | + | 7.11E+02 | 2.60E+02 | + | 6.32E+02 | 1.29E+02 | + | **2.10E+01** | **4.05E+00** |
| F21 | 4.03E+02 | 1.53E+01 | + | 1.02E+03 | 5.93E+01 | + | 4.73E+02 | 8.96E+01 | + | 7.20E+02 | 7.66E+01 | + | 6.45E+02 | 6.20E+01 | + | **2.10E+02** | **2.51E+00** |
| F22 | 1.23E+02 | 1.58E+00 | + | 4.80E+03 | 2.87E+03 | + | 2.20E+03 | 2.29E+03 | + | 3.64E+03 | 2.93E+03 | + | 3.75E+02 | 2.03E+00 | + | **1.12E+02** | **2.68E+00** |
| F23 | 5.60E+02 | 1.42E+01 | + | 1.60E+03 | 1.08E+03 | + | 6.53E+02 | 1.19E+02 | + | 9.58E+02 | 1.27E+02 | + | 8.54E+02 | 2.60E+01 | + | **3.57E+02** | **7.93E+00** |
| F24 | 6.24E+02 | 1.12E+01 | + | 2.75E+03 | 1.87E+01 | + | 6.72E+02 | 1.04E+02 | + | 9.98E+02 | 1.21E+02 | + | 9.27E+02 | 2.15E+01 | + | **4.31E+02** | **4.71E+00** |
| F25 | 4.16E+02 | 7.48E+00 | + | 7.50E+02 | 6.61E+02 | + | 1.26E+03 | 1.86E+03 | + | 9.18E+02 | 1.54E+02 | + | 6.38E+02 | 3.38E+01 | + | **3.96E+02** | **4.92E+00** |
| F26 | 2.88E+03 | 1.16E+02 | + | 6.29E+03 | 5.49E+03 | + | 1.51E+03 | 7.42E+02 | + | 3.79E+03 | 7.72E+02 | + | 3.54E+03 | 1.89E+02 | + | **8.71E+02** | **5.58E+01** |
| F27 | 5.62E+02 | 7.70E+00 | + | 2.30E+03 | 2.03E+03 | + | 6.91E+02 | 1.31E+02 | + | 8.80E+02 | 1.47E+02 | + | 8.78E+02 | 3.76E+01 | + | **5.29E+02** | **7.65E+00** |
| F28 | 4.87E+02 | 1.38E+01 | + | 5.00E+03 | 2.67E+03 | + | 1.67E+03 | 1.62E+03 | + | 1.26E+03 | 3.51E+02 | + | 8.75E+02 | 7.10E+00 | + | **4.58E+02** | **1.47E+01** |
| F29 | 9.00E+02 | 1.53E+02 | + | 1.09E+03 | 1.34E+02 | + | 2.15E+03 | 1.32E+03 | + | 1.62E+03 | 5.72E+02 | + | 1.35E+03 | 1.65E+02 | + | **4.27E+02** | **7.25E+00** |
| F30 | 2.70E+03 | 1.89E+02 | + | 5.94E+03 | 2.30E+03 | + | 5.15E+03 | 1.12E+04 | + | 1.83E+05 | 3.23E+05 | + | 6.27E+03 | 3.93E+03 | + | **2.24E+03** | **1.03E+02** |
| **W** | **27** | | | **29** | | | **29** | | | **29** | | | **28** | | | | |
| **T** | **1** | | | **0** | | | **0** | | | **0** | | | **1** | | | | |
| **L** | **1** | | | **0** | | | **0** | | | **0** | | | **0** | | | | |

TABLE S18 (CONTINUED) PERFORMANCE COMPARISONS OF DTDEN WITH POPULAR NEAS ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH SLIGHT NOISE

50-D

| | ODE | | | MUDE | | | IPOP-UH-CMA-ES | | | BBPSO_CJ | | | DEPSO | | | DTDEn | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | **3.05E+03** | **2.65E+03** | = | 3.36E+03 | 3.99E+03 | - | 8.02E+08 | 1.15E+09 | + | 1.79E+06 | 3.41E+06 | + | 2.51E+05 | 1.45E+05 | + | 3.72E+03 | 2.16E+03 |
| F3 | 1.14E+05 | 2.00E+04 | + | 1.56E+04 | 9.24E+03 | + | 4.23E+03 | 4.62E+03 | + | 1.57E+06 | 7.66E+06 | + | 9.29E+03 | 3.16E+03 | + | **4.81E-09** | **1.26E-08** |
| F4 | **1.74E+02** | **5.02E+01** | - | 2.83E+02 | 2.92E+01 | + | 1.29E+03 | 7.20E+03 | = | 6.00E+02 | 1.28E+02 | + | 3.61E+02 | 5.51E+01 | + | 2.03E+02 | 3.77E+01 |
| F5 | 3.90E+02 | 1.52E+01 | + | 4.63E+02 | 2.87E+01 | + | 2.27E+02 | 2.27E+02 | + | 5.98E+02 | 8.06E+01 | + | 6.04E+02 | 1.59E+01 | + | **6.05E+00** | **2.79E+00** |
| F6 | 8.79E-04 | 4.74E-04 | + | 1.01E+02 | 8.22E+00 | + | 7.73E+01 | 2.55E+01 | + | 1.51E+02 | 2.29E+01 | + | 1.30E+02 | 1.35E+01 | + | **5.74E-08** | **1.66E-07** |
| F7 | 4.43E+02 | 1.46E+01 | + | 5.56E+02 | 2.69E+01 | + | 3.98E+02 | 1.03E+02 | + | 9.61E+02 | 1.40E+02 | + | 7.60E+02 | 1.76E+01 | + | **6.15E+01** | **1.82E+00** |
| F8 | 3.88E+02 | 1.61E+01 | + | 5.21E+02 | 3.44E+01 | + | 3.65E+02 | 3.21E+02 | + | 7.29E+02 | 1.11E+02 | + | 7.10E+02 | 5.57E+01 | + | **5.69E+00** | **2.24E+00** |
| F9 | 2.00E-01 | 1.07E+00 | + | 8.12E+01 | 1.63E+01 | + | 3.84E+03 | 2.58E+03 | + | 6.29E+03 | 4.52E+03 | + | 2.71E+02 | 6.74E+01 | + | **0.00E+00** | **0.00E+00** |
| F10 | 1.33E+04 | 3.09E+02 | + | 1.27E+04 | 5.27E+02 | + | 3.82E+03 | 3.35E+03 | + | 1.32E+04 | 1.26E+03 | + | 1.56E+04 | 4.73E+02 | + | **4.46E+02** | **3.29E+02** |
| F11 | 1.72E+02 | 1.48E+01 | + | 3.76E+02 | 4.53E+01 | + | 1.23E+04 | 1.05E+04 | + | 9.44E+02 | 3.00E+02 | + | 5.28E+02 | 1.51E+01 | + | **2.97E+01** | **2.96E+00** |
| F12 | 3.17E+05 | 4.75E+05 | + | 2.07E+06 | 1.83E+06 | + | 1.85E+05 | 5.72E+05 | - | 1.96E+07 | 1.36E+07 | + | 4.24E+06 | 8.86E+05 | + | **1.03E+04** | **9.92E+03** |
| F13 | 1.30E+03 | 2.55E+03 | + | 5.53E+03 | 6.96E+03 | + | 5.78E+03 | 8.83E+03 | + | 6.05E+05 | 1.93E+06 | + | 2.30E+03 | 1.42E+03 | + | **1.03E+02** | **3.75E+01** |
| F14 | 1.39E+02 | 8.82E+00 | + | 3.52E+02 | 9.79E+01 | + | 3.55E+06 | 8.02E+06 | + | 2.27E+05 | 2.21E+05 | + | 1.15E+05 | 1.69E+04 | + | **2.80E+01** | **2.62E+00** |
| F15 | 1.26E+02 | 9.64E+00 | + | 1.41E+03 | 1.91E+03 | + | 1.46E+08 | 9.15E+08 | + | 3.42E+05 | 6.66E+05 | + | 1.21E+04 | 4.97E+03 | + | **2.82E+01** | **5.17E+00** |
| F16 | 2.95E+03 | 1.71E+02 | + | 2.68E+03 | 3.52E+02 | + | 1.62E+03 | 1.27E+03 | + | 2.43E+03 | 5.57E+02 | + | 2.58E+03 | 1.52E+03 | + | **1.61E+02** | **9.25E+01** |
| F17 | 1.69E+03 | 2.14E+02 | + | 1.70E+03 | 1.76E+02 | + | 7.63E+03 | 4.54E+04 | + | 1.88E+03 | 4.42E+02 | + | 2.85E+03 | 1.41E+02 | + | **8.44E+01** | **7.92E+01** |
| F18 | 2.89E+03 | 3.29E+03 | + | 3.33E+04 | 1.93E+04 | + | 4.23E+07 | 1.48E+08 | + | 1.37E+06 | 1.27E+06 | + | 5.03E+05 | 1.14E+05 | + | **4.53E+01** | **1.01E+01** |
| F19 | 6.94E+01 | 4.64E+00 | + | 2.79E+03 | 5.70E+03 | + | 2.90E+05 | 1.69E+06 | + | 1.64E+05 | 3.60E+05 | + | 1.95E+04 | 6.43E+03 | + | **1.11E+01** | **2.56E+00** |
| F20 | 1.55E+03 | 2.08E+02 | + | 1.61E+03 | 2.49E+02 | + | 1.61E+03 | 8.21E+02 | + | 1.66E+03 | 4.01E+02 | + | 2.11E+03 | 2.31E+01 | + | **2.98E+01** | **3.14E+01** |
| F21 | 6.22E+02 | 2.38E+01 | + | 8.49E+02 | 4.28E+01 | + | 6.70E+02 | 1.48E+02 | + | 1.11E+03 | 9.82E+01 | + | 1.00E+03 | 5.61E+01 | + | **2.17E+02** | **6.83E+00** |
| F22 | 1.25E+04 | 3.63E+03 | + | 1.33E+04 | 8.19E+02 | + | 4.15E+03 | 3.67E+03 | + | 1.42E+04 | 1.21E+03 | + | 8.72E+03 | 7.75E+03 | + | **7.29E+02** | **8.19E+02** |
| F23 | 8.62E+02 | 2.32E+01 | + | 1.11E+03 | 3.96E+01 | + | 8.71E+02 | 3.56E+02 | + | 1.50E+03 | 1.69E+02 | + | 1.28E+03 | 9.65E+01 | + | **4.46E+02** | **1.52E+01** |
| F24 | 9.12E+02 | 2.06E+01 | + | 1.14E+03 | 3.65E+01 | + | 8.75E+02 | 2.77E+02 | + | 1.51E+03 | 1.45E+02 | + | 1.69E+03 | 1.11E+02 | + | **5.21E+02** | **1.20E+01** |
| F25 | 6.18E+02 | 1.59E+01 | + | 8.46E+02 | 4.30E+01 | + | 3.19E+03 | 6.54E+03 | + | 1.65E+03 | 5.14E+02 | + | 1.37E+03 | 2.11E+02 | + | **5.59E+02** | **5.67E+00** |
| F26 | 5.21E+03 | 2.17E+02 | + | 5.44E+03 | 2.74E+02 | + | 1.60E+03 | 5.83E+02 | + | 7.18E+03 | 1.01E+03 | + | 6.46E+03 | 4.54E+02 | + | **9.85E+02** | **7.69E+01** |
| F27 | 7.39E+02 | 7.05E+01 | + | 1.07E+03 | 8.26E+01 | + | 1.21E+03 | 7.10E+02 | + | 1.59E+03 | 4.37E+02 | + | 1.81E+03 | 9.30E+01 | + | **5.81E+02** | **3.77E+01** |
| F28 | 5.91E+02 | 2.52E+01 | + | 8.97E+02 | 8.39E+01 | + | 3.50E+03 | 4.12E+03 | + | 2.92E+03 | 1.25E+03 | + | 1.26E+03 | 1.46E+02 | + | **5.16E+02** | **2.26E+01** |
| F29 | 1.75E+03 | 2.25E+02 | + | 1.83E+03 | 2.50E+02 | + | 9.20E+03 | 2.55E+04 | + | 2.36E+03 | 4.30E+02 | + | 2.47E+03 | 2.57E+02 | + | **3.24E+02** | **9.85E+00** |
| F30 | 8.15E+05 | 4.18E+04 | + | 1.05E+06 | 2.30E+05 | + | 9.76E+05 | 1.48E+06 | = | 2.21E+06 | 9.32E+05 | + | 1.73E+06 | 1.88E+05 | + | **7.40E+05** | **8.15E+04** |
| **W** | **27** | | | **28** | | | **26** | | | **29** | | | **29** | | | | |
| **T** | **1** | | | **0** | | | **2** | | | **0** | | | **0** | | | | |
| **L** | **1** | | | **1** | | | **1** | | | **0** | | | **0** | | | | |

TABLE S18 (CONTINUED) PERFORMANCE COMPARISONS OF DTDEN WITH POPULAR NEAS ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH SLIGHT NOISE

100-D

| | ODE | | | MUDE | | | IPOP-UH-CMA-ES | | | BBPSO_CJ | | | DEPSO | | | DTDEn | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 2.61E+03 | 9.04E+02 | = | 8.71E+03 | 8.04E+03 | + | 4.30E+08 | 6.56E+08 | + | 3.01E+09 | 3.35E+09 | + | 2.63E+09 | 1.40E+09 | + | **3.16E+03** | **2.18E+03** |
| F3 | 4.34E+05 | 1.69E+04 | + | 2.78E+05 | 8.88E+04 | + | 5.57E+04 | 2.83E+04 | + | 7.32E+07 | 3.55E+08 | + | 1.42E+05 | 1.92E+04 | + | **7.20E+02** | **5.09E+02** |
| F4 | 5.73E+02 | 8.40E+01 | + | 5.68E+02 | 6.05E+01 | + | **2.09E+02** | **1.70E+01** | - | 1.83E+03 | 4.04E+02 | + | 9.48E+02 | 1.92E+02 | + | 2.86E+02 | 1.56E+01 |
| F5 | 9.35E+02 | 2.74E+01 | + | 1.09E+03 | 4.82E+01 | + | 4.75E+02 | 3.53E+02 | + | 1.56E+03 | 1.60E+02 | + | 1.48E+03 | 1.02E+02 | + | **2.23E+01** | **5.92E+00** |
| F6 | 6.68E-02 | 2.63E-02 | + | 1.31E+02 | 6.60E+00 | + | 9.87E+01 | 2.39E+01 | + | 1.72E+02 | 1.76E+01 | + | 1.62E+02 | 5.72E+00 | + | **2.55E-03** | **2.25E-03** |
| F7 | 1.12E+03 | 3.96E+01 | + | 1.26E+03 | 6.41E+01 | + | 5.76E+02 | 4.48E+02 | + | 3.17E+03 | 4.72E+02 | + | 1.54E+03 | 6.61E+01 | + | **1.46E+02** | **9.02E+00** |
| F8 | 9.25E+02 | 2.64E+01 | + | 1.18E+03 | 4.71E+01 | + | 8.03E+02 | 6.32E+02 | + | 1.71E+03 | 1.73E+02 | + | 1.42E+03 | 7.01E+01 | + | **2.29E+01** | **7.23E+00** |
| F9 | 7.45E+00 | 6.30E+00 | + | 2.14E+02 | 6.25E+01 | + | 4.07E+04 | 1.53E+04 | + | 4.02E+04 | 1.27E+04 | + | 5.14E+03 | 8.22E+02 | + | **6.04E-02** | **1.24E-01** |
| F10 | 3.02E+04 | 4.29E+02 | + | 3.08E+04 | 9.54E+02 | + | 1.26E+04 | 6.84E+03 | + | 3.24E+04 | 1.61E+03 | + | 3.50E+04 | 3.96E+02 | + | **3.72E+03** | **1.90E+03** |
| F11 | 1.03E+03 | 2.47E+02 | + | 2.46E+03 | 5.71E+02 | + | 1.34E+03 | 5.68E+02 | + | 1.62E+04 | 1.32E+04 | + | 2.35E+03 | 1.60E+02 | + | **3.96E+02** | **7.71E+01** |
| F12 | 5.17E+06 | 4.92E+06 | + | 1.67E+07 | 1.40E+07 | + | **2.11E+05** | **9.03E+05** | - | 2.43E+08 | 1.60E+08 | + | 7.76E+07 | 1.39E+07 | + | 6.68E+05 | 3.72E+05 |
| F13 | **4.17E+03** | **3.35E+03** | - | 4.93E+03 | 4.04E+03 | = | 4.30E+03 | 7.59E+02 | - | 4.90E+05 | 1.15E+06 | + | 4.40E+03 | 3.14E+03 | = | 5.05E+03 | 1.30E+03 |
| F14 | 4.36E+04 | 6.61E+04 | + | 2.40E+05 | 2.10E+05 | + | 1.95E+06 | 1.01E+07 | + | 3.67E+06 | 2.46E+06 | + | 1.42E+06 | 6.14E+05 | + | **7.61E+01** | **2.01E+01** |
| F15 | 4.32E+03 | 3.64E+03 | + | 3.00E+03 | 3.33E+03 | + | 6.59E+03 | 4.59E+03 | + | 5.20E+05 | 9.33E+05 | + | 1.13E+03 | 2.80E+01 | + | **5.09E+02** | **7.40E+01** |
| F16 | 8.08E+03 | 3.28E+02 | + | 7.89E+03 | 4.60E+02 | + | 2.04E+03 | 7.84E+02 | + | 8.56E+03 | 1.28E+03 | + | 8.08E+03 | 7.62E+02 | + | **3.66E+02** | **1.80E+02** |
| F17 | 4.99E+03 | 2.58E+02 | + | 5.01E+03 | 3.33E+02 | + | 2.40E+03 | 7.60E+02 | + | 5.17E+03 | 9.17E+02 | + | 7.13E+03 | 6.54E+02 | + | **9.48E+01** | **9.40E+01** |
| F18 | 1.82E+05 | 7.81E+04 | + | 4.11E+05 | 2.77E+05 | + | 1.26E+06 | 2.38E+06 | + | 8.21E+06 | 4.98E+06 | + | 1.70E+06 | 2.37E+05 | + | **4.10E+02** | **7.21E+01** |
| F19 | 2.62E+03 | 3.78E+03 | + | 2.39E+03 | 3.51E+03 | + | 1.52E+06 | 4.13E+06 | + | 1.82E+05 | 6.01E+05 | + | 2.52E+03 | 3.30E+03 | + | **1.71E+02** | **2.94E+01** |
| F20 | 4.81E+03 | 3.04E+02 | + | 4.93E+03 | 3.43E+02 | + | 2.05E+03 | 4.41E+02 | + | 5.12E+03 | 5.69E+02 | + | 6.11E+03 | 2.46E+02 | + | **1.92E+02** | **7.08E+01** |
| F21 | 1.24E+03 | 2.40E+01 | + | 1.68E+03 | 6.42E+01 | + | 1.13E+03 | 5.26E+02 | + | 2.27E+03 | 1.53E+02 | + | 2.18E+03 | 3.43E+01 | + | **2.73E+02** | **2.64E+01** |
| F22 | 3.13E+04 | 4.59E+02 | + | 3.23E+04 | 9.54E+02 | + | 1.35E+04 | 6.49E+03 | + | 3.40E+04 | 1.92E+03 | + | 3.74E+04 | 1.40E+03 | + | **5.10E+03** | **2.32E+03** |
| F23 | 1.68E+03 | 5.41E+01 | + | 2.00E+03 | 6.75E+01 | + | 1.12E+03 | 5.80E+02 | + | 2.63E+03 | 2.63E+02 | + | 2.65E+03 | 7.75E+01 | + | **6.06E+02** | **4.33E+01** |
| F24 | 2.01E+03 | 5.59E+01 | + | 2.36E+03 | 7.58E+01 | + | 1.09E+03 | 3.47E+02 | - | 3.32E+03 | 3.32E+02 | + | 3.08E+03 | 1.79E+02 | + | **9.91E+02** | **5.36E+01** |
| F25 | 1.24E+03 | 6.98E+01 | + | 1.75E+03 | 1.40E+02 | + | 6.59E+03 | 1.59E+04 | = | 5.04E+03 | 1.17E+03 | + | 2.49E+03 | 1.47E+02 | + | **9.83E+02** | **3.86E+01** |
| F26 | 1.33E+04 | 4.51E+02 | + | 1.43E+04 | 6.85E+02 | + | 3.59E+03 | 3.71E+02 | + | 2.00E+04 | 1.97E+03 | + | 1.81E+04 | 2.06E+03 | + | **3.09E+03** | **1.60E+02** |
| F27 | 9.23E+02 | 5.34E+01 | + | 1.41E+03 | 1.21E+02 | + | 1.18E+03 | 9.17E+02 | + | 2.45E+03 | 4.17E+02 | + | 2.63E+03 | 3.92E+01 | + | **7.05E+02** | **2.25E+01** |
| F28 | 9.28E+02 | 7.38E+01 | + | 2.03E+03 | 4.10E+02 | + | 4.76E+03 | 3.94E+03 | + | 1.15E+04 | 4.38E+03 | + | 2.70E+03 | 3.04E+02 | + | **7.11E+02** | **3.10E+01** |
| F29 | 5.88E+03 | 3.29E+02 | + | 5.92E+03 | 3.35E+02 | + | 3.36E+03 | 4.97E+02 | + | 7.46E+03 | 1.16E+03 | + | 7.96E+03 | 4.30E+02 | + | **9.98E+02** | **1.93E+02** |
| F30 | 7.56E+03 | 2.56E+03 | = | 2.03E+04 | 1.22E+04 | + | **4.99E+03** | **6.92E+02** | - | 1.05E+06 | 1.97E+06 | + | 4.42E+04 | 1.34E+04 | + | 6.81E+03 | 1.52E+03 |
| **W** | **26** | | | **28** | | | **23** | | | **29** | | | **28** | | | | |
| **T** | **2** | | | **1** | | | **1** | | | **0** | | | **1** | | | | |
| **L** | **1** | | | **0** | | | **5** | | | **0** | | | **0** | | | | |

TABLE S19 PERFORMANCE COMPARISONS OF DTDEN WITH POPULAR NEAS ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH MODERATE NOISE

30-D

| | ODE | | | MUDE | | | IPOP-UH-CMA-ES | | | BBPSO_CJ | | | DEPSO | | | DTDEn | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 8.90E+06 | 1.72E+07 | + | 8.21E+10 | 9.99E+08 | + | 2.50E+04 | 5.84E+04 | + | 2.62E+10 | 2.80E+10 | + | 2.45E+09 | 1.34E+09 | + | **2.37E+03** | **2.37E+03** |
| F3 | 3.19E+04 | 8.61E+03 | + | 8.31E+04 | 4.22E+03 | + | 2.44E+04 | 1.98E+04 | + | 2.47E+05 | 3.65E+05 | + | 1.10E+05 | 1.09E+04 | + | **4.92E+00** | **1.51E+01** |
| F4 | 2.16E+02 | 3.39E+01 | + | 3.18E+04 | 1.04E+03 | + | 8.01E+02 | 9.25E+02 | + | 1.23E+03 | 8.54E+02 | + | 9.84E+02 | 3.71E+02 | + | **1.12E+02** | **9.05E+00** |
| F5 | 2.98E+02 | 3.11E+01 | + | 5.59E+02 | 2.27E+01 | + | 3.93E+02 | 6.63E+01 | + | 7.38E+02 | 9.35E+01 | + | 6.66E+02 | 7.16E+00 | + | **4.81E+01** | **3.78E+01** |
| F6 | 6.04E+01 | 7.57E+00 | + | 1.22E+02 | 4.68E+00 | + | 9.70E+01 | 2.27E+01 | + | 1.85E+02 | 3.09E+01 | + | 1.70E+02 | 4.92E+00 | + | **1.26E-01** | **3.44E-01** |
| F7 | 5.65E+02 | 8.23E+01 | + | 8.39E+02 | 1.94E+01 | + | 9.32E+02 | 5.16E+02 | + | 2.13E+03 | 8.03E+02 | + | 1.27E+03 | 5.52E+01 | + | **1.32E+02** | **4.24E+01** |
| F8 | 2.78E+02 | 1.83E+01 | + | 4.62E+02 | 1.50E+01 | + | 4.04E+02 | 6.95E+01 | + | 7.26E+02 | 9.09E+01 | + | 5.86E+02 | 3.88E+01 | + | **4.93E+01** | **4.23E+01** |
| F9 | 8.40E+01 | 7.98E+01 | + | 9.57E+03 | 9.77E+02 | + | 7.53E+03 | 6.46E+03 | + | 9.56E+03 | 7.05E+03 | + | 3.23E+03 | 3.69E+02 | + | **7.81E-02** | **1.65E-01** |
| F10 | 7.30E+03 | 2.91E+02 | + | 8.82E+03 | 2.94E+02 | + | 5.16E+03 | 3.05E+03 | = | 1.10E+04 | 1.27E+03 | + | 1.03E+04 | 9.81E+02 | + | **4.20E+03** | **1.24E+03** |
| F11 | 2.33E+02 | 2.75E+01 | + | 7.94E+02 | 7.55E+02 | + | 1.34E+04 | 7.21E+03 | + | 2.69E+03 | 2.06E+03 | + | 1.59E+03 | 9.17E+01 | + | **7.87E+01** | **2.64E+01** |
| F12 | 2.46E+05 | 2.30E+05 | + | 2.79E+10 | 4.36E+08 | + | 4.19E+08 | 1.50E+09 | = | 1.98E+07 | 2.18E+07 | + | 1.40E+06 | 6.82E+05 | + | **6.78E+03** | **5.27E+03** |
| F13 | 4.07E+02 | 1.26E+02 | + | 4.12E+10 | 1.73E+09 | + | 1.39E+09 | 2.98E+09 | + | 3.41E+05 | 7.76E+05 | + | 1.90E+04 | 7.32E+03 | + | **2.13E+02** | **1.01E+02** |
| F14 | 1.14E+02 | 1.27E+01 | + | 1.07E+08 | 3.00E+08 | + | 1.89E+05 | 2.74E+05 | + | 3.56E+05 | 7.41E+05 | + | 1.24E+04 | 1.82E+04 | + | **6.34E+01** | **1.77E+01** |
| F15 | 1.55E+02 | 3.19E+01 | + | 2.64E+09 | 2.49E+09 | + | 3.70E+08 | 4.70E+08 | + | 1.59E+05 | 3.39E+05 | + | 1.19E+04 | 4.87E+03 | + | **5.30E+01** | **2.24E+01** |
| F16 | 1.71E+03 | 1.68E+02 | + | 2.36E+04 | 2.37E+03 | + | 2.95E+03 | 9.81E+02 | + | 4.16E+03 | 8.09E+02 | + | 5.26E+03 | 9.64E+02 | + | **3.33E+02** | **2.85E+02** |
| F17 | 5.48E+02 | 8.12E+01 | + | 9.98E+03 | 3.67E+04 | + | 1.83E+03 | 1.07E+03 | + | 1.91E+03 | 5.12E+02 | + | 2.73E+03 | 1.30E+02 | + | **5.15E+01** | **5.08E+01** |
| F18 | 1.15E+02 | 2.72E+01 | + | 1.91E+09 | 1.82E+09 | + | 3.74E+05 | 5.27E+05 | + | 3.02E+06 | 5.58E+06 | + | 4.85E+05 | 6.05E+04 | + | **6.92E+01** | **1.43E+01** |
| F19 | 4.34E+01 | 4.05E+00 | + | 2.99E+09 | 2.54E+09 | + | 4.95E+06 | 1.11E+07 | + | 1.16E+05 | 4.93E+05 | + | 1.37E+04 | 3.59E+03 | + | **1.85E+01** | **5.92E+00** |
| F20 | 6.65E+02 | 9.98E+01 | + | 2.37E+03 | 5.32E+02 | + | 1.04E+03 | 4.19E+02 | + | 2.27E+03 | 5.60E+02 | + | 2.73E+03 | 5.28E+02 | + | **1.37E+02** | **1.15E+02** |
| F21 | 4.73E+02 | 1.35E+01 | + | 1.07E+03 | 2.20E+01 | + | 6.30E+02 | 7.97E+01 | + | 9.60E+02 | 1.42E+02 | + | 9.55E+02 | 2.43E+02 | + | **3.31E+02** | **3.43E+01** |
| F22 | 7.68E+02 | 1.05E+03 | + | 9.93E+03 | 3.27E+02 | + | 7.66E+03 | 1.73E+03 | + | 1.13E+04 | 1.80E+03 | + | 5.51E+03 | 2.63E+02 | + | **1.39E+02** | **1.84E+01** |
| F23 | 6.84E+02 | 3.50E+01 | + | 4.90E+03 | 1.87E+02 | + | 8.89E+02 | 1.97E+02 | + | 1.74E+03 | 4.18E+02 | + | 1.38E+03 | 1.46E+02 | + | **5.06E+02** | **3.52E+01** |
| F24 | 7.32E+02 | 3.14E+01 | + | 2.75E+03 | 1.57E+01 | + | 9.41E+02 | 1.97E+02 | + | 1.87E+03 | 5.69E+02 | + | 1.50E+03 | 1.21E+02 | + | **5.78E+02** | **3.24E+01** |
| F25 | 5.68E+02 | 3.52E+01 | + | 5.94E+03 | 2.47E+02 | + | 1.97E+03 | 1.46E+03 | + | 2.97E+03 | 1.34E+03 | + | 2.01E+03 | 4.36E+02 | + | **4.37E+02** | **1.39E+01** |
| F26 | 4.77E+03 | 3.83E+02 | + | 1.29E+04 | 2.07E+02 | + | 4.83E+03 | 8.72E+02 | + | 9.14E+03 | 2.02E+03 | + | 8.94E+03 | 1.32E+03 | + | **1.79E+03** | **4.57E+02** |
| F27 | 6.47E+02 | 2.30E+01 | + | 6.94E+03 | 2.68E+02 | + | 9.68E+02 | 3.53E+02 | + | 2.03E+03 | 6.55E+02 | + | 1.38E+03 | 1.11E+02 | + | **5.97E+02** | **1.60E+01** |
| F28 | 6.83E+02 | 3.46E+01 | + | 7.03E+03 | 1.04E+02 | + | 2.95E+03 | 1.35E+03 | + | 4.51E+03 | 1.78E+03 | + | 2.95E+03 | 3.45E+02 | + | **5.30E+02** | **2.50E+01** |
| F29 | 1.43E+03 | 1.38E+02 | + | 2.77E+03 | 4.12E+02 | + | 3.31E+03 | 1.40E+03 | + | 3.69E+03 | 1.01E+03 | + | 3.42E+03 | 4.53E+02 | + | **5.77E+02** | **7.92E+01** |
| F30 | 6.42E+03 | 1.88E+03 | + | 9.49E+09 | 3.16E+08 | + | 3.16E+07 | 2.13E+08 | + | 3.91E+05 | 4.98E+05 | + | 5.54E+04 | 9.88E+03 | + | **4.40E+03** | **1.07E+03** |
| **W** | **29** | | | **29** | | | **27** | | | **29** | | | **29** | | | | |
| **T** | **0** | | | **0** | | | **2** | | | **0** | | | **0** | | | | |
| **L** | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | | | |

TABLE S19 (CONTINUED) PERFORMANCE COMPARISONS OF DTDEN WITH POPULAR NEAS ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH MODERATE NOISE

50-D

| | ODE | | | MUDE | | | IPOP-UH-CMA-ES | | | BBPSO_CJ | | | DEPSO | | | DTDEn | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 5.03E+10 | 1.36E+10 | + | 1.16E+10 | 8.02E+09 | + | 5.71E+08 | 1.77E+09 | + | 1.28E+11 | 5.02E+10 | + | 4.34E+10 | 1.55E+10 | + | **2.08E+06** | **3.83E+06** |
| F3 | 1.69E+05 | 2.17E+04 | + | 1.70E+05 | 3.66E+04 | + | **1.08E+02** | **1.71E+02** | - | 1.36E+06 | 6.20E+06 | + | 2.60E+05 | 3.02E+04 | + | 4.58E+03 | 3.58E+03 |
| F4 | 6.00E+02 | 1.82E+02 | + | 8.26E+02 | 1.40E+02 | + | 2.78E+03 | 9.92E+03 | + | 8.14E+03 | 6.78E+03 | + | 1.61E+03 | 3.83E+02 | + | **2.66E+02** | **1.49E+01** |
| F5 | 7.13E+02 | 6.61E+01 | + | 8.91E+02 | 6.86E+01 | + | 6.88E+02 | 1.34E+02 | + | 1.34E+03 | 1.94E+02 | + | 9.42E+02 | 3.93E+01 | + | **1.91E+02** | **6.72E+01** |
| F6 | 8.44E+01 | 9.09E+00 | + | 1.38E+02 | 9.64E+00 | + | 2.74E+02 | 8.70E+01 | + | 1.90E+02 | 1.89E+01 | + | 1.53E+02 | 1.19E+01 | + | **1.18E+00** | **1.64E+00** |
| F7 | 2.11E+03 | 7.39E+02 | + | 2.62E+03 | 4.40E+02 | + | 1.57E+03 | 1.13E+03 | + | 4.72E+03 | 7.63E+02 | + | 2.25E+03 | 5.66E+01 | + | **3.61E+02** | **7.30E+01** |
| F8 | 6.51E+02 | 4.21E+01 | + | 9.13E+02 | 7.31E+01 | + | 7.30E+02 | 1.37E+02 | + | 1.36E+03 | 2.27E+02 | + | 9.43E+02 | 9.64E+00 | + | **2.00E+02** | **6.15E+01** |
| F9 | 2.54E+03 | 1.33E+03 | + | 8.66E+03 | 3.67E+03 | + | 2.44E+03 | 1.97E+03 | + | 4.73E+04 | 2.01E+04 | + | 2.49E+04 | 9.27E+03 | + | **4.13E+00** | **4.94E+00** |
| F10 | 1.36E+04 | 3.53E+02 | + | 1.59E+04 | 6.82E+02 | + | 1.17E+04 | 4.82E+03 | + | 1.90E+04 | 1.23E+03 | + | 1.77E+04 | 5.84E+02 | + | **9.69E+03** | **1.71E+03** |
| F11 | 4.79E+02 | 5.40E+01 | + | 9.50E+02 | 1.61E+02 | + | 1.48E+04 | 5.24E+03 | + | 1.41E+04 | 1.29E+04 | + | 3.35E+03 | 9.87E+02 | + | **1.49E+02** | **6.48E+01** |
| F12 | 8.38E+07 | 6.10E+07 | + | 1.51E+07 | 1.20E+07 | + | 1.15E+09 | 7.07E+09 | - | 3.38E+09 | 4.93E+09 | + | 2.20E+08 | 3.96E+08 | + | **1.98E+06** | **1.15E+06** |
| F13 | 9.81E+03 | 5.36E+03 | + | 2.28E+04 | 1.80E+04 | + | 9.06E+08 | 3.70E+09 | + | 8.14E+06 | 4.28E+07 | + | 2.59E+04 | 7.77E+03 | + | **4.46E+03** | **1.99E+03** |
| F14 | 2.38E+02 | 1.76E+01 | + | 1.22E+03 | 1.98E+03 | + | 1.98E+06 | 3.04E+06 | + | 1.85E+06 | 3.47E+06 | + | 1.23E+04 | 9.97E+03 | + | **1.61E+02** | **4.24E+01** |
| F15 | 6.75E+02 | 1.03E+02 | + | 6.59E+03 | 5.76E+03 | + | 1.30E+07 | 6.09E+07 | + | 5.16E+05 | 1.78E+06 | + | 1.07E+04 | 3.35E+03 | + | **3.20E+02** | **1.39E+02** |
| F16 | 3.67E+03 | 2.62E+02 | + | 4.95E+03 | 4.03E+02 | + | 4.62E+03 | 1.07E+03 | + | 6.94E+03 | 1.29E+03 | + | 8.68E+03 | 2.26E+02 | + | **7.38E+02** | **2.74E+02** |
| F17 | 2.10E+03 | 1.84E+02 | + | 2.99E+03 | 2.30E+02 | + | 8.45E+03 | 1.49E+04 | + | 4.72E+03 | 9.37E+02 | + | 4.92E+03 | 3.29E+02 | + | **4.91E+02** | **2.70E+02** |
| F18 | 1.91E+04 | 1.80E+04 | + | 9.73E+04 | 9.99E+04 | + | 6.16E+06 | 9.53E+06 | + | 9.07E+06 | 1.33E+07 | + | 1.38E+06 | 2.62E+04 | + | **3.96E+02** | **7.70E+01** |
| F19 | 1.18E+02 | 1.46E+01 | + | 6.90E+03 | 7.23E+03 | + | 1.52E+07 | 7.57E+07 | + | 1.30E+05 | 2.89E+05 | + | 3.27E+04 | 1.24E+04 | + | **4.61E+01** | **1.77E+01** |
| F20 | 1.88E+03 | 1.51E+02 | + | 2.82E+03 | 2.76E+02 | + | 2.68E+03 | 9.54E+02 | + | 4.13E+03 | 8.02E+02 | + | 4.14E+03 | 4.01E+02 | + | **2.77E+02** | **2.38E+02** |
| F21 | 8.68E+02 | 3.93E+01 | + | 1.17E+03 | 6.03E+01 | + | 1.01E+03 | 1.94E+02 | + | 1.60E+03 | 2.18E+02 | + | 1.68E+03 | 9.78E+01 | + | **4.89E+02** | **4.85E+01** |
| F22 | 1.38E+04 | 4.45E+02 | + | 1.62E+04 | 5.46E+02 | + | 1.37E+04 | 4.54E+03 | + | 1.94E+04 | 1.43E+03 | + | 2.01E+04 | 1.06E+03 | + | **4.91E+03** | **5.12E+03** |
| F23 | 1.26E+03 | 8.45E+01 | + | 1.69E+03 | 1.01E+02 | + | 1.30E+03 | 2.80E+02 | + | 2.65E+03 | 4.78E+02 | + | 2.28E+03 | 2.61E+01 | + | **7.83E+02** | **5.25E+01** |
| F24 | 1.26E+03 | 8.11E+01 | + | 1.74E+03 | 1.10E+02 | + | 1.31E+03 | 2.14E+02 | + | 3.11E+03 | 7.73E+02 | + | 3.09E+03 | 2.22E+02 | + | **8.63E+02** | **6.10E+01** |
| F25 | 1.15E+03 | 1.08E+02 | + | 2.45E+03 | 4.36E+02 | + | 4.80E+03 | 8.54E+03 | + | 1.52E+04 | 1.12E+04 | + | 7.47E+03 | 4.35E+02 | + | **6.43E+02** | **3.30E+01** |
| F26 | 8.11E+03 | 4.75E+02 | + | 1.03E+04 | 6.20E+02 | + | 6.82E+03 | 1.90E+03 | + | 1.88E+04 | 4.55E+03 | + | 2.13E+04 | 1.47E+03 | + | **3.61E+03** | **7.12E+02** |
| F27 | 1.31E+03 | 1.49E+02 | + | 2.28E+03 | 2.52E+02 | + | 1.97E+03 | 9.25E+02 | + | 4.40E+03 | 1.28E+03 | + | 4.02E+03 | 5.32E+02 | + | **8.83E+02** | **6.23E+01** |
| F28 | 5.45E+03 | 1.43E+03 | + | 5.46E+03 | 1.18E+03 | + | 5.74E+03 | 2.96E+03 | + | 1.15E+04 | 3.05E+03 | + | 8.59E+03 | 1.59E+03 | + | **6.63E+02** | **6.42E+01** |
| F29 | 2.82E+03 | 1.71E+02 | + | 4.01E+03 | 3.27E+02 | + | 1.07E+04 | 1.30E+04 | + | 6.38E+03 | 1.63E+03 | + | 6.30E+03 | 7.63E+02 | + | **6.49E+02** | **2.21E+02** |
| F30 | 6.57E+06 | 1.79E+06 | + | 5.80E+06 | 2.21E+06 | + | **6.98E+05** | **6.50E+04** | - | 5.18E+07 | 4.61E+07 | + | 5.88E+07 | 2.13E+07 | + | 1.94E+06 | 4.58E+05 |
| **W** | **29** | | | **29** | | | **26** | | | **29** | | | **29** | | | | |
| **T** | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | | | |
| **L** | **0** | | | **0** | | | **3** | | | **0** | | | **0** | | | | |

TABLE S19 (CONTINUED) PERFORMANCE COMPARISONS OF DTDEN WITH POPULAR NEAS ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH MODERATE NOISE

100-D

| | ODE | | | MUDE | | | IPOP-UH-CMA-ES | | | BBPSO_CJ | | | DEPSO | | | DTDEn | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 2.74E+11 | 5.05E+10 | + | 2.57E+11 | 5.03E+10 | + | **6.23E+07** | **1.16E+08** | = | 5.54E+11 | 1.00E+11 | + | 3.68E+11 | 5.97E+10 | + | 7.90E+08 | 2.68E+09 |
| F3 | 5.14E+05 | 4.66E+04 | + | 5.50E+05 | 6.88E+04 | + | **1.25E+04** | **1.73E+04** | - | 1.40E+13 | 9.97E+13 | + | 5.64E+05 | 3.43E+04 | + | 8.88E+04 | 2.07E+04 |
| F4 | 4.28E+03 | 1.00E+03 | + | 3.39E+03 | 1.03E+03 | + | 4.36E+03 | 7.68E+03 | + | 7.65E+04 | 3.55E+04 | + | 2.45E+04 | 7.35E+02 | + | **4.84E+02** | **7.20E+01** |
| F5 | 1.69E+03 | 8.13E+01 | + | 2.14E+03 | 1.18E+02 | + | 1.38E+03 | 3.23E+02 | + | 2.80E+03 | 3.52E+02 | + | 2.42E+03 | 8.39E+01 | + | **8.24E+02** | **9.52E+01** |
| F6 | 1.11E+02 | 5.27E+00 | + | 1.55E+02 | 7.11E+00 | + | 8.52E+02 | 2.00E+01 | + | 1.91E+02 | 1.39E+01 | + | 1.90E+02 | 9.05E+00 | + | **9.42E+00** | **6.96E+00** |
| F7 | 6.94E+03 | 8.24E+02 | + | 7.41E+03 | 1.05E+03 | + | 5.72E+03 | 1.87E+03 | + | 1.21E+04 | 1.57E+03 | + | 7.77E+03 | 1.37E+03 | + | **1.07E+03** | **1.41E+02** |
| F8 | 1.76E+03 | 7.88E+01 | + | 2.24E+03 | 1.25E+02 | + | 1.43E+03 | 2.36E+02 | + | 2.94E+03 | 3.05E+02 | + | 2.67E+03 | 3.17E+01 | + | **7.98E+02** | **1.03E+02** |
| F9 | 6.69E+04 | 1.23E+04 | + | 9.21E+04 | 1.74E+04 | + | 4.07E+04 | 3.85E+04 | + | 2.01E+05 | 5.12E+04 | + | 1.04E+05 | 1.63E+04 | + | **2.02E+02** | **5.85E+02** |
| F10 | 3.02E+04 | 5.68E+02 | + | 3.40E+04 | 8.57E+02 | + | **1.09E+04** | **2.92E+03** | - | 3.89E+04 | 1.76E+03 | + | 3.88E+04 | 1.32E+03 | + | 2.78E+04 | 1.67E+03 |
| F11 | 2.36E+04 | 1.19E+04 | + | 3.44E+04 | 1.60E+04 | + | 2.73E+05 | 3.18E+05 | = | 4.20E+05 | 3.44E+05 | + | 1.71E+05 | 2.53E+04 | + | **1.93E+03** | **2.10E+02** |
| F12 | 1.33E+10 | 5.09E+09 | + | 6.41E+09 | 3.75E+09 | + | **1.95E+07** | **1.27E+08** | - | 1.52E+11 | 1.04E+11 | + | 6.70E+10 | 2.19E+10 | + | 7.75E+07 | 4.75E+07 |
| F13 | 4.86E+04 | 3.26E+04 | + | 4.78E+04 | 2.04E+04 | + | 8.27E+07 | 5.86E+08 | - | 7.89E+09 | 1.27E+10 | + | 3.99E+08 | 2.22E+08 | + | **2.57E+04** | **4.11E+03** |
| F14 | 1.06E+05 | 1.09E+05 | + | 6.41E+05 | 4.48E+05 | + | 1.69E+06 | 6.28E+06 | + | 2.80E+07 | 2.02E+07 | + | 9.12E+06 | 2.69E+06 | + | **5.92E+02** | **5.64E+01** |
| F15 | 1.14E+04 | 6.67E+03 | + | 1.12E+04 | 7.26E+03 | + | 1.08E+08 | 7.50E+08 | + | 4.53E+07 | 2.04E+08 | + | 2.28E+05 | 8.52E+04 | + | **3.83E+03** | **1.77E+03** |
| F16 | 1.03E+04 | 3.58E+02 | + | 1.22E+04 | 5.94E+02 | + | 1.13E+04 | 2.37E+03 | + | 1.79E+04 | 3.48E+03 | + | 1.67E+04 | 1.00E+03 | + | **3.47E+03** | **1.34E+03** |
| F17 | 5.62E+03 | 3.22E+02 | + | 7.17E+03 | 4.44E+02 | + | 7.92E+04 | 3.64E+05 | + | 1.02E+04 | 1.55E+03 | + | 8.22E+03 | 6.01E+02 | + | **1.61E+03** | **8.32E+02** |
| F18 | 6.39E+05 | 3.61E+05 | + | 9.39E+05 | 6.12E+05 | + | 2.85E+05 | 1.54E+05 | + | 3.56E+07 | 2.25E+07 | + | 3.54E+06 | 2.45E+06 | + | **1.14E+04** | **8.23E+03** |
| F19 | 6.90E+03 | 7.52E+03 | + | 5.61E+03 | 6.95E+03 | + | 2.35E+09 | 8.03E+09 | + | 8.91E+07 | 4.50E+08 | + | 5.64E+04 | 3.19E+04 | + | **5.40E+02** | **2.57E+02** |
| F20 | 5.30E+03 | 2.10E+02 | + | 6.74E+03 | 4.89E+02 | + | 6.21E+03 | 1.32E+03 | + | 8.65E+03 | 8.77E+02 | + | 8.38E+03 | 1.01E+03 | + | **1.89E+03** | **7.67E+02** |
| F21 | 2.06E+03 | 1.16E+02 | + | 2.58E+03 | 1.34E+02 | + | 1.95E+03 | 3.32E+02 | + | 3.65E+03 | 5.27E+02 | + | 3.15E+03 | 8.64E+01 | + | **1.11E+03** | **8.41E+01** |
| F22 | 3.15E+04 | 4.85E+02 | + | 3.57E+04 | 9.11E+02 | + | **2.12E+04** | **1.24E+04** | = | 4.02E+04 | 1.97E+03 | + | 4.13E+04 | 1.21E+03 | + | 2.58E+04 | 9.36E+03 |
| F23 | 2.56E+03 | 1.52E+02 | + | 3.16E+03 | 2.17E+02 | + | 2.30E+03 | 6.82E+02 | + | 5.33E+03 | 1.09E+03 | + | 5.27E+03 | 5.37E+02 | + | **1.49E+03** | **1.17E+02** |
| F24 | 3.67E+03 | 2.23E+02 | + | 4.74E+03 | 3.84E+02 | + | 2.79E+03 | 8.03E+02 | + | 9.01E+03 | 2.13E+03 | + | 8.61E+03 | 5.23E+02 | + | **1.95E+03** | **1.26E+02** |
| F25 | 6.32E+03 | 1.30E+03 | + | 1.06E+04 | 2.59E+03 | + | 2.46E+03 | 5.64E+02 | + | 5.86E+04 | 2.16E+04 | + | 1.74E+04 | 5.85E+03 | + | **1.31E+03** | **1.11E+02** |
| F26 | 2.68E+04 | 1.86E+03 | + | 2.97E+04 | 2.20E+03 | + | 1.90E+04 | 5.41E+03 | + | 5.97E+04 | 1.48E+04 | + | 6.04E+04 | 3.82E+03 | + | **1.26E+04** | **1.33E+03** |
| F27 | 2.88E+03 | 2.72E+02 | + | 4.57E+03 | 6.13E+02 | + | 2.83E+03 | 1.44E+03 | + | 9.73E+03 | 3.03E+03 | + | 1.03E+04 | 1.10E+03 | + | **1.14E+03** | **1.33E+02** |
| F28 | 2.19E+04 | 3.00E+03 | + | 2.75E+04 | 4.18E+03 | + | 1.57E+04 | 2.69E+03 | + | 5.15E+04 | 1.13E+04 | + | 4.85E+04 | 5.92E+03 | + | **1.46E+03** | **4.68E+02** |
| F29 | 8.38E+03 | 3.74E+02 | + | 1.01E+04 | 6.77E+02 | + | 5.94E+04 | 2.04E+05 | + | 1.66E+04 | 4.32E+03 | + | 1.57E+04 | 2.68E+02 | + | **2.92E+03** | **6.83E+02** |
| F30 | 6.79E+06 | 6.05E+06 | + | 1.39E+06 | 1.27E+06 | + | 4.55E+07 | 2.78E+08 | - | 3.16E+09 | 1.18E+10 | + | 2.70E+08 | 1.14E+08 | + | **2.05E+05** | **9.38E+04** |
| **W** | **29** | | | **29** | | | **21** | | | **29** | | | **29** | | | | |
| **T** | **0** | | | **0** | | | **3** | | | **0** | | | **0** | | | | |
| **L** | **0** | | | **0** | | | **5** | | | **0** | | | **0** | | | | |

TABLE S20 PERFORMANCE COMPARISONS OF DTDEN WITH POPULAR NEAS ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH SEVERE NOISE

30-D

| | ODE | | | MUDE | | | IPOP-UH-CMA-ES | | | BBPSO_CJ | | | DEPSO | | | DTDEn | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 2.29E+10 | 5.33E+09 | + | 8.20E+10 | 1.27E+09 | + | 1.92E+09 | 1.02E+10 | = | 1.04E+11 | 4.32E+10 | + | 8.13E+10 | 8.39E+09 | + | **2.63E+03** | **2.10E+03** |
| F3 | 6.42E+04 | 1.09E+04 | - | 8.58E+04 | 3.70E+03 | + | **1.65E+04** | **4.64E+04** | - | 2.89E+05 | 2.10E+05 | + | 1.50E+05 | 4.14E+04 | + | 7.11E+04 | 1.05E+04 |
| F4 | 5.65E+02 | 1.35E+02 | + | 3.21E+04 | 7.94E+02 | + | 2.71E+03 | 3.42E+03 | + | 1.16E+04 | 1.16E+04 | + | 2.22E+03 | 5.59E+02 | + | **1.44E+02** | **1.08E+01** |
| F5 | 3.56E+02 | 3.16E+01 | + | 5.63E+02 | 1.77E+01 | + | 4.42E+02 | 1.02E+02 | + | 8.48E+02 | 1.50E+02 | + | 7.88E+02 | 6.28E+01 | + | **9.79E+01** | **2.95E+01** |
| F6 | 7.06E+01 | 7.25E+00 | + | 1.19E+02 | 4.99E+00 | + | 6.48E+02 | 3.85E+01 | + | 2.02E+02 | 2.96E+01 | + | 1.65E+02 | 4.80E+00 | + | **2.59E-01** | **1.21E-01** |
| F7 | 9.96E+02 | 1.21E+02 | + | 8.42E+02 | 1.86E+01 | + | 1.37E+03 | 5.79E+02 | + | 2.97E+03 | 6.83E+02 | + | 1.77E+03 | 2.19E+02 | + | **1.85E+02** | **2.61E+01** |
| F8 | 3.24E+02 | 2.23E+01 | + | 4.60E+02 | 1.48E+01 | + | 4.65E+02 | 8.72E+01 | + | 7.77E+02 | 1.29E+02 | + | 5.62E+02 | 5.50E+01 | + | **9.77E+01** | **3.00E+01** |
| F9 | 5.58E+03 | 1.32E+03 | + | 1.26E+04 | 1.59E+03 | + | 3.23E+03 | 3.82E+03 | + | 3.14E+04 | 1.38E+04 | + | 2.26E+04 | 6.12E+02 | + | **1.93E-02** | **4.63E-02** |
| F10 | 7.30E+03 | 3.04E+02 | + | 8.96E+03 | 3.08E+02 | + | 8.44E+03 | 2.07E+03 | + | 1.20E+04 | 9.16E+02 | + | 1.36E+04 | 4.97E+02 | + | **5.33E+03** | **8.35E+02** |
| F11 | **4.23E+02** | **4.61E+01** | - | 2.92E+07 | 9.41E+07 | + | 9.07E+03 | 6.93E+03 | + | 1.11E+04 | 8.34E+03 | + | 2.25E+03 | 6.98E+02 | = | 2.52E+03 | 1.33E+03 |
| F12 | 2.32E+08 | 1.13E+08 | + | 2.82E+10 | 3.34E+08 | + | 8.82E+07 | 2.75E+08 | - | 8.41E+09 | 1.04E+10 | + | 1.24E+09 | 3.69E+08 | + | **7.69E+05** | **4.07E+05** |
| F13 | 1.67E+04 | 1.10E+04 | + | 4.10E+10 | 1.30E+09 | + | 1.90E+09 | 3.60E+09 | = | 4.84E+07 | 2.07E+08 | + | 6.95E+04 | 2.21E+04 | + | **9.11E+03** | **4.61E+03** |
| F14 | **1.49E+02** | **1.69E+01** | - | 8.15E+08 | 3.55E+08 | + | 2.62E+04 | 2.65E+04 | - | 4.35E+05 | 1.34E+06 | - | 8.38E+05 | 1.53E+06 | - | 2.66E+05 | 1.46E+05 |
| F15 | **4.11E+02** | **9.09E+01** | = | 4.88E+09 | 1.12E+09 | + | 3.59E+07 | 2.54E+08 | + | 1.54E+05 | 3.45E+05 | + | 6.36E+03 | 3.32E+03 | + | 9.45E+02 | 1.24E+03 |
| F16 | 1.76E+03 | 1.61E+02 | + | 2.42E+04 | 8.94E+02 | + | 3.30E+03 | 9.47E+02 | + | 4.87E+03 | 9.67E+02 | + | 5.93E+03 | 1.16E+03 | + | **4.91E+02** | **2.73E+02** |
| F17 | 6.28E+02 | 1.09E+02 | + | 1.59E+05 | 7.03E+04 | + | 2.33E+03 | 1.23E+03 | + | 2.90E+03 | 9.04E+02 | + | 3.77E+03 | 3.85E+02 | + | **7.38E+01** | **6.80E+01** |
| F18 | **3.09E+03** | **2.73E+03** | - | 3.77E+09 | 6.54E+08 | + | 1.28E+06 | 8.89E+06 | - | 3.88E+06 | 4.20E+06 | + | 1.68E+06 | 2.29E+06 | + | 4.80E+05 | 3.86E+05 |
| F19 | **8.70E+01** | **1.47E+01** | - | 5.16E+09 | 9.94E+08 | + | 9.28E+07 | 2.48E+08 | + | 2.50E+05 | 4.62E+05 | + | 5.22E+03 | 3.54E+03 | + | 3.04E+03 | 2.21E+03 |
| F20 | 7.74E+02 | 9.67E+01 | + | 2.78E+03 | 3.49E+02 | + | 1.45E+03 | 7.79E+02 | + | 2.55E+03 | 4.49E+02 | + | 2.32E+03 | 4.18E+02 | + | **2.49E+02** | **9.86E+01** |
| F21 | 5.09E+02 | 2.54E+01 | + | 1.06E+03 | 2.06E+01 | + | 6.33E+02 | 7.15E+01 | + | 1.08E+03 | 1.96E+02 | + | 1.28E+03 | 2.60E+01 | + | **3.66E+02** | **1.78E+01** |
| F22 | 4.80E+03 | 1.49E+03 | + | 1.00E+04 | 2.49E+02 | + | 9.72E+03 | 2.27E+03 | + | 1.20E+04 | 1.50E+03 | + | 9.31E+03 | 1.41E+03 | + | **1.38E+02** | **4.49E+00** |
| F23 | 8.12E+02 | 6.43E+01 | + | 5.05E+03 | 1.42E+02 | + | 9.03E+02 | 1.71E+02 | + | 2.34E+03 | 7.75E+02 | + | 2.44E+03 | 2.07E+02 | + | **5.38E+02** | **2.21E+01** |
| F24 | 8.58E+02 | 5.68E+01 | + | 2.75E+03 | 1.35E+01 | + | 9.83E+02 | 2.33E+02 | + | 2.67E+03 | 6.48E+02 | + | 1.97E+03 | 5.75E+02 | + | **6.00E+02** | **2.11E+01** |
| F25 | 7.87E+02 | 1.01E+02 | + | 5.98E+03 | 2.10E+02 | + | 3.85E+03 | 2.71E+03 | + | 7.23E+03 | 4.84E+03 | + | 3.51E+03 | 5.79E+02 | + | **4.47E+02** | **1.38E+01** |
| F26 | 5.37E+03 | 3.84E+02 | + | 1.29E+04 | 1.92E+02 | + | 5.70E+03 | 1.07E+03 | + | 1.30E+04 | 3.28E+03 | + | 1.08E+04 | 7.48E+02 | + | **2.44E+03** | **2.99E+02** |
| F27 | 7.87E+02 | 6.77E+01 | + | 7.04E+03 | 2.26E+02 | + | 1.15E+03 | 7.56E+02 | + | 3.17E+03 | 9.06E+02 | + | 2.59E+03 | 3.33E+02 | + | **6.17E+02** | **1.53E+01** |
| F28 | 1.45E+03 | 2.78E+02 | + | 7.06E+03 | 1.24E+02 | + | 4.20E+03 | 1.53E+03 | + | 9.20E+03 | 3.95E+03 | + | 5.08E+03 | 9.82E+01 | + | **5.42E+02** | **1.95E+01** |
| F29 | 1.65E+03 | 1.91E+02 | + | 4.73E+04 | 5.97E+04 | + | 3.68E+03 | 1.84E+03 | + | 4.67E+03 | 1.52E+03 | + | 4.16E+03 | 5.86E+02 | + | **7.13E+02** | **1.32E+02** |
| F30 | 3.07E+05 | 2.44E+05 | + | 9.66E+09 | 1.76E+08 | + | 4.05E+07 | 1.15E+08 | + | 5.82E+06 | 9.96E+06 | + | 2.53E+06 | 7.79E+05 | + | **7.62E+03** | **3.44E+03** |
| **W** | **23** | | | **29** | | | **23** | | | **28** | | | **27** | | | | |
| **T** | **1** | | | **0** | | | **2** | | | **0** | | | **1** | | | | |
| **L** | **5** | | | **0** | | | **4** | | | **1** | | | **1** | | | | |

TABLE S20 (CONTINUED) PERFORMANCE COMPARISONS OF DTDEN WITH POPULAR NEAS ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH SEVERE NOISE

50-D

| | ODE | | | MUDE | | | IPOP-UH-CMA-ES | | | BBPSO_CJ | | | DEPSO | | | DTDEn | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 8.59E+10 | 1.22E+10 | + | 1.38E+11 | 1.92E+10 | + | 2.17E+10 | 3.00E+10 | + | 2.67E+11 | 6.12E+10 | + | 2.08E+11 | 4.62E+10 | + | **3.06E+04** | **2.97E+04** |
| F3 | 1.97E+05 | 1.97E+04 | + | 2.31E+05 | 3.55E+04 | + | 2.00E+05 | 2.71E+05 | - | 2.93E+06 | 1.37E+07 | + | 3.86E+05 | 2.26E+04 | + | **1.50E+05** | **1.63E+04** |
| F4 | 6.64E+03 | 2.31E+03 | + | 6.60E+03 | 2.70E+03 | + | 2.29E+03 | 2.35E+03 | + | 5.95E+04 | 3.46E+04 | + | 1.80E+04 | 9.63E+03 | + | **2.61E+02** | **1.07E+01** |
| F5 | 7.16E+02 | 3.91E+01 | + | 1.01E+03 | 7.31E+01 | + | 8.18E+02 | 1.75E+02 | + | 1.39E+03 | 1.94E+02 | + | 1.50E+03 | 2.02E+02 | + | **3.16E+02** | **4.32E+01** |
| F6 | 9.18E+01 | 5.81E+00 | + | 1.43E+02 | 8.13E+00 | + | 1.54E+03 | 5.40E+01 | + | 1.94E+02 | 2.82E+01 | + | 1.73E+02 | 1.85E+01 | + | **1.92E+00** | **5.19E-01** |
| F7 | 2.37E+03 | 2.12E+02 | + | 4.00E+03 | 3.91E+02 | + | 2.33E+03 | 1.34E+03 | + | 6.22E+03 | 1.03E+03 | + | 4.26E+03 | 2.89E+02 | + | **4.24E+02** | **2.58E+01** |
| F8 | 7.11E+02 | 4.79E+01 | + | 1.05E+03 | 4.97E+01 | + | 3.26E+03 | 4.73E+02 | + | 1.46E+03 | 2.18E+02 | + | 1.29E+03 | 9.38E+01 | + | **3.16E+02** | **4.13E+01** |
| F9 | 2.81E+04 | 6.05E+03 | + | 4.77E+04 | 7.65E+03 | + | 1.02E+04 | 1.47E+04 | + | 1.17E+05 | 3.58E+04 | + | 8.93E+04 | 2.71E+04 | + | **6.09E-01** | **2.28E-01** |
| F10 | 1.36E+04 | 3.49E+02 | + | 1.62E+04 | 5.78E+02 | + | 1.60E+04 | 2.61E+03 | + | 1.98E+04 | 1.41E+03 | + | 1.97E+04 | 9.96E+02 | + | **1.18E+04** | **7.52E+02** |
| F11 | **1.89E+03** | **4.94E+02** | - | 4.36E+03 | 1.70E+03 | - | 2.78E+04 | 2.44E+04 | + | 4.13E+04 | 2.61E+04 | + | 3.47E+04 | 1.03E+04 | + | 7.58E+03 | 2.79E+03 |
| F12 | 8.74E+09 | 3.35E+09 | + | 1.17E+10 | 3.81E+09 | + | 5.15E+09 | 1.56E+10 | - | 7.22E+10 | 5.00E+10 | + | 1.94E+10 | 1.55E+10 | + | **3.27E+06** | **1.31E+06** |
| F13 | 2.82E+08 | 1.47E+08 | + | 2.14E+08 | 2.41E+08 | + | 2.48E+09 | 7.20E+09 | + | 1.46E+10 | 2.04E+10 | + | 1.37E+08 | 4.57E+07 | + | **1.85E+03** | **1.07E+03** |
| F14 | **5.14E+02** | **7.33E+01** | - | 1.02E+04 | 2.91E+04 | - | 1.17E+05 | 3.01E+05 | - | 8.19E+06 | 1.14E+07 | + | 2.03E+05 | 1.65E+05 | - | 3.43E+05 | 2.18E+05 |
| F15 | 9.55E+03 | 4.92E+03 | + | 2.79E+04 | 1.56E+04 | + | 9.91E+08 | 1.66E+09 | + | 9.93E+08 | 3.60E+09 | + | 3.61E+04 | 1.95E+04 | + | **2.03E+03** | **1.08E+03** |
| F16 | 4.06E+03 | 2.61E+02 | + | 5.90E+03 | 4.64E+02 | + | 5.17E+03 | 1.12E+03 | + | 8.68E+03 | 1.78E+03 | + | 1.26E+04 | 2.10E+03 | + | **9.49E+02** | **2.91E+02** |
| F17 | 2.25E+03 | 1.88E+02 | + | 3.42E+03 | 3.24E+02 | + | 1.70E+04 | 3.38E+04 | + | 5.38E+03 | 1.13E+03 | + | 4.78E+03 | 1.63E+01 | + | **7.23E+02** | **3.03E+02** |
| F18 | **1.14E+05** | **6.26E+04** | - | 1.16E+05 | 6.00E+04 | - | 3.21E+06 | 1.60E+07 | - | 4.25E+07 | 4.09E+07 | + | 1.11E+07 | 4.93E+06 | + | 1.87E+06 | 5.68E+05 |
| F19 | **6.55E+03** | **1.09E+04** | - | 1.69E+04 | 1.27E+04 | = | 2.04E+09 | 1.90E+09 | + | 1.32E+07 | 2.65E+07 | + | 9.96E+04 | 1.20E+04 | + | 1.36E+04 | 2.75E+03 |
| F20 | 1.95E+03 | 1.26E+02 | + | 3.13E+03 | 2.70E+02 | + | 2.83E+03 | 1.01E+03 | + | 4.47E+03 | 7.00E+02 | + | 3.48E+03 | 2.18E+02 | + | **2.88E+02** | **1.43E+02** |
| F21 | 9.04E+02 | 4.04E+01 | + | 1.26E+03 | 7.26E+01 | + | 1.05E+03 | 1.63E+02 | + | 1.75E+03 | 2.50E+02 | + | 1.45E+03 | 1.67E+01 | + | **5.49E+02** | **2.69E+01** |
| F22 | 1.39E+04 | 4.18E+02 | + | 1.68E+04 | 5.99E+02 | + | 1.66E+04 | 2.72E+03 | + | 2.04E+04 | 1.40E+03 | + | 2.16E+04 | 3.79E+00 | + | **1.03E+03** | **2.73E+03** |
| F23 | 1.46E+03 | 9.88E+01 | + | 1.99E+03 | 1.59E+02 | + | 1.46E+03 | 3.15E+02 | + | 3.64E+03 | 1.16E+03 | + | 3.27E+03 | 8.55E+01 | + | **8.25E+02** | **2.81E+01** |
| F24 | 1.54E+03 | 1.27E+02 | + | 2.13E+03 | 2.14E+02 | + | 1.58E+03 | 3.83E+02 | + | 4.61E+03 | 1.21E+03 | + | 3.76E+03 | 6.24E+02 | + | **8.70E+02** | **2.67E+01** |
| F25 | 5.39E+03 | 1.62E+03 | + | 1.23E+04 | 2.86E+03 | + | 1.04E+04 | 1.36E+04 | + | 3.81E+04 | 1.67E+04 | + | 2.59E+04 | 3.66E+03 | + | **6.65E+02** | **1.54E+01** |
| F26 | 9.46E+03 | 1.43E+03 | + | 1.42E+04 | 1.23E+03 | + | 1.03E+04 | 3.01E+03 | + | 2.72E+04 | 7.08E+03 | + | 2.28E+04 | 1.56E+03 | + | **4.54E+03** | **3.76E+02** |
| F27 | 2.05E+03 | 2.47E+02 | + | 3.17E+03 | 4.07E+02 | + | 2.42E+03 | 1.41E+03 | + | 6.98E+03 | 1.66E+03 | + | 5.80E+03 | 8.53E+01 | + | **9.50E+02** | **3.95E+01** |
| F28 | 6.08E+03 | 8.95E+02 | + | 1.03E+04 | 1.58E+03 | + | 8.60E+03 | 3.41E+03 | + | 1.97E+04 | 4.79E+03 | + | 1.34E+04 | 1.51E+03 | + | **8.38E+02** | **7.18E+01** |
| F29 | 3.36E+03 | 2.12E+02 | + | 4.99E+03 | 4.09E+02 | + | 1.25E+04 | 1.42E+04 | + | 1.04E+04 | 4.09E+03 | + | 7.00E+03 | 4.08E+03 | + | **8.57E+02** | **2.38E+02** |
| F30 | 1.95E+08 | 9.09E+07 | + | 1.70E+08 | 1.08E+08 | + | **7.33E+05** | **9.82E+04** | - | 1.66E+09 | 2.46E+09 | + | 4.46E+08 | 3.32E+07 | + | 2.03E+06 | 2.08E+05 |
| **W** | **25** | | | **25** | | | **24** | | | **29** | | | **28** | | | | |
| **T** | **0** | | | **1** | | | **0** | | | **0** | | | **0** | | | | |
| **L** | **4** | | | **3** | | | **5** | | | **0** | | | **1** | | | | |

TABLE S20 (CONTINUED) PERFORMANCE COMPARISONS OF DTDEN WITH POPULAR NEAS ON 30-D, 50-D AND 100-D CEC2017 FUNCTIONS WITH SEVERE NOISE

100-D

| | ODE | | | MUDE | | | IPOP-UH-CMA-ES | | | BBPSO_CJ | | | DEPSO | | | DTDEn | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std | sig | mean | std |
| F1 | 3.34E+11 | 3.36E+10 | + | 4.52E+11 | 4.43E+10 | + | 7.91E+10 | 8.78E+10 | + | 7.00E+11 | 8.68E+10 | + | 5.46E+11 | 3.04E+10 | + | **4.52E+07** | **1.35E+07** |
| F3 | 5.18E+05 | 3.91E+04 | + | 6.17E+05 | 4.17E+04 | + | 3.17E+08 | 2.12E+09 | = | 1.09E+09 | 5.52E+09 | + | 5.29E+05 | 1.29E+04 | + | **3.47E+05** | **2.26E+04** |
| F4 | 4.98E+04 | 9.14E+03 | + | 7.08E+04 | 1.55E+04 | + | 3.26E+03 | 8.78E+03 | + | 2.13E+05 | 7.65E+04 | + | 1.24E+05 | 2.06E+04 | + | **5.72E+02** | **2.39E+01** |
| F5 | 1.89E+03 | 7.42E+01 | + | 2.37E+03 | 1.11E+02 | + | 1.54E+03 | 3.31E+02 | + | 2.95E+03 | 3.11E+02 | + | 2.87E+03 | 8.79E+01 | + | **9.13E+02** | **2.98E+01** |
| F6 | 1.17E+02 | 4.49E+00 | + | 1.59E+02 | 7.58E+00 | + | 6.34E+02 | 4.30E+01 | + | 1.94E+02 | 1.43E+01 | + | 1.75E+02 | 1.08E+00 | + | **1.36E+01** | **1.92E+00** |
| F7 | 6.89E+03 | 5.00E+02 | + | 1.02E+04 | 7.54E+02 | + | 5.92E+03 | 2.53E+03 | + | 1.38E+04 | 1.54E+03 | + | 1.01E+04 | 4.09E+02 | + | **1.14E+03** | **3.53E+01** |
| F8 | 1.90E+03 | 8.14E+01 | + | 2.44E+03 | 1.27E+02 | + | 8.70E+03 | 4.38E+02 | + | 3.16E+03 | 2.91E+02 | + | 2.74E+03 | 7.17E+01 | + | **9.11E+02** | **3.43E+01** |
| F9 | 1.10E+05 | 1.03E+04 | + | 1.63E+05 | 1.65E+04 | + | 3.74E+04 | 3.39E+04 | + | 2.65E+05 | 4.91E+04 | + | 1.71E+05 | 5.28E+03 | + | **1.91E+01** | **6.49E+00** |
| F10 | 3.02E+04 | 4.99E+02 | + | 3.44E+04 | 8.34E+02 | + | 3.36E+04 | 3.61E+03 | + | 3.96E+04 | 1.95E+03 | + | 4.01E+04 | 1.51E+02 | + | **2.88E+04** | **6.22E+02** |
| F11 | 8.45E+04 | 1.60E+04 | - | 1.63E+05 | 4.33E+04 | + | **8.01E+04** | **3.97E+04** | - | 4.42E+05 | 1.22E+05 | + | 3.20E+05 | 8.50E+04 | + | 1.05E+05 | 1.87E+04 |
| F12 | 8.85E+10 | 1.96E+10 | + | 1.54E+11 | 2.61E+10 | + | **1.14E+07** | **4.60E+07** | - | 3.36E+11 | 1.02E+11 | + | 3.29E+11 | 5.30E+09 | + | 3.20E+07 | 9.55E+06 |
| F13 | 1.28E+10 | 4.14E+09 | + | 1.61E+10 | 4.96E+09 | + | 2.08E+09 | 6.60E+09 | + | 7.91E+10 | 3.43E+10 | + | 5.89E+10 | 1.24E+10 | + | **6.94E+03** | **1.22E+03** |
| F14 | **1.71E+06** | **1.17E+06** | - | 3.01E+06 | 2.69E+06 | = | 9.67E+07 | 1.73E+08 | - | 6.55E+07 | 4.95E+07 | + | 3.17E+07 | 3.94E+05 | + | 2.00E+06 | 4.00E+05 |
| F15 | 3.80E+09 | 1.71E+09 | + | 1.51E+09 | 1.08E+09 | + | 7.61E+08 | 3.60E+09 | + | 2.05E+10 | 1.52E+10 | + | 6.37E+09 | 1.86E+09 | + | **1.04E+03** | **3.49E+02** |
| F16 | 1.10E+04 | 5.92E+02 | + | 1.47E+04 | 1.09E+03 | + | 1.26E+04 | 2.57E+03 | + | 3.19E+04 | 1.09E+04 | + | 2.34E+04 | 3.43E+03 | + | **5.16E+03** | **1.10E+03** |
| F17 | 5.93E+03 | 2.36E+02 | + | 7.93E+03 | 4.38E+02 | + | 1.75E+05 | 7.82E+05 | + | 1.39E+04 | 6.54E+03 | + | 9.07E+03 | 2.47E+02 | + | **2.86E+03** | **8.25E+02** |
| F18 | 1.21E+07 | 4.14E+06 | + | 6.06E+06 | 5.03E+06 | + | 8.66E+07 | 1.34E+08 | + | 8.36E+07 | 6.62E+07 | + | 1.52E+08 | 7.84E+07 | + | **1.80E+06** | **3.82E+05** |
| F19 | 4.48E+08 | 1.89E+08 | + | 1.32E+09 | 8.27E+08 | + | 1.45E+09 | 4.03E+09 | + | 2.29E+10 | 1.75E+10 | + | 4.38E+09 | 1.85E+09 | + | **9.33E+02** | **5.21E+02** |
| F20 | 5.44E+03 | 2.64E+02 | + | 7.23E+03 | 3.34E+02 | + | 6.86E+03 | 1.65E+03 | + | 9.38E+03 | 9.47E+02 | + | 1.00E+04 | 1.76E+02 | + | **3.08E+03** | **7.93E+02** |
| F21 | 2.18E+03 | 9.36E+01 | + | 2.88E+03 | 1.45E+02 | + | 3.27E+03 | 3.64E+02 | + | 4.02E+03 | 7.43E+02 | + | 3.51E+03 | 1.92E+02 | + | **1.15E+03** | **3.35E+01** |
| F22 | 3.16E+04 | 4.64E+02 | + | 3.59E+04 | 7.62E+02 | + | 3.48E+04 | 3.74E+03 | + | 4.08E+04 | 1.74E+03 | + | 4.18E+04 | 1.55E+02 | + | **1.28E+04** | **1.30E+04** |
| F23 | 2.86E+03 | 1.71E+02 | + | 3.89E+03 | 3.07E+02 | + | 2.55E+03 | 7.76E+02 | + | 7.39E+03 | 1.93E+03 | + | 8.22E+03 | 5.30E+02 | + | **1.56E+03** | **4.83E+01** |
| F24 | 5.20E+03 | 4.40E+02 | + | 6.86E+03 | 7.19E+02 | + | 4.63E+03 | 5.52E+02 | + | 1.36E+04 | 3.42E+03 | + | 1.34E+04 | 1.95E+02 | + | **1.92E+03** | **4.21E+01** |
| F25 | 2.89E+04 | 4.29E+03 | + | 4.90E+04 | 8.99E+03 | + | 1.49E+04 | 3.19E+04 | + | 1.23E+05 | 3.70E+04 | + | 7.65E+04 | 1.08E+04 | + | **1.33E+03** | **4.73E+01** |
| F26 | 3.87E+04 | 3.59E+03 | + | 4.60E+04 | 4.33E+03 | + | 1.96E+04 | 4.70E+03 | + | 9.61E+04 | 2.94E+04 | + | 7.62E+04 | 1.39E+04 | + | **1.36E+04** | **5.90E+02** |
| F27 | 5.11E+03 | 7.56E+02 | + | 7.65E+03 | 9.97E+02 | + | 5.00E+03 | 2.59E+03 | + | 1.58E+04 | 3.90E+03 | + | 1.02E+04 | 1.15E+03 | + | **1.19E+03** | **5.43E+01** |
| F28 | 3.00E+04 | 2.68E+03 | + | 4.30E+04 | 4.76E+03 | + | 1.98E+04 | 7.83E+03 | + | 7.67E+04 | 1.57E+04 | + | 4.64E+04 | 4.19E+03 | + | **1.51E+03** | **1.62E+02** |
| F29 | 9.43E+03 | 4.80E+02 | + | 1.19E+04 | 1.01E+03 | + | 6.64E+04 | 5.69E+04 | + | 2.61E+04 | 1.12E+04 | + | 1.52E+04 | 1.87E+03 | + | **3.66E+03** | **6.71E+02** |
| F30 | 1.15E+09 | 2.98E+08 | + | 2.91E+09 | 1.09E+09 | + | 7.29E+08 | 3.82E+09 | + | 5.34E+10 | 4.03E+10 | + | 1.75E+10 | 2.70E+09 | + | **5.88E+04** | **2.35E+04** |
| **W** | **27** | | | **28** | | | **25** | | | **29** | | | **29** | | | | |
| **T** | **0** | | | **1** | | | **1** | | | **0** | | | **0** | | | | |
| **L** | **2** | | | **0** | | | **3** | | | **0** | | | **0** | | | | |

## A Brief Introduction of the Classic Differential Evolution (DE)

DE consists of four basic components, as described in the followings.

**(1) Initialization:** Assuming that a population $\boldsymbol{P}_G$ at generation $G$ is composed of $NP$ $D$-dimensional individuals. The $i$-th ($i \in [1, NP]$) individual at the initial generation $G = 0$ is represented as $\mathbf{X}_{i,0}=[x_{i,1,0}, x_{i,2,0}, \ldots, x_{i,D,0}]$, where $x_{i,d,0}$ ($d \in [1, D]$) is obtained by

$$x_{i,d,0} = x_{\min,d} + rand_{i,d}(0,1) \cdot \left( x_{\max,d} - x_{\min,d} \right) \tag{1}$$

where $x_{\min,d}$ and $x_{\max,d}$ denote the lower and upper bounds of the $d$-th dimension respectively and $rand_{i,d}(0,1)$ is a uniformly distributed random number between 0 and 1.

Afterwards, at each generation $G > 0$, the following three genetic operations, namely mutation, crossover and selection are performed.

**(2) Mutation:** Mutation in DE is implemented by adding one or more differential vectors to a basic vector to obtain a donor vector $\mathbf{V}_{i,G}$. Some widely used mutation strategies include:

"DE/rand/1":

$$\mathbf{V}_{i,G} = \mathbf{X}_{r_{1,G}^i} + F \cdot \left( \mathbf{X}_{r_{2,G}^i} - \mathbf{X}_{r_{3,G}^i} \right) \tag{2}$$

"DE/best/1":

$$\mathbf{V}_{i,G} = \mathbf{X}_{best,G} + F \cdot \left( \mathbf{X}_{r_1^i,G} - \mathbf{X}_{r_{2,G}^i} \right) \tag{3}$$

"DE/current-to-best/1":

$$\mathbf{V}_{i,G} = \mathbf{X}_{i,G} + F \cdot \left( \mathbf{X}_{best,G} - \mathbf{X}_{i,G} \right) + F \cdot \left( \mathbf{X}_{r_1^i,G} - \mathbf{X}_{r_{2,G}^i} \right) \tag{4}$$

"DE/current-to-*p*best/1":

$$\mathbf{V}_{i,G} = \mathbf{X}_{i,G} + F \cdot \left( \mathbf{X}_{pbest,G} - \mathbf{X}_{i,G} \right) + F \cdot \left( \mathbf{X}_{r_1^i,G} - \mathbf{X}_{r_{2,G}^i} \right) \tag{5}$$

where $\mathbf{X}_{r_{1,G}^i}$, $\mathbf{X}_{r_{2,G}^i}$ and $\mathbf{X}_{r_{3,G}^i}$ are three randomly selected distinct individuals from the current population $\boldsymbol{P}_G$ and are different from the target vector $\mathbf{X}_{i,G}$. $\mathbf{X}_{best,G}$ and $\mathbf{X}_{pbest,G}$ represent the fittest and one of the top $p \times 100\%$ ($p \in (0,1]$) fittest solutions respectively. $F$ is a scaling factor within (0,1].

**(3) Crossover:** The trial vector $\mathbf{U}_{i,G}=[u_{i,1,G}, u_{i,2,G}, \ldots, u_{i,D,G}]$ is formed by exchanging elements from the donor vector $\mathbf{V}_{i,G}$ and the target vector $\mathbf{X}_{i,G}$ on the dimension level. The binomial crossover is outlined as follows:

$$u_{i,d,G} = \begin{cases} v_{i,d,G} & \text{if } rand_{i,d}(0,1) \le CR \text{ or } d = d_{rand} \\ x_{i,d,G} & \text{otherwise} \end{cases} \tag{6}$$

where $CR$ denotes the crossover rate and the definition of $rand_{i,d}(0,1)$ is the same as that of Equation (1). $d_{rand}$ represents a random integer ranging from 1 to $D$.

**(4) Selection:** DE's selection is to compare the fitness of the target vector and the corresponding trial vector and select the fitter one for the next generation. Without loss of generality, a minimization optimization problem is considered here to describe the selection process, which is given by

$$\mathbf{X}_{i,G+1} = \begin{cases} \mathbf{U}_{i,G} & \text{if } f\left(\mathbf{U}_{i,G}\right) \le f\left(\mathbf{X}_{i,G}\right) \\ \mathbf{X}_{i,G} & \text{if } f\left(\mathbf{U}_{i,G}\right) > f\left(\mathbf{X}_{i,G}\right) \end{cases} \tag{7}$$

where $f(\cdot)$ represents the objective fitness. From Equation (7), an individual with better or at least the same fitness value as the target individual is selected for the next generation $G + 1$.