New Designs of *k*-means Clustering and Crossover Operator for Solving Traveling Salesman Problems using Evolutionary Algorithms

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APPENDIX

The detailed results of the proposed GA and other comparative algorithms are shown in Table 1. In Table 1, the results of 10 TSPs with different number of cities, Mean values, average error (%), and average computational time in seconds, are given. For conducting a fair comparison, the proposed GA has been run for 4 runs and the results of each have been compared with those from other algorithms.

Table 1: Best distances for 10 TSPs in 4 runs with mean, error (%) and average time values obtained from the proposed versions of GA other recent 3 state-of-the-art algorithms.

Probs	Optimal	Algorithms	RUNS				Mean	Error(%)	Time (s)
			1	2	3	4			
ATT48	10,628	GA	10,890	10,862	10,862	10,898	10,878.0	2.35	0.51
		PSO	10,962	10,884	10,860	10,986	10,923.0	2.78	**0.35**
		Hybrid GA-PSO	10,641	10,690	10,686	10,639	**10,664.0**	**0.34**	0.44
		Proposed GA	10,742	10,696	10,634	10,672	10,686.0	0.54	0.48
EIL51	426	GA	428	430	432	458	437.0	2.58	0.57
		PSO	446	442	433	435	439.0	3.05	**0.38**
		Hybrid GA-PSO	433	431	428	432	**431.0**	**1.17**	0.49
		Proposed GA	427	444	427	427	431.3	1.22	0.50
ST70	675	GA	690	694	713	715	703.0	4.15	0.90
		PSO	726	698	696	712	708.0	4.89	**0.64**
		Hybrid GA-PSO	683	681	679	669	678.0	0.76	0.74
		Proposed GA	679	675	675	675	**676.0**	**0.15**	0.74
PR76	108,159	GA	111,676	110,508	109,383	110,521	110,522.0	2.18	1.20
		PSO	111,044	111,030	110,976	110,958	111,002.0	2.63	**0.80**
		Hybrid GA-PSO	108,914	108,987	108,963	108,924	108,947.0	0.73	1.00
		Proposed GA	108,160	108,361	109,492	108,292	**108,576.3**	**0.38**	1.56
RD100	7,910	GA	8,276	8,292	8,258	8,238	8,266.0	4.50	1.77
		PSO	8,347	8,305	8,339	8,333	8,331.0	5.32	**1.27**
		Hybrid GA-PSO	8,022	8,048	8,072	8,002	8,036.0	1.58	1.54
		Proposed GA	7,913	7,914	7,915	7,912	**7,913.5**	**0.04**	1.52
KROA100	21,282	GA	22,325	22,152	22,035	22,033	22,136.0	4.01	1.75
		PSO	22,347	22,313	22,328	22,208	22,299.0	4.78	**1.25**
		Hybrid GA-PSO	21,502	21,527	21,518	21,421	21,492.0	0.99	1.52
		Proposed GA	21,299	21,297	21,282	21,310	**21,297.0**	**0.07**	1.54
KROB100	22,141	GA	22,412	22,955	23,256	22,709	22,833.0	3.12	1.76
		PSO	22,921	22,975	22,937	22,979	22,953.0	3.67	**1.19**
		Hybrid GA-PSO	22,446	22,583	22,587	22,512	22,532.0	1.77	1.48
		Proposed GA	22,188	22,156	22,161	22,141	**22,161.5**	**0.09**	1.32
PR107	44,303	GA	46,116	45,887	45,182	45,711	45,724.0	3.21	2.13
		PSO	46,002	46,103	45,745	46,034	45,971.0	3.77	**1.45**
		Hybrid GA-PSO	44,838	44,782	44,818	44,842	44,820.0	1.17	1.72
		Proposed GA	44,305	44,325	44,324	44,316	**44,317.5**	**0.03**	1.81
PR124	59,030	GA	59,832	60,060	60,668	60,312	60,218.0	2.01	2.36

		PSO	60,434	60,453	60,457	60,432	60,444.0	2.40	**1.64**
		Hybrid GA-PSO	59,207	59,218	59,189	59,154	59,192.0	0.27	2.05
		Proposed GA	59,067	59,052	59,050	59,035	**59,051.0**	**0.04**	2.30
GIL262	2,378	GA	2,539	2,492	2,506	2,559	2,524.0	6.34	10.01
		PSO	2,550	2,565	2,548	2,561	2,556.0	7.48	**7.13**
		Hybrid GA-PSO	2,427	2,469	2,463	2,437	2,449.0	2.99	8.55
		Proposed GA	2,378	2,378	2,378	2,378	**2,378.0**	**0.00**	7.32