Supplementary report for the paper *A Distance-based Ranking Model Estimation of Distribution Algorithm for Flowshop Scheduling Problem* submitted to the journal *IEEE Transactions on Evolutionary Computation*.

Supplementary Report: the Analysis of Execution Times

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February 26, 2013

Abstract

In this report we introduce supplementary material that extend the experimental study presented in the paper *A Distance-based Ranking Model Estimation of Distribution Algorithm for Flowshop Scheduling Problem*, submitted to the journal *IEEE Transactions on Evolutionary Computation*. In addition to the results provided in the paper, which were obtained by fixing a given number of evaluations, in this report we rerun the experiments replacing the former stopping criterion and allowing the algorithms to perform the same execution time.

1 Execution time measurements for AGA, VNS$_4$, GM-EDA, VNS and HGM-EDA

When estimation of distribution algorithms are executed, a stopping criterion must be set. The most common options proposed in the literature are the number of evaluations and execution time. In this case, we think that to set a maximum number of evaluations is a more appropriate criterion than the execution time, since other factors such as the characteristics of the hardware, the abilities of different compilers, or the programming skills might change the execution time of the algorithm.

However, in order to extend the experimental study introduced in the paper, we provide the execution times for the different approaches tested: AGA, VNS$_4$, GM-EDA, VNS and HGM-EDA. All the algorithms have been implemented by us, trying to provide efficient codes in all the cases.

Fig. 1 and Table 1 show the average CPU time spent by the algorithms when running the maximum number of evaluations allowed (see Tables III and IV of the paper). 20 repetitions of each algorithm were performed. For the sake of readability, the first instance of each configuration was only considered in this analysis.

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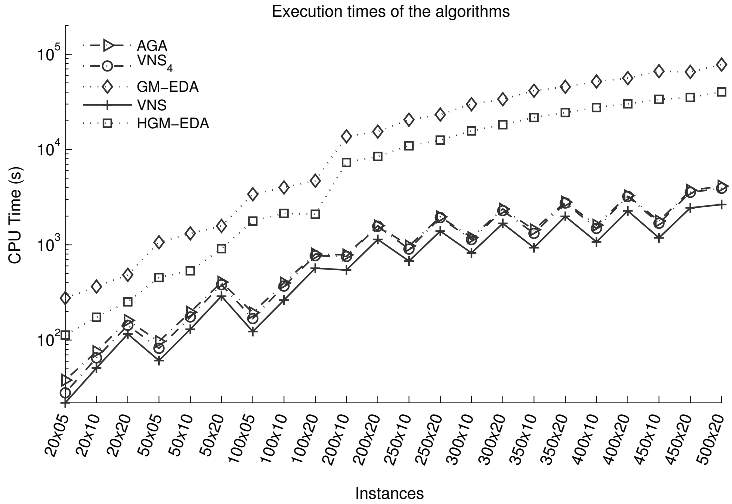

Figure 1: CPU-time (seconds) spent by AGA, VNS_4, GM-EDA, VNS and HGM-EDA to complete the maximum number of evaluations for the first instance of each configuration. The average execution times of 20 repetitions are presented. Note that CPU-time is in log scale.

Table 1: CPU-time (seconds) spent by AGA, VNS_4, GM-EDA, VNS and HGM-EDA to complete the maximum number of evaluations for the first instance of each configuration. The average execution times of 20 repetitions are presented.

Instance	AGA	VNS_4	GM-EDA	VNS	HGM-EDA
20×05	38	28	276	22	113
20×10	76	65	364	51	174
20×20	161	143	484	116	252
50×05	97	82	1062	61	454
50×10	196	175	1316	130	534
50×20	406	381	1578	289	910
100×05	194	168	3394	123	1774
100×10	398	369	4000	263	2134
100×20	799	769	4697	568	2094
200×10	785	755	13737	544	7298
200×20	1585	1568	15424	1138	8455
250×10	973	903	20554	675	10950
250×20	1971	1931	23259	1392	12550
300×10	1190	1133	29944	820	15696
300×20	2379	2288	33690	1676	18237
350×10	1441	1318	41379	933	21616
350×20	2808	2742	45537	1986	24405
400×10	1608	1486	51757	1073	27551
400×20	3289	3220	56154	2275	30240
450×10	1779	1683	66203	1184	33592
450×20	3733	3552	65224	2443	35217
500×20	4130	3919	77734	2648	40304

In view of the results, we conclude that GM-EDA and HGM-EDA are significantly slower than the rest of the approaches, spending in some cases 18 times more execution time to complete the maximum number of evaluations set. Taking into account these differences, we wonder what would happen if all the algorithms were allowed to spend the same execution time.

For this purpose, and due to the restrictions of time and resources, we decided to perform some additional experiments allowing AGA (the second best performing algorithm) to make use of as much CPU-time as that used by HGM-EDA.

Table 2 shows the best and average results of 10 repetitions of HGM-EDA and AGA over the first instance of each configuration type. Additionally, the number of evaluations performed by each algorithm is introduced as well as the evaluation ratio between them.

Table 2: Best and average results of HGM-EDA and AGA of 10 repetitions performed over the first instance of each configuration type. The results in bold denote best average result obtained for the instance.

Instance	Time(s)	HGM-EDA			AGA			Evals. Ratio
		Evals.	Best	Avg.	Evals.	Best	Avg.	
20×05	113	1.82×10^8	14033	**14033**	5.13×10^8	14033	**14033**	2.8
20×10	174	2.25×10^8	20911	**20911**	4.97×10^8	20911	**20911**	2.2
20×20	252	2.57×10^8	33623	**33623**	4.00×10^8	33623	**33623**	1.6
50×05	454	2.21×10^8	64803	64953	1.00×10^9	64803	**64842**	4.5
50×10	534	2.56×10^8	87193	87889	6.81×10^8	87314	**87621**	2.7
50×20	910	2.76×10^8	125877	126833	6.16×10^8	125831	**125958**	2.2
100×05	1774	2.36×10^8	253941	254941	2.10×10^9	253664	**254276**	8.9
100×10	2134	2.66×10^8	299048	301184	1.40×10^9	298980	**299981**	5.3
100×20	2094	2.83×10^8	368349	**370025**	7.33×10^8	367966	370140	2.6
200×10	7298	2.73×10^8	1048145	**1051679**	2.47×10^9	1048446	1052212	9.1
200×20	8455	2.88×10^8	1229236	1233432	1.51×10^9	1226049	**1233180**	5.3
250×10	10950	2.68×10^8	1565640	**1572209**	2.95×10^9	1569665	1577148	11.0
250×20	12550	2.85×10^8	1846835	**1854439**	1.79×10^9	1850545	1863765	6.3
300×10	15696	2.74×10^8	2240948	**2244491**	3.51×10^9	2246421	2256549	12.8
300×20	18237	2.85×10^8	2586955	**2600887**	2.16×10^9	2599202	2611472	7.6
350×10	21616	2.78×10^8	3049101	**3057335**	4.22×10^9	3057753	3067347	15.2
350×20	24405	2.86×10^8	3459723	**3478886**	2.42×10^9	3475016	3499466	8.5
400×10	27551	2.75×10^8	3953089	3978503	4.71×10^9	3932573	**3938924**	17.1
400×20	30240	2.84×10^8	4497990	4533893	2.62×10^9	4456497	**4484353**	9.2
450×10	33592	2.77×10^8	4921735	4953706	5.06×10^9	4871315	**4882779**	18.2
450×20	35217	2.69×10^8	5596363	5634471	2.56×10^9	5525827	**5552125**	9.5
500×20	40304	2.60×10^8	6812874	6876140	2.53×10^9	6691613	**6722294**	9.7

As presented in Table 2, although AGA is allowed to make use of as much as CPU-time as that used by HGM-EDA, the results are similar to those provided throughout the main paper, with the exception of the configurations 100×5 and 200×20. We see that even though the number of evaluations performed by AGA in some cases reaches ratios of 1:18, HGM-EDA still beats AGA in almost all the instances where it did on the experimental study in the main paper.