Multi-objective sequence dependent setup times flowshop scheduling: a new algorithm and a comprehensive study

Online materials

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Chapter 1

Pseudo Codes

```
1  UBCalculate; // Computation of the upper bounds for each objective;
2  W1 = 0.0;
3  W2 = 1.0;
   // 10 iterations;
4  while (W1 ≤ 0.9) do
5  |  InitialAntsGeneration(Ant1,Ant2); // Two initial solution are generated;
6  |  AddSolutionToFront(Ant1,Ant2); // the solutions are added to the non
   |  dominated archive;
7  |  LocalSearches(Ant1,Ant2);// a sequence of local searches is applied on
   |  the ants;
8  |  AddSolutionToFront(Ant1,Ant2);
9  |  BestAnt = FindBestAnt(Ant1,Ant2); // the best Ant is calculated
   |  according to the weighted objective function;
10 |  PheromoneMatrixInitialization;
11 |  PairWiseJobInterchange;
12 |  Num_Iter = 0;
   |  // Internal loop:  16 iterations;
13 |  while (Num_Iter < 16) do
14 |  |  PheromoneMatrixUpdating;
15 |  |  AntsGeneration(Ant1,Ant2);
16 |  |  AddSolutionToFront(Ant1,Ant2);
17 |  |  LocalSearches(Ant1,Ant2);
18 |  |  AddSolutionToFront(Ant1,Ant2);
19 |  |  BestAnt = FindBestAnt(Ant1,Ant2);
20 |  |  PairWiseJobInterchange;
21 |  |  Num_Iter = Num_Iter + 1;
22 |  end
23 |  W1 = W1 + 0.1;
24 |  W2 = W2 − 0.1;
25 end
```

Algorithm 1: MOACA algorithm

```
1  UBCalculate; // Computation of the upper bounds for each objective;
2  W1 = 0.0;
3  W2 = 1.0;
   // 10 iterations;
4  while (W1 ≤ 0.9)) do
5  |  InitialAntsGeneration(Ant1,Ant2); // Two initial solution are generated;
6  |  AddSolutionToFront(Ant1,Ant2); // the solutions are added to the non
   |  dominated archive;
7  |  LocalSearches(Ant1,Ant2);// a sequence of local searches is applied on
   |  the ants;
8  |  AddSolutionToFront(Ant1,Ant2);
9  |  BestAnt = FindBestAnt(Ant1,Ant2); // the best Ant is calculated
   |  according to the weighted objective function;
10 |  PheromoneMatrixInitialization;
11 |  PairWiseJobInterchange;
12 |  Time = now();
   |  // Internal loop:  To each iterations has been allotted one tenth of
   |  the total computation time;
13 |  while ( (now() − Time) < TotalTimeAllowed / 10 ) do
14 |  |  PheromoneMatrixUpdating;
15 |  |  AntsGeneration(Ant1,Ant2);
16 |  |  AddSolutionToFront(Ant1,Ant2);
17 |  |  LocalSearches(Ant1,Ant2);
18 |  |  AddSolutionToFront(Ant1,Ant2);
19 |  |  BestAnt = FindBestAnt(Ant1,Ant2);
20 |  |  PairWiseJobInterchange;
21 |  end
22 |  W1 = W1 + 0.1;
23 |  W2 = W2 − 0.1;
24 end
```

Algorithm 2: MOACA modified algorithm

```
1  Generation of initial solutions; // STEP 1;
2  K := 0; ;
3  repeat // 2 times
4  |  K = K + 1 ;
   |  // STEP 2.1;
5  |  if K = 1 then S = SIni1;
6  |  else S = SIni2;
7  |  repeat // 4 times
8  |  |  T = 575; // STEP 3.1:  Initialize the temperature;
9  |  |  repeat
10 |  |  |  for n ← 1 to 30 do
11 |  |  |  |  Choose the objective to optimize; // STEP 3.2.1;
   |  |  |  |  // STEP 3.2.2;
12 |  |  |  |  S' := RIPS(S);
13 |  |  |  |  UpdateArchive;
14 |  |  |  |  Compute Δ;
15 |  |  |  |  if Δ < 0 then  S' = S ;
16 |  |  |  |  else
17 |  |  |  |  |  Sample an uniform random number U;
18 |  |  |  |  |  Exp = exp(-Δ/T);
19 |  |  |  |  |  if U ≤ Exp then S' = S ;
20 |  |  |  |
21 |  |  |  end
22 |  |  |  T := T * 0.9; // STEP 3.3;
23 |  |  until  (T ≤ 20);
   |  |  // STEP 4;
24 |  |  if K = 1 then
25 |  |  |  X2 = X2 − 0.1666, X1 = 1 − X2;
26 |  |  |  if X2 ≥ 0.5 then S = SIni1
27 |  |  else
28 |  |  |  X1 := X1 − 0.1666, X2 := 1˘X1;
29 |  |  |  if X1 ≥ 0.5 then S = SIni2
30 |  |
31 |  until ((K = 1) and (X2 < 0.5) or (K = 2) and (X1 < 0.5));
32 until K = 2;
33 PairWiseJobInterchange; // STEP 5;
```

Algorithm 3: MOSA_Varad original algorithm

```
1  Generation of initial solutions; // STEP 1;
2  K := 0; ;
3  repeat // 2 times
4  |  K = K + 1 ;
   |  // STEP 2.1;
5  |  if K = 1 then S = SIni1;
6  |  else S = SIni2;
7  |  repeat // 4 times
8  |  |  T = 575; // STEP 3.1:  Initialize the temperature;
9  |  |  Time = now();
10 |  |  while (now() − Time) < TotalTimeAllowed / 8 do
11 |  |  |  for n ← 1 to 30 do
12 |  |  |  |  Choose the objective to optimize; // STEP 3.2.1;
   |  |  |  |  // STEP 3.2.2;
13 |  |  |  |  S' := RIPS(S);
14 |  |  |  |  UpdateArchive;
15 |  |  |  |  Compute Δ;
16 |  |  |  |  if Δ < 0 then S' = S ;
17 |  |  |  |  else
18 |  |  |  |  |  Sample an uniform random number U;
19 |  |  |  |  |  Exp = exp −Δ/T;
20 |  |  |  |  |  if U ≤ Exp then S' = S ;
21 |  |  |  |
22 |  |  |  end
23 |  |  |  T := T ∗ 0.9; // STEP 3.3;
24 |  |  end
   |  |  // STEP 4;
25 |  |  if K = 1 then
26 |  |  |  X2 = X2 − 0.1666, X1 = 1 − X2;
27 |  |  |  if X2 ≥ 0.5 then S = SIni1
28 |  |  else
29 |  |  |  X1 := X1 − 0.1666, X2 := 1˘X1;
30 |  |  |  if X1 ≥ 0.5 then S = SIni2
31 |  |
32 |  until ((K = 1) and (X2 < 0.5) or (K = 2) and (X1 < 0.5));
33 until K = 2;
34 PairWiseJobInterchange; // STEP 5;
```

Algorithm 4: MOSA_Varad_M algorithm

Chapter 2

Tables

2.1 Tables of mean values

SSD50	Time	150				200		
#	Method	I_H	I_ε^1	$Eval(10^3)$	Method	I_H	I_ε^1	$Eval(10^3)$
1	RIPG	1.296	1.067	2.548.679	RIPG	1.313	1.057	3.423.776
2	MOSA_Varad_M	1.272	1.102	3.587.690	MOSA_Varad_M	1.282	1.096	4.772.831
3	MOSA_Varad	1.232	1.127	1.339.338	MOSA_Varad	1.232	1.127	1.339.338
4	MOIGS	1.186	1.164	2.023.348	MOIGS	1.202	1.150	2.510.204
5	MOGALS_Arroyo	1.179	1.132	920.041	MOGALS_Arroyo	1.189	1.127	1.148.871
6	MOTS	1.151	1.136	685.987	MOTS	1.163	1.130	798.745
7	PESAII	1.106	1.201	583.685	PESAII	1.123	1.189	757.140
8	PESA	1.104	1.202	552.473	PESA	1.121	1.191	712.579
9	MOACA17_M	1.087	1.189	2.201.857	MOACA17_M	1.095	1.185	2.751.410
10	MOACA18_M	1.087	1.188	2.208.651	MOACA18_M	1.095	1.185	2.750.188
11	MOACA19_M	1.083	1.192	2.211.429	MOACA19_M	1.091	1.187	2.750.047
12	MOACA20_M	1.082	1.191	2.211.536	MOACA20_M	1.091	1.187	2.748.924
13	PGA_ALS	1.024	1.250	617.776	PGA_ALS	1.034	1.246	798.703
14	MOGA_Murata	0.980	1.276	1.366.304	MOGA_Murata	1.004	1.263	1.826.234
15	ε−NSGAII	0.969	1.266	1.215.814	ε−NSGAII	0.989	1.255	1.629.181
16	CMOGA	0.897	1.332	1.155.755	CMOGA	0.930	1.313	1.537.986
17	hMGA	0.804	1.356	498.624	hMGA	0.815	1.348	667.361
18	PILS	0.741	1.441	426.402	PILS	0.791	1.401	565.870

Table 2.1: Results for the $C_{max} - TWT$ criteria and SSD50. Average quality indicator values for the 18 algorithms tested under the two different termination criteria. Instance group where setup times length is 50% that of the processing times. For each termination criteria level, the methods are sorted according to I_H.

SSD125	Time	150				200		
#	Method	I_H	I_ε^1	$Eval(10^3)$	Method	I_H	I_ε^1	$Eval(10^3)$
1	RIPG	1.318	1.064	2.762.511	RIPG	1.336	1.054	3.615.022
2	MOSA_Varad_M	1.237	1.146	3.623.574	MOSA_Varad_M	1.248	1.140	4.713.809
3	MOIGS	1.225	1.147	2.698.486	MOIGS	1.241	1.134	3.392.280
4	MOSA_Varad	1.182	1.178	1.338.261	MOSA_Varad	1.182	1.178	1.338.261
5	MOGALS_Arroyo	1.154	1.157	912.086	MOGALS_Arroyo	1.163	1.153	1.150.823
6	MOTS	1.126	1.162	627.080	MOTS	1.135	1.158	732.265
7	PESA	1.075	1.216	710.123	PESA	1.092	1.205	908.765
8	PESAII	1.067	1.221	707.241	PESAII	1.086	1.208	907.282
9	MOACA17_M	1.060	1.228	2.206.634	MOACA17_M	1.065	1.226	2.686.160
10	MOACA18_M	1.059	1.227	2.205.608	MOACA18_M	1.065	1.225	2.684.479
11	MOACA20_M	1.056	1.231	2.203.806	MOACA20_M	1.063	1.227	2.685.790
12	MOACA19_M	1.056	1.232	2.202.398	MOACA19_M	1.062	1.228	2.686.138
13	PGA_ALS	0.955	1.323	656.617	PGA_ALS	0.967	1.318	834.233
14	ε−NSGAII	0.913	1.296	1.219.000	MOGA_Murata	0.934	1.297	1.822.611
15	MOGA_Murata	0.908	1.313	1.398.489	ε−NSGAII	0.934	1.284	1.593.860
16	CMOGA	0.810	1.380	1.167.108	CMOGA	0.843	1.360	1.522.397
17	PILS	0.729	1.448	448.360	PILS	0.774	1.410	581.475
18	hMGA	0.699	1.425	509.212	hMGA	0.709	1.417	665.950

Table 2.2: Results for the $C_{max} - TWT$ criteria and SSD125. Average quality indicator values for the 18 algorithms tested under the two different termination criteria. Instance group where setup times length is 125% that of the processing times. For each termination criteria level, the methods are sorted according to I_H.

SSD50	Time	150				200		
#	Method	I_H	I_ε^1	$Eval(10^3)$	Method	I_H	I_ε^1	$Eval(10^3)$
1	RIPG	1.314	1.062	2.886.704	RIPG	1.333	1.053	3.899.048
2	MOSA_Varad_M	1.217	1.138	3.190.094	MOSA_Varad_M	1.232	1.133	4.271.434
3	MOIGS	1.197	1.121	3.144.601	MOIGS	1.219	1.109	4.182.232
4	MOSA_Varad	1.151	1.170	1.337.774	MOSA_Varad	1.151	1.170	1.337.774
5	MOGALS_Arroyo	1.131	1.166	890.481	MOGALS_Arroyo	1.143	1.159	1.213.891
6	MOTS	1.093	1.188	528.608	MOTS	1.108	1.181	654.054
7	PESA	1.023	1.212	847.249	PESA	1.044	1.201	1.131.626
8	PESAII	1.002	1.222	811.593	PESAII	1.023	1.211	1.083.591
9	MOACA18_M	0.995	1.253	2.271.125	MOACA18_M	0.999	1.249	2.808.732
10	MOACA17_M	0.992	1.254	2.266.600	MOACA17_M	0.998	1.249	2.806.738
11	MOACA20_M	0.990	1.255	2.271.435	MOACA20_M	0.996	1.251	2.809.364
12	MOACA19_M	0.989	1.256	2.225.466	MOACA19_M	0.993	1.253	2.775.174
13	PGA_ALS	0.921	1.306	661.826	PGA_ALS	0.934	1.300	867.378
14	MOGA_Murata	0.821	1.336	1.434.468	MOGA_Murata	0.850	1.319	1.935.043
15	ε−NSGAII	0.799	1.345	1.231.011	ε−NSGAII	0.827	1.328	1.660.687
16	CMOGA	0.753	1.374	1.188.429	CMOGA	0.790	1.350	1.602.032
17	PILS	0.661	1.476	486.066	PILS	0.713	1.429	654.566
18	hMGA	0.585	1.505	512.607	hMGA	0.598	1.495	691.926

Table 2.3: Results for the $C_{max} - TFT$ criteria and SSD50. Average quality indicator values for the 18 algorithms tested under the two different termination criteria. Instance group where setup times length is 50% that of the processing times. For each termination criteria level, the methods are sorted according to I_H.

SSD125	Time	150				200		
#	Method	I_H	I_ε^1	$Eval(10^3)$	Method	I_H	I_ε^1	$Eval(10^3)$
1	RIPG	1.322	1.063	2.963.529	RIPG	1.339	1.055	3.913.874
2	MOIGS	1.196	1.124	3.490.327	MOIGS	1.218	1.114	4.607.469
3	MOSA_Varad_M	1.148	1.168	3.207.332	MOSA_Varad_M	1.166	1.161	4.231.502
4	MOSA_Varad	1.067	1.208	1.336.762	MOSA_Varad	1.067	1.208	1.336.762
5	MOGALS_Arroyo	1.043	1.210	893.042	MOGALS_Arroyo	1.056	1.203	1.192.328
6	MOTS	1.029	1.220	487.054	MOTS	1.041	1.213	603.787
7	MOACA18_M	0.946	1.280	2.269.013	PESA	0.961	1.248	1.242.884
8	MOACA17_M	0.943	1.281	2.266.877	MOACA18_M	0.952	1.277	2.805.182
9	MOACA20_M	0.941	1.283	2.269.028	MOACA17_M	0.950	1.277	2.803.932
10	PESA	0.940	1.259	945.584	MOACA20_M	0.948	1.279	2.803.418
11	MOACA19_M	0.937	1.284	2.224.286	MOACA19_M	0.945	1.281	2.784.915
12	PESAII	0.916	1.272	897.434	PESAII	0.937	1.261	1.183.023
13	PGA_ALS	0.835	1.349	681.036	PGA_ALS	0.847	1.342	877.647
14	ε−NSGAII	0.705	1.400	1.227.838	MOGA_Murata	0.731	1.385	1.910.583
15	MOGA_Murata	0.702	1.404	1.443.474	ε−NSGAII	0.729	1.385	1.627.731
16	CMOGA	0.626	1.450	1.191.594	CMOGA	0.663	1.426	1.581.127
17	PILS	0.607	1.508	508.728	PILS	0.650	1.467	673.374
18	hMGA	0.468	1.584	517.613	hMGA	0.479	1.575	687.022

Table 2.4: Results for the $C_{max} - TFT$ criteria and SSD125. Average quality indicator values for the 18 algorithms tested under the two different termination criteria. Instance group where setup times length is 125% that of the processing times. For each termination criteria level, the methods are sorted according to I_H.

Chapter 3

Figures

3.1 Figures

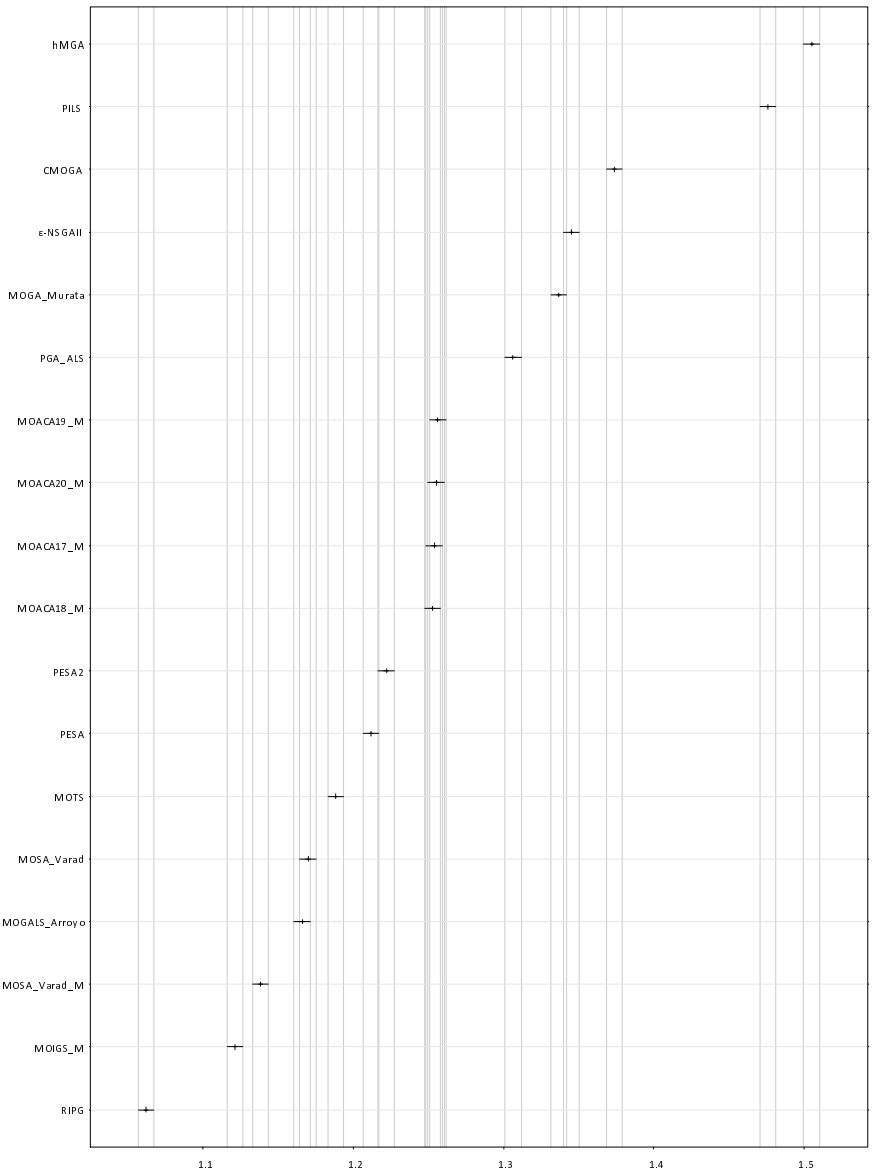

Figure 3.1: SSD50 instance set where setup times length is 50% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the ANOVA experiment. Epsilon indicator response variable and $t = 150ms$ CPU time stopping criterion. Makespan and total flowtime criteria.

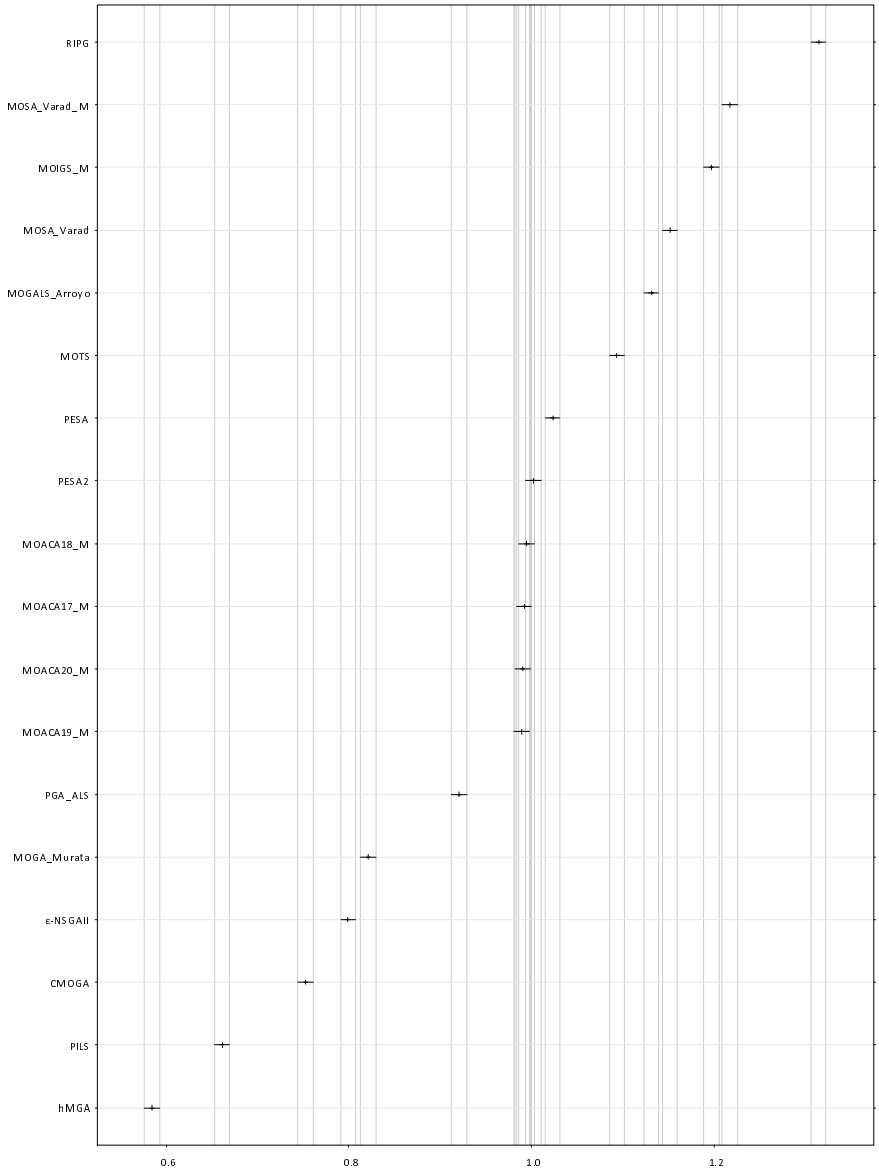

Figure 3.2: SSD50 instance set where setup times length is 50% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01$, $\alpha = 0.05$) for the algorithm factor in the ANOVA experiment. Hypervolume response variable and $t = 150ms$ CPU time stopping criterion. Makespan and total flowtime criteria.

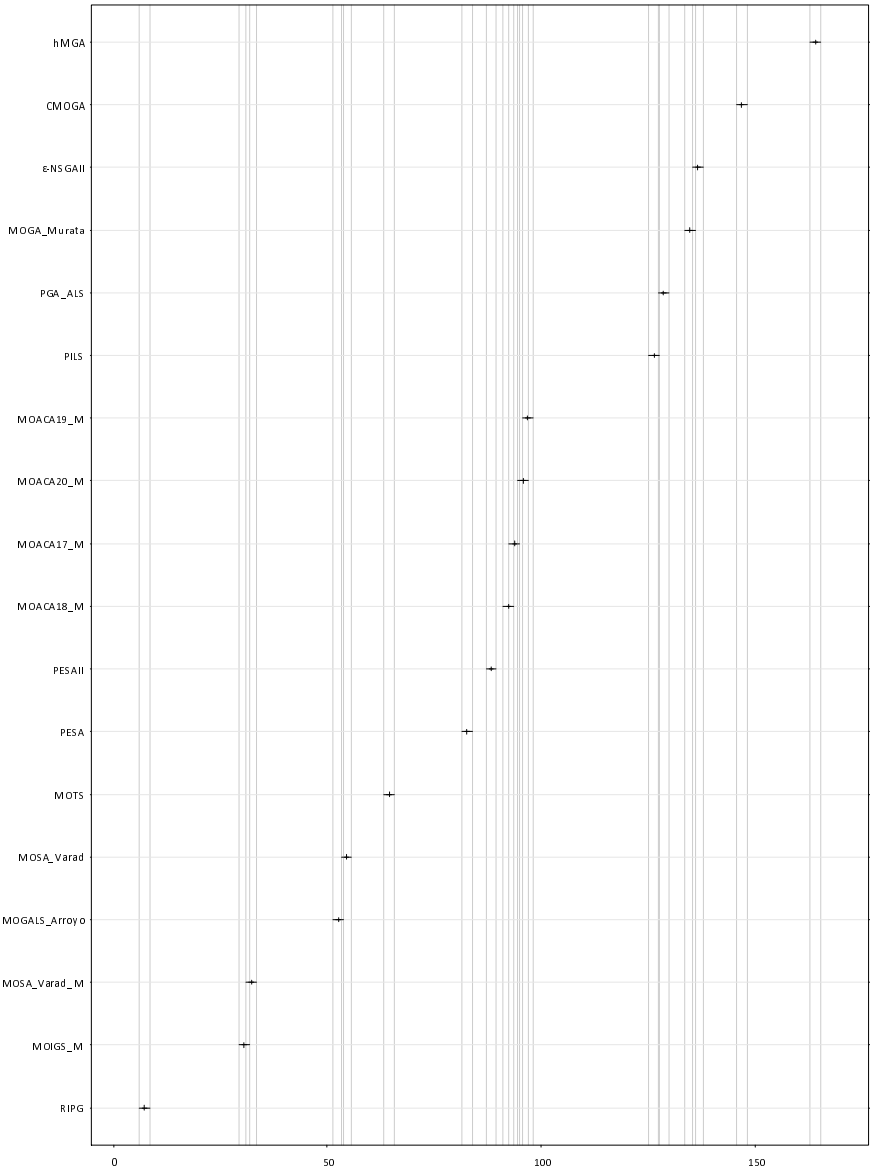

Figure 3.3: SSD50 instance set where setup times length is 50% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the Friedman rank-based experiment. Epsilon indicator response variable and $t = 150ms$ CPU time stopping criterion. Makespan and total flowtime criteria.

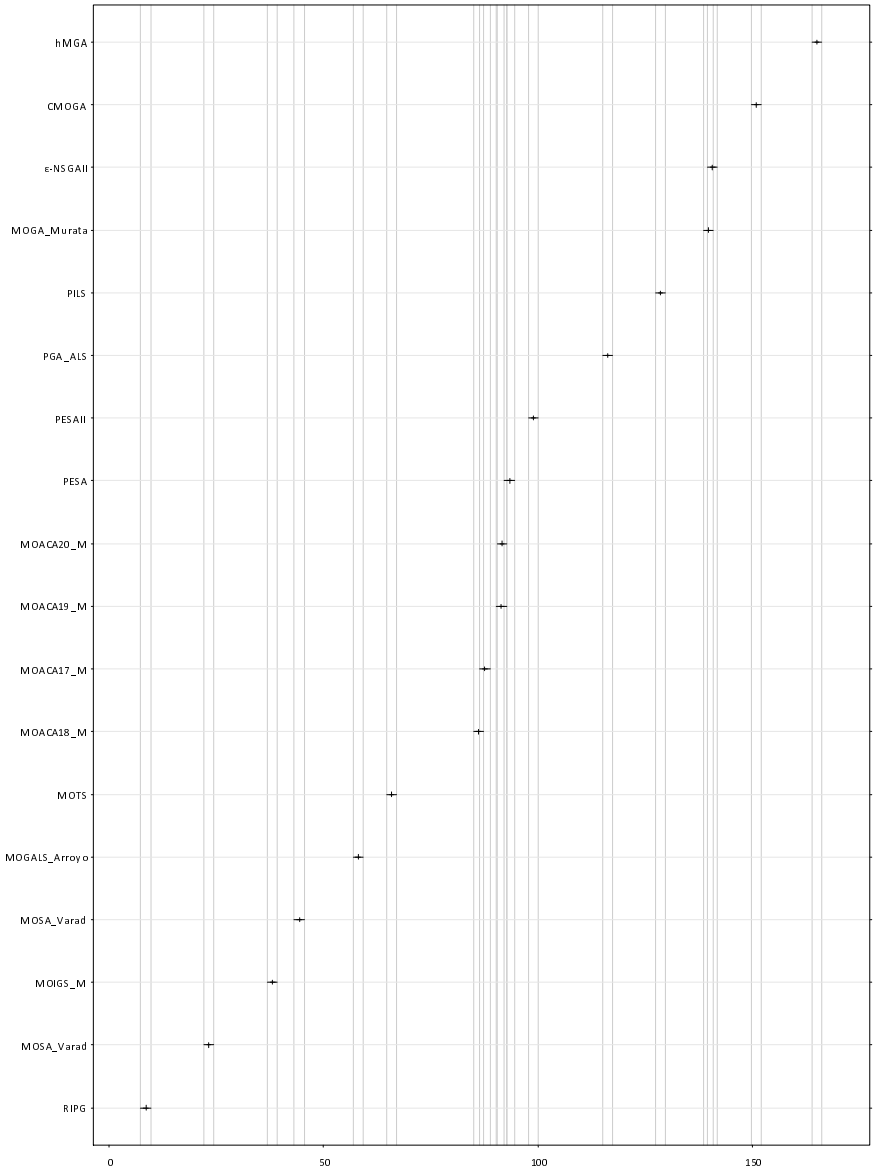

Figure 3.4: SSD50 instance set where setup times length is 50% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the in the Friedman rank-based experiment. Hypervolume response variable and $t = 150ms$ CPU time stopping criterion. Makespan and total flowtime criteria.

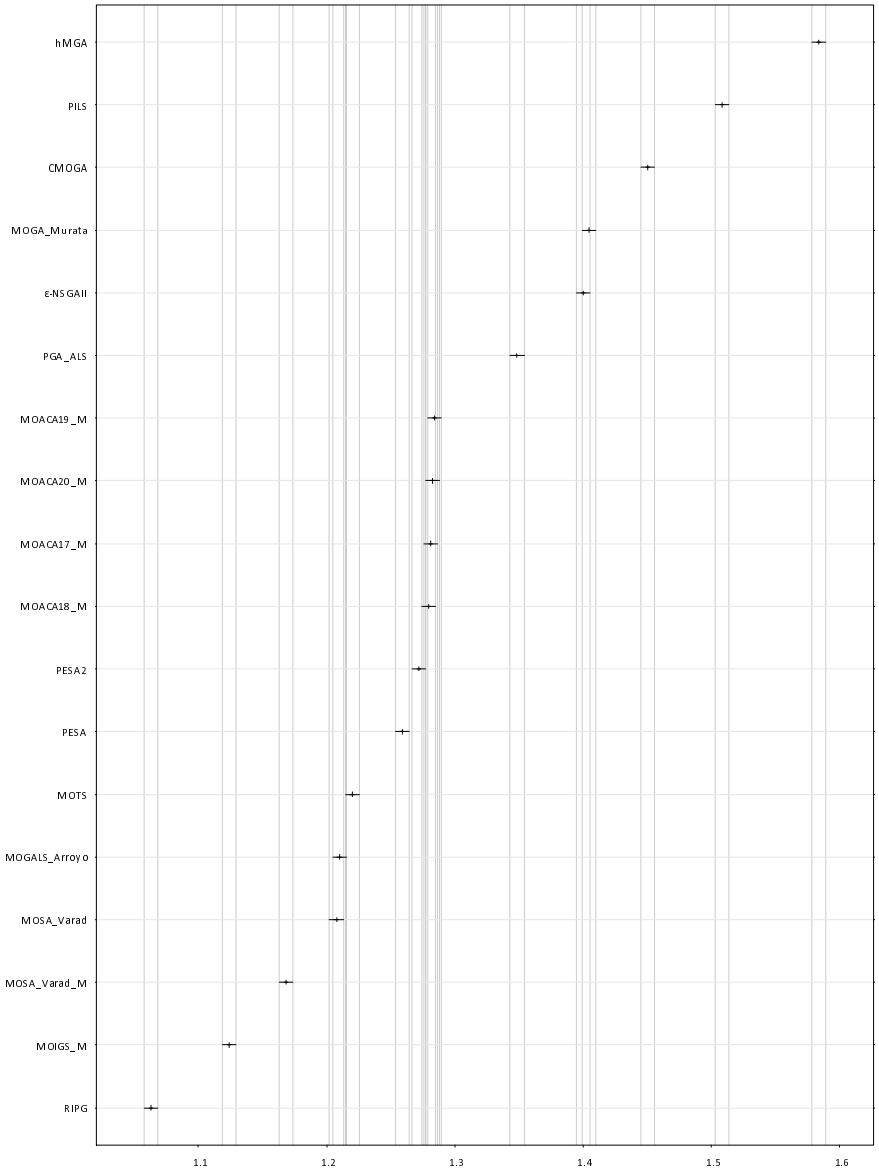

Figure 3.5: SSD125 instance set where setup times length is 125% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the ANOVA experiment. Epsilon indicator response variable and $t = 150ms$ CPU time stopping criterion. Makespan and total flowtime criteria.

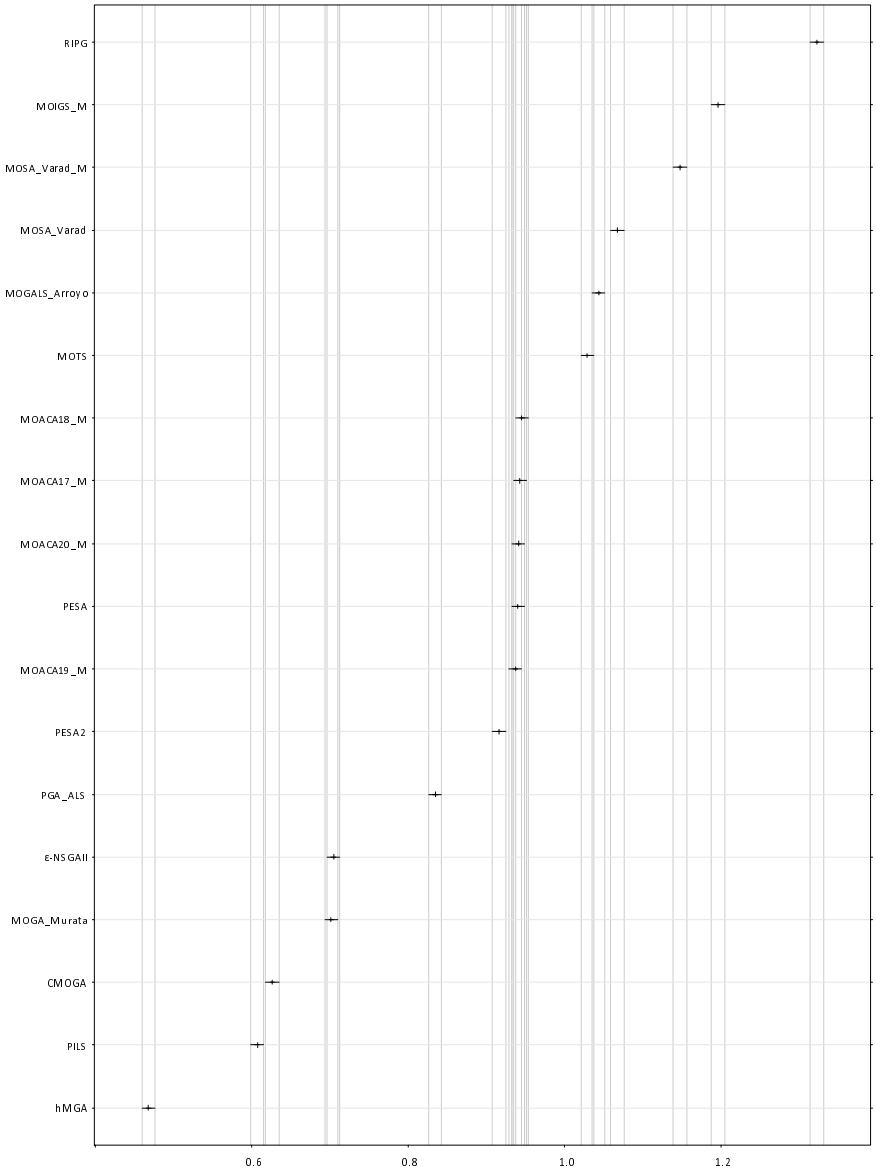

Figure 3.6: SSD125 instance set where setup times length is 125% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the ANOVA experiment. Hypervolume response variable and $t = 150ms$ CPU time stopping criterion. Makespan and total flowtime criteria.

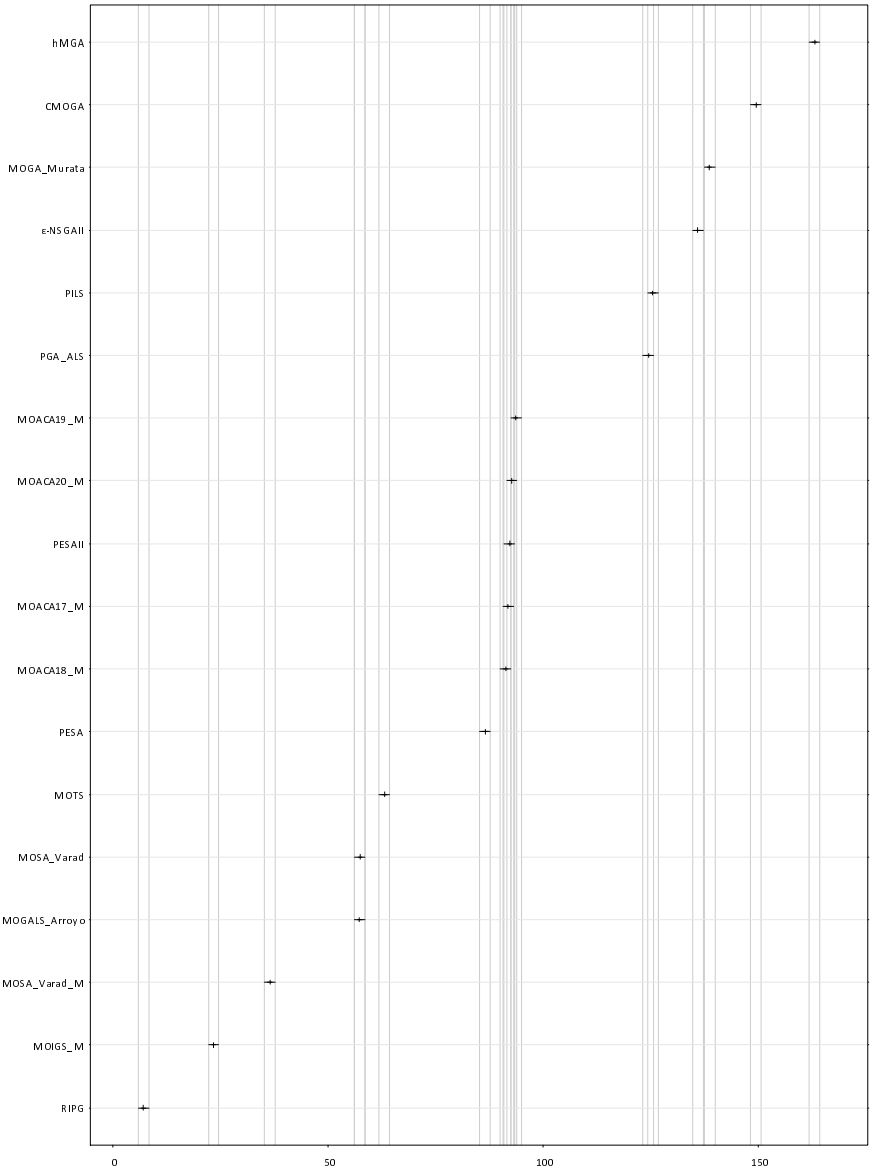

Figure 3.7: SSD125 instance set where setup times length is 125% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the Friedman rank-based experiment. Epsilon indicator response variable and $t = 150ms$ CPU time stopping criterion. Makespan and total flowtime criteria.

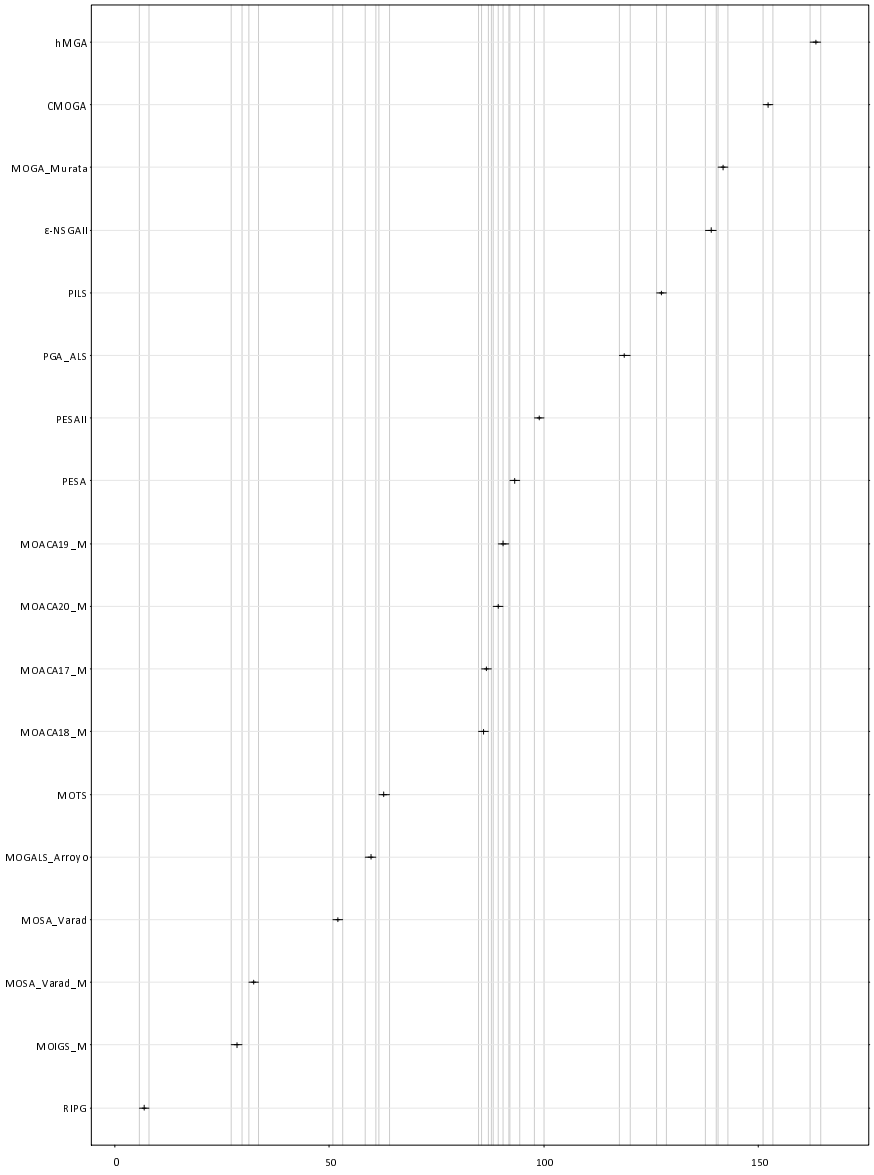

Figure 3.8: SSD125 instance set where setup times length is 125% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the Friedman rank-based experiment. Hypervolume response variable and $t = 150ms$ CPU time stopping criterion. Makespan and total flowtime criteria.

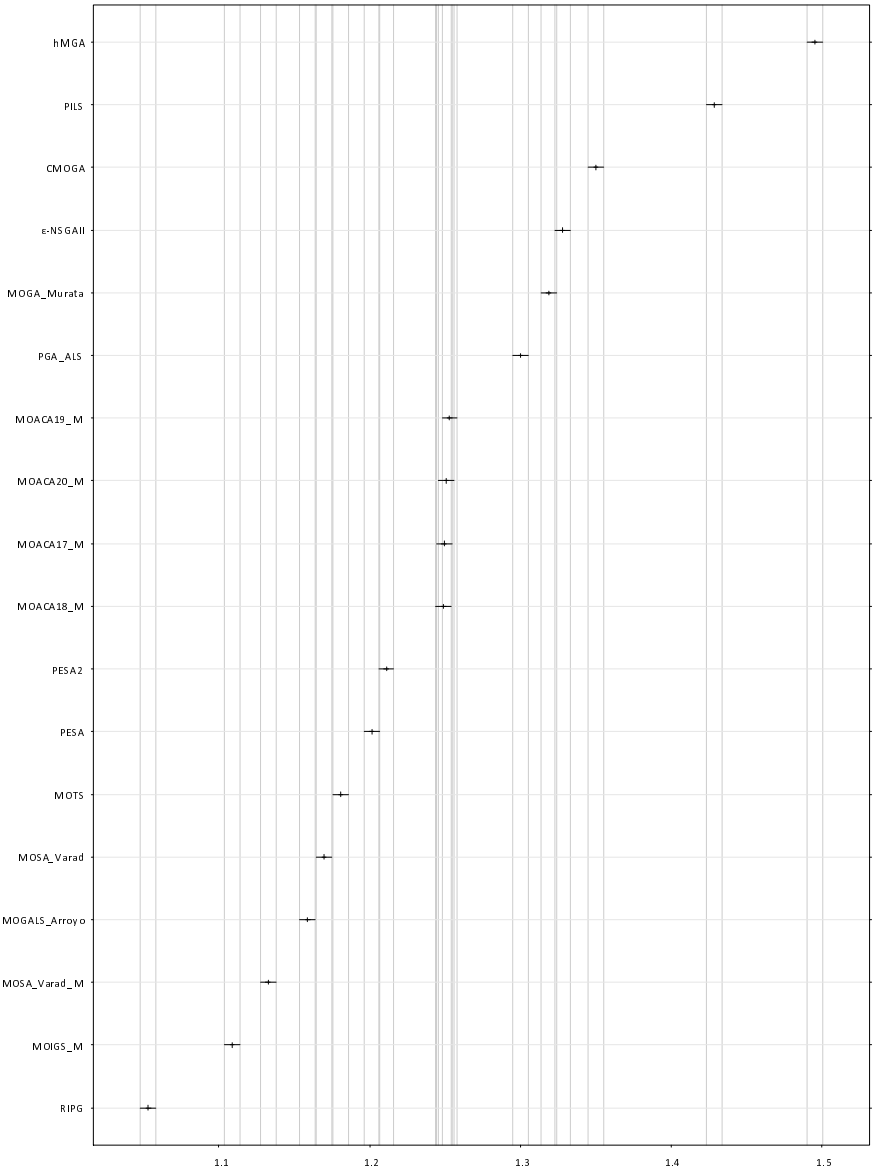

Figure 3.9: SSD50 instance set where setup times length is 50% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the ANOVA experiment. Epsilon indicator response variable and $t = 200ms$ CPU time stopping criterion. Makespan and total flowtime criteria.

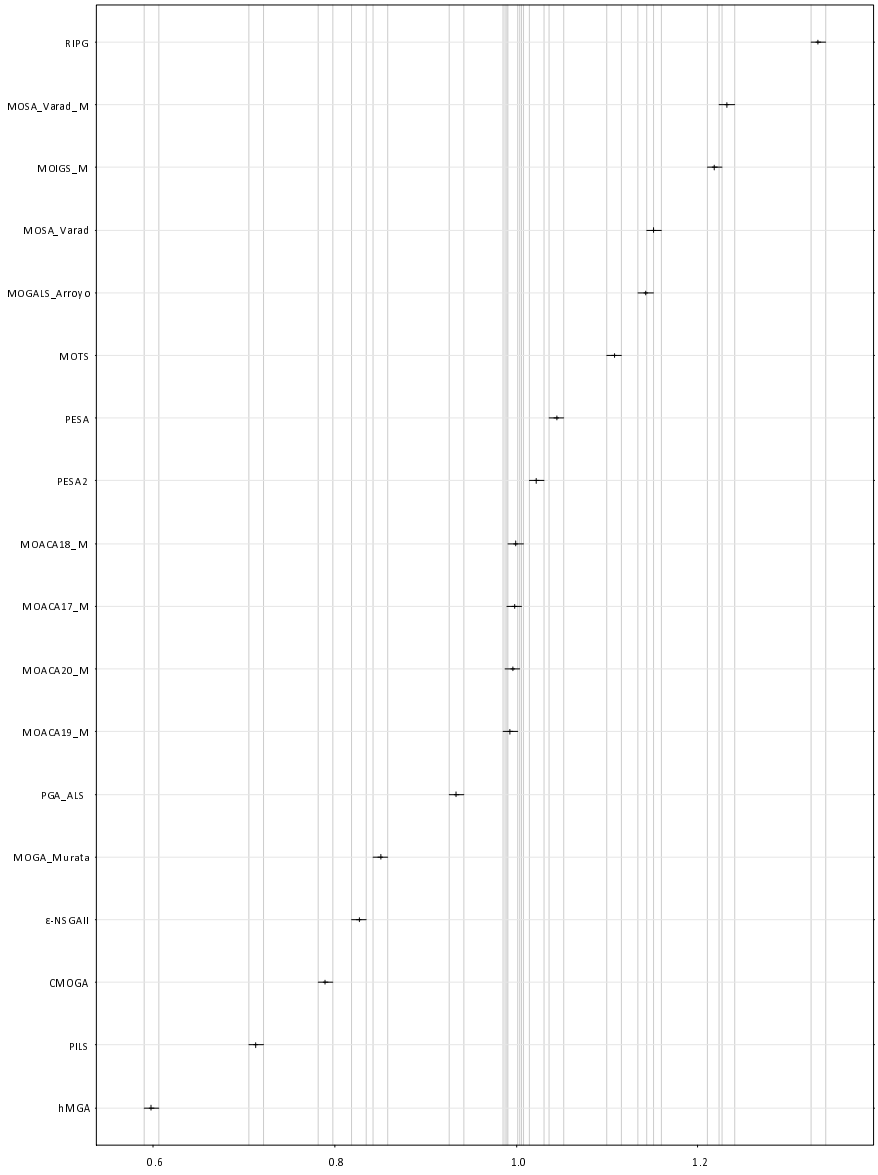

Figure 3.10: SSD50 instance set where setup times length is 50% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the ANOVA experiment. Hypervolume response variable and $t = 200ms$ CPU time stopping criterion. Makespan and total flowtime criteria.

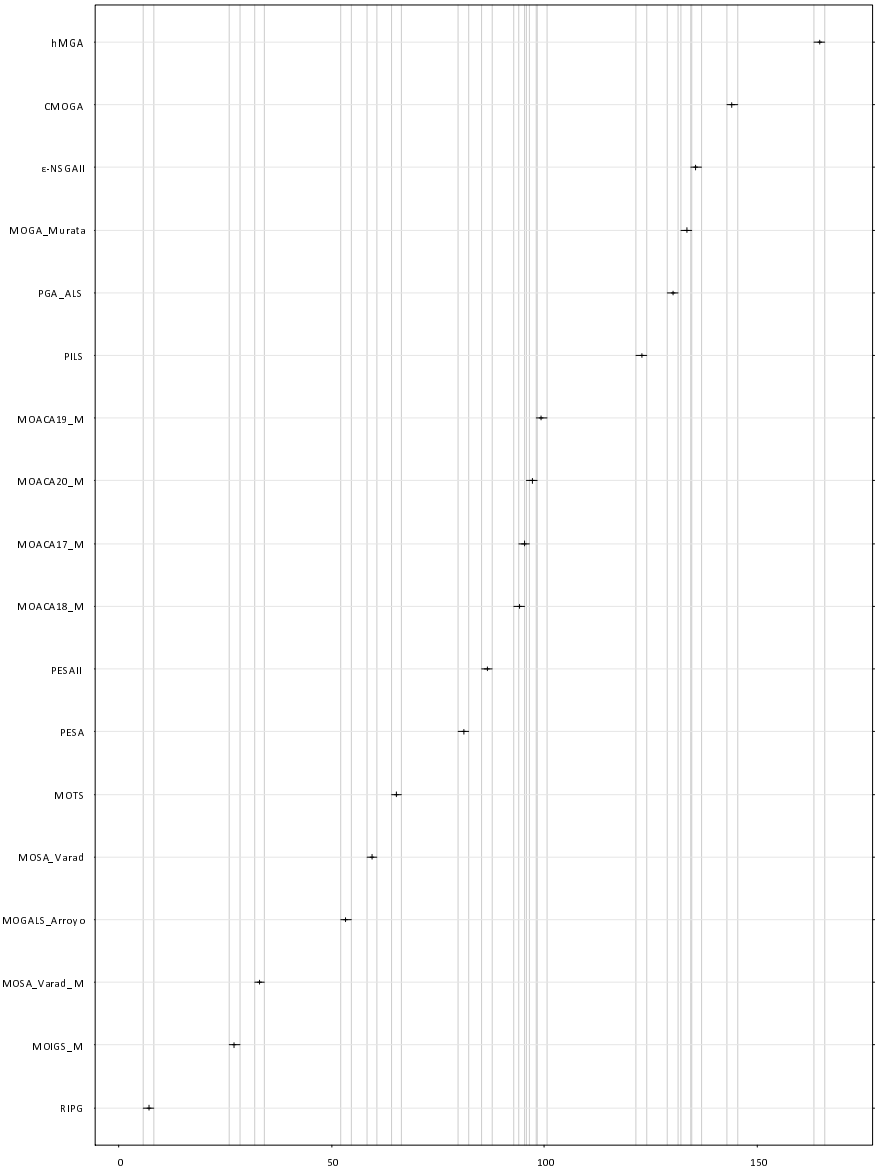

Figure 3.11: SSD50 instance set where setup times length is 50% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the Friedman rank-based experiment. Epsilon indicator response variable and $t = 200ms$ CPU time stopping criterion. Makespan and total flowtime criteria.

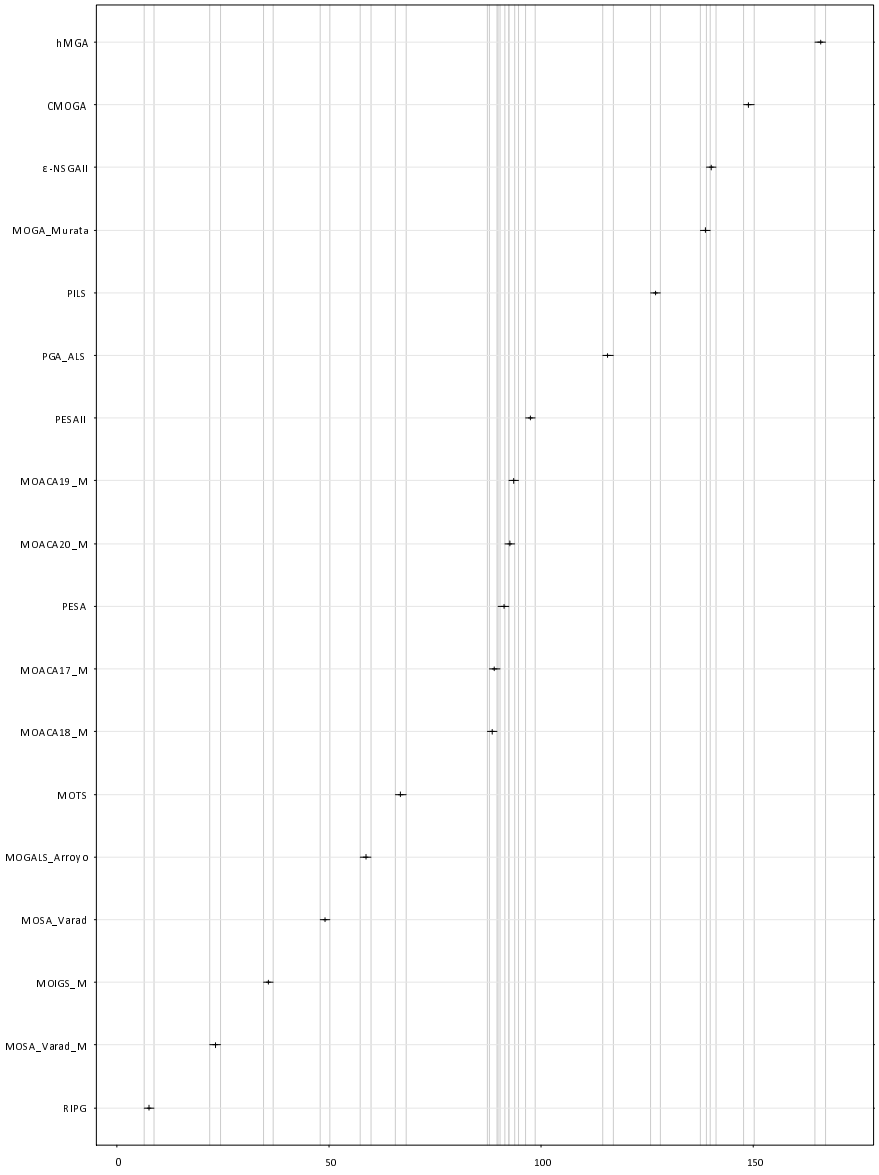

Figure 3.12: SSD50 instance set where setup times length is 50% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the Friedman rank-based experiment. Hypervolume response variable and $t = 200ms$ CPU time stopping criterion. Makespan and total flowtime criteria.

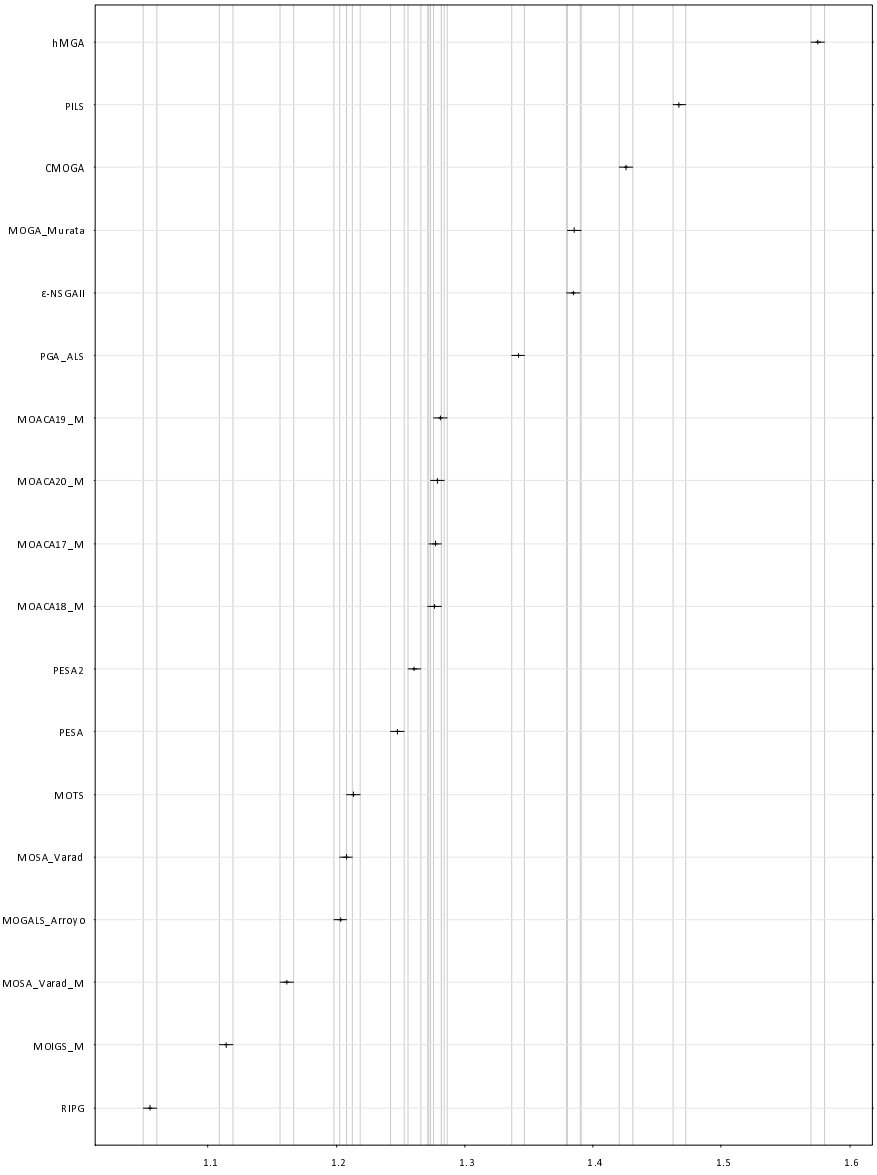

Figure 3.13: SSD125 instance set where setup times length is 125% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the ANOVA experiment. Epsilon indicator response variable and $t = 200ms$ CPU time stopping criterion. Makespan and total flowtime criteria.

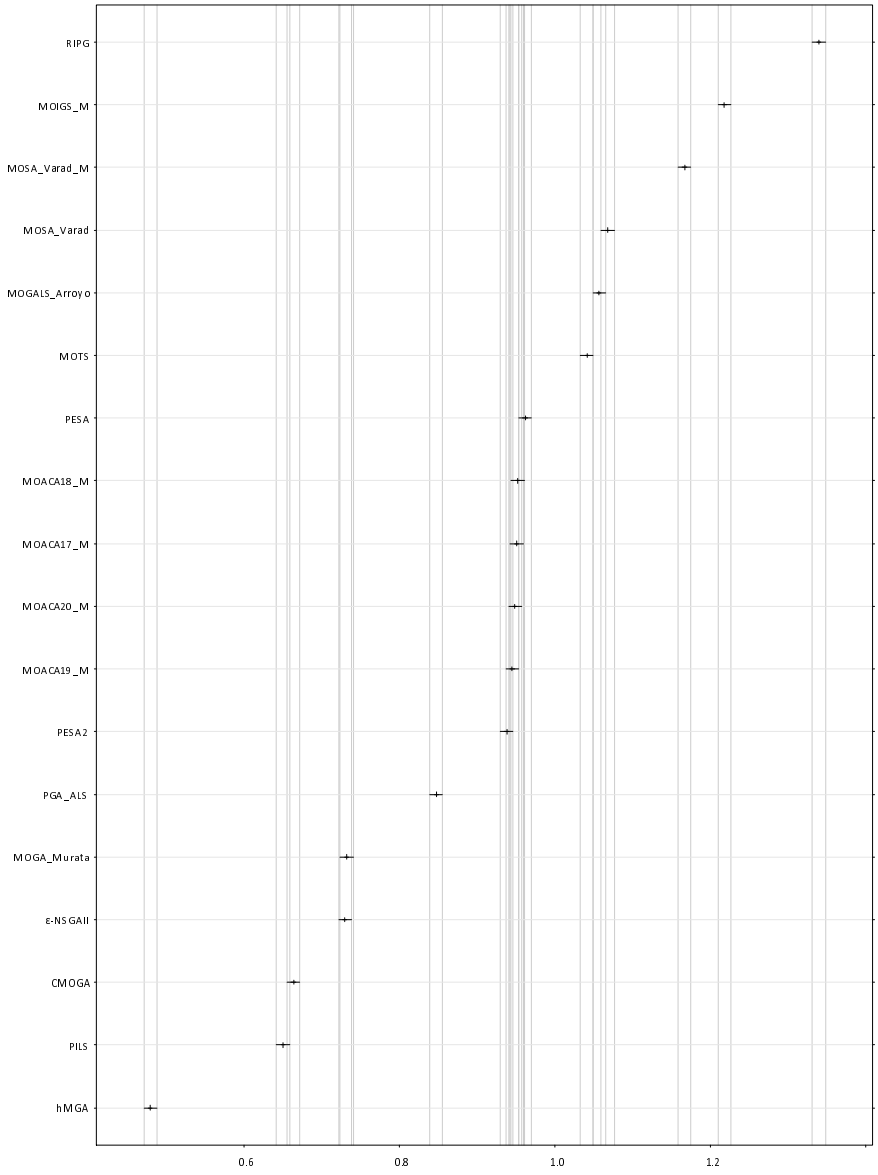

Figure 3.14: SSD125 instance set where setup times length is 125% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the ANOVA experiment. Hypervolume response variable and $t = 200ms$ CPU time stopping criterion. Makespan and total flowtime criteria.

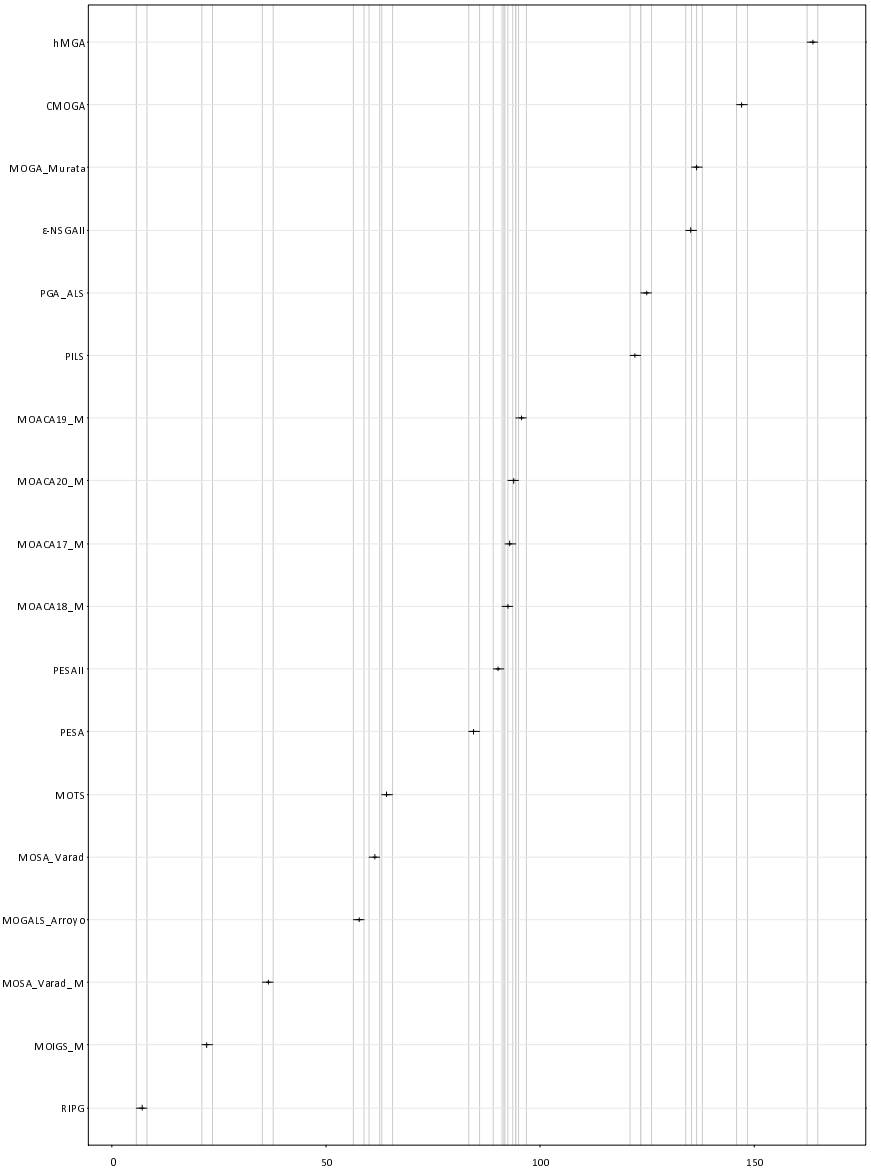

Figure 3.15: SSD125 instance set where setup times length is 125% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the Friedman rank-based experiment. Epsilon indicator response variable and $t = 200ms$ CPU time stopping criterion. Makespan and total flowtime criteria.

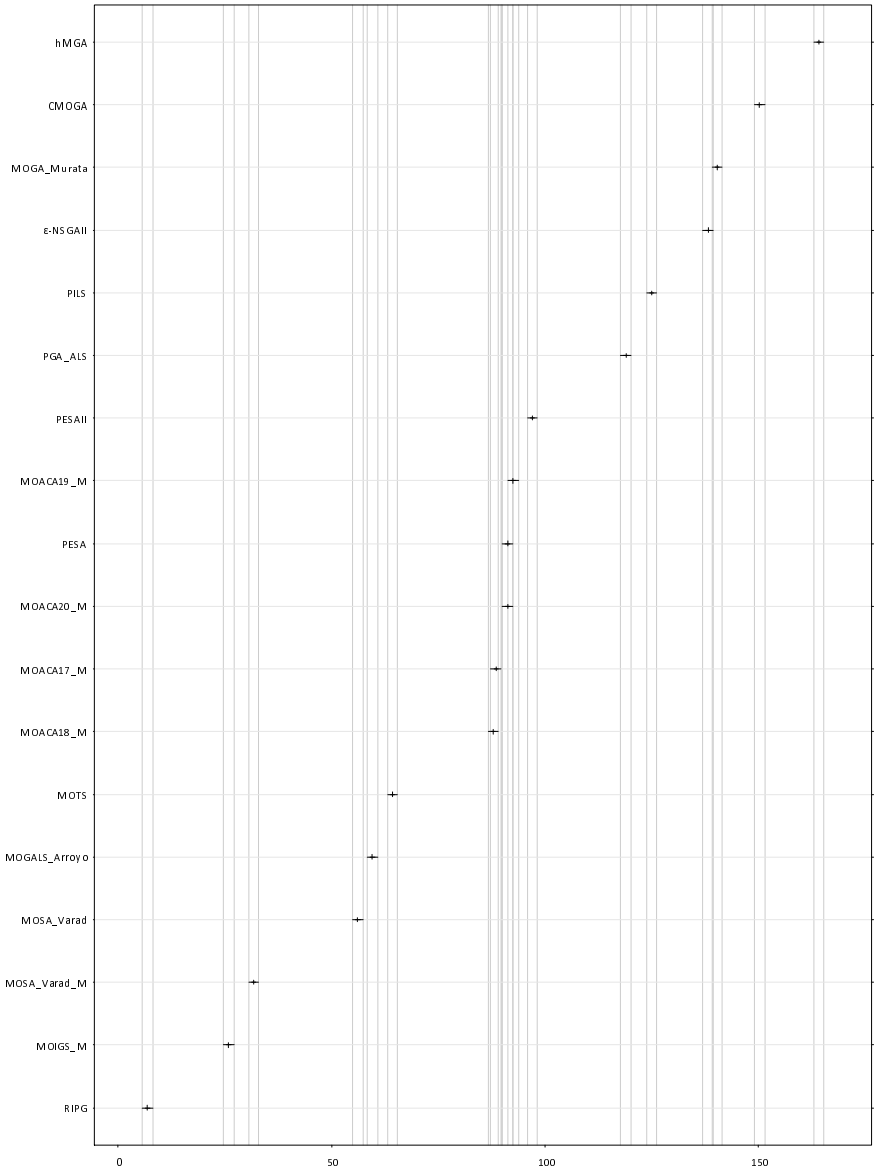

Figure 3.16: SSD125 instance set where setup times length is 125% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the Friedman rank-based experiment. Hypervolume response variable and $t = 200ms$ CPU time stopping criterion. Makespan and total flowtime criteria.

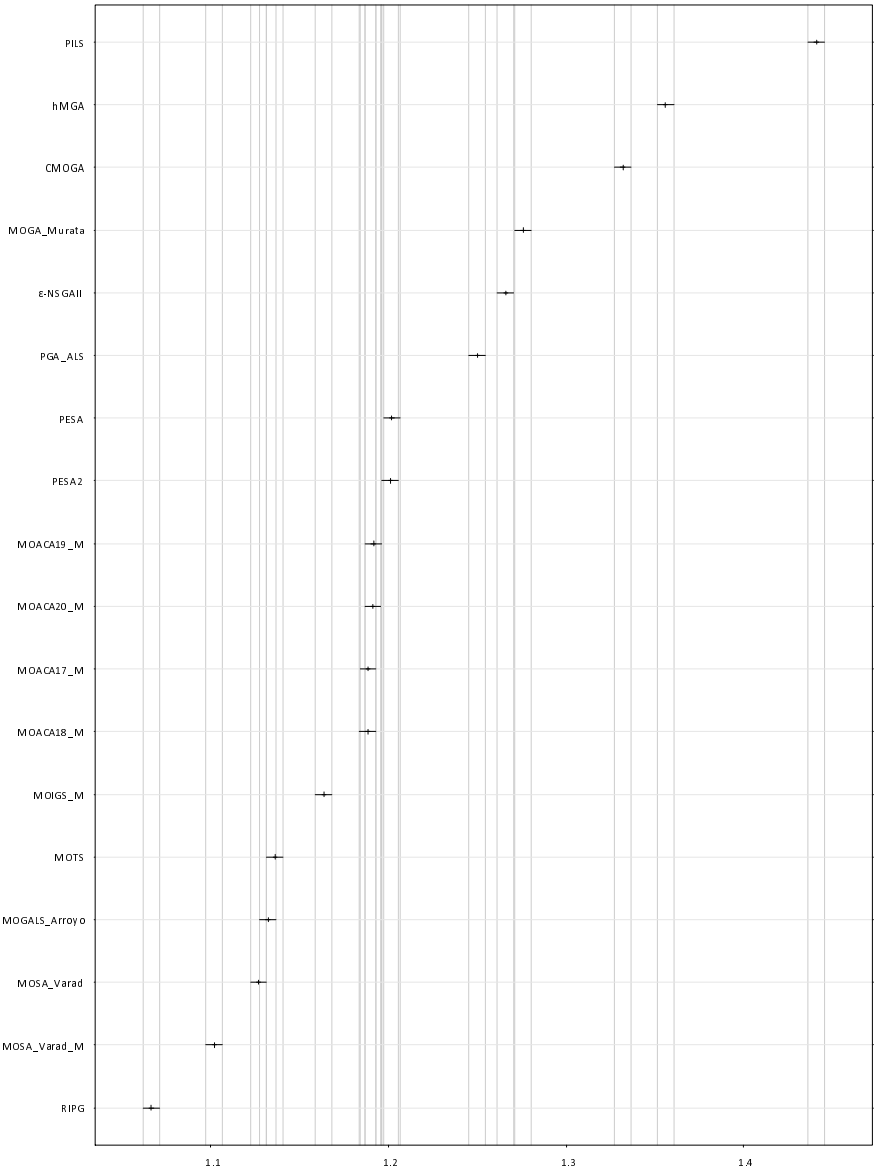

Figure 3.17: SSD50 instance set where setup times length is 50% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the ANOVA experiment. Epsilon indicator response variable and $t = 150ms$ CPU time stopping criterion. Makespan and total weighted tardiness criteria.

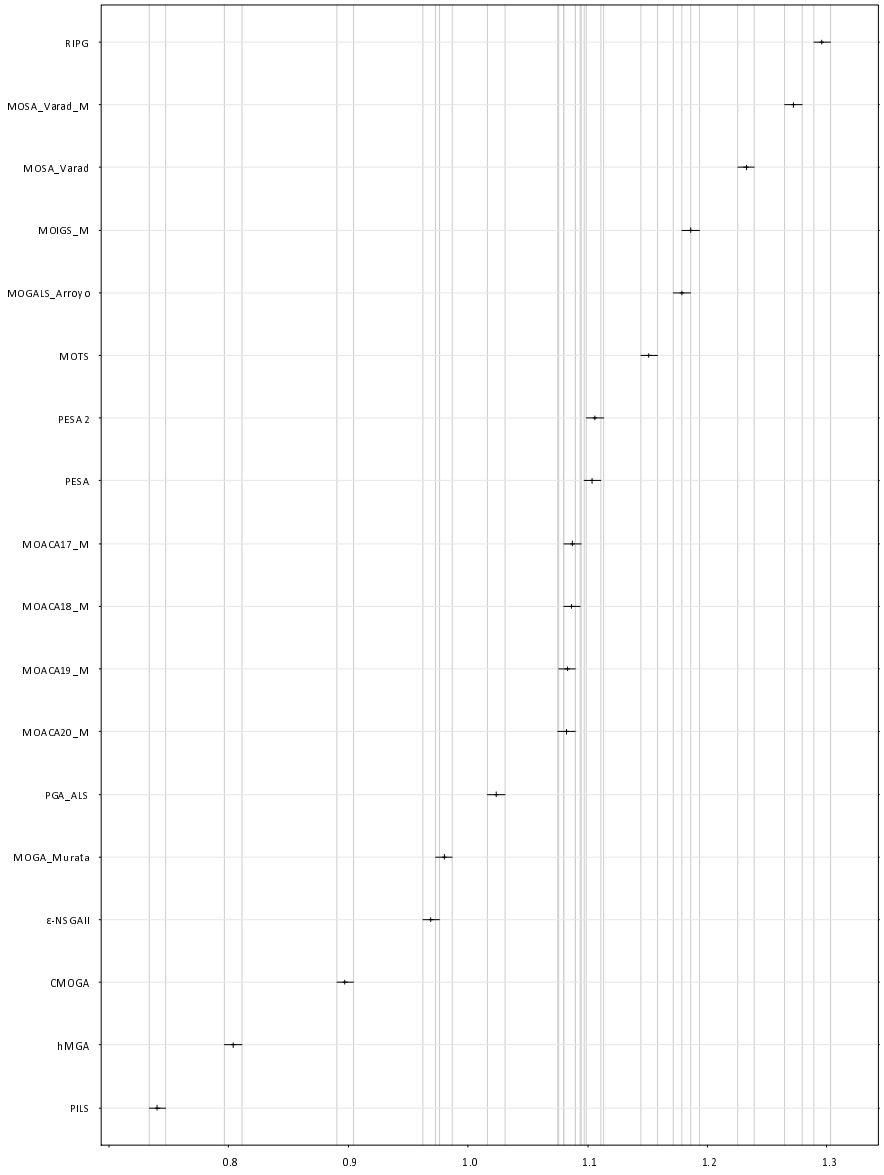

Figure 3.18: SSD50 instance set where setup times length is 50% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the ANOVA experiment. Hypervolume response variable and $t = 150ms$ CPU time stopping criterion. Makespan and total weighted tardiness criteria.

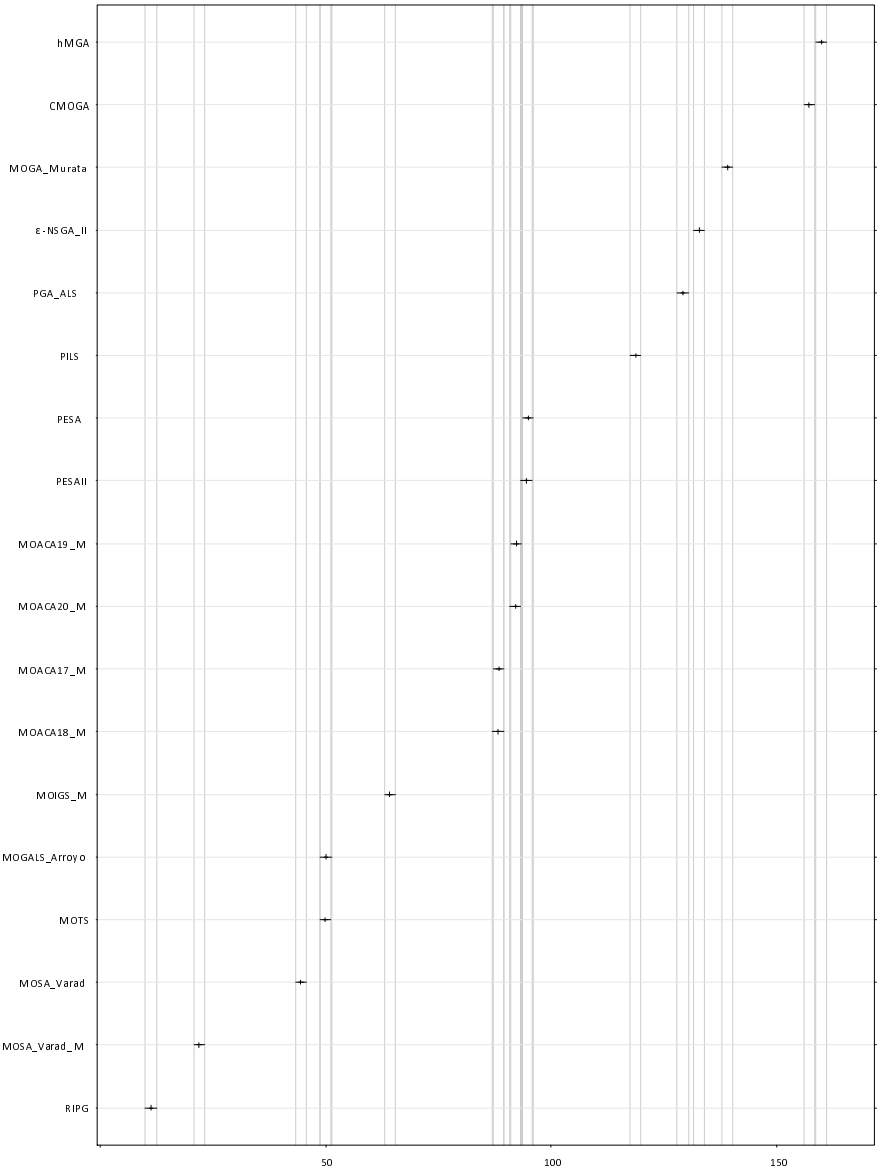

Figure 3.19: SSD50 instance set where setup times length is 50% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the Friedman rank-based experiment. Epsilon indicator response variable and $t = 150ms$ CPU time stopping criterion. Makespan and total weighted tardiness criteria.

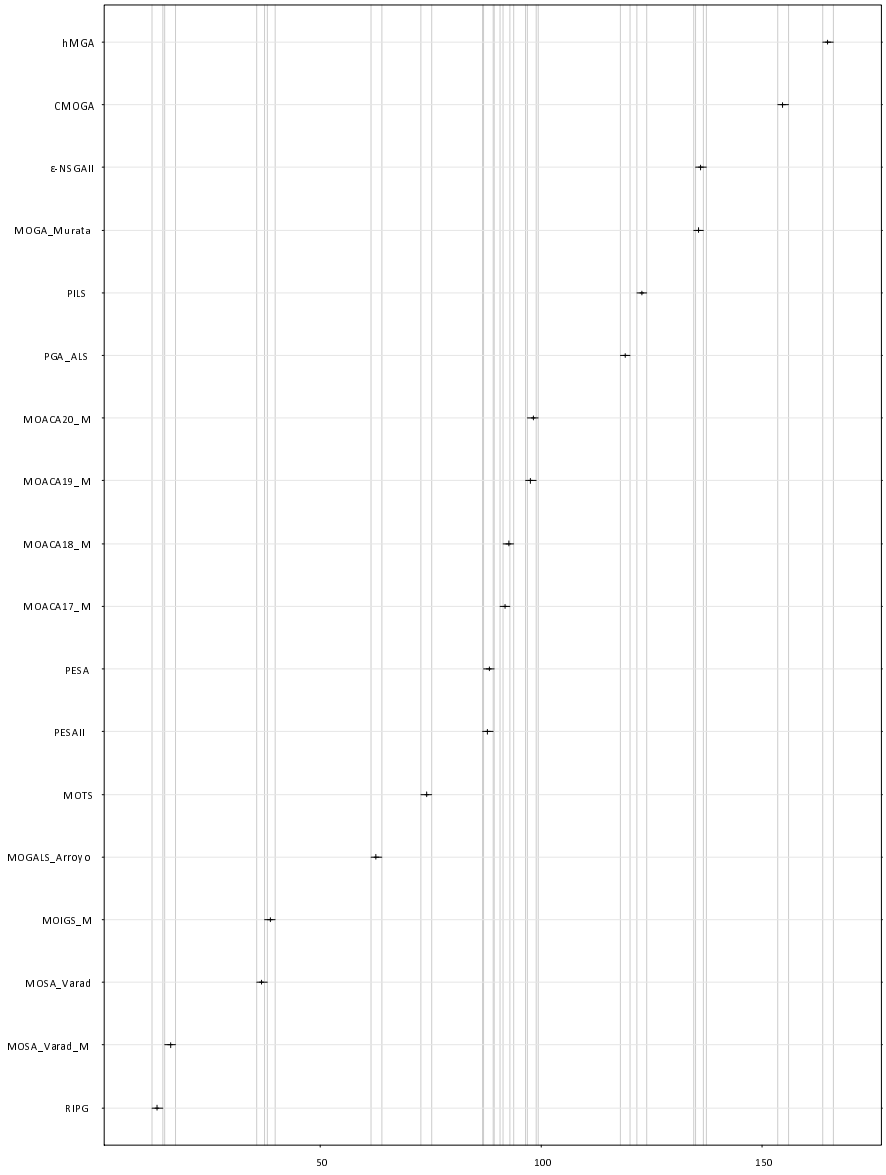

Figure 3.20: SSD50 instance set where setup times length is 50% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the Friedman rank-based experiment. Hypervolume response variable and $t = 150ms$ CPU time stopping criterion. Makespan and total weighted tardiness criteria.

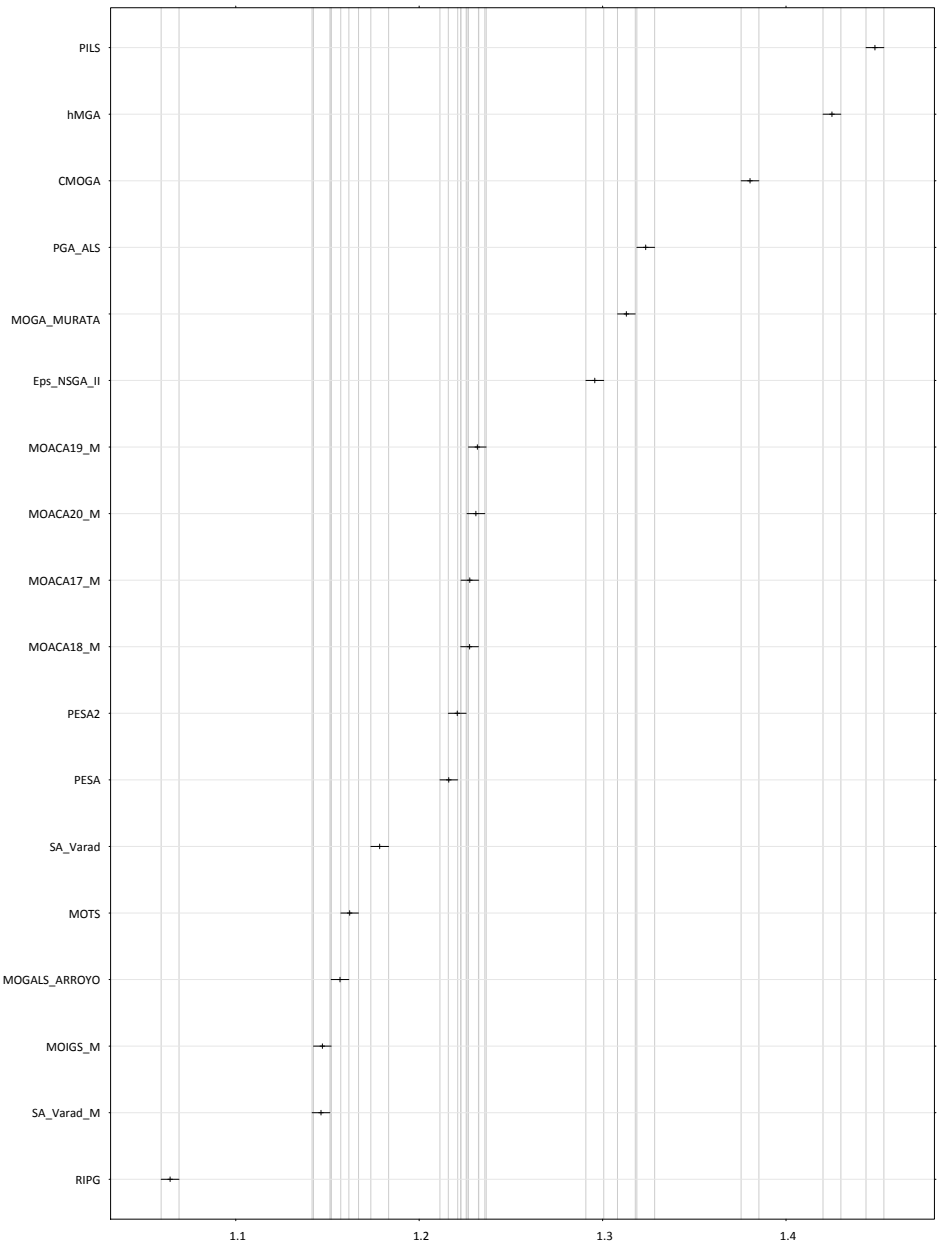

Figure 3.21: SSD125 instance set where setup times length is 125% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the ANOVA experiment. Epsilon indicator response variable and $t = 150ms$ CPU time stopping criterion. Makespan and total weighted tardiness criteria.

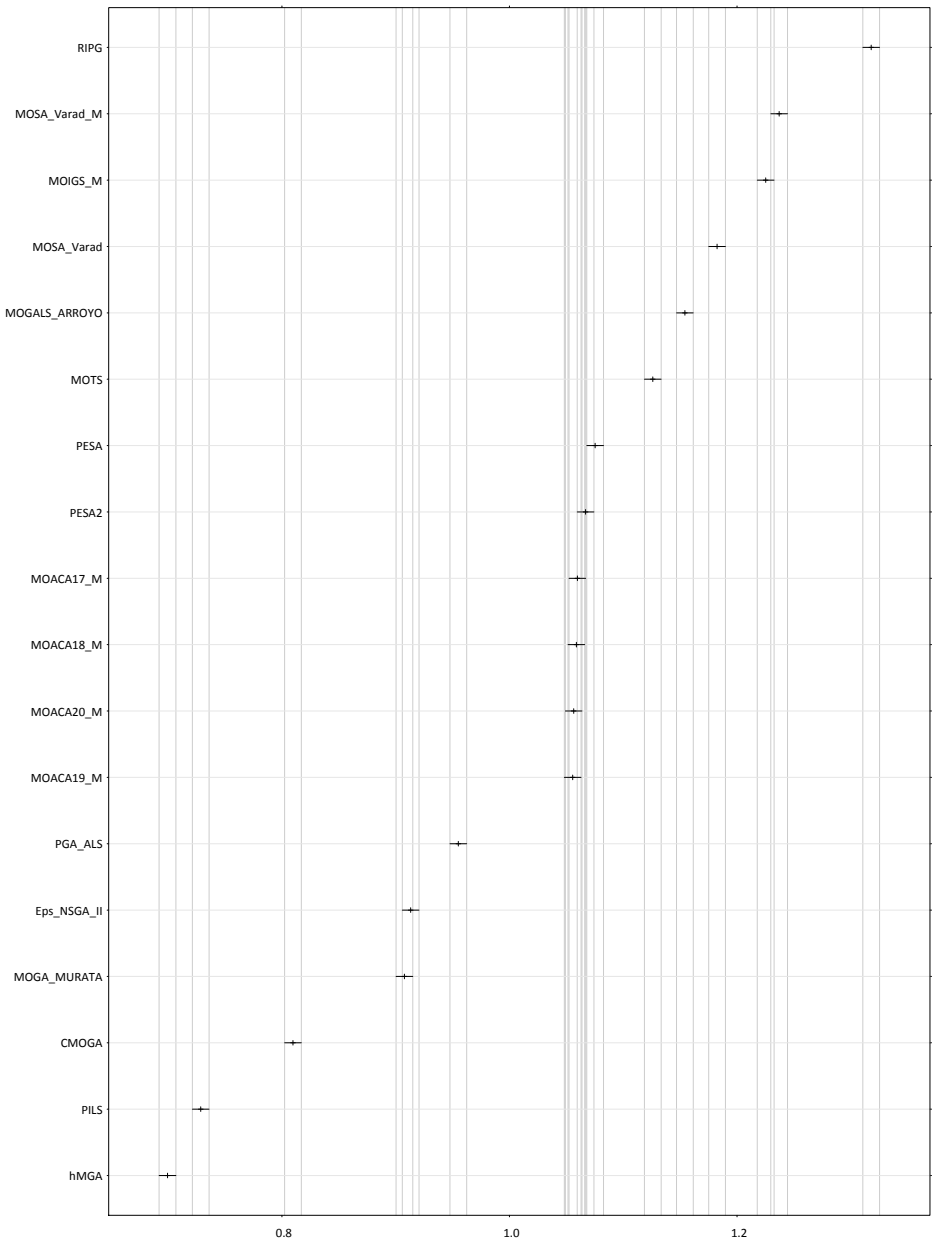

Figure 3.22: SSD125 instance set where setup times length is 125% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the ANOVA experiment. Hypervolume response variable and $t = 150ms$ CPU time stopping criterion. Makespan and total weighted tardiness criteria.

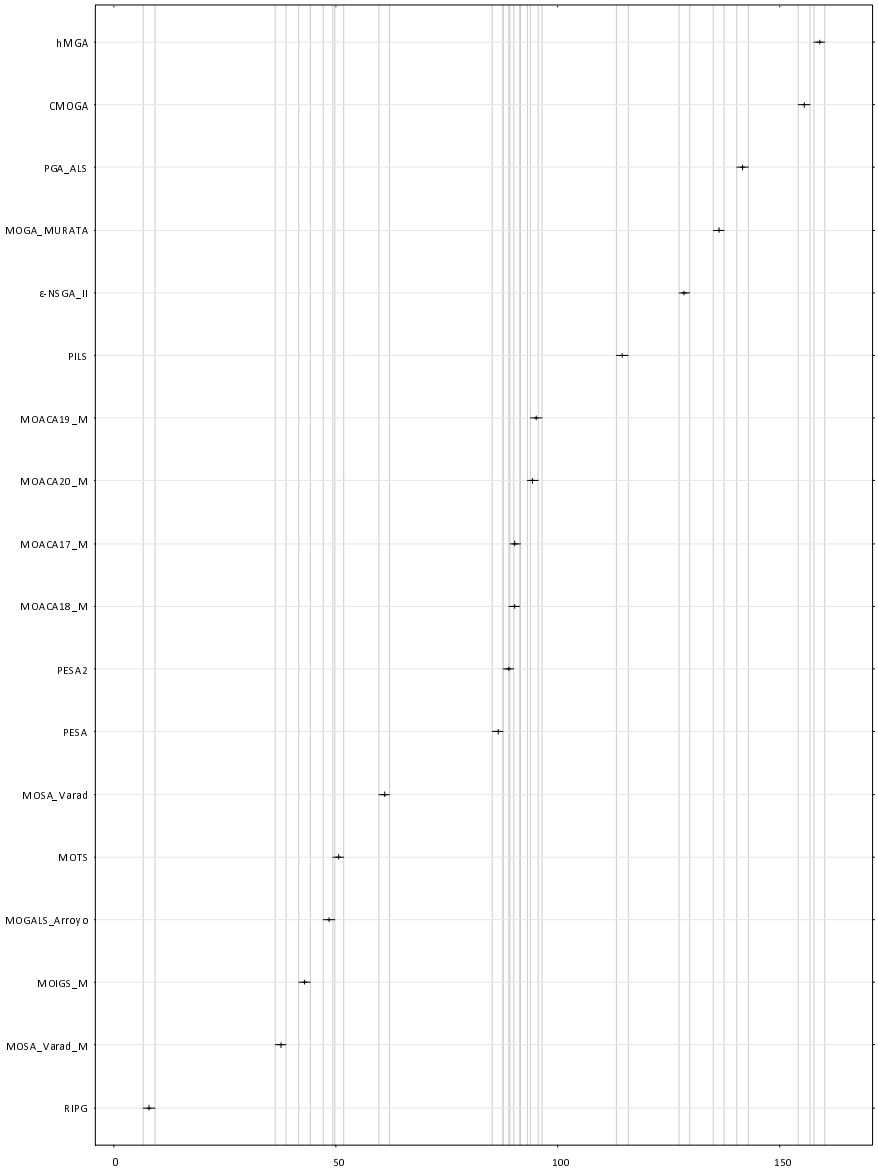

Figure 3.23: SSD125 instance set where setup times length is 125% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the Friedman rank-based experiment. Epsilon indicator response variable and $t = 150ms$ CPU time stopping criterion. Makespan and total weighted tardiness criteria.

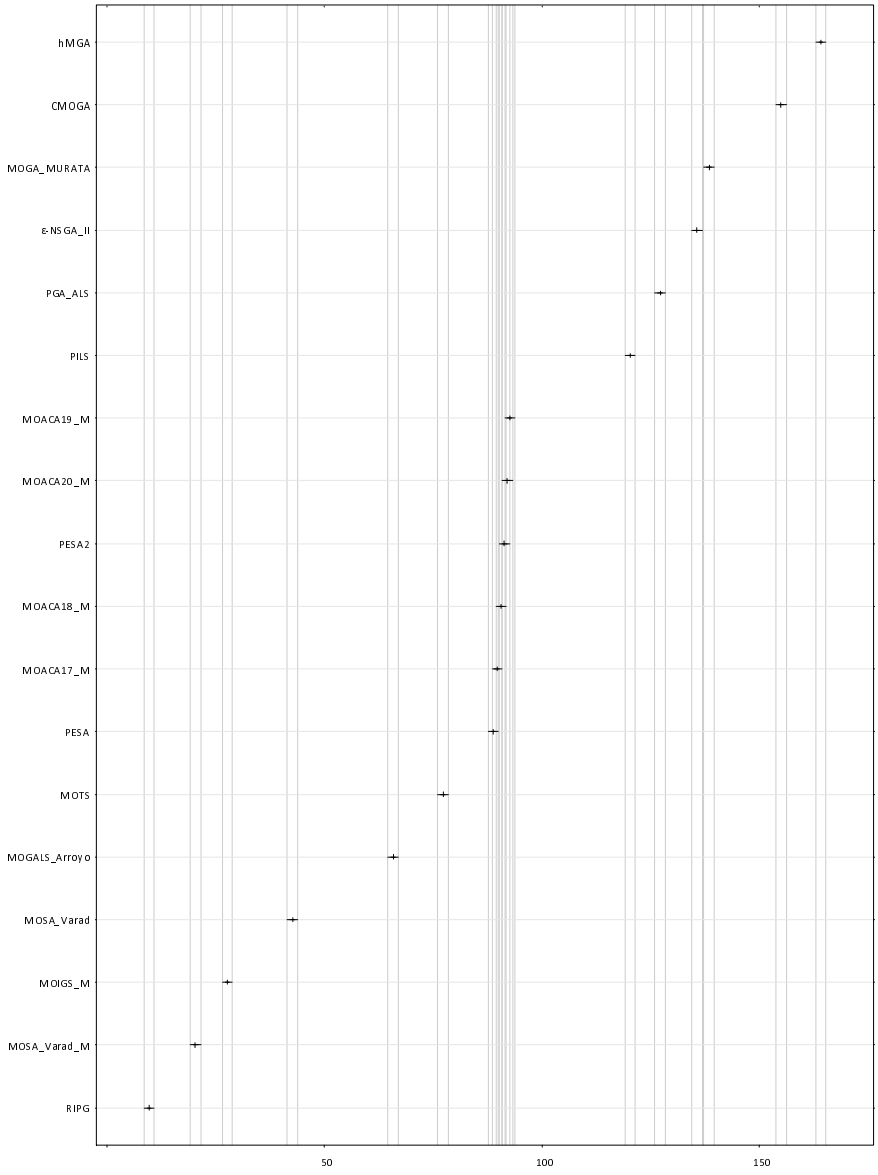

Figure 3.24: SSD125 instance set where setup times length is 125% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the Friendman rank-based experiment. Hypervolume response variable and $t = 150ms$ CPU time stopping criterion. Makespan and total weighted tardiness criteria.

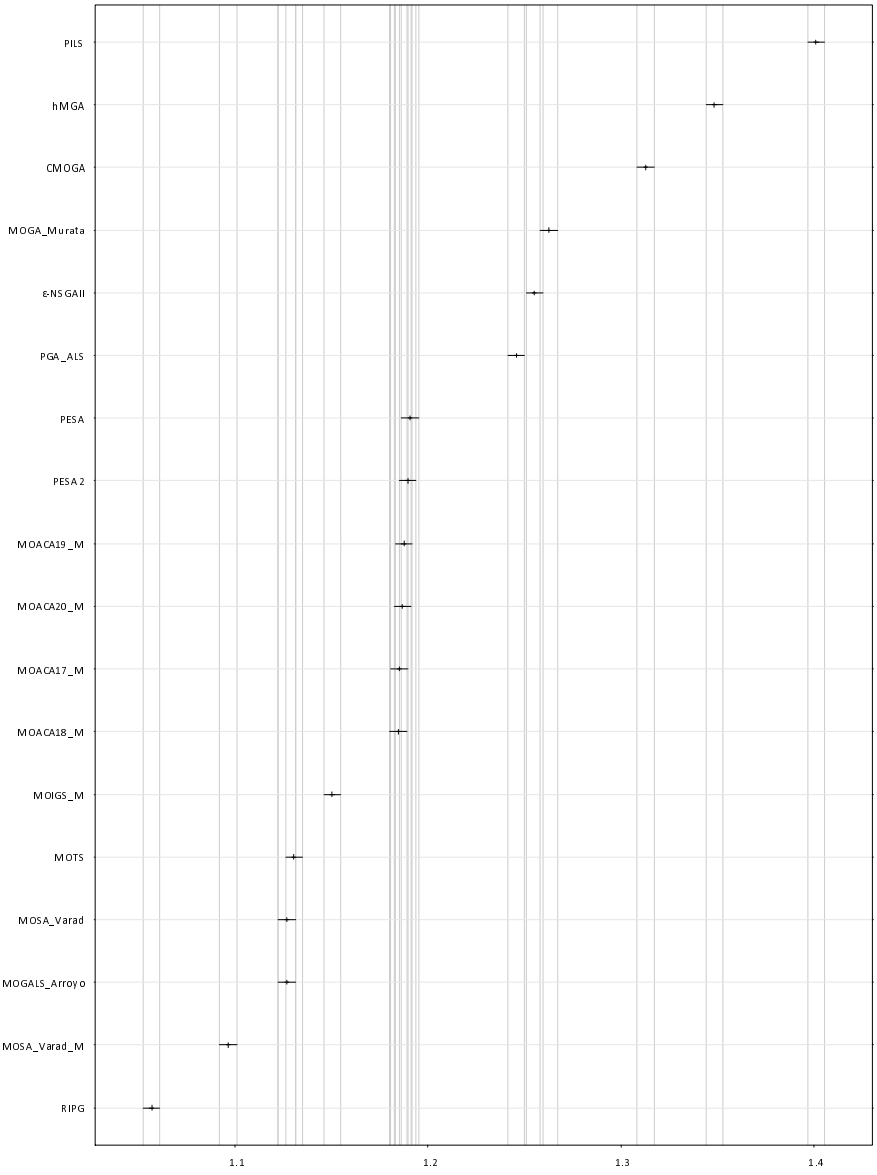

Figure 3.25: SSD50 instance set where setup times length is 50% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the ANOVA experiment. Epsilon indicator response variable and $t = 200ms$ CPU time stopping criterion. Makespan and total weighted tardiness criteria.

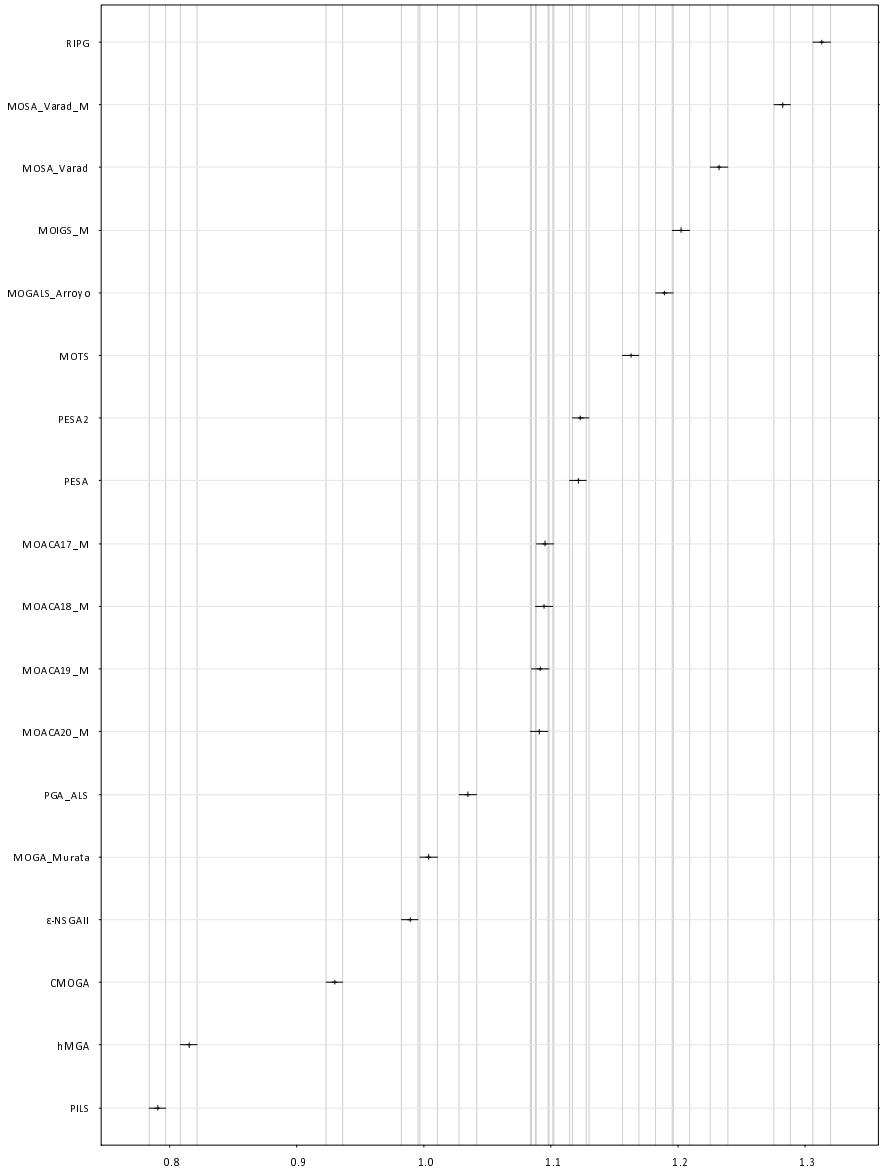

Figure 3.26: SSD50 instance set where setup times length is 50% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the ANOVA experiment. Hypervolume response variable and $t = 200ms$ CPU time stopping criterion. Makespan and total weighted tardiness criteria.

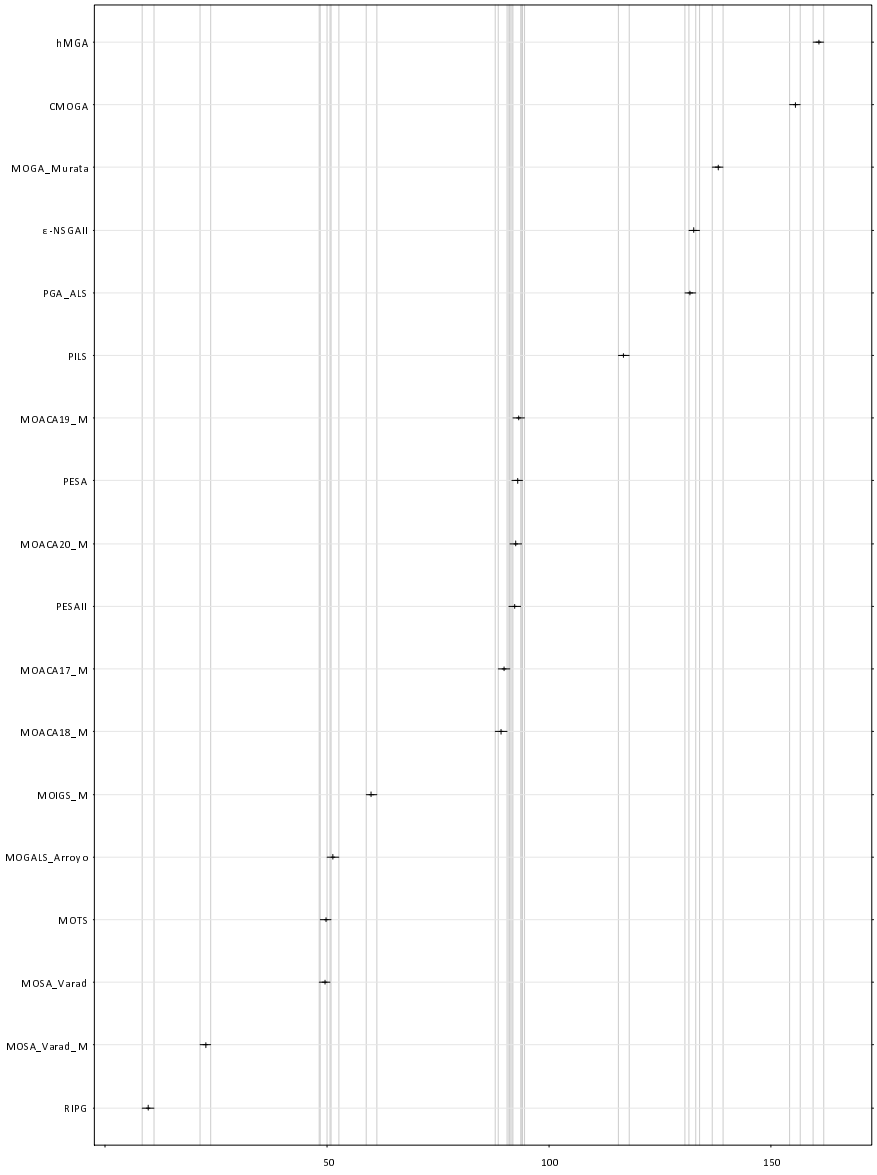

Figure 3.27: SSD50 instance set where setup times length is 50% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the Friedman rank-based experiment. Epsilon indicator response variable and $t = 200ms$ CPU time stopping criterion. Makespan and total weighted tardiness criteria.

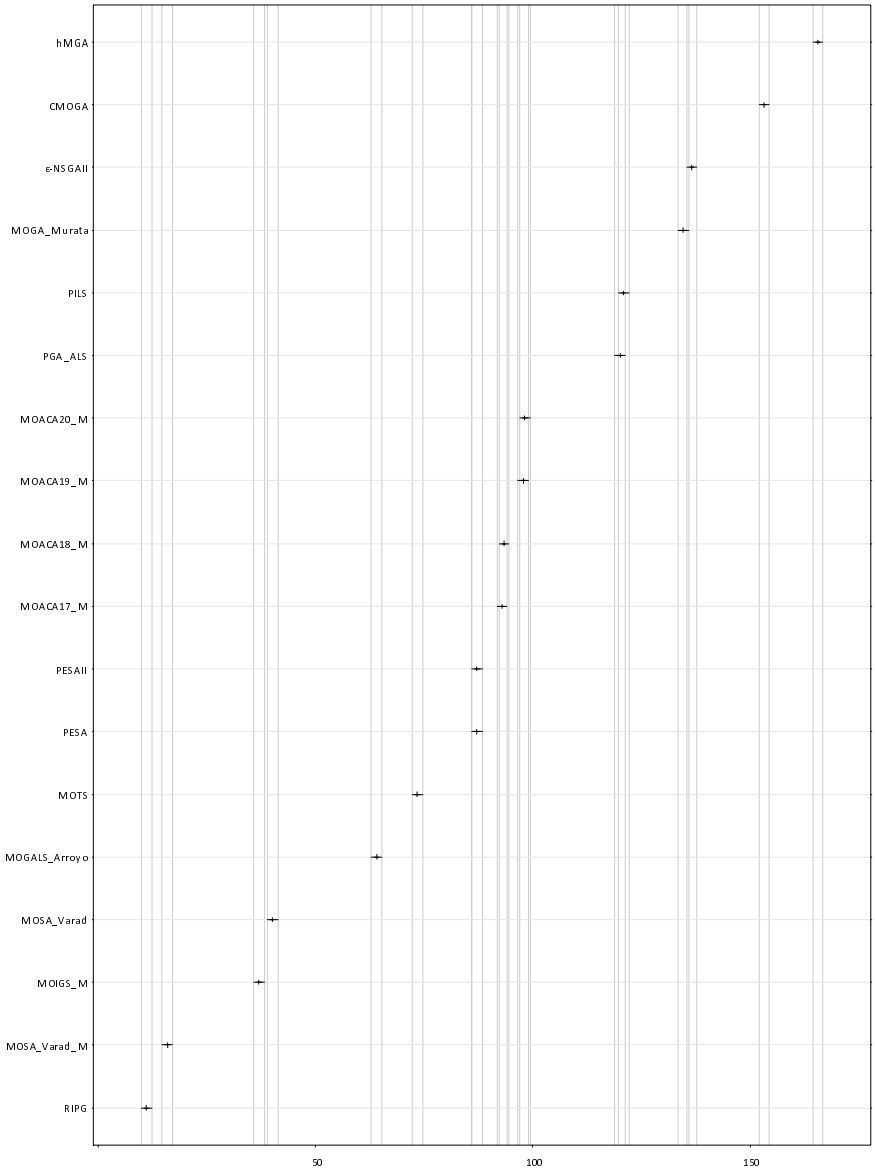

Figure 3.28: SSD50 instance set where setup times length is 50% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the Friedman rank-based experiment. Hypervolume response variable and $t = 200ms$ CPU time stopping criterion. Makespan and total weighted tardiness criteria.

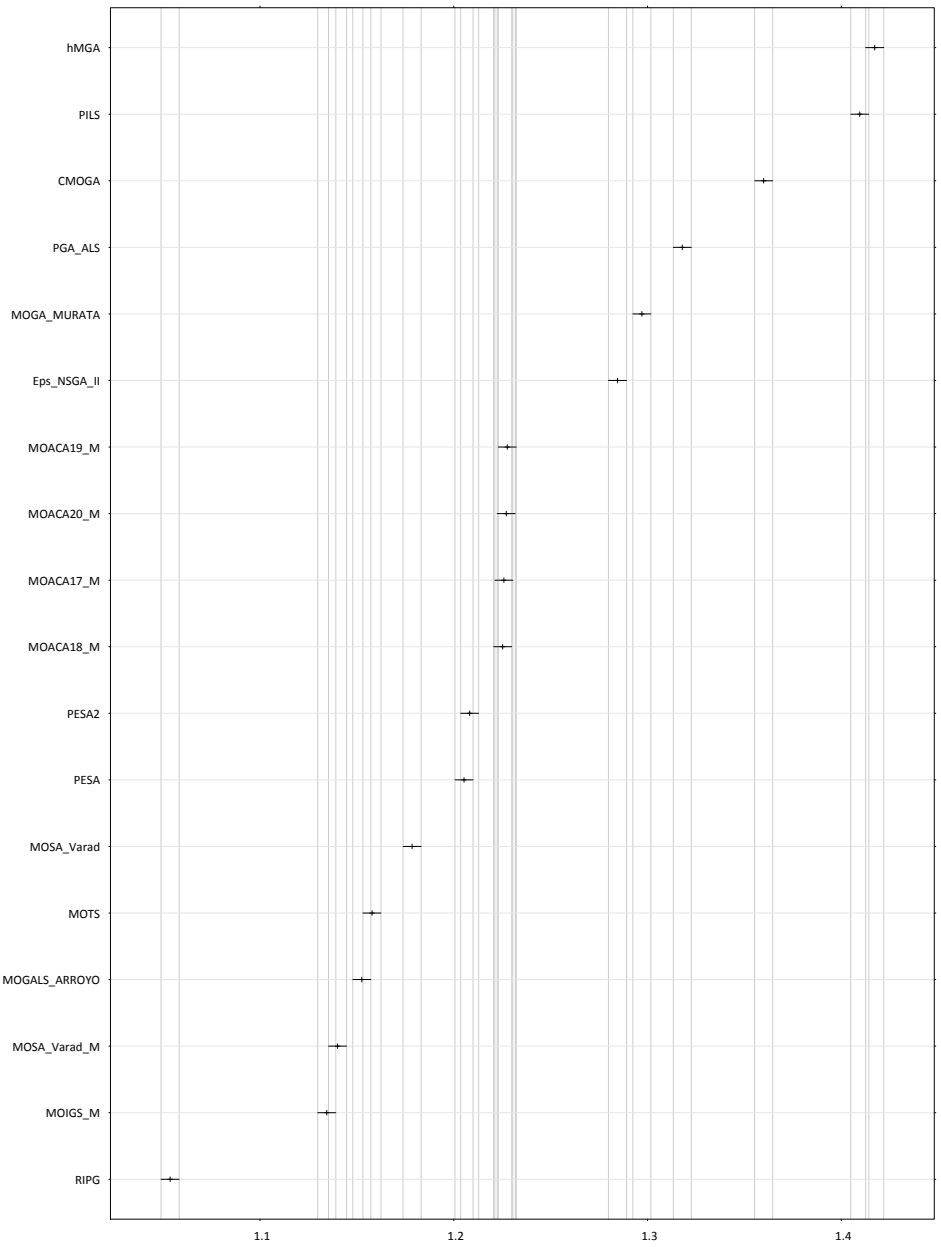

Figure 3.29: SSD125 instance set where setup times length is 125% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the ANOVA experiment. Epsilon indicator response variable and $t = 200ms$ CPU time stopping criterion. Makespan and total weighted tardiness criteria.

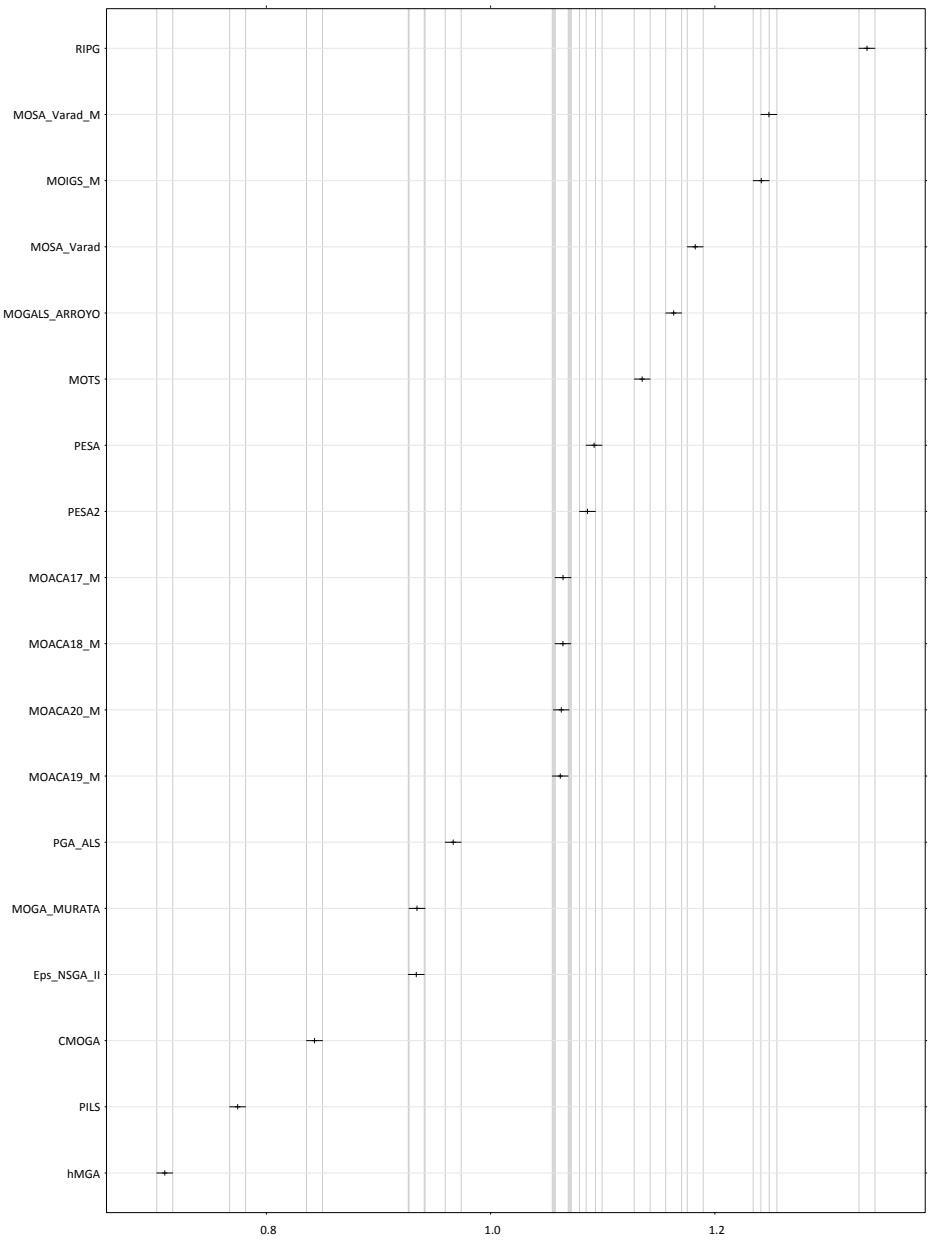

Figure 3.30: SSD125 instance set where setup times length is 125% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the ANOVA experiment. Hypervolume response variable and $t = 200ms$ CPU time stopping criterion. Makespan and total weighted tardiness criteria.

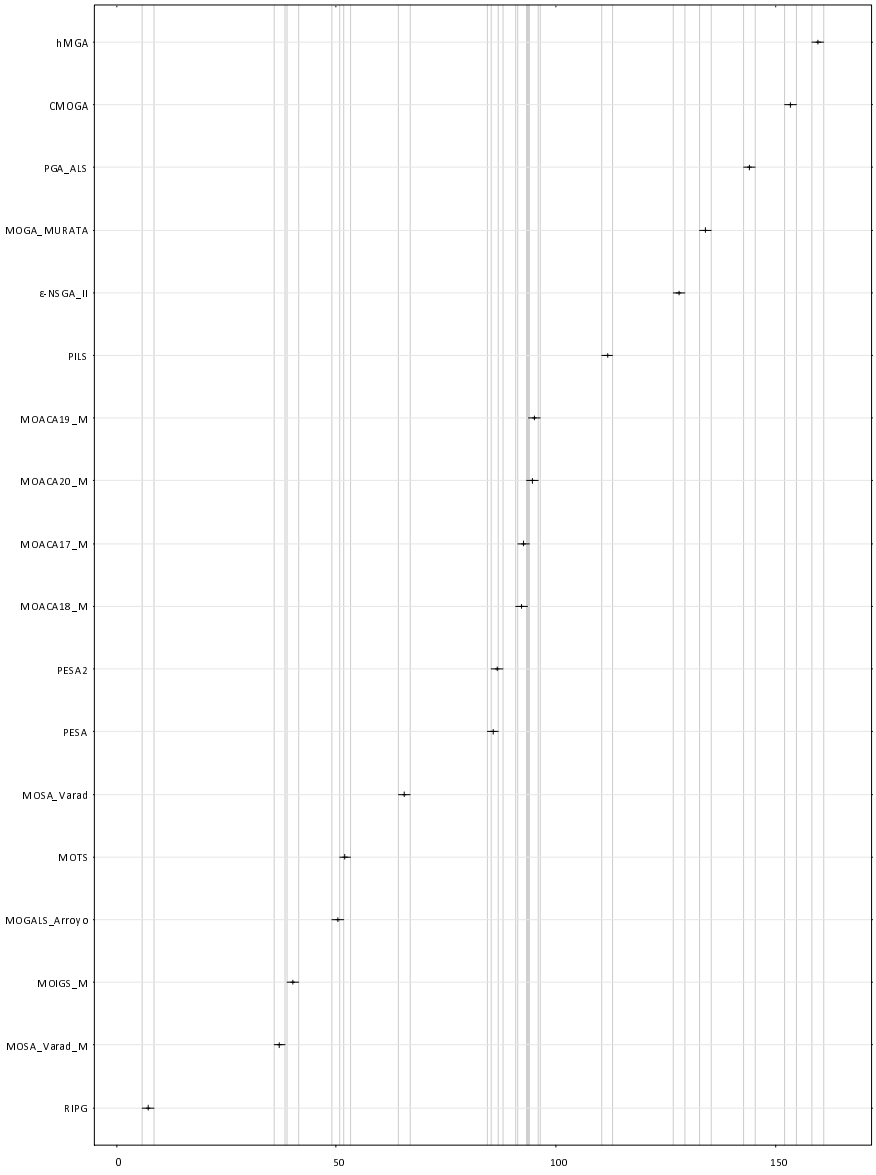

Figure 3.31: SSD125 instance set where setup times length is 125% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the Friedman rank-based experiment. Epsilon indicator response variable and $t = 200ms$ CPU time stopping criterion. Makespan and total weighted tardiness criteria.

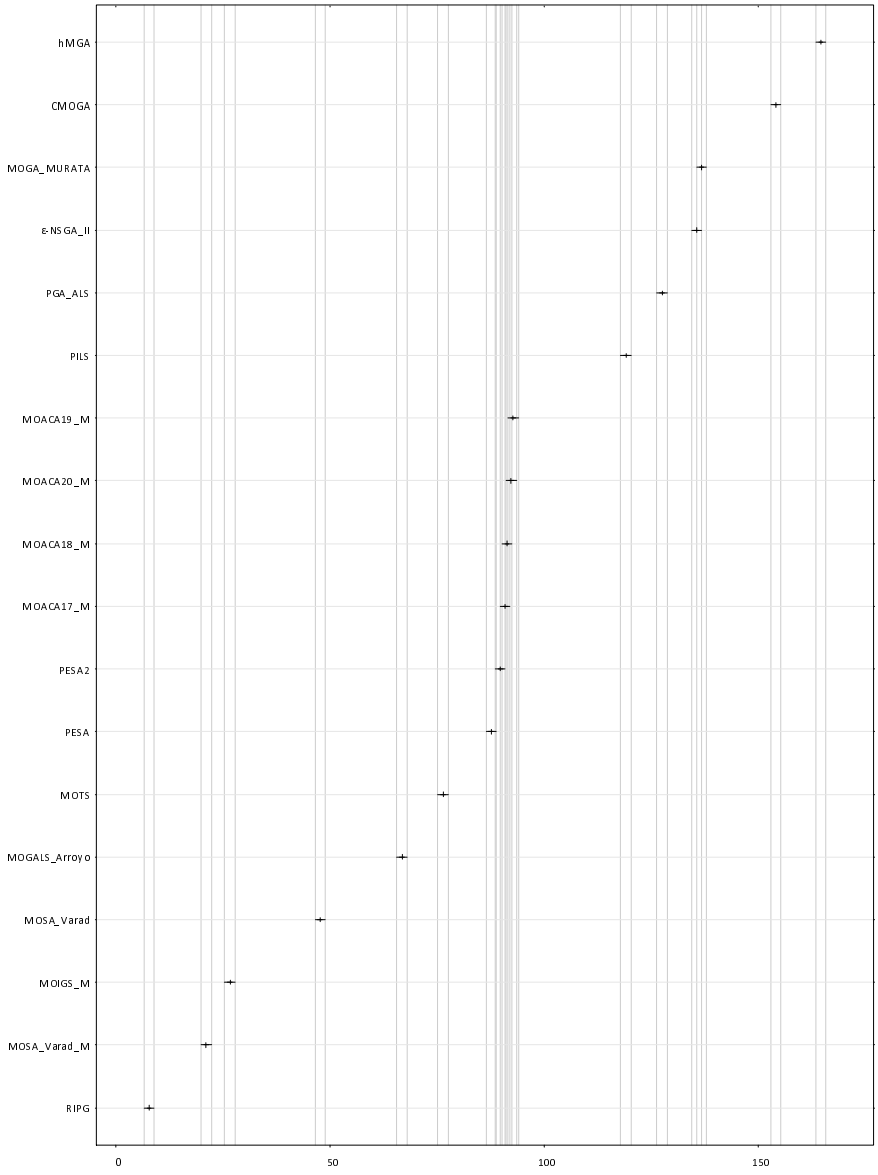

Figure 3.32: SSD125 instance set where setup times length is 125% the length of processing times. Means plot and Tukey HSD confidence intervals ($\alpha_s = 0.01, \alpha = 0.05$) for the algorithm factor in the Friedman rank-based experiment. Hypervolume response variable and $t = 200ms$ CPU time stopping criterion. Makespan and total weighted tardiness criteria.