A Two-Individual Based Evolutionary Algorithm for the Flexible Job Shop Scheduling Problem

Abstract

Population-based evolutionary algorithms usually manage a large number of individuals to maintain the diversity of the search, which is complex and time-consuming. In this paper, we propose an evolutionary algorithm using only two individuals, called master-apprentice evolutionary algorithm (MAE), for solving the flexible job shop scheduling problem (FJSP). In order to ensure the diversity and the quality of the evolution, MAE integrates a tabu search procedure, a recombination operator based on path relinking using a novel distance definition, and an effective individual updating strategy, taking into account the multiple complex constraints of FJSP. Experiments on 178 public instances show that MAE achieves highly competitive results in terms of both solution quality and computational efficiency compared with the state-of-the-art algorithms. Specifically, it improves the previous best known results for 47 instances while matching the best known results on all except 5 of the remaining instances with reasonable computational time.

1 The computational results of MAE

This paper is an appendix of the paper submitted to IJCAI-2018, which provides the overall computational results of MAE on the benchmark sets (*DPdata* [Dauzère-Pérès and Paulli, 1997], *BCdata* [Barnes and Chambers, 1998], *BRdata* [Brandimarte, 1993], and *HUdata* [Hurink *et al.*, 1994]) and make comparisons with the recent state-of-the-art algorithms in the literature.

We compare our MAE algorithm with the recent state-of-the-art algorithms (CDDS [Hmida *et al.*, 2010], HDE-N2 [Yuan and Xu, 2013a; 2013b], SSPR [González *et al.*, 2015], HGTS [Palacios *et al.*, 2015], HA [Li and Gao, 2016], and GRASP-mELS [Kemmoé-Tchomté *et al.*, 2017]) on the four benchmark sets. The comparative results are reported in Tables 1-6. Note that columns best (avg) and t(s) are the best (average) solutions obtained and average computational time in seconds required by each algorithm, the LB and UB are the lower and upper bounds provided in Quintiq[1], the LB values marked with $*$ denote the optimal solutions, and the best known solutions that can be obtained by each reference algorithm are indicated in bold. Rows #better, #even, and #worse give the number of instances for which the best solutions obtained by MAE within 5 minutes or 90 seconds are better, equal, and worse than each reference algorithm. The best known solutions obtained by MAE which are smaller than the UB values of Quintiq are marked in red. To the best of our knowledge, these solutions, which break the world records of Quintiq, are best in the world up to now.

From Table 1- Table6, one observes that MAE improves the best known solutions provided by Quintiq for 10 instances. The corresponding sequences of the improved solutions are reported in Section 2. The format of the sequences are as follows: the first line gives the instance name and makespan. The following lines are the operations assigned on each of the machines. For each of the lines, the first number is the machine index, the second number is the number of operations assigned on this machine. The rest numbers in the line are composed of pairs, each pair represents one operation which contains two numbers, the first number is the job index of the operation, the second number is the index of the operation in the job.

[1] http://www.quintiq.com/optimization/flexible-job-shop-scheduling-problem-results.html

Table 1: Comparison between MAE and other reference algorithms on the *DPdata* instance set

Ins.	Quintiq		2010 CCDS	2013 HDE-N2		2015 SSPR		2015 HGTS		2016 HA		2017 GRASP-mELS		This paper MAE(5 min)		This paper MAE(30 min)	
	LB	UB	best(avg)	best(avg)	t(s)	best(avg)	t(s)	best(avg)	t(s)	best	t(s)	best(avg)	t(s)	best(avg)	t(s)	best(avg)	t(s)
01a	2505*	2505	2518(2525)	**2505**(2513)	838	**2505**(2508)	68	**2505**(2505)	122	2505	108	**2505**(2505)	62	**2505**(2505)	36.44	**2505**(2505)	36.44
02a	2228*	2228	2231(2235)	2230(2231)	973	2229(2230)	100	2230(2234)	205	2230	133	2229(2231)	86	**2228**(2230.7)	145.12	**2228**(2229.9)	696.9
03a	2228*	2228	2229(2232)	**2228**(2229)	1165	**2228**(2228)	110	**2228**(2230)	181	2229	97	**2228**(2230)	94	**2228**(2228)	48.09	**2228**(2228)	48.09
04a	2503*	2503	**2503**(2510)	2506(2506)	850	**2503**(2504)	57	**2503**(2503)	112	2503	87	**2503**(2503)	31	**2503**(2503)	16.52	**2503**(2503)	16.52
05a	2192	2204	2216(2218)	2212(2215)	931	2211(2215)	112	2214(2218)	208	2212	116	2212(2215)	126	2208(2211.5)	145.28	**2203**(2207.95)	784.77
06a	2163	2171	2196(2203)	2187(2192)	1167	2183(2192)	181	2193(2198)	260	2197	93	2195(2200)	181	2182(2188.85)	171.04	**2181**(2185.6)	1019.31
07a	2216	2264	2283(2296)	2288(2303)	1547	2274(2285)	139	2270(2280)	344	2279	204	2276(2284)	127	2269(2274.6)	167.97	**2254**(2273.75)	878.76
08a	2061*	2061	2069(2069)	2067(2074)	1906	2064(2066)	181	2070(2074)	318	2067	184	2069(2072)	144	2063(2064.2)	135.1	**2062**(2063)	1390.7
09a	2061*	2061	2066(2067)	2069(2073)	943	**2062**(2063)	213	2067(2069)	376	2065	201	2069(2071)	170	**2062**(2063.15)	170.11	**2062**(2063.05)	682.24
10a	2212	2241	2291(2303)	2297(2302)	1590	2269(2287)	120	2247(2266)	369	2287	238	2263(2278)	110	2247(2266.45)	184.83	**2245**(2266.15)	1299.08
11a	2018	2037	2063(2072)	2061(2067)	1826	2051(2058)	193	2064(2069)	294	2060	181	2065(2068)	170	2050(2051.8)	209.17	**2045**(2049.5)	1382.6
12a	1969	1984	2031(2034)	2027(2036)	914	2018(2020)	280	2027(2033)	486	2027	151	2039(2045)	148	2016(2021.3)	207.57	**2008**(2019.65)	1126.43
13a	2197	2239	2257(2260)	2263(2269)	2900	2248(2257)	119	2250(2264)	416	2248	293	2252(2263)	158	2247(2251.75)	137.46	**2236**(2246.3)	1488.82
14a	2161*	2161	2167(2179)	2164(2168)	3238	2163(2164)	269	2170(2173)	396	2167	210	2170(2174)	191	2163(2163.9)	187.22	**2162**(2163)	1506.83
15a	2161*	2161	2165(2170)	2163(2166)	2112	**2162**(2163)	376	2168(2169)	523	2163	192	2172(2174)	173	**2162**(2164.35)	193.82	**2162**(2162.9)	504.73
16a	2193	2231	2256(2258)	2259(2266)	2802	2244(2253)	131	2246(2257)	384	2249	160	2243(2258)	151	2242(2251.7)	194.16	**2232**(2245.4)	1343.03
17a	2088	2105	2140(2146)	2137(2141)	3096	2130(2134)	299	2142(2146)	483	2140	203	2145(2152)	190	2128(2132.7)	231.26	**2121**(2128.95)	1568.38
18a	2057	2070	2127(2132)	2124(2128)	2489	2119(2123)	409	2129(2133)	650	2132	133	2146(2151)	164	2118(2124.8)	240.6	**2108**(2114.6)	1126.1
RPD			1.55(1.8)	1.5(1.73)		1.18(1.4)		1.34(1.59)		1.43		1.49(1.73)		1.01(1.14)		0.85(1.17)	
CI-CPU			170	1181.96		139.88		214.45		1105.03		149.94		156.76		938.87	
#better			17	16		12		14		16		15					
#even			1	2		6		4		2		3					
#worse			0	0		0		0		0		0					

Table 2: Comparison between MAE and other reference algorithms on the *BCdata* instance set

Ins.	Quintiq		2010 CCDS	2013 HDE-N2		2015 SSPR		2015 HGTS		2016 HA		2017 GRASP-mELS		This paper MAE(5 min)		This paper MAE(30 min)	
	LB	UB	best(avg)	best(avg)	t(s)	best(avg)	t(s)	best(avg)	t(s)	best	t(s)	best(avg)	t(s)	best(avg)	t(s)	best(avg)	t(s)
mt10c1	927*	927	928(929)	**927**(928)	179	**927**(928)	26	**927**(927)	13	**927**	12	**927**(927)	8	**927**(927.35)	40.88	**927**(927)	65.38
mt10cc	908*	908	910(911)	**908**(911)	180	**908**(908)	20	**908**(910)	13	**908**	10	**908**(909)	17	**908**(909.9)	13.21	**908**(909.4)	109.18
mt10x	918*	918	**918**(918)	**918**(919)	179	**918**(918)	23	**918**(918)	15	**918**	11	**918**(918)	2	**918**(918)	33.14	**918**(918)	33.14
mt10xx	918*	918	**918**(918)	**918**(918)	170	**918**(918)	19	**918**(918)	12	**918**	11	**918**(918)	2	**918**(918)	6.65	**918**(918)	6.65
mt10xxx	918*	918	**918**(918)	**918**(918)	160	**918**(918)	20	**918**(918)	12	**918**	11	**918**(918)	2	**918**(918)	5.64	**918**(918)	5.64
mt10xy	905*	905	906(906)	**905**(906)	174	**905**(906)	21	**905**(905)	13	**905**	11	**905**(905)	26	**905**(905)	35.47	**905**(905)	35.47
mt10xyz	847*	847	849(851)	**847**(851)	166	**847**(847)	20	**847**(850)	18	**847**	9	**847**(847)	26	**847**(847.7)	32.15	**847**(847)	241.01
setb4c9	914*	914	919(919)	**914**(917)	338	**914**(916)	28	**914**(914)	16	**914**	15	**914**(914)	11	**914**(918.25)	43.5	**914**(914)	326.14
setb4cc	907*	907	909(911)	**907**(910)	336	**907**(907)	21	**907**(908)	15	**907**	15	**907**(907)	29	**907**(907)	17.39	**907**(907)	17.39
setb4x	925*	925	**925**(925)	**925**(926)	354	**925**(925)	19	**925**(925)	15	**925**	13	**925**(925)	4	**925**(925)	14.7	**925**(925)	14.7
setb4xx	925*	925	**925**(925)	**925**(926)	330	**925**(925)	21	**925**(925)	14	**925**	5	**925**(925)	2	**925**(925)	7.59	**925**(925)	7.59
setb4xxx	925*	925	**925**(925)	**925**(926)	315	**925**(925)	22	**925**(925)	15	**925**	9	**925**(925)	3	**925**(925)	7.22	**925**(925)	7.22
setb4xy	910*	910	916(916)	**910**(914)	313	**910**(912)	32	**910**(910)	19	**910**	12	**910**(910)	18	**910**(910)	43.39	**910**(910)	43.39
setb4xyz	902*	902	905(907)	903(905)	317	905(905)	21	905(905)	15	905	14	**902**(904)	11	**902**(905.6)	36.9	**902**(903.75)	411.96
seti5c12	1169*	1169	1174(1175)	1171(1175)	1113	1170(1173)	25	1170(1171)	41	1170	31	**1169**(1172)	39	1170(1174.35)	41.85	1170(1173.45)	216.16
seti5cc	1135*	1135	1136(1137)	1136(1138)	1079	**1135**(1136)	29	1136(1137)	34	1136	17	**1135**(1136)	24	1136(1136)	34.23	**1135**(1135.65)	243.58
seti5x	1198*	1198	1201(1202)	1200(1206)	1087	**1198**(1199)	41	1199(1201)	38	**1198**	27	**1198**(1199)	36	**1198**(1201.5)	70.86	**1198**(1199.4)	460.91
seti5xx	1194*	1194	1199(1199)	1197(1203)	1251	1197(1199)	37	1197(1198)	34	1197	29	**1194**(1197)	26	1197(1198.5)	39.47	1197(1197)	531.53
seti5xxx	1194*	1194	1197(1198)	1197(1202)	1244	**1194**(1198)	38	1197(1198)	31	1197	19	**1194**(1197)	27	1197(1198.65)	46.37	**1194**(1196.65)	498.73
seti5xy	1135*	1135	1136(1138)	1136(1138)	1141	**1135**(1136)	29	1136(1137)	34	1136	17	**1135**(1136)	28	1136(1136.1)	24.59	**1135**(1136)	285.01
seti5xyz	1125*	1125	**1125**(1125)	**1125**(1130)	1223	**1125**(1126)	35	**1125**(1126)	43	**1125**	33	**1125**(1127)	42	**1125**(1128.7)	29.34	**1125**(1125.6)	268.12
RPD			0.19(0.26)	0.05(0.3)		0.03(0.12)		0.07(0.13)		0.05		0(0.07)		0.04(0.17)		0.02(0.08)	
CI-CPU			12.75	377.2		19.54		13.8		7.88		19.88		29.74		182.33	
#better			11	3		1		2		1		0					
#even			10	18		17		19		20		16					
#worse			0	0		3		0		0		5					

Table 3: Comparison between MAE and other reference algorithms on the *BRdata* instance set

Ins.	Quintiq		2010 CCDS	2013 HDE-N2		2015 SSPR		2015 HGTS		2016 HA		2017 GRASP-mELS		This paper MAE(5 min)		This paper MAE(30 min)	
	LB	UB	best(avg)	best(avg)	t(s)	best(avg)	t(s)	best(avg)	t(s)	best	t(s)	best(avg)	t(s)	best(avg)	t(s)	best(avg)	t(s)
Mk01	40*	40	**40**(40	**40**(40)	4	**40**(40)	11	**40**(40)	5	**40**	0	**40**(40)	0	**40**(40)	0.2	**40**(40)	0.2
Mk02	26*	26	**26**(26	**26**(26)	6	**26**(26)	15	**26**(26)	15	**26**	1	**26**(26)	10	**26**(26)	0.52	**26**(26)	0.52
Mk03	204*	204	**204**(204	**204**(204)	31	**204**(204)	24	**204**(204)	2	**204**	0	**204**(204)	0	**204**(204)	0.18	**204**(204)	0.18
Mk04	60*	60	**60**(60	**60**(60)	13	**60**(60)	19	**60**(60)	10	**60**	0	**60**(60)	0	**60**(60)	0.51	**60**(60)	0.51
Mk05	172*	172	173(174	**172**(173)	38	**172**(172)	57	**172**(172)	18	**172**	5	**172**(173)	15	**172**(172)	1.46	**172**(172)	1.46
Mk06	57*	57	58(59	**57**(59)	98	**57**(58)	40	**57**(58)	63	**57**	54	58(58)	36	**57**(58.05)	33.65	**57**(57.4)	204.39
Mk07	139*	139	**139**(139	**139**(139)	26	**139**(141)	84	**139**(139)	33	**139**	20	**139**(140)	32	**139**(139.7)	53.5	**139**(139)	432.9
Mk08	523*	523	**523**(523	**523**(523)	189	**523**(523)	83	**523**(523)	3	**523**	0	**523**(523)	0	**523**(523)	0.45	**523**(523)	0.45
Mk09	307*	307	**307**(307	**307**(307)	123	**307**(307)	52	**307**(307)	24	**307**	1	**307**(307)	0	**307**(307)	1.47	**307**(307)	1.47
Mk10	189	193	197(198)	198(202)	266	196(197)	94	198(199)	104	197	33	197(199)	59	195(195.95)	40.21	**193**(194.6)	763.92
RPD			0.66(0.94)	0.48(1.1)		0.37(0.74)		0.48(0.71)		0.42		0.6(0.83)		0.35(0.43)		0.23(0.34)	
CI-CPU			12.75	53.99		35.93		17.45		5.7		16.57		13.22		140.6	
#better			3	1		1		1		1		2					
#even			7	9		9		9		9		8					
#worse			0	0		0		0		0		0					

Table 4: Comparison between MAE and other reference algorithms on the *edata* of *HUdata* instance set

Ins.	Quintiq		2015 SSPR			2017 GRASP-mELS			This paper MAE(5 min)			This paper MAE(30 min)		
	LB	UB	best	avg	t(s)	best	avg	t(s)	best	avg	t(s)	best	avg	t(s)
edata-abz5	1167*	1167	-	-	-	-	-	-	**1167**	1167	33	**1167**	1167	33
edata-abz6	925*	925	-	-	-	-	-	-	**925**	925	18.4	**925**	925	18.4
edata-abz7	604	610	-	-	-	-	-	-	613	614.85	70.39	613	613.45	481.43
edata-abz8	625	636	-	-	-	-	-	-	643	647.5	82.04	643	646.3	441.87
edata-abz9	644*	644	-	-	-	-	-	-	648	649.05	126.2	646	648.7	314.42
edata-car1	6176*	6176	-	-	-	-	-	-	**6176**	6191.75	120.94	**6176**	6180.6	638.31
edata-car2	6327*	6327	-	-	-	-	-	-	6335	6414.25	98.6	6335	6370.25	790.27
edata-car3	6856*	6856	-	-	-	-	-	-	**6856**	6875.75	125.77	**6856**	6858.25	763.1
edata-car4	7789*	7789	-	-	-	-	-	-	**7789**	7789	0.75	**7789**	7789	0.75
edata-car5	7229*	7229	-	-	-	-	-	-	**7229**	7229	8.6	**7229**	7229	8.6
edata-car6	7990*	7990	-	-	-	-	-	-	**7990**	7990.5	92.9	**7990**	7990	113.04
edata-car7	6123*	6123	-	-	-	-	-	-	**6123**	6123	7.74	**6123**	6123	7.74
edata-car8	7689*	7689	-	-	-	-	-	-	**7689**	7689	6.36	**7689**	7689	6.36
edata-la01	609*	609	**609**	609	13.3	**609**	609	0	**609**	609	0.36	**609**	609	0.36
edata-la02	655*	655	**655**	655	16.5	**655**	655	0	**655**	655	0.35	**655**	655	0.35
edata-la03	550*	550	**550**	550	16	**550**	550	0.2	**550**	550	14.44	**550**	550	14.44
edata-la04	568*	568	**568**	568	19.6	**568**	568	0	**568**	568	2.2	**568**	568	2.2
edata-la05	503*	503	**503**	503	13.1	**503**	503	0	**503**	503	0.37	**503**	503	0.37
edata-la06	833*	833	**833**	833	23.5	**833**	833	0	**833**	833	0.45	**833**	833	0.45
edata-la07	762*	762	**762**	762	28.1	**762**	762	1.95	**762**	762	21.22	**762**	762	21.22
edata-la08	845*	845	**845**	845	29.2	**845**	845	0	**845**	845	0.63	**845**	845	0.63
edata-la09	878*	878	**878**	878	25.9	**878**	878	0	**878**	878	0.64	**878**	878	0.64
edata-la10	866*	866	**866**	866	24.8	**866**	866	0	**866**	866	0.53	**866**	866	0.53
edata-la11	1103*	1103	**1103**	1103	43.4	**1103**	1103	0.7	**1103**	1103	49	**1103**	1103	49
edata-la12	960*	960	**960**	960	44.6	**960**	960	0	**960**	960	0.86	**960**	960	0.86
edata-la13	1053*	1053	**1053**	1053	43	**1053**	1053	0	**1053**	1053	0.63	**1053**	1053	0.63
edata-la14	1123*	1123	**1123**	1123	42.8	**1123**	1123	0	**1123**	1123	1.14	**1123**	1123	1.14
edata-la15	1111*	1111	**1111**	1111	49.5	**1111**	1111	0	**1111**	1111	1.41	**1111**	1111	1.41
edata-la16	892*	892	**892**	892	16	**892**	892	6	**892**	892	2.25	**892**	892	2.25
edata-la17	707*	707	**707**	707	14	**707**	707	0.05	**707**	707	3.71	**707**	707	3.71
edata-la18	842*	842	**842**	842	17.5	**842**	842	1.1	**842**	842	6.85	**842**	842	6.85
edata-la19	796*	796	**796**	796	16.9	**796**	796	3.55	**796**	796	26.11	**796**	796	26.11
edata-la20	857*	857	**857**	857	17.1	**857**	857	0.95	**857**	857	1.63	**857**	857	1.63
edata-la21	1009*	1009	1010	1014.4	36.5	**1009**	1016.7	90.55	**1009**	1014.4	31.12	**1009**	1014.15	314.86
edata-la22	880*	880	**880**	880.1	32.3	**880**	880	7.75	**880**	880.15	84.2	**880**	880	213.66
edata-la23	950*	950	**950**	950	23.4	**950**	950	2.7	**950**	950	17.16	**950**	950	17.16
edata-la24	908*	908	**908**	908.9	21.4	**908**	908	52.65	**908**	908.2	17.42	**908**	908	86.19
edata-la25	936*	936	939	940.7	28.9	**936**	940	74.6	**936**	941	22.66	**936**	940.7	238.67
edata-la26	1106*	1106	1109	1112.8	48.3	1107	1111.2	109.45	1107	1116.05	30.98	1107	1115.85	569.94
edata-la27	1181*	1181	**1181**	1182.4	48.5	**1181**	1181.35	55.9	**1181**	1182	75	**1181**	1181.95	126.21
edata-la28	1142*	1142	1144	1145.9	56.7	1144	1146.55	94.6	**1142**	1146.9	23.52	**1142**	1146.5	245.31
edata-la29	1107*	1107	1111	1114.5	53.1	1113	1116.45	84.25	1111	1117.6	28.5	1111	1116.2	679.98
edata-la30	1188*	1188	1204	1206.5	62.4	1198	1203.5	90.45	1195	1202.1	104.94	1193	1201.2	676.23
edata-la31	1532*	1532	1533	1537.1	111.3	1536	1540.45	19.55	**1532**	1533.1	36.03	**1532**	1532.95	430.02
edata-la32	1698*	1698	**1698**	1698	82.8	**1698**	1698	0.85	**1698**	1698	5.5	**1698**	1698	5.5
edata-la33	1547*	1547	**1547**	1547	78.7	**1547**	1547	0.35	**1547**	1547	5.28	**1547**	1547	5.28
edata-la34	1599*	1599	**1599**	1599	70	**1599**	1599	5.5	**1599**	1599	7.27	**1599**	1599	7.27
edata-la35	1736*	1736	**1736**	1736	66.2	**1736**	1736	0	**1736**	1736	2.47	**1736**	1736	2.47
edata-la36	1160*	1160	**1160**	1160.2	31.8	**1160**	1160	20.1	**1160**	1160.6	45.46	**1160**	1160.45	694.43
edata-la37	1397*	1397	**1397**	1397	30.4	**1397**	1397	7.65	**1397**	1397	5.28	**1397**	1397	5.28
edata-la38	1141*	1141	**1141**	1143.1	36.6	**1141**	1142.85	85.4	**1141**	1141.2	30.59	**1141**	1141.1	224.3
edata-la39	1184*	1184	**1184**	1184.4	31.3	**1184**	1184	8.2	**1184**	1184.1	46.24	**1184**	1184	112.51
edata-la40	1144*	1144	**1144**	1144	27.7	**1144**	1144.3	65.65	**1144**	1144.35	33.95	**1144**	1144.2	492.63
edata-mt06	55*	55	**55**	55	30.8	**55**	55	0	**55**	55	0.18	**55**	55	0.18
edata-mt10	871*	871	**871**	872	25.9	**871**	871	10.2	**871**	872.7	28.68	**871**	871.7	602.17
edata-mt20	1088*	1088	**1088**	1088	48.8	**1088**	1088	5.9	**1088**	1088	7.14	**1088**	1088	7.14
edata-orb1	977*	977	-	-	-	-	-	-	**977**	977	49.64	**977**	977	49.64
edata-orb10	933*	933	-	-	-	-	-	-	**933**	933.45	78.32	**933**	933	132.64
edata-orb2	865*	865	-	-	-	-	-	-	**865**	865	7.61	**865**	865	7.61
edata-orb3	951*	951	-	-	-	-	-	-	**951**	951.8	104.69	**951**	951	709.31
edata-orb4	984*	984	-	-	-	-	-	-	**984**	984.15	93.67	**984**	984	108.39
edata-orb5	842*	842	-	-	-	-	-	-	**842**	842	21.33	**842**	842	21.33
edata-orb6	958*	958	-	-	-	-	-	-	**958**	959.1	70.84	**958**	958.65	369.28
edata-orb7	389*	389	-	-	-	-	-	-	**389**	389.4	67.91	**389**	389	261.5
edata-orb8	894*	894	-	-	-	-	-	-	**894**	894	1.59	**894**	894	1.59
edata-orb9	933*	933	-	-	-	-	-	-	**933**	933.4	62.58	**933**	933	300.37
CI-CPU			37.18			21.09			19.17			137.03		
#better			5			4								
#even			38			39								
#worse			0			0								
#opt			36			38			59			59		

Table 5: Comparison between MAE and other reference algorithms on the *rdata* of *HUdata* instance set

Ins.	Quintiq		2015 SSPR			2017 GRASP-mELS			This paper MAE(5 min)			This paper MAE(30 min)		
	LB	UB	best	avg	t(s)	best	avg	t(s)	best	avg	t(s)	best	avg	t(s)
rdata-abz5	954*	954	-	-	-	-	-	-	**954**	954	7.08	**954**	954	7.08
rdata-abz6	807*	807	-	-	-	-	-	-	**807**	807	0.83	**807**	807	0.83
rdata-abz7	493	524	-	-	-	-	-	-	527	529.9	106.45	**522**	528.45	683.97
rdata-abz8	507	536	-	-	-	-	-	-	540	542	113.51	**535**	540.05	810.74
rdata-abz9	517	536	-	-	-	-	-	-	541	542.8	166.36	541	541	723.12
rdata-car1	5034*	5034	-	-	-	-	-	-	5035	5040.6	134.19	5035	5036.65	776.78
rdata-car2	5985*	5985	-	-	-	-	-	-	**5985**	5985.85	24.41	**5985**	5985.15	656.76
rdata-car3	5622*	5622	-	-	-	-	-	-	5623	5625.1	123.17	5623	5623.65	709.79
rdata-car4	6514*	6514	-	-	-	-	-	-	**6514**	6514.15	108.29	**6514**	6514	182.3
rdata-car5	5615*	5615	-	-	-	-	-	-	5621	5640.35	141.02	5621	5630.9	860.54
rdata-car6	6147*	6147	-	-	-	-	-	-	**6147**	6147	6.59	**6147**	6147	6.59
rdata-car7	4425*	4425	-	-	-	-	-	-	**4425**	4429.55	44.92	**4425**	4426.05	602.56
rdata-car8	5692*	5692	-	-	-	-	-	-	**5692**	5692	85.92	**5692**	5692	85.92
rdata-la01	570*	570	571	571	16.1	**570**	570.8	38.2	**570**	570.9	10.11	**570**	570.3	555.87
rdata-la02	529*	529	530	530	17	**529**	529.95	33.2	**529**	529.95	16.43	**529**	529.25	666.68
rdata-la03	477*	477	**477**	477.1	19.3	**477**	477.1	73.6	**477**	477	5.98	**477**	477	5.98
rdata-la04	502*	502	**502**	502.3	19.6	**502**	502	43.95	**502**	502	23.67	**502**	502	23.67
rdata-la05	457*	457	**457**	457	17.3	**457**	457	20.2	**457**	457	1.58	**457**	457	1.58
rdata-la06	799*	799	**799**	799	27.4	**799**	799	5.2	**799**	799	1.14	**799**	799	1.14
rdata-la07	749*	749	**749**	749.3	35.4	**749**	749.1	47.85	**749**	749	4.7	**749**	749	4.7
rdata-la08	765*	765	**765**	765	37.8	**765**	765	37.75	**765**	765	2.14	**765**	765	2.14
rdata-la09	853*	853	**853**	853	31.5	**853**	853	8.3	**853**	853	1.65	**853**	853	1.65
rdata-la10	804*	804	**804**	804	33	**804**	804.05	52.35	**804**	804	3.61	**804**	804	3.61
rdata-la11	1071*	1071	**1071**	1071	52.5	**1071**	1071	0.95	**1071**	1071	1.55	**1071**	1071	1.55
rdata-la12	936*	936	**936**	936	50.6	**936**	936	0	**936**	936	1.1	**936**	936	1.1
rdata-la13	1038*	1038	**1038**	1038	49.3	**1038**	1038	0.5	**1038**	1038	1.32	**1038**	1038	1.32
rdata-la14	1070*	1070	**1070**	1070	49.5	**1070**	1070	0.4	**1070**	1070	1.28	**1070**	1070	1.28
rdata-la15	1089*	1089	**1089**	1089.2	71.5	**1089**	1089	71.15	**1089**	1089	25.55	**1089**	1089	25.55
rdata-la16	717*	717	**717**	717	13.8	**717**	717	0.55	**717**	717	1.04	**717**	717	1.04
rdata-la17	646*	646	**646**	646	9.4	**646**	646	0	**646**	646	0.7	**646**	646	0.7
rdata-la18	666*	666	**666**	666	10.2	**666**	666	3.4	**666**	666	1.6	**666**	666	1.6
rdata-la19	700*	700	**700**	700.9	19.8	**700**	700	49.5	**700**	700	2.65	**700**	700	2.65
rdata-la20	756*	756	**756**	756	9.7	**756**	756	0	**756**	756	0.88	**756**	756	0.88
rdata-la21	808	825	830	833.8	44.4	832	837.75	92.75	825	828.95	95.25	825	828.45	612.06
rdata-la22	741	755	756	760.1	35.5	757	761.2	79	755	757.05	100.85	**753**	756.8	505.54
rdata-la23	816	832	835	837.6	42.1	836	840.3	63.15	833	833.2	83.54	**831**	832.85	725.96
rdata-la24	775	796	802	804.1	42.3	802	806.85	88.75	799	798.9	94.58	**795**	798.6	349.52
rdata-la25	768	783	784	786.4	44	784	789.75	93.15	783	783.15	111.56	**779**	783.05	562.87
rdata-la26	1056	1057	1059	1060.7	79.5	1060	1063.15	92.9	1057	1058.5	78.58	1057	1058.3	494.06
rdata-la27	1085*	1085	1089	1089.8	70.6	1089	1091.8	76.95	1086	1087.4	95.13	1086	1087.15	780.53
rdata-la28	1075	1076	1078	1078.9	65.8	1077	1080.1	67.5	1076	1077.25	88.22	1076	1077.1	353.35
rdata-la29	993	994	996	996.7	71.3	996	998.15	64.25	994	995.35	90.61	994	995.2	349.54
rdata-la30	1068	1071	1074	1076.1	72.1	1074	1081.45	90.95	1071	1072.55	61.16	1071	1072.1	765.48
rdata-la31	1520*	1520	**1520**	1520.6	114.7	1521	1522.45	78.9	**1520**	1520	56.79	**1520**	1520	56.79
rdata-la32	1657*	1657	1658	1658	113.8	1658	1659.25	84	**1657**	1657.95	90.49	**1657**	1657.65	352.86
rdata-la33	1497*	1497	1498	1498	109.8	1498	1499.15	66.65	**1497**	1497.95	72.54	**1497**	1497.3	434
rdata-la34	1535*	1535	**1535**	1535.4	125.1	**1535**	1535.95	57	**1535**	1535	21.63	**1535**	1535	21.63
rdata-la35	1549*	1549	1550	1550	105.6	1550	1550.4	56.65	**1549**	1549.1	67.32	**1549**	1549	67.32
rdata-la36	1023*	1023	**1023**	1027.1	30.4	**1023**	1028.5	78.55	**1023**	1023	53.46	**1023**	1023	174.55
rdata-la37	1062*	1062	1069	1072	44.3	1066	1076.7	83.45	**1062**	1063.4	60.66	**1062**	1063.2	581.74
rdata-la38	954*	954	961	962.4	44.9	958	970.95	46.7	**954**	954.45	89.63	**954**	954.3	884.23
rdata-la39	1011*	1011	1024	1024	26.4	1018	1023.9	88.2	**1011**	1013.45	162.49	**1011**	1012.85	726.13
rdata-la40	955*	955	961	964.3	44.3	958	965.85	87.4	**955**	955.95	104.95	**955**	955.8	160.51
rdata-mt06	47*	47	**47**	47	4.4	**47**	47	0	**47**	47	0.17	**47**	47	0.17
rdata-mt10	686*	686	**686**	686	11.9	**686**	686	6.4	**686**	686	3.66	**686**	686	3.66
rdata-mt20	1022*	1022	**1022**	1022	56.9	**1022**	1022	10.55	**1022**	1022	12.09	**1022**	1022	12.09
rdata-orb1	746*	746	-	-	-	-	-	-	**746**	746	1.29	**746**	746	1.29
rdata-orb10	742*	742	-	-	-	-	-	-	**742**	742	30.28	**742**	742	30.28
rdata-orb2	696*	696	-	-	-	-	-	-	**696**	696	3.41	**696**	696	3.41
rdata-orb3	712*	712	-	-	-	-	-	-	**712**	712	16.36	**712**	712	16.36
rdata-orb4	753*	753	-	-	-	-	-	-	**753**	753	1.48	**753**	753	1.48
rdata-orb5	639*	639	-	-	-	-	-	-	**639**	639	6.62	**639**	639	6.62
rdata-orb6	754*	754	-	-	-	-	-	-	**754**	754	2.03	**754**	754	2.03
rdata-orb7	302*	302	-	-	-	-	-	-	**302**	302	9.37	**302**	302	9.37
rdata-orb8	639*	639	-	-	-	-	-	-	**639**	639	2.14	**639**	639	2.14
rdata-orb9	694*	694	-	-	-	-	-	-	**694**	694	1.29	**694**	694	1.29
CI-CPU			46.3			47.46			41.95			239.05		
#better			19			18								
#even			24			25								
#worse			0			0								
#opt			24			25			50			50		

Table 6: Comparison between MAE and other reference algorithms on the *vdata* of *HUdata* instance set

Ins.	Quintiq		2015 SSPR			2017 GRASP-mELS			This paper MAE(5 min)			This paper MAE(30 min)		
	LB	UB	best	avg	t(s)	best	avg	t(s)	best	avg	t(s)	best	avg	t(s)
vdata-abz5	859*	859	-	-	-	-	-	-	**859**	859	1.47	**859**	859	1.47
vdata-abz6	742*	742	-	-	-	-	-	-	**742**	742	0.48	**742**	742	0.48
vdata-abz7	492*	492	-	-	-	-	-	-	499	499.85	102.25	499	499.6	377.98
vdata-abz8	506	507	-	-	-	-	-	-	513	514.4	138.3	513	513.9	440.71
vdata-abz9	497*	497	-	-	-	-	-	-	504	504.5	129.6	503	503.9	682.11
vdata-car1	5005*	5005	-	-	-	-	-	-	**5005**	5005.9	40.83	**5005**	5005.2	649.82
vdata-car2	5929*	5929	-	-	-	-	-	-	**5929**	5929	8.92	**5929**	5929	8.92
vdata-car3	5597*	5597	-	-	-	-	-	-	**5597**	5597.8	61.27	**5597**	5597.3	485.95
vdata-car4	6514*	6514	-	-	-	-	-	-	**6514**	6514	36.17	**6514**	6514	36.17
vdata-car5	4909	4911	-	-	-	-	-	-	4912	4915.05	130.95	**4910**	4912.65	868.08
vdata-car6	5486*	5486	-	-	-	-	-	-	**5486**	5486	0.18	**5486**	5486	0.18
vdata-car7	4281*	4281	-	-	-	-	-	-	**4281**	4281	0.29	**4281**	4281	0.29
vdata-car8	4613*	4613	-	-	-	-	-	-	**4613**	4613	0.81	**4613**	4613	0.81
vdata-la01	570*	570	**570**	570.1	23.2	**570**	570	15.2	**570**	570	2.25	**570**	570	2.25
vdata-la02	529*	529	**529**	529	17.2	**529**	529	9.9	**529**	529	1.2	**529**	529	1.2
vdata-la03	477*	477	**477**	477	18.6	**477**	477	22	**477**	477	1.76	**477**	477	1.76
vdata-la04	502*	502	**502**	502	15.5	**502**	502	3.3	**502**	502	1.01	**502**	502	1.01
vdata-la05	457*	457	**457**	457	19.7	**457**	457.05	24.4	**457**	457	7.24	**457**	457	7.24
vdata-la06	799*	799	**799**	799	31.1	**799**	799	1.8	**799**	799	1.12	**799**	799	1.12
vdata-la07	749*	749	**749**	749	42.8	**749**	749	35.5	**749**	749	2.77	**749**	749	2.77
vdata-la08	765*	765	**765**	765	31.2	**765**	765	10.65	**765**	765	1.69	**765**	765	1.69
vdata-la09	853*	853	**853**	853	30.8	**853**	853	2.1	**853**	853	1.36	**853**	853	1.36
vdata-la10	804*	804	**804**	804	29.9	**804**	804	3.85	**804**	804	1.36	**804**	804	1.36
vdata-la11	1071*	1071	**1071**	1071	54.4	**1071**	1071	0.35	**1071**	1071	1.5	**1071**	1071	1.5
vdata-la12	936*	936	**936**	936	56.3	**936**	936	0.15	**936**	936	1.25	**936**	936	1.25
vdata-la13	1038*	1038	**1038**	1038	56.5	**1038**	1038	0.45	**1038**	1038	1.35	**1038**	1038	1.35
vdata-la14	1070*	1070	**1070**	1070	53.4	**1070**	1070	0.05	**1070**	1070	1.39	**1070**	1070	1.39
vdata-la15	1089*	1089	**1089**	1089	50.3	**1089**	1089	5.7	**1089**	1089	3.5	**1089**	1089	3.5
vdata-la16	717*	717	**717**	717	13.3	**717**	717	0	**717**	717	0.24	**717**	717	0.24
vdata-la17	646*	646	**646**	646	12.4	**646**	646	0	**646**	646	0.18	**646**	646	0.18
vdata-la18	663*	663	**663**	663	15.4	**663**	663	0	**663**	663	0.33	**663**	663	0.33
vdata-la19	617*	617	**617**	617	23	**617**	617	0.55	**617**	617	1.22	**617**	617	1.22
vdata-la20	756*	756	**756**	756	13.6	**756**	756	0	**756**	756	0.16	**756**	756	0.16
vdata-la21	800*	800	802	803.3	63.6	804	807.2	87.7	801	802.35	109.09	801	801.95	353.46
vdata-la22	733*	733	734	735.5	70.3	737	739.2	87.55	**733**	734.1	122.21	**733**	733.95	238.05
vdata-la23	809*	809	811	811.5	62.1	813	815.8	77	810	810.85	85.75	810	810.25	513.61
vdata-la24	773*	773	775	775.6	61.7	776	778.95	78.2	774	774.8	78.34	774	774.3	520.42
vdata-la25	751*	751	753	753.8	66	755	758.2	100.55	752	753.2	98.3	752	752.9	270.5
vdata-la26	1052*	1052	1053	1053.1	108.6	1054	1055.1	71.25	**1052**	1052.15	120.62	**1052**	1052	192.35
vdata-la27	1084*	1084	**1084**	1084.4	100.5	1086	1086.25	78.7	**1084**	1084	31.9	**1084**	1084	31.9
vdata-la28	1069*	1069	**1069**	1069.2	101.9	1070	1071.1	62.75	**1069**	1069	36.55	**1069**	1069	36.55
vdata-la29	993*	993	994	994	89.7	995	995.8	70.55	**993**	993.85	58.55	**993**	993.05	604.83
vdata-la30	1068*	1068	1069	1069.3	98.9	1070	1071.25	80.35	**1068**	1068.8	50.17	**1068**	1068.3	462.16
vdata-la31	1520*	1520	**1520**	1520	169.2	1521	1521	40.7	**1520**	1520	17.06	**1520**	1520	17.06
vdata-la32	1657*	1657	1658	1658	174.4	1658	1658.65	70.8	**1657**	1657.05	79.27	**1657**	1657	106.67
vdata-la33	1497*	1497	**1497**	1497.9	185.6	1498	1498.35	63.35	**1497**	1497.05	112.06	**1497**	1497	135.63
vdata-la34	1535*	1535	**1535**	1535	174.1	**1535**	1535.95	35.45	**1535**	1535	31.72	**1535**	1535	31.72
vdata-la35	1549*	1549	**1549**	1549	181.8	**1549**	1549.95	40.3	**1549**	1549	46.56	**1549**	1549	46.56
vdata-la36	948*	948	**948**	948	69.9	**948**	948	1.1	**948**	948	4.57	**948**	948	4.57
vdata-la37	986*	986	**986**	986	75.3	**986**	986	2.55	**986**	986	5.45	**986**	986	5.45
vdata-la38	943*	943	**943**	943	61.7	**943**	943	0.05	**943**	943	2.22	**943**	943	2.22
vdata-la39	922*	922	**922**	922	69.2	**922**	922	3.35	**922**	922	4.64	**922**	922	4.64
vdata-la40	955*	955	**955**	955	62.8	**955**	955	0.05	**955**	955	2.25	**955**	955	2.25
vdata-mt06	47*	47	**47**	47	4.2	**47**	47	0	**47**	47	0.09	**47**	47	0.09
vdata-mt10	655*	655	**655**	655	14.9	**655**	655	0	**655**	655	0.4	**655**	655	0.4
vdata-mt20	1022*	1022	**1022**	1022	48.8	**1022**	1022	1.3	**1022**	1022	2.17	**1022**	1022	2.17
vdata-orb1	695*	695	-	-	-	-	-	-	**695**	695	0.41	**695**	695	0.41
vdata-orb10	681*	681	-	-	-	-	-	-	**681**	681	0.57	**681**	681	0.57
vdata-orb2	620*	620	-	-	-	-	-	-	**620**	620	1.11	**620**	620	1.11
vdata-orb3	648*	648	-	-	-	-	-	-	**648**	648	0.56	**648**	648	0.56
vdata-orb4	753*	753	-	-	-	-	-	-	**753**	753	0.19	**753**	753	0.19
vdata-orb5	584*	584	-	-	-	-	-	-	**584**	584	0.8	**584**	584	0.8
vdata-orb6	715*	715	-	-	-	-	-	-	**715**	715	0.31	**715**	715	0.31
vdata-orb7	275*	275	-	-	-	-	-	-	**275**	275	1.28	**275**	275	1.28
vdata-orb8	573*	573	-	-	-	-	-	-	**573**	573	0.47	**573**	573	0.47
vdata-orb9	659*	659	-	-	-	-	-	-	**659**	659	0.48	**659**	659	0.48
CI-CPU			63.34			27.66			26.34			84.1		
#better			9			13								
#even			34			30								
#worse			0			0								
#opt			34			30			58			58		

Table 7: Comparison between MAE and other reference algorithms on the *sdata* of *HUdata* instance set

Ins.	Quintiq		2015 SSPR			2017 GRASP-mELS			This paper MAE(5 min)			This paper MAE(30 min)		
	LB	UB	best	avg	t(s)	best	avg	t(s)	best	avg	t(s)	best	avg	t(s)
sdata-abz5	1234*	1234	-	-	-	-	-	-	**1234**	1234.2	92.85	**1234**	1234	120.07
sdata-abz6	943*	943	-	-	-	-	-	-	**943**	943	3.16	**943**	943	3.16
sdata-abz7	656*	656	-	-	-	-	-	-	664	666	90	661	664.75	546.87
sdata-abz8	653	667	-	-	-	-	-	-	675	678.4	99.91	675	676.3	769.54
sdata-abz9	678*	678	-	-	-	-	-	-	688	688.25	126.04	688	688	192.76
sdata-car1	7038*	7038	-	-	-	-	-	-	**7038**	7038	1.1	**7038**	7038	1.1
sdata-car2	7166*	7166	-	-	-	-	-	-	**7166**	7166	2.6	**7166**	7166	2.6
sdata-car3	7312*	7312	-	-	-	-	-	-	**7312**	7362.7	119.51	**7312**	7316.4	524.78
sdata-car4	8003*	8003	-	-	-	-	-	-	**8003**	8003	1.2	**8003**	8003	1.2
sdata-car5	7702*	7702	-	-	-	-	-	-	**7702**	7705.6	129.73	**7702**	7702	284.17
sdata-car6	8313*	8313	-	-	-	-	-	-	**8313**	8313	42.84	**8313**	8313	42.84
sdata-car7	6558*	6558	-	-	-	-	-	-	**6558**	6558.75	64.82	**6558**	6558	80.44
sdata-car8	8264*	8264	-	-	-	-	-	-	**8264**	8295.05	128.71	**8264**	8271.5	664.49
sdata-la01	666*	666	**666**	666	13.3	-	-	-	**666**	666	0.28	**666**	666	0.28
sdata-la02	655*	655	**655**	655	18.4	-	-	-	**655**	655	0.5	**655**	655	0.5
sdata-la03	597*	597	**597**	597	24.6	-	-	-	**597**	597	3.05	**597**	597	3.05
sdata-la04	590*	590	**590**	590	17.7	-	-	-	**590**	590	0.93	**590**	590	0.93
sdata-la05	593*	593	**593**	593	17.3	-	-	-	**593**	593	0.2	**593**	593	0.2
sdata-la06	926*	926	**926**	926	32.2	-	-	-	**926**	926	0.23	**926**	926	0.23
sdata-la07	890*	890	**890**	890	27.4	-	-	-	**890**	890	0.68	**890**	890	0.68
sdata-la08	863*	863	**863**	863	29.3	-	-	-	**863**	863	0.43	**863**	863	0.43
sdata-la09	951*	951	**951**	951	32.9	-	-	-	**951**	951	0.32	**951**	951	0.32
sdata-la10	958*	958	**958**	958	35	-	-	-	**958**	958	0.2	**958**	958	0.2
sdata-la11	1222*	1222	**1222**	1222	59.6	-	-	-	**1222**	1222	0.36	**1222**	1222	0.36
sdata-la12	1039*	1039	**1039**	1039	54	-	-	-	**1039**	1039	0.35	**1039**	1039	0.35
sdata-la13	1150*	1150	**1150**	1150	59.1	-	-	-	**1150**	1150	0.31	**1150**	1150	0.31
sdata-la14	1292*	1292	**1292**	1292	70.1	-	-	-	**1292**	1292	0.19	**1292**	1292	0.19
sdata-la15	1207*	1207	**1207**	1207	47.6	-	-	-	**1207**	1207	1.02	**1207**	1207	1.02
sdata-la16	945*	945	**945**	945	22.1	-	-	-	**945**	945	61.36	**945**	945	247.49
sdata-la17	784*	784	**784**	784	22.9	-	-	-	**784**	784	2.74	**784**	784	2.74
sdata-la18	848*	848	**848**	848	17.9	-	-	-	**848**	848	3.92	**848**	848	3.92
sdata-la19	842*	842	**842**	842	14.8	-	-	-	**842**	842	79.23	**842**	842	213.48
sdata-la20	902*	902	**902**	902	17.9	-	-	-	**902**	902	66.9	**902**	902	66.9
sdata-la21	1046*	1046	**1046**	1046.4	35.2	-	-	-	**1046**	1046.7	113.26	**1046**	1046.4	310.64
sdata-la22	927*	927	**927**	927.6	33.7	-	-	-	**927**	927.5	105.5	**927**	927.15	507.85
sdata-la23	1032*	1032	**1032**	1032	21.5	-	-	-	**1032**	1032	1.53	**1032**	1032	1.53
sdata-la24	935*	935	**935**	935.9	30.8	-	-	-	**935**	936.2	122.09	**935**	935.8	360.56
sdata-la25	977*	977	**977**	978.1	36	-	-	-	**977**	978.4	127.61	**977**	978.2	728.2
sdata-la26	1218*	1218	**1218**	1218	40.2	-	-	-	**1218**	1218	2.62	**1218**	1218	2.62
sdata-la27	1235*	1235	**1235**	1235	41.6	-	-	-	**1235**	1235.35	78.7	**1235**	1235	109.4
sdata-la28	1216*	1216	**1216**	1216	41.3	-	-	-	**1216**	1216	4.19	**1216**	1216	4.19
sdata-la29	1152*	1152	1160	1163.2	67.9	-	-	-	1160	1164.85	124.58	1156	1161.4	997.67
sdata-la30	1355*	1355	**1355**	1355	42.2	-	-	-	**1355**	1355	2.3	**1355**	1355	2.3
sdata-la31	1784*	1784	**1784**	1784	68.1	-	-	-	**1784**	1784	1.54	**1784**	1784	1.54
sdata-la32	1850*	1850	**1850**	1850	64.9	-	-	-	**1850**	1850	1.81	**1850**	1850	1.81
sdata-la33	1719*	1719	**1719**	1719	64.6	-	-	-	**1719**	1719	1.72	**1719**	1719	1.72
sdata-la34	1721*	1721	**1721**	1721	66.6	-	-	-	**1721**	1721	2.9	**1721**	1721	2.9
sdata-la35	1888*	1888	**1888**	1888	74.3	-	-	-	**1888**	1888	2.55	**1888**	1888	2.55
sdata-la36	1268*	1268	**1268**	1268.2	30.2	-	-	-	**1268**	1268.4	114.46	**1268**	1268.2	789.8
sdata-la37	1397*	1397	**1397**	1398.6	37.7	-	-	-	**1397**	1398.9	138.22	**1397**	1398.7	633.24
sdata-la38	1196*	1196	1198	1200.7	33.3	-	-	-	**1196**	1200.4	130.12	**1196**	1200.3	334.82
sdata-la39	1233*	1233	**1233**	1233.2	35	-	-	-	**1233**	1233.75	109.48	**1233**	1233.1	824.65
sdata-la40	1222*	1222	1224	1224.8	36.9	-	-	-	1224	1225.2	96.4	1224	1224.6	500.12
sdata-mt06	55*	55	**55**	55	75.2	-	-	-	**55**	55	0.3	**55**	55	0.3
sdata-mt10	930*	930	**930**	931.8	33.9	-	-	-	**930**	930.2	98.81	**930**	930	113.89
sdata-mt20	1165*	1165	**1165**	1165	66.7	-	-	-	**1165**	1165	2.02	**1165**	1165	2.02
sdata-orb1	1059*	1059	-	-	-	-	-	-	**1059**	1063	93.83	**1059**	1059	407.23
sdata-orb10	944*	944	-	-	-	-	-	-	**944**	944	9.53	**944**	944	9.53
sdata-orb2	888*	888	-	-	-	-	-	-	**888**	888.15	123.52	**888**	888	224.73
sdata-orb3	1005*	1005	-	-	-	-	-	-	**1005**	1005	21.17	**1005**	1005	21.17
sdata-orb4	1005*	1005	-	-	-	-	-	-	**1005**	1011.75	137.52	**1005**	1009.3	617.61
sdata-orb5	887*	887	-	-	-	-	-	-	**887**	888.5	66.28	**887**	887.8	435.75
sdata-orb6	1010*	1010	-	-	-	-	-	-	**1010**	1010.3	78.88	**1010**	1010	139.13
sdata-orb7	397*	397	-	-	-	-	-	-	**397**	397	35.46	**397**	397	35.46
sdata-orb8	899*	899	-	-	-	-	-	-	**899**	903.9	144.78	**899**	899.25	547.21
sdata-orb9	934*	934	-	-	-	-	-	-	**934**	934	6.91	**934**	934	6.91
CI-CPU			39.81						37.35			157.63		
#better			1											
#even			42											
#worse			0											
#opt			40						61			61		

2 The sequences of improved solutions

- 05a 2203

  1 41 4 1 1 1 5 2 2 3 10 2 9 5 10 3 6 2 2 6 1 5 4 7 4 8 3 6 3 7 10 9 8 8 8 9 7 5 8 11 10 11 5 10 4 11 8 13 3 11 5 12 8 15 10 13 4 13 3 14 5 15 2 18 9 21 7 12 6 12 2 20 3 19 10 17 7 15 8 25 7 16 10 19

  2 36 5 1 2 2 8 2 9 4 6 1 2 5 9 7 9 8 3 4 8 6 6 4 6 5 10 8 5 8 4 9 9 12 9 13 2 11 2 12 1 9 5 11 4 12 9 17 9 18 10 14 1 12 8 18 8 19 8 20 8 21 6 13 9 22 8 23 8 24 10 18 6 15

  3 42 9 1 9 2 9 3 1 2 8 3 2 4 5 4 9 6 5 6 10 6 10 7 5 7 8 7 6 6 6 7 9 11 2 9 5 9 4 10 3 9 7 6 3 10 9 15 1 10 9 16 8 14 2 15 5 13 9 19 8 17 6 11 10 15 4 15 2 19 4 16 10 16 4 17 4 18 1 14 3 22 5 21 7 17

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  5 38 3 1 4 2 7 1 5 3 1 3 3 3 5 5 10 4 10 5 8 5 9 9 3 5 9 10 1 6 7 4 1 7 2 10 10 10 8 10 1 8 6 10 10 12 7 7 7 8 1 11 3 13 2 16 7 11 4 14 1 13 5 16 5 17 5 18 8 22 5 19 6 14 5 20 1 15

- 07a 2254

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  2 34 13 2 13 4 15 4 7 3 15 7 9 4 4 6 4 7 13 7 15 10 14 6 11 7 15 13 15 14 10 13 15 16 10 16 6 5 2 14 3 12 5 9 14 14 15 23 12 13 6 9 12 15 3 16 3 17 8 19 3 19 3 20 5 19 4 17 8 25

  3 33 7 2 10 2 12 3 15 6 2 3 2 5 10 6 13 8 15 11 13 10 10 11 3 6 12 10 10 14 15 17 2 13 14 13 9 16 10 19 3 13 15 22 8 14 7 9 15 24 13 13 11 16 6 11 6 12 2 20 8 22 13 16 11 19 3 23

  4 38 15 1 9 1 12 1 10 1 1 1 14 1 11 3 4 5 6 1 6 2 11 4 14 5 10 8 13 9 12 6 12 7 11 8 9 11 11 9 8 4 2 11 7 6 8 7 8 8 7 7 1 4 8 11 13 11 6 8 3 14 9 19 14 15 11 17 12 17 7 14 5 18 7 16 1 14

  5 38 7 1 5 1 15 3 9 3 4 4 8 1 10 5 15 9 3 3 3 4 3 5 5 4 2 9 10 12 4 11 5 5 8 6 14 12 5 7 3 11 15 19 7 8 11 14 8 13 6 7 5 12 5 13 1 8 3 15 8 17 4 15 14 16 7 12 1 12 7 15 1 13 7 17 5 21

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  7 39 4 1 15 2 4 3 10 3 15 8 14 3 5 3 6 3 10 7 8 2 2 7 9 8 9 9 12 8 4 10 2 10 9 13 2 12 10 17 11 11 15 18 12 11 1 5 5 10 9 17 2 17 11 15 15 25 2 19 3 18 5 16 8 20 8 21 13 15 9 22 6 14 3 22 5 20 4 18

  8 35 11 1 12 2 5 2 1 2 9 5 2 4 14 4 11 5 9 7 14 7 15 12 2 8 9 10 8 3 15 15 11 10 3 8 5 6 9 15 3 10 8 9 8 10 6 6 8 12 5 11 1 7 8 15 6 10 1 9 5 15 7 13 12 18 12 19 8 24 12 21

- 13a 2236

  1 41 3 1 16 2 20 2 17 2 13 3 9 4 9 5 20 6 17 7 15 7 2 7 20 8 17 9 19 5 13 8 12 6 10 7 7 5 8 14 14 6 17 13 3 12 4 9 4 10 10 13 13 11 1 15 9 18 20 15 12 13 8 19 19 15 17 18 8 21 11 16 4 17 15 23 8 24 2 20 19 22 19 23

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  4 42 2 1 20 1 15 3 19 2 12 4 3 2 5 5 3 3 16 4 10 4 5 7 16 6 11 3 5 9 4 5 20 9 7 4 18 9 4 7 12 7 8 15 18 10 7 9 15 14 16 11 11 9 11 10 15 17 3 15 15 18 4 14 14 13 19 14 11 14 8 20 10 16 14 15 3 20 2 18 9 22 12 20 10 19

  5 36 18 2 8 1 17 1 1 3 6 4 12 3 16 3 5 4 6 6 3 4 8 9 3 7 14 3 14 4 5 11 13 9 13 10 2 9 3 11 6 10 16 10 12 9 18 12 15 16 3 14 9 17 2 13 9 20 9 21 12 15 7 14 13 15 3 21 19 20 6 15 3 23

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  8 40 18 1 12 1 6 3 1 4 17 3 17 4 13 4 2 5 9 7 16 5 20 7 3 6 15 9 18 6 19 6 17 10 8 12 16 8 14 5 5 12 7 6 4 8 15 13 17 14 15 15 20 13 18 13 11 11 16 13 14 11 13 12 13 13 7 12 7 13 12 16 17 19 15 21 18 17 17 21 15 25

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  10 44 6 1 15 1 1 2 12 2 2 2 8 3 6 5 2 4 15 6 8 6 8 7 2 6 3 5 7 2 8 10 16 7 10 6 3 8 4 6 6 8 6 9 7 7 11 7 2 10 10 11 9 15 19 10 2 11 19 11 2 12 14 12 5 18 5 19 3 17 15 20 2 15 6 13 8 22 2 17 7 16 16 16 3 22 9 23 12 21

- rdata-abz7 522

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  2 20 14 2 5 2 5 3 20 4 18 6 2 5 5 5 17 6 15 5 16 9 4 6 7 10 3 10 16 12 7 12 7 13 20 11 13 12 12 12 15 15

  3 20 1 1 8 1 1 3 18 4 10 3 9 4 3 4 3 5 7 7 2 8 19 10 16 11 8 10 5 11 10 12 10 13 2 13 11 14 20 14 4 15

  4 23 17 1 1 2 2 2 7 2 15 3 11 3 7 5 8 5 20 6 3 6 10 7 19 8 17 8 5 9 18 10 6 10 6 11 20 10 9 11 18 13 15 14 12 13 11 15

  5 20 16 2 1 4 16 4 12 5 14 5 7 6 16 8 6 7 9 6 4 7 10 11 17 10 15 11 4 10 14 13 20 12 13 13 4 13 5 15 12 15

  6 20 19 1 17 2 12 3 11 2 18 5 20 5 18 7 14 6 9 5 1 10 2 9 6 9 3 11 1 14 14 12 8 12 5 13 4 12 10 15 13 15

  7 18 2 1 3 1 4 2 8 3 1 6 12 6 1 8 6 6 3 7 16 10 17 9 13 8 11 11 9 10 11 13 16 14 9 14 18 15

  8 18 5 1 16 3 19 3 10 4 10 5 4 4 11 5 4 5 8 8 1 11 14 10 4 8 2 10 3 12 6 12 9 13 7 15 6 15

  9 20 14 1 6 1 13 1 9 3 7 4 5 4 13 4 16 7 11 6 8 7 5 7 10 9 15 9 15 10 18 11 2 12 19 13 3 14 8 14 4 14

  10 23 16 1 18 1 4 1 8 2 10 2 7 3 3 2 6 4 12 7 13 5 19 7 7 8 5 8 3 9 9 7 11 10 4 9 19 12 18 12 10 14 2 14 13 14 20 15

  11 20 11 1 18 2 19 2 13 2 14 4 11 4 8 6 2 7 10 8 3 8 6 8 5 10 13 9 17 11 12 11 9 12 15 13 5 14 3 15 9 15

  12 21 12 2 9 2 6 2 4 3 8 4 17 5 19 6 20 7 15 6 14 8 20 8 10 10 7 11 14 11 13 10 11 12 16 13 8 13 20 13 18 14 14 15

  13 18 15 1 10 1 2 3 20 3 17 4 1 7 15 4 17 7 15 7 11 8 11 9 19 11 12 10 1 15 14 14 16 15 6 14 12 14

  14 17 9 1 20 2 12 4 2 4 3 3 19 5 6 5 1 9 13 6 15 8 8 9 1 13 8 11 15 12 6 13 17 14 19 15

  15 20 20 1 15 2 14 3 6 3 19 4 16 6 2 6 12 8 14 7 11 7 7 9 18 9 1 12 12 9 9 9 13 11 4 11 17 12 19 14 2 15

- rdata-abz8 535

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  2 22 8 1 10 1 3 2 5 3 15 4 18 3 16 6 10 4 12 6 5 7 4 7 18 9 16 10 3 10 2 11 8 12 1 11 7 15 20 12 13 14 14 14 9 15

  3 21 20 1 19 2 12 1 16 3 1 3 4 3 13 5 13 6 7 7 8 8 8 9 9 7 12 10 15 11 14 9 3 12 17 12 18 14 9 13 10 14 10 15

  4 17 3 1 18 2 4 2 16 5 9 4 14 5 11 6 19 8 11 8 20 9 10 8 10 9 2 12 5 11 6 12 1 13 17 15

  5 21 16 1 5 2 17 2 20 4 2 5 15 6 12 5 4 5 19 7 7 8 5 8 6 8 14 8 9 8 14 10 18 12 1 12 14 12 11 14 15 15 14 15

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  7 19 17 1 6 2 12 2 3 4 18 4 8 5 16 7 6 6 1 7 17 8 8 10 6 9 19 10 15 13 12 13 2 13 14 13 3 14 2 15

  8 21 11 1 20 2 10 2 7 3 5 4 3 5 19 6 17 6 2 8 10 6 4 9 11 9 7 12 18 11 7 14 20 11 19 12 9 12 18 15 12 15 1 15

  9 20 14 1 9 1 7 2 8 4 13 4 2 6 11 5 1 6 13 8 4 8 12 9 10 7 11 10 5 10 11 11 9 10 8 14 11 13 4 14 3 15

  10 19 2 1 1 2 20 3 19 4 14 4 7 6 6 5 13 7 18 8 3 8 7 9 16 11 17 10 10 10 18 13 12 14 8 15 5 14 5 15

  11 17 6 1 14 2 8 3 9 3 17 4 7 5 1 5 18 7 16 9 13 9 18 10 12 11 4 11 19 11 13 13 5 12 20 15

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  14 19 2 2 13 2 9 2 16 4 11 3 1 4 20 6 9 5 3 7 12 8 7 10 1 9 8 11 20 10 6 11 15 14 6 13 19 14 9 14

  15 21 18 1 13 1 4 1 2 3 6 4 20 5 10 3 8 6 3 6 20 7 11 7 1 8 7 11 16 12 15 12 8 13 14 11 3 13 19 13 2 14 16 15

- rdata-la22 753

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