Table 7. Comparison of the proposed algorithms according to NPS, MID, and DM.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem size | Sample No. | J | I | B | F | NPS | | | | |  | MID | | | | |  | DM | | | | |
| MOEA/D | NSGA-II | PESA-II | SPEA2 | MOTSSA | MOEA/D | NSGA-II | PESA-II | SPEA2 | MOTSSA | MOEA/D | NSGA-II | PESA-II | SPEA2 | MOTSSA |
| Small | 01 | 8 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |  | 1.21 | 1.21 | 1.21 | 1.21 | 1.21 |  | 48.06 | 42.65 | 42.65 | 42.65 | 0.67 |
| 02 |  | 3 | 2 | 1 | 2 | 6 | 6 | 6 | 10 |  | 1.21 | 1.18 | 1.16 | 1.18 | 1.01 |  | 18.04 | 20.39 | 21.83 | 20.39 | 49.23 |
| 03 | 10 | 3 | 1 | 1 | 2 | 5 | 4 | 5 | 8 |  | 1.21 | 0.89 | 0.89 | 0.89 | 1.00 |  | 25.68 | 27.35 | 27.35 | 27.35 | 28.43 |
| 04 |  | 3 | 2 | 1 | 3 | 4 | 3 | 5 | 10 |  | 1.31 | 1.14 | 1.22 | 1.07 | 0.91 |  | 22.03 | 23.84 | 18.95 | 29.58 | 56.66 |
| 05 |  | 4 | 2 | 2 | 7 | 6 | 8 | 8 | 7 |  | 0.97 | 1.14 | 1.11 | 1.11 | 1.29 |  | 46.85 | 39.49 | 39.49 | 39.49 | 62.35 |
| 06 | 12 | 3 | 1 | 1 | 4 | 15 | 15 | 17 | 11 |  | 1.17 | 0.88 | 0.88 | 0.87 | 1.07 |  | 97.18 | 97.47 | 94.81 | 96.84 | 40.54 |
| 07 |  | 3 | 2 | 1 | 4 | 20 | 26 | 27 | 25 |  | 1.02 | 0.97 | 0.87 | 0.88 | 0.95 |  | 55.89 | 67.29 | 77.45 | 75.60 | 99.49 |
| 08 |  | 4 | 2 | 2 | 2 | 2 | 2 | 2 | 6 |  | 1.21 | 1.21 | 1.21 | 1.21 | 1.17 |  | 16.96 | 15.31 | 12.66 | 15.31 | 11.25 |
| **Ave.** |  |  |  |  | **3.25** | **7.50** | **8.25** | **9.00** | **9.88** |  | **1.16** | **1.08** | **1.07** | **1.05** | **1.08** |  | **41.34** | **41.72** | **41.9** | **43.4** | **43.58** |
| Medium | 09 | 15 | 4 | 2 | 1 | 2 | 6 | 6 | 7 | 5 |  | 1.21 | 1.16 | 1.15 | 1.15 | 0.89 |  | 37.68 | 30.45 | 32.76 | 32.89 | 37.03 |
| 10 |  | 6 | 3 | 2 | 4 | 14 | 15 | 18 | 10 |  | 0.99 | 0.81 | 0.84 | 0.79 | 1.13 |  | 36.65 | 57.79 | 64.18 | 57.79 | 78.09 |
| 11 | 20 | 4 | 2 | 1 | 4 | 28 | 35 | 59 | 21 |  | 1.01 | 0.90 | 0.85 | 0.83 | 1.04 |  | 142.63 | 140.77 | 142.39 | 157.34 | 150.46 |
| 12 |  | 6 | 3 | 2 | 3 | 23 | 51 | 32 | 35 |  | 0.90 | 0.88 | 0.85 | 0.90 | 1.07 |  | 90.50 | 109.07 | 94.81 | 87.48 | 141.34 |
| 13 | 25 | 4 | 2 | 1 | 4 | 18 | 32 | 16 | 28 |  | 1.00 | 0.78 | 0.79 | 0.85 | 1.15 |  | 212.68 | 198.73 | 161.63 | 130.63 | 191.37 |
| 14 |  | 6 | 3 | 2 | 6 | 20 | 31 | 39 | 50 |  | 0.94 | 0.97 | 1.02 | 0.89 | 1.17 |  | 185.70 | 235.09 | 184.34 | 275.00 | 164.97 |
| 15 | 30 | 4 | 2 | 1 | 2 | 18 | 22 | 29 | 33 |  | 1.21 | 0.66 | 1.03 | 0.97 | 1.16 |  | 45.23 | 145.43 | 120.29 | 122.11 | 266.03 |
| 16 |  | 6 | 3 | 2 | 4 | 12 | 10 | 8 | 26 |  | 0.99 | 0.82 | 1.03 | 1.00 | 1.01 |  | 93.25 | 81.58 | 33.35 | 46.31 | 170.04 |
| **Ave.** |  |  |  |  | **3.63** | **17.38** | **25.25** | **26.00** | **26.00** |  | **1.03** | **0.87** | **0.95** | **0.92** | **1.08** |  | **105.54** | **124.86** | **104.22** | **113.7** | **149.92** |
| Large | 17 | 40 | 8 | 3 | 2 | 3 | 22 | 38 | 25 | 43 |  | 0.87 | 0.85 | 0.88 | 1.00 | 0.96 |  | 159.83 | 412.84 | 277.51 | 216.63 | 737.75 |
| 18 |  | 10 | 4 | 3 | 2 | 8 | 18 | 15 | 24 |  | 1.21 | 0.82 | 0.85 | 0.69 | 1.15 |  | 18.46 | 70.64 | 89.58 | 248.81 | 124.43 |
| 19 | 50 | 10 | 3 | 2 | 2 | 15 | 13 | 18 | 55 |  | 1.21 | 0.71 | 1.02 | 0.75 | 1.18 |  | 159.42 | 193.10 | 140.78 | 115.88 | 494.61 |
| 20 |  | 12 | 4 | 3 | 3 | 17 | 34 | 38 | 25 |  | 1.10 | 0.83 | 0.76 | 0.81 | 1.05 |  | 171.25 | 147.23 | 216.84 | 364.95 | 437.95 |
| 21 | 60 | 12 | 3 | 2 | 5 | 24 | 24 | 43 | 22 |  | 1.00 | 0.80 | 0.71 | 0.77 | 1.00 |  | 217.51 | 202.35 | 154.15 | 165.48 | 284.28 |
| 22 |  | 15 | 4 | 3 | 5 | 20 | 17 | 23 | 12 |  | 1.01 | 0.95 | 0.84 | 0.70 | 1.36 |  | 123.39 | 110.90 | 103.62 | 224.68 | 322.14 |
| 23 | 80 | 15 | 3 | 2 | 3 | 15 | 10 | 52 | 36 |  | 1.11 | 0.57 | 0.91 | 0.89 | 1.05 |  | 151.22 | 153.47 | 113.38 | 249.33 | 344.42 |
| 24 |  | 20 | 4 | 3 | 3 | 21 | 10 | 48 | 10 |  | 0.98 | 0.68 | 0.89 | 0.55 | 1.38 |  | 95.96 | 260.97 | 108.63 | 357.87 | 444.18 |
| **Ave.** |  |  |  |  | **3.25** | **17.75** | **20.5** | **32.75** | **28.38** |  | **1.06** | **0.78** | **0.86** | **0.77** | **1.14** |  | **137.13** | **193.94** | **150.56** | **242.96** | **398.72** |
| **Average** | |  |  |  |  | **3.38** | **14.21** | **18.00** | **22.58** | **21.42** |  | **1.08** | **0.91** | **0.96** | **0.91** | **1.10** |  | **94.67** | **120.18** | **98.89** | **133.35** | **197.41** |

Table 8. Comparison of the proposed algorithms according to SNS, RAS, and QM.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem size | Sample No. | J | I | B | F | SNS | | | | |  | RAS | | | | |  | QM | | | | |
| MOEA/D | NSGA-II | PESA-II | SPEA2 | MOTSSA | MOEA/D | NSGA-II | PESA-II | SPEA2 | MOTSSA | MOEA/D | NSGA-II | PESA-II | SPEA2 | MOTSSA |
| Small | 01 | 8 | 2 | 1 | 1 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 |  | 4.93 | 4.76 | 4.76 | 4.76 | 5.33 |  | 0.00 | 1.00 | 1.00 | 1.00 | 0.00 |
| 02 |  | 3 | 2 | 1 | 0.29 | 0.12 | 0.11 | 0.13 | 0.23 |  | 7.78 | 7.28 | 7.30 | 7.29 | 6.57 |  | 0.00 | 1.00 | 0.83 | 0.83 | 0.00 |
| 03 | 10 | 3 | 1 | 1 | 0.29 | 0.35 | 0.41 | 0.35 | 0.18 |  | 11.89 | 13.94 | 13.72 | 13.94 | 10.92 |  | 0.50 | 1.00 | 1.00 | 1.00 | 0.00 |
| 04 |  | 3 | 2 | 1 | 0.28 | 0.31 | 0.21 | 0.34 | 0.29 |  | 7.85 | 7.89 | 7.90 | 8.35 | 6.02 |  | 0.00 | 1.00 | 1.00 | 1.00 | 0.00 |
| 05 |  | 4 | 2 | 2 | 0.29 | 0.25 | 0.27 | 0.27 | 0.14 |  | 8.07 | 8.45 | 8.54 | 8.55 | 7.06 |  | 0.00 | 1.00 | 1.00 | 0.75 | 0.00 |
| 06 | 12 | 3 | 1 | 1 | 0.26 | 0.21 | 0.21 | 0.20 | 0.12 |  | 8.13 | 8.86 | 8.85 | 8.87 | 8.88 |  | 0.00 | 0.60 | 0.93 | 0.41 | 0.00 |
| 07 |  | 3 | 2 | 1 | 0.27 | 0.16 | 0.11 | 0.10 | 0.13 |  | 11.46 | 12.22 | 12.42 | 12.46 | 9.04 |  | 0.00 | 0.75 | 0.73 | 0.56 | 0.00 |
| 08 |  | 4 | 2 | 2 | 0.29 | 0.29 | 0.29 | 0.29 | 0.17 |  | 12.79 | 12.48 | 12.61 | 12.48 | 9.42 |  | 0.00 | 1.00 | 0.50 | 1.00 | 0.00 |
| **Ave.** |  |  |  |  | **0.28** | **0.25** | **0.24** | **0.25** | **0.19** |  | **9.11** | **9.49** | **9.51** | **9.59** | **7.91** |  | **0.06** | **0.92** | **0.87** | **0.82** | **0.00** |
| Medium | 09 | 15 | 4 | 2 | 1 | 0.29 | 0.14 | 0.13 | 0.12 | 0.32 |  | 9.49 | 12.90 | 12.93 | 13.30 | 11.08 |  | 0.00 | 0.83 | 0.50 | 0.71 | 0.00 |
| 10 |  | 6 | 3 | 2 | 0.40 | 0.30 | 0.29 | 0.29 | 0.25 |  | 16.66 | 17.03 | 17.32 | 17.33 | 13.20 |  | 0.50 | 0.93 | 0.47 | 0.72 | 0.00 |
| 11 | 20 | 4 | 2 | 1 | 0.30 | 0.15 | 0.16 | 0.12 | 0.26 |  | 12.91 | 13.20 | 13.45 | 13.72 | 14.90 |  | 0.00 | 0.18 | 0.66 | 0.51 | 0.00 |
| 12 |  | 6 | 3 | 2 | 0.58 | 0.23 | 0.18 | 0.19 | 0.09 |  | 16.94 | 23.22 | 21.32 | 22.45 | 19.26 |  | 0.00 | 0.30 | 0.53 | 0.66 | 0.00 |
| 13 | 25 | 4 | 2 | 1 | 0.30 | 0.25 | 0.21 | 0.22 | 0.15 |  | 14.14 | 13.98 | 13.99 | 13.36 | 14.92 |  | 0.00 | 0.28 | 0.59 | 0.50 | 0.00 |
| 14 |  | 6 | 3 | 2 | 0.37 | 0.20 | 0.26 | 0.22 | 0.09 |  | 15.77 | 16.42 | 16.43 | 16.60 | 13.79 |  | 0.00 | 0.40 | 0.06 | 0.97 | 0.00 |
| 15 | 30 | 4 | 2 | 1 | 0.29 | 0.31 | 0.15 | 0.15 | 0.13 |  | 16.27 | 18.03 | 18.21 | 18.32 | 16.13 |  | 0.00 | 0.67 | 0.68 | 0.52 | 0.00 |
| 16 |  | 6 | 3 | 2 | 0.37 | 0.32 | 0.22 | 0.32 | 0.22 |  | 18.70 | 20.01 | 20.72 | 20.44 | 18.50 |  | 0.00 | 0.33 | 1.00 | 0.50 | 0.00 |
| **Ave.** |  |  |  |  | **0.36** | **0.24** | **0.20** | **0.20** | **0.19** |  | **15.11** | **16.85** | **16.80** | **16.94** | **15.22** |  | **0.60** | **0.49** | **0.56** | **0.64** | **0.00** |
| Large | 17 | 40 | 8 | 3 | 2 | 0.61 | 0.24 | 0.19 | 0.25 | 0.23 |  | 28.75 | 25.44 | 25.24 | 25.77 | 21.03 |  | 0.00 | 0.36 | 0.26 | 0.72 | 0.00 |
| 18 |  | 10 | 4 | 3 | 0.29 | 0.39 | 0.32 | 0.32 | 0.18 |  | 19.82 | 22.54 | 22.85 | 22.38 | 19.71 |  | 0.00 | 1.00 | 0.11 | 0.8 | 0.00 |
| 19 | 50 | 10 | 3 | 2 | 0.29 | 0.46 | 0.39 | 0.39 | 0.08 |  | 26.54 | 26.42 | 24.67 | 28.24 | 25.14 |  | 0.00 | 0.33 | 0.23 | 0.78 | 0.00 |
| 20 |  | 12 | 4 | 3 | 0.28 | 0.22 | 0.27 | 0.35 | 0.10 |  | 26.45 | 27.35 | 27.13 | 26.40 | 25.19 |  | 0.00 | 0.59 | 0.15 | 0.92 | 0.00 |
| 21 | 60 | 12 | 3 | 2 | 0.24 | 0.21 | 0.22 | 0.24 | 0.19 |  | 26.30 | 25.86 | 26.05 | 24.80 | 26.50 |  | 0.00 | 0.33 | 0.17 | 1.00 | 0.00 |
| 22 |  | 15 | 4 | 3 | 0.23 | 0.15 | 0.21 | 0.29 | 0.13 |  | 33.05 | 33.85 | 33.10 | 32.51 | 28.17 |  | 0.00 | 0.15 | 0.65 | 0.78 | 0.00 |
| 23 | 80 | 15 | 3 | 2 | 0.27 | 0.33 | 0.31 | 0.20 | 0.11 |  | 34.76 | 43.07 | 44.08 | 43.40 | 36.21 |  | 0.00 | 0.53 | 0.00 | 0.98 | 0.00 |
| 24 |  | 20 | 4 | 3 | 0.45 | 0.29 | 0.28 | 0.28 | 0.17 |  | 46.26 | 49.18 | 47.93 | 49.86 | 42.95 |  | 0.00 | 0.14 | 1.00 | 0.56 | 0.00 |
| **Ave.** |  |  |  |  | **0.33** | **0.28** | **0.28** | **0.29** | **0.15** |  | **30.24** | **31.71** | **31.38** | **31.67** | **28.11** |  | **0.00** | **0.43** | **0.32** | **0.82** | **0.00** |
| **Average** | |  |  |  |  | **0.33** | **0.26** | **0.24** | **0.25** | **0.18** |  | **18.15** | **19.35** | **19.23** | **19.40** | **17.08** |  | **0.04** | **0.61** | **0.59** | **0.76** | **0.00** |