**Appendix of MOBOA**

**Appendix 1**

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| MSSA-CF1 | MSSA-CF6 | MSSA-CF8 |

**Fig. 4.** Results of PF generated by competing algorithms on CF1, CF6 and CF8 problems.

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| MSSA-DTLZ4 | MSSA-DTLZ6 | MSSA-DTLZ7 |

**Fig. 5.** Results of PF generated by competing algorithms on DTLZ4, DTLZ6 and DTLZ7 problems.

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|  |  |  |
| MSSA-UF2 | MSSA-UF7 | MSSA-UF9 |

**Fig. 6.** Results of PF generated by competing algorithms on UF2, UF7 and UF9 problems.

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|  |  |  |
| MSSA-WFG2 | MSSA-WFG6 | MSSA-WFG10 |

**Fig. 7.** Results of PF generated by competing algorithms on WFG2, WFG6 and WFG10 problems.

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| MSSA-ZDT1 | MSSA-ZDT3 | MSSA-ZDT6 |

**Fig. 8.** Results of PF generated by competing algorithms on ZDT1, ZDT3 and ZDT6 problems.

**Appendix 2**

**Table 2.** Statistical Finding of IGD on ZDT, DTLZ, WFG, UF and CF problem sets.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Function** | **Index** | **Algorithms** | | | |
| **MOMVO** | **MSSA** | **MOEAD** | **MOBOA** |
| ZTD1 | Ave | 0.034849 | 0.026180 | 0.014065 | **0.004649** |
| Std | 0.025541 | 0.009214 | 0.003422 | **0.000182** |
| ZTD2 | Ave | 0.060782 | 0.080719 | **0.016082** | 0.085597 |
| Std | 0.054608 | 0.256393 | **0.022981** | 0.209299 |
| ZTD3 | Ave | 0.048630 | 0.045421 | 0.185226 | **0.005218** |
| Std | 0.018534 | 0.012077 | 0.069485 | **0.000209** |
| ZTD4 | Ave | 2.811806 | **0.132503** | 4.301548 | 0.533261 |
| Std | 1.030211 | **0.357277** | 4.438946 | 0.409080 |
| ZTD6 | Ave | 0.018305 | 0.044244 | 0.837605 | **0.003766** |
| Std | 0.021926 | 0.017204 | 1.495488 | **0.000213** |
| DTLZ1 | Ave | 11.093063 | **7.137184** | 12.355846 | 8.347611 |
| Std | 4.909021 | 7.518130 | 4.474360 | **2.133394** |
| DTLZ2 | Ave | 0.245530 | 0.511180 | **0.097171** | 0.122574 |
| Std | 0.113086 | 0.043207 | 0.008402 | **0.005380** |
| DTLZ3 | Ave | **47.399415** | 139.461641 | 96.826958 | 155.442337 |
| Std | 30.219198 | 30.534752 | 33.871272 | **13.356470** |
| DTLZ4 | Ave | 0.250036 | 0.442202 | 0.273282 | **0.115976** |
| Std | 0.177423 | 0.088958 | 0.247744 | **0.005209** |
| DTLZ5 | Ave | 0.098067 | 0.079035 | **0.019212** | 0.027369 |
| Std | 0.103646 | 0.037294 | 0.007108 | **0.002050** |
| DTLZ6 | Ave | 0.459473 | 0.244917 | 0.022583 | **0.005879** |
| Std | 1.355572 | 0.232136 | 0.008185 | **0.000476** |
| DTLZ7 | Ave | 0.607922 | 2.419035 | 1.986484 | **0.080225** |
| Std | 1.403819 | 2.651765 | 1.129195 | **0.004320** |
| WFG1 | Ave | 1.147396 | 1.087347 | **0.477987** | 1.196707 |
| Std | 0.012073 | 0.023293 | 0.155454 | **0.005107** |
| WFG2 | Ave | 0.052422 | 0.081000 | 0.231888 | **0.021996** |
| Std | 0.035410 | 0.019814 | 0.075757 | **0.001431** |
| WFG3 | Ave | 0.066091 | 0.096739 | 0.061153 | **0.024219** |
| Std | 0.007174 | 0.043234 | 0.041557 | **0.000642** |
| WFG4 | Ave | 0.080563 | 0.189854 | 0.085152 | **0.066422** |
| Std | 0.013757 | 0.084126 | 0.010242 | **0.003711** |
| WFG5 | Ave | 0.082600 | 0.149990 | 0.091589 | **0.065813** |
| Std | 0.013630 | 0.042623 | 0.021125 | **0.004446** |
| WFG6 | Ave | 0.055246 | 0.177636 | 0.084342 | **0.024257** |
| Std | 0.005847 | 0.087981 | 0.038694 | **0.001128** |
| WFG7 | Ave | 0.062608 | 0.216031 | 0.043577 | **0.024018** |
| Std | 0.009394 | 0.104770 | 0.015519 | **0.000849** |
| WFG8 | Ave | 0.337935 | 0.318267 | 0.313595 | **0.264085** |
| Std | 0.081891 | **0.035083** | 0.043763 | 0.037131 |
| WFG9 | Ave | 0.042740 | 0.185430 | 0.062584 | **0.025257** |
| Std | 0.014637 | 0.092689 | 0.038110 | **0.000567** |
| WFG10 | Ave | - | - | - | - |
| Std | - | - | - | - |
| UF1 | Ave | 0.124254 | 0.085323 | 0.185135 | **0.032025** |
| Std | 0.109783 | 0.013847 | 0.077260 | **0.003638** |
| UF2 | Ave | 0.058769 | 0.067135 | 0.077909 | **0.015091** |
| Std | 0.049015 | 0.032366 | 0.049487 | **0.000700** |
| UF3 | Ave | 0.458694 | 0.394442 | 0.459002 | **0.319845** |
| Std | 0.245364 | 0.168236 | 0.137619 | **0.066039** |
| UF4 | Ave | 0.079261 | 0.081250 | 0.065581 | **0.041709** |
| Std | 0.018413 | 0.010642 | 0.006305 | **0.001357** |
| UF5 | Ave | 0.819189 | **0.445341** | 1.399695 | 0.479083 |
| Std | 0.419979 | **0.130704** | 0.502660 | 0.132425 |
| UF6 | Ave | 0.765604 | **0.358260** | 1.362883 | 0.611990 |
| Std | 0.444462 | **0.073408** | 0.569511 | 0.084689 |
| UF7 | Ave | 0.167219 | 0.061567 | 0.311226 | **0.019167** |
| Std | 0.124124 | 0.009855 | 0.175380 | **0.001405** |
| UF8 | Ave | 0.315857 | 0.472168 | 0.248871 | **0.121173** |
| Std | 0.082920 | 0.173585 | 0.082821 | **0.007028** |
| UF9 | Ave | 0.354750 | 0.421269 | 0.270217 | **0.141737** |
| Std | 0.200933 | 0.207201 | 0.058109 | **0.010368** |
| UF10 | Ave | 2.125174 | 2.136047 | 1.132581 | **0.963175** |
| Std | 3.098541 | 1.146747 | 0.464702 | **0.434650** |
| CF1 | Ave | 0.010426 | 0.051480 | 0.026751 | **0.007848** |
| Std | **0.000606** | 0.020174 | 0.008821 | 0.000624 |
| CF2 | Ave | 0.065686 | 0.093280 | 0.200932 | **0.033714** |
| Std | 0.008070 | 0.016057 | 0.134806 | **0.004478** |
| CF3 | Ave | 0.990127 | **0.392080** | 1.346767 | 0.762795 |
| Std | 0.245839 | **0.150476** | 0.665763 | 0.179491 |
| CF4 | Ave | 0.164865 | **0.115662** | 0.314873 | 0.121759 |
| Std | 0.050917 | **0.019011** | 0.141827 | 0.022107 |
| CF5 | Ave | 0.802676 | 0.658076 | 1.975154 | **0.494571** |
| Std | 0.442912 | 0.227018 | 0.976804 | **0.147586** |
| CF6 | Ave | 0.098630 | 0.065134 | 0.270599 | **0.024454** |
| Std | 0.021627 | 0.014758 | 0.172664 | **0.002779** |
| CF7 | Ave | 1.178499 | 1.150425 | 2.484774 | **1.135390** |
| Std | 0.817803 | **0.421404** | 0.969018 | 0.432710 |
| CF8 | Ave | 0.287411 | 0.956892 | 0.262158 | **0.139124** |
| Std | 0.041666 | 0.534201 | 0.123107 | **0.007687** |
| CF9 | Ave | 0.160136 | 0.464228 | 0.193783 | **0.101336** |
| Std | 0.020421 | 0.163077 | 0.058343 | **0.005415** |
| CF10 | Ave | 1.537629 | 1.841740 | 1.226842 | **0.940977** |
| Std | **0.287434** | 0.663404 | 0.667911 | 0.438447 |

**Table 3.** Statistical Finding of SP on ZDT, DTLZ, WFG, UF and CF problem sets.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Function** | **Index** | **Algorithms** | | | |
| **MOMVO** | **MSSA** | **MOEAD** | **MOBOA** |
| ZTD1 | Ave | 0.067653 | 0.014268 | 0.016660 | **0.006672** |
| Std | 0.146569 | 0.007801 | 0.005983 | **0.000737** |
| ZTD2 | Ave | 0.019277 | 0.012134 | 0.012999 | **0.005719** |
| Std | 0.015815 | 0.005456 | 0.003186 | **0.002540** |
| ZTD3 | Ave | 0.067121 | 0.018177 | 0.019093 | **0.007433** |
| Std | 0.139153 | 0.011494 | 0.014321 | **0.000734** |
| ZTD4 | Ave | 1.551974 | 0.013357 | 0.285584 | **0.002535** |
| Std | 3.357535 | 0.005196 | 1.078354 | **0.003402** |
| ZTD6 | Ave | 0.058435 | 0.019250 | **0.012788** | 0.026537 |
| Std | 0.043463 | 0.024796 | **0.005353** | 0.109351 |
| DTLZ1 | Ave | 4.755963 | **0.572350** | 1.109234 | 2.111654 |
| Std | 6.965717 | 0.691166 | **0.429678** | 0.485493 |
| DTLZ2 | Ave | 0.053288 | **0.010255** | 0.067260 | 0.076271 |
| Std | 0.011084 | 0.007165 | **0.006841** | 0.006880 |
| DTLZ3 | Ave | - | 4.362766 | 6.033100 | 18.309429 |
| Std | - | 5.124259 | 2.876926 | 9.297340 |
| DTLZ4 | Ave | 0.058869 | **0.022391** | 0.045342 | 0.076492 |
| Std | 0.018393 | 0.014688 | 0.025952 | **0.004923** |
| DTLZ5 | Ave | **0.012091** | 0.012637 | 0.015817 | 0.031984 |
| Std | 0.010410 | 0.006546 | **0.003346** | 0.011617 |
| DTLZ6 | Ave | 0.025124 | 0.037781 | 0.017725 | **0.008891** |
| Std | 0.024199 | 0.035546 | 0.005969 | **0.001317** |
| DTLZ7 | Ave | 0.109410 | 0.066423 | **0.016176** | 0.068843 |
| Std | 0.191828 | 0.045552 | 0.041377 | **0.007953** |
| WFG1 | Ave | 0.080594 | 0.103368 | **0.048035** | 0.109510 |
| Std | 0.045456 | **0.007062** | 0.021073 | 0.010443 |
| WFG2 | Ave | 0.033005 | 0.028848 | 0.042107 | **0.020853** |
| Std | 0.006426 | 0.014956 | 0.020139 | **0.001416** |
| WFG3 | Ave | 0.028948 | 0.034697 | 0.045505 | **0.018988** |
| Std | 0.008868 | 0.013572 | 0.013498 | **0.002285** |
| WFG4 | Ave | 0.033077 | 0.034657 | 0.040272 | **0.020361** |
| Std | 0.005899 | 0.018621 | 0.011181 | **0.001679** |
| WFG5 | Ave | 0.036307 | 0.041348 | 0.040026 | **0.020789** |
| Std | 0.008160 | 0.017353 | 0.010451 | **0.001803** |
| WFG6 | Ave | 0.032672 | 0.035726 | 0.036809 | **0.027887** |
| Std | 0.008600 | 0.018039 | 0.006687 | **0.004035** |
| WFG7 | Ave | 0.034330 | 0.043537 | 0.042361 | **0.026223** |
| Std | 0.012003 | 0.024945 | 0.013927 | **0.003855** |
| WFG8 | Ave | 0.036564 | 0.036909 | 0.043395 | **0.026098** |
| Std | 0.017453 | 0.016219 | 0.015578 | **0.005132** |
| WFG9 | Ave | 0.034823 | 0.035995 | 0.037098 | **0.018717** |
| Std | 0.008922 | 0.013433 | 0.007763 | **0.001793** |
| WFG10 | Ave | 0.041521 | 0.033958 | 0.052927 | **0.025978** |
| Std | 0.007251 | 0.011544 | 0.030777 | **0.007197** |
| UF1 | Ave | 0.006936 | 0.006657 | **0.002364** | 0.019231 |
| Std | 0.004240 | 0.010644 | **0.003354** | 0.013505 |
| UF2 | Ave | 0.009421 | **0.009361** | 0.011506 | 0.009790 |
| Std | 0.005216 | **0.004932** | 0.005518 | 0.007262 |
| UF3 | Ave | - | 0.001464 | 0.001289 | 0.069053 |
| Std | - | 0.003059 | 0.002301 | 0.066477 |
| UF4 | Ave | 0.011216 | 0.009129 | 0.011065 | **0.007285** |
| Std | 0.004039 | 0.008408 | 0.002622 | **0.002315** |
| UF5 | Ave | 0.037433 | **0.000946** | 0.002954 | 0.110072 |
| Std | 0.045442 | **0.002625** | 0.005689 | 0.061507 |
| UF6 | Ave | 0.028598 | **0.000039** | 0.006482 | 0.094820 |
| Std | 0.019419 | **0.000083** | 0.016979 | 0.101617 |
| UF7 | Ave | 0.010124 | 0.007092 | **0.004067** | 0.013355 |
| Std | 0.009864 | **0.006196** | 0.007313 | 0.010584 |
| UF8 | Ave | 0.200818 | 0.106242 | **0.048019** | 0.399678 |
| Std | 0.127480 | 0.069711 | **0.013830** | 0.376341 |
| UF9 | Ave | 0.211104 | 0.164277 | **0.038277** | 0.337006 |
| Std | 0.109033 | 0.217667 | **0.012781** | 0.193031 |
| UF10 | Ave | 0.662376 | 0.599419 | **0.035775** | 0.914704 |
| Std | 0.477811 | 1.048788 | **0.052723** | 1.382992 |
| CF1 | Ave | **0.004452** | 0.012440 | 0.016612 | 0.005284 |
| Std | **0.000463** | 0.006922 | 0.006091 | 0.000608 |
| CF2 | Ave | 0.049630 | **0.005828** | 0.021522 | 0.025896 |
| Std | 0.034931 | **0.005449** | 0.102417 | 0.028462 |
| CF3 | Ave | 1.260806 | **0.000106** | 0.001889 | 0.188869 |
| Std | 1.694001 | **0.000250** | 0.004099 | 0.236746 |
| CF4 | Ave | 0.321679 | 0.004979 | **0.003675** | 0.136183 |
| Std | 0.284697 | **0.008316** | 0.008728 | 0.192488 |
| CF5 | Ave | 1.176446 | **0.004388** | 0.009866 | 0.201301 |
| Std | 1.018666 | **0.006835** | 0.047138 | 0.419833 |
| CF6 | Ave | 0.321347 | 0.008525 | **0.005000** | 0.026837 |
| Std | 0.298902 | 0.004910 | **0.004482** | 0.033610 |
| CF7 | Ave | 0.963991 | 0.005087 | **0.001417** | 0.336693 |
| Std | 1.132045 | 0.011361 | **0.003990** | 0.306621 |
| CF8 | Ave | 2.010827 | 0.276514 | **0.054184** | 0.608542 |
| Std | 0.693327 | 0.157920 | **0.033625** | 0.373948 |
| CF9 | Ave | 0.911392 | 0.103503 | **0.041634** | 0.286174 |
| Std | 0.412449 | 0.083711 | **0.011895** | 0.202653 |
| CF10 | Ave | 1.806069 | 0.355041 | **0.038245** | 0.944514 |
| Std | 0.894840 | 0.381710 | **0.047304** | 1.268887 |

**Table 4.** Statistical Finding of HV on ZDT, DTLZ, WFG, UF and CF problem sets.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Function** | **Index** | **Algorithms** | | | |
| **MOMVO** | **MSSA** | **MOEAD** | **MOBOA** |
| ZTD1 | Ave | 0.685461 | 0.691562 | 0.706822 | **0.719451** |
| Std | 0.018240 | 0.007747 | 0.004020 | **0.000189** |
| ZTD2 | Ave | 0.381556 | 0.392029 | **0.428041** | 0.397033 |
| Std | 0.054420 | 0.075958 | **0.030262** | 0.122125 |
| ZTD3 | Ave | 0.601917 | **0.606160** | 0.574213 | 0.599553 |
| Std | 0.047798 | 0.031198 | 0.103925 | **0.000065** |
| ZTD4 | Ave | 0.000000 | **0.629178** | 0.009737 | 0.321439 |
| Std | **0.000000** | 0.198725 | 0.048035 | 0.308168 |
| ZTD6 | Ave | 0.375753 | 0.346088 | 0.249215 | **0.388208** |
| Std | 0.017204 | 0.018552 | 0.171917 | **0.000216** |
| DTLZ1 | Ave | 0.000000 | **0.001544** | 0.000000 | 0.000000 |
| Std | **0.000000** | 0.008455 | **0.000000** | **0.000000** |
| DTLZ2 | Ave | 0.341257 | 0.150639 | **0.479219** | 0.422887 |
| Std | 0.140862 | 0.027572 | 0.013535 | **0.009581** |
| DTLZ3 | Ave | **0.000000** | **0.000000** | **0.000000** | **0.000000** |
| Std | **0.000000** | **0.000000** | **0.000000** | **0.000000** |
| DTLZ4 | Ave | 0.373305 | 0.202843 | 0.416501 | **0.458918** |
| Std | 0.064591 | 0.093451 | 0.094711 | **0.006557** |
| DTLZ5 | Ave | 0.145205 | 0.148600 | **0.191469** | 0.180892 |
| Std | 0.054893 | 0.019846 | **0.003981** | 0.003998 |
| DTLZ6 | Ave | 0.173912 | 0.117982 | 0.188961 | **0.199666** |
| Std | 0.060594 | 0.045951 | 0.005151 | **0.000179** |
| DTLZ7 | Ave | 0.175739 | 0.049601 | 0.006429 | **0.270145** |
| Std | 0.043867 | 0.041332 | 0.010000 | **0.002131** |
| WFG1 | Ave | 0.188735 | 0.221584 | **0.453168** | 0.188238 |
| Std | 0.004049 | 0.008144 | 0.067427 | **0.001518** |
| WFG2 | Ave | 0.621657 | 0.612784 | 0.592446 | **0.627458** |
| Std | 0.004743 | 0.007726 | 0.023436 | **0.000503** |
| WFG3 | Ave | 0.557779 | 0.545547 | 0.559916 | **0.573604** |
| Std | 0.002703 | 0.012384 | 0.015787 | **0.000392** |
| WFG4 | Ave | 0.303378 | 0.271522 | 0.298787 | **0.310067** |
| Std | 0.004389 | 0.015800 | 0.003703 | **0.002197** |
| WFG5 | Ave | 0.302489 | 0.281770 | 0.296822 | **0.310261** |
| Std | 0.003962 | 0.011457 | 0.005608 | **0.002417** |
| WFG6 | Ave | 0.330930 | 0.302005 | 0.302119 | **0.340570** |
| Std | 0.003918 | 0.014481 | 0.023299 | **0.000416** |
| WFG7 | Ave | 0.330780 | 0.301188 | 0.333640 | **0.340748** |
| Std | 0.003936 | 0.017548 | 0.006301 | **0.000459** |
| WFG8 | Ave | 0.219441 | 0.218580 | 0.218133 | **0.240414** |
| Std | 0.019037 | **0.009683** | 0.010198 | 0.010233 |
| WFG9 | Ave | 0.328207 | 0.296105 | 0.318514 | **0.334004** |
| Std | 0.005291 | 0.013095 | 0.017301 | **0.000312** |
| WFG10 | Ave | - | - | - | - |
| Std | - | - | - | - |
| UF1 | Ave | 0.561645 | 0.603601 | 0.511170 | **0.679172** |
| Std | 0.117069 | 0.018079 | 0.067474 | **0.005236** |
| UF2 | Ave | 0.652262 | 0.650700 | 0.652144 | **0.705319** |
| Std | 0.056328 | 0.018156 | 0.027317 | **0.000805** |
| UF3 | Ave | 0.240378 | 0.248887 | 0.198759 | **0.273789** |
| Std | 0.117277 | 0.107802 | **0.081211** | 0.106228 |
| UF4 | Ave | 0.333707 | 0.326462 | 0.351569 | **0.389476** |
| Std | 0.028258 | 0.010727 | 0.008512 | **0.001953** |
| UF5 | Ave | 0.047673 | **0.090256** | 0.002369 | 0.073897 |
| Std | 0.068635 | 0.082429 | **0.008959** | 0.065708 |
| UF6 | Ave | **0.079055** | 0.072303 | 0.003378 | 0.014092 |
| Std | 0.088780 | 0.065175 | **0.009347** | 0.026704 |
| UF7 | Ave | 0.413427 | 0.500661 | 0.309508 | **0.557788** |
| Std | 0.097156 | 0.013440 | 0.129818 | **0.002241** |
| UF8 | Ave | 0.227996 | 0.132030 | 0.367453 | **0.417184** |
| Std | 0.047644 | 0.086153 | 0.049580 | **0.010394** |
| UF9 | Ave | 0.379303 | 0.292100 | 0.562623 | **0.622550** |
| Std | 0.138922 | 0.139815 | 0.053944 | **0.014413** |
| UF10 | Ave | 0.007382 | 0.003070 | 0.012647 | **0.042581** |
| Std | 0.020371 | **0.013028** | 0.021363 | 0.071530 |
| CF1 | Ave | 0.570288 | 0.518701 | 0.546686 | **0.574135** |
| Std | 0.000775 | 0.017305 | 0.011980 | **0.000481** |
| CF2 | Ave | 0.635667 | 0.600919 | 0.521186 | **0.677694** |
| Std | 0.008993 | 0.015483 | 0.087187 | **0.005934** |
| CF3 | Ave | 0.000000 | **0.056311** | 0.003449 | 0.000915 |
| Std | **0.000000** | 0.052226 | 0.011728 | 0.004833 |
| CF4 | Ave | 0.312308 | **0.392881** | 0.253004 | 0.370910 |
| Std | 0.067983 | 0.034851 | 0.107377 | **0.030846** |
| CF5 | Ave | 0.039672 | 0.056062 | 0.003597 | **0.127897** |
| Std | 0.057659 | 0.092882 | **0.013690** | 0.069758 |
| CF6 | Ave | 0.569821 | 0.635199 | 0.450000 | **0.681121** |
| Std | 0.028467 | 0.018380 | 0.138037 | **0.004874** |
| CF7 | Ave | **0.091916** | 0.020073 | 0.000000 | 0.015863 |
| Std | 0.148351 | 0.074233 | **0.000000** | 0.057578 |
| CF8 | Ave | 0.151872 | 0.030431 | 0.317060 | **0.400711** |
| Std | 0.046130 | 0.049970 | 0.103629 | **0.014487** |
| CF9 | Ave | 0.310429 | 0.134514 | 0.349187 | **0.417546** |
| Std | 0.028701 | 0.087529 | 0.033991 | **0.009754** |
| CF10 | Ave | 0.000000 | 0.000019 | 0.002160 | **0.044717** |
| Std | **0.000000** | 0.000105 | 0.005712 | 0.066771 |

**Table 5.** Statistical Finding of GD on ZDT, DTLZ, WFG, UF and CF problem sets.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Function** | **Index** | **Algorithms** | | | |
| **MOMVO** | **MSSA** | **MOEAD** | **MOBOA** |
| ZTD1 | Ave | 0.013881 | 0.000507 | **0.000044** | 0.000154 |
| Std | 0.040060 | 0.000219 | **0.000005** | 0.000029 |
| ZTD2 | Ave | Inf | 0.033598 | 0.000528 | **0.000071** |
| Std | - | 0.182524 | 0.002306 | 0.000037 |
| ZTD3 | Ave | 0.016262 | 0.000888 | 0.012013 | **0.000180** |
| Std | 0.040134 | 0.000423 | 0.008424 | **0.000013** |
| ZTD4 | Ave | Inf | 0.052349 | 0.544218 | **0.000028** |
| Std | - | 0.206320 | 0.847932 | 0.000037 |
| ZTD6 | Ave | Inf | 0.023458 | 0.081903 | **0.002056** |
| Std | - | 0.012046 | 0.141519 | 0.011071 |
| DTLZ1 | Ave | Inf | 2.724180 | **1.482198** | 1.913647 |
| Std | - | 0.265177 | 0.534224 | 0.253689 |
| DTLZ2 | Ave | Inf | 0.002392 | **0.001714** | 0.015041 |
| Std | - | 0.000321 | 0.000090 | 0.002450 |
| DTLZ3 | Ave | Inf | 19.019774 | **9.778786** | 20.199642 |
| Std | - | 1.178804 | 3.400907 | 0.877740 |
| DTLZ4 | Ave | Inf | 0.006611 | **0.001593** | 0.010059 |
| Std | - | 0.004316 | 0.000431 | 0.000689 |
| DTLZ5 | Ave | Inf | 0.000299 | **0.000055** | 0.006088 |
| Std | - | 0.000307 | 0.000003 | 0.001264 |
| DTLZ6 | Ave | Inf | 0.080154 | 0.000052 | **0.000048** |
| Std | - | 0.075711 | 0.000003 | 0.000003 |
| DTLZ7 | Ave | Inf | 1.437953 | 0.176928 | **0.004252** |
| Std | - | 2.378914 | 0.097869 | 0.000478 |
| WFG1 | Ave | 0.113012 | 0.111866 | **0.048270** | 0.120414 |
| Std | 0.001522 | 0.005191 | 0.016350 | **0.000493** |
| WFG2 | Ave | **0.000740** | 0.001499 | 0.003453 | 0.001238 |
| Std | 0.000178 | 0.001955 | 0.004350 | **0.000088** |
| WFG3 | Ave | 0.000670 | **0.000402** | 0.000759 | 0.002199 |
| Std | 0.000130 | 0.000384 | 0.002350 | **0.000092** |
| WFG4 | Ave | 0.006623 | 0.008415 | **0.006104** | 0.006299 |
| Std | 0.000287 | 0.002531 | **0.000084** | 0.000310 |
| WFG5 | Ave | 0.006723 | 0.007235 | **0.006071** | 0.006195 |
| Std | 0.000372 | 0.001049 | **0.000076** | 0.000380 |
| WFG6 | Ave | 0.000784 | **0.000454** | 0.006450 | 0.001772 |
| Std | 0.000130 | 0.000384 | 0.004422 | **0.000117** |
| WFG7 | Ave | 0.000626 | **0.000277** | 0.000410 | 0.001796 |
| Std | 0.000129 | 0.000162 | 0.001349 | **0.000101** |
| WFG8 | Ave | Inf | 0.031664 | 0.036598 | **0.029826** |
| Std | - | 0.005967 | 0.005565 | 0.006527 |
| WFG9 | Ave | **0.001187** | 0.001368 | 0.002699 | 0.001775 |
| Std | 0.000439 | 0.000546 | 0.004388 | **0.000070** |
| WFG10 | Ave | - | - | - | - |
| Std | - | - | - | - |
| UF1 | Ave | Inf | 0.006354 | 0.007793 | **0.004609** |
| Std | - | 0.002517 | 0.008247 | 0.001817 |
| UF2 | Ave | Inf | 0.003386 | **0.002185** | 0.002198 |
| Std | - | 0.001942 | 0.000865 | 0.001262 |
| UF3 | Ave | Inf | 0.029947 | 0.041162 | **0.013150** |
| Std | - | 0.029709 | 0.019457 | 0.008056 |
| UF4 | Ave | Inf | 0.007006 | 0.006134 | **0.004588** |
| Std | - | 0.000847 | 0.000710 | 0.000185 |
| UF5 | Ave | Inf | **0.053508** | 0.176871 | 0.098020 |
| Std | - | 0.026383 | 0.080357 | 0.049087 |
| UF6 | Ave | Inf | **0.043869** | 0.163253 | 0.084102 |
| Std | - | 0.084492 | 0.096740 | 0.020352 |
| UF7 | Ave | Inf | 0.004685 | 0.009503 | **0.002936** |
| Std | - | 0.002340 | 0.013533 | 0.001426 |
| UF8 | Ave | 0.212363 | 0.134668 | **0.008766** | 0.065757 |
| Std | 0.182305 | 0.129367 | **0.007168** | 0.034344 |
| UF9 | Ave | Inf | 0.233233 | **0.013808** | 0.090537 |
| Std | - | 0.197213 | 0.009486 | 0.082604 |
| UF10 | Ave | Inf | 1.337247 | **0.118994** | 0.835805 |
| Std | - | 0.916789 | 0.073907 | 0.585702 |
| CF1 | Ave | 0.002359 | 0.003492 | 0.004095 | **0.002189** |
| Std | 0.000049 | 0.000652 | 0.001474 | **0.000031** |
| CF2 | Ave | 0.016882 | 0.009778 | 0.012481 | **0.009159** |
| Std | 0.006209 | 0.004576 | 0.012211 | **0.002617** |
| CF3 | Ave | 0.707863 | 0.167790 | 0.156984 | **0.127719** |
| Std | 0.601442 | 0.262659 | 0.095294 | **0.062844** |
| CF4 | Ave | 0.164641 | 0.020439 | **0.014088** | 0.051360 |
| Std | 0.186400 | 0.028498 | **0.013643** | 0.089532 |
| CF5 | Ave | 0.954919 | **0.114464** | 0.226195 | 0.155732 |
| Std | 0.626799 | **0.076138** | 0.141539 | 0.178969 |
| CF6 | Ave | 0.138504 | 0.025659 | 0.013115 | **0.008657** |
| Std | 0.140087 | 0.029275 | 0.032000 | **0.013070** |
| CF7 | Ave | 0.932406 | 0.301613 | 0.323032 | **0.244062** |
| Std | 0.691968 | 0.248705 | 0.145823 | **0.122048** |
| CF8 | Ave | 0.691487 | 0.445244 | **0.021319** | 0.145217 |
| Std | 0.174181 | 0.294697 | **0.024127** | 0.081197 |
| CF9 | Ave | 0.208343 | 0.247776 | **0.006660** | 0.068164 |
| Std | 0.089854 | 0.210060 | **0.004049** | 0.043996 |
| CF10 | Ave | 0.782735 | 1.338141 | **0.143581** | 0.964823 |
| Std | 0.206822 | 0.998007 | **0.086064** | 0.665810 |

**Appendix 3**

1. **Inverted Generational Distance (IGD)**

IGD is used to measure convergence. It is a metric that evaluates the quality of approximations to the PF achieved by MOO algorithms. It is defined as follows:



where stands for the quantity of elements within and stands for the Euclidean distance between the solution within and its nearest solution within . A zero value means that all generated solutions lie exactly on the true PF.

1. **Spacing (SP)**

Spacing is used to quantify and assess the coverage. It indicates how evenly the solutions achieved are distributed along the *.* It is defined as follows:



where in refers to the quantity of non-dominated solutions and refers to the Euclidean distance between the solution within and the nearest solution within . When is low, the convergence is better in terms of robustness and reliability.

1. **Hypervolume (HV)**

HV computes the volume, within the objective space, covered by members of set A, mathematically. The reference point is determined by creating a vector from the worst values of the objective functions. The combined hypercubes and their corresponding HV values are then computed as follow:



where, for every solution, a hypercube is constructed with the reference point and where the solution is the diagonal of the hypercube.

1. **Generational Distance (GD)**

Distance between the true Pareto () and the achieved Pareto front () is denoted by generational distance. This metric is mathematically defined as follows:



where in is the quantity of non-dominated solutions and is the Euclidean distance between the solution within and its nearest solution within in . Notably, a lower GD value refers to better algorithm convergence.