

An Evolutionary Algorithm with Classifier Guided Constraint Evaluation Strategy for Computationally Expensive Optimization Problems: Supplementary Materials

Kalyan Shankar Bhattacharjee, and Tapabrata Ray

School of Engineering and Information Technology
University of New South Wales, Canberra ACT2600, Australia
{kalyan.bhattacharjee,t.ray}@adfa.edu.au

1 Tabulated Results

Table 1. Statistics for Problems

Problem	Algorithms	Feasibility	Best	Mean	Median	Worst	Std	Success
G1	CGCSM	Feasible	-10.9659	-6.7971	-6.8569	1.0558	2.3529	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	mIDEA	Feasible	-9.1300	-5.5195	-5.3730	-3.0344	1.6814	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	IDEA	Feasible	-9.9385	-6.6248	-6.6551	-2.6674	1.8357	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	mNSGA-II	Feasible	-8.8486	-5.3880	-4.9895	-2.7330	1.8464	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	NSGA-II	Feasible	-9.6822	-6.6938	-6.6383	-2.7636	1.8265	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
G2	CGCSM	Feasible	-0.5851	-0.4586	-0.4604	-0.3412	-0.0498	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	mIDEA	Feasible	-0.5835	-0.4738	-0.4805	-0.3658	-0.0503	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	IDEA	Feasible	-0.5796	-0.4997	-0.4963	-0.4211	-0.0432	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	mNSGA-II	Feasible	-0.5774	-0.4830	-0.4853	-0.3688	-0.0552	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	NSGA-II	Feasible	-0.5913	-0.5046	-0.5073	-0.4216	-0.0423	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 2. Continued Statistics for Problems

Problem	Algorithms	Feasibility	Best	Mean	Median	Worst	Std	Success
G3	CGCSM	Feasible	-0.2135	-0.0520	-0.0345	-0.0012	-0.0518	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	mIDEA	Feasible	-0.1630	-0.0317	-0.0079	-0.0000	-0.0453	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	IDEA	Feasible	-0.4399	-0.0512	-0.0203	-0.0000	-0.0906	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	mNSGA-II	Feasible	-0.3501	-0.0502	-0.0158	-0.0001	-0.0852	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	NSGA-II	Feasible	-0.1328	-0.0406	-0.0292	-0.0002	-0.0384	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
G4	CGCSM	Feasible	-30448.0730	-30058.8330	-30054.4750	-29448.3700	229.7780	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	mIDEA	Feasible	-30392.9860	-30006.9370	-30029.6400	-29281.6250	240.6976	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	IDEA	Feasible	-30385.3230	-29974.5050	-30013.3570	-29502.6750	243.7638	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	mNSGA-II	Feasible	-30490.6440	-30039.1410	-30100.9800	-29490.7410	249.2237	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	NSGA-II	Feasible	-30416.6000	-30043.3670	-30073.4500	-29569.4000	232.1968	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
G5	CGCSM	Feasible	NaN	NaN	NaN	NaN	NaN	0.0000
		Infeasible	0.1736	12.9208	6.2660	62.7408	16.1884	30.0000
	mIDEA	Feasible	NaN	NaN	NaN	NaN	NaN	0.0000
		Infeasible	0.3728	21.5070	9.6122	182.5875	33.7595	30.0000
	IDEA	Feasible	NaN	NaN	NaN	NaN	NaN	0.0000
		Infeasible	0.0146	13.0976	7.8327	68.5710	14.3451	30.0000
	mNSGA-II	Feasible	NaN	NaN	NaN	NaN	NaN	0.0000
		Infeasible	0.3728	21.5070	9.6122	182.5875	33.7595	30.0000
	NSGA-II	Feasible	NaN	NaN	NaN	NaN	NaN	0.0000
		Infeasible	0.0146	13.0976	7.8327	68.5710	14.3451	30.0000
G6	CGCSM	Feasible	-6785.8082	-5041.0477	-5442.2036	-1228.3475	1604.7222	22.0000
		Infeasible	0.0000	0.4081	0.0000	2.1366	0.7414	8.0000
	mIDEA	Feasible	-6940.9847	-4515.2380	-4898.1419	-1419.7396	1858.8212	16.0000
		Infeasible	0.0000	0.3759	0.0000	2.4447	0.6164	14.0000
	IDEA	Feasible	-6862.1727	-4584.3221	-4551.0424	-1301.3530	1548.0995	21.0000
		Infeasible	0.0000	0.3384	0.0000	2.0739	0.6171	9.0000
	mNSGA-II	Feasible	-6941.7057	-4690.6937	-5114.0011	-1543.6420	1933.9216	16.0000
		Infeasible	0.0000	0.3759	0.0000	2.4447	0.6164	14.0000
	NSGA-II	Feasible	-6794.6500	-4408.2119	-4609.0700	-1303.6800	1593.5562	21.0000
		Infeasible	0.0000	0.3384	0.0000	2.0739	0.6171	9.0000
G7	CGCSM	Feasible	54.7492	507.0867	220.5982	2915.4455	675.4734	29.0000
		Infeasible	0.0000	0.0697	0.0000	2.0920	0.3755	1.0000
	mIDEA	Feasible	31.5096	555.5588	261.2200	2441.2033	674.9718	29.0000
		Infeasible	0.0000	0.3032	0.0000	9.0961	1.6328	1.0000
	IDEA	Feasible	52.7887	415.3156	188.5009	2179.5559	554.0955	29.0000
		Infeasible	0.0000	0.1063	0.0000	3.1882	0.5723	1.0000
	mNSGA-II	Feasible	58.9722	705.3611	361.9152	2473.2012	708.7253	29.0000
		Infeasible	0.0000	0.3032	0.0000	9.0961	1.6328	1.0000
	NSGA-II	Feasible	73.3749	555.6650	252.2570	2155.3900	623.0730	29.0000
		Infeasible	0.0000	0.1063	0.0000	3.1882	0.5723	1.0000

Table 3. Continued Statistics for Problems

Problem	Algorithms	Feasibility	Best	Mean	Median	Worst	Std	Success
G8	CGCSM	Feasible	-0.0958	-0.0822	-0.0958	-0.0223	-0.0271	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	mIDEA	Feasible	-0.0958	-0.0723	-0.0947	-0.0206	-0.0311	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	IDEA	Feasible	-0.0958	-0.0843	-0.0957	-0.0232	-0.0252	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	mNSGA-II	Feasible	-0.0958	-0.0819	-0.0955	-0.0262	-0.0267	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	NSGA-II	Feasible	-0.0958	-0.0835	-0.0957	-0.0025	-0.0271	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
G9	CGCSM	Feasible	686.4636	764.3004	707.3293	1568.1440	184.7771	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	mIDEA	Feasible	688.2573	823.6930	726.0827	2009.0022	266.4399	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	IDEA	Feasible	695.3294	768.6452	729.0826	1093.7403	97.7995	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	mNSGA-II	Feasible	703.1072	840.3656	759.4013	1629.0904	200.9010	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	NSGA-II	Feasible	697.5250	894.5203	793.5265	2270.3800	294.0191	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
G10	CGCSM	Feasible	11359.3530	14515.3490	13199.5510	20757.3260	3317.8333	5.0000
		Infeasible	0.0000	0.2530	0.2198	0.8224	0.1972	25.0000
	mIDEA	Feasible	11022.9560	15979.5150	16039.2490	21009.7940	3247.5869	12.0000
		Infeasible	0.0000	0.1603	0.0711	0.9349	0.2314	18.0000
	IDEA	Feasible	11229.9500	15279.5970	14828.4810	21254.6960	3075.8376	13.0000
		Infeasible	0.0000	0.1121	0.0248	0.5381	0.1559	17.0000
	mNSGA-II	Feasible	9490.0911	17176.5230	17285.0210	23230.9600	3813.8877	12.0000
		Infeasible	0.0000	0.1603	0.0711	0.9349	0.2314	18.0000
	NSGA-II	Feasible	11169.3000	16534.5230	16556.1000	23171.2000	3109.7093	13.0000
		Infeasible	0.0000	0.1121	0.0248	0.5381	0.1559	17.0000
G11	CGCSM	Feasible	0.7497	0.8467	0.8324	0.9948	0.0868	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	mIDEA	Feasible	0.7492	0.8335	0.8069	0.9889	0.0824	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	IDEA	Feasible	0.7490	0.8449	0.8212	0.9883	0.0853	29.0000
		Infeasible	0.0000	0.0000	0.0000	0.0002	0.0000	1.0000
	mNSGA-II	Feasible	0.7492	0.8194	0.7909	0.9968	0.0801	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	NSGA-II	Feasible	0.7492	0.8613	0.8598	0.9982	0.0834	29.0000
		Infeasible	0.0000	0.0000	0.0000	0.0002	0.0000	1.0000
Belleville_Spring	CGCSM	Feasible	2.2507	2.9440	2.6626	6.7106	0.9822	29.0000
		Infeasible	0.0000	0.0007	0.0000	0.0205	0.0037	1.0000
	mIDEA	Feasible	2.4326	3.3025	3.1011	6.6564	0.9821	27.0000
		Infeasible	0.0000	0.0040	0.0000	0.0813	0.0151	3.0000
	IDEA	Feasible	2.4369	3.0897	2.8994	4.9255	0.5972	29.0000
		Infeasible	0.0000	0.0006	0.0000	0.0167	0.0030	1.0000
	mNSGA-II	Feasible	2.3338	3.5097	3.1195	8.1684	1.2613	27.0000
		Infeasible	0.0000	0.0040	0.0000	0.0813	0.0151	3.0000
	NSGA-II	Feasible	2.2319	3.1649	2.9879	6.4377	0.8304	29.0000
		Infeasible	0.0000	0.0006	0.0000	0.0167	0.0030	1.0000

Table 4. Continued Statistics for Problems

Problem	Algorithms	Feasibility	Best	Mean	Median	Worst	Std	Success
Speed Reducer	CGCSM	Feasible	3000.0118	3024.7515	3014.0820	3182.4136	33.0295	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	mIDEA	Feasible	3005.9436	3118.6952	3032.6851	4383.6595	296.0062	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	IDEA	Feasible	3005.2093	3073.7129	3033.5242	3578.8939	116.8753	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	mNSGA-II	Feasible	3004.3306	3124.5127	3038.6579	3866.7508	219.8066	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pressure Vessel	CGCSM	Feasible	3007.6700	3138.1980	3042.9750	4152.7100	249.6746	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	CGCSM	Feasible	6106.6238	7392.0347	6930.6232	15990.4700	1855.4541	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	mIDEA	Feasible	6364.4815	7570.4664	7368.3561	10554.9510	979.5328	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	IDEA	Feasible	6472.8200	7528.5532	7389.1381	11412.7170	917.0340	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Welded Beam	mNSGA-II	Feasible	6126.1504	7015.1352	6854.0715	9961.4517	712.9438	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	NSGA-II	Feasible	6182.8500	7152.7067	7226.6350	8551.6500	541.2656	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	CGCSM	Feasible	2.4631	3.9029	3.6728	5.6493	0.9163	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	mIDEA	Feasible	2.4319	3.3477	2.9786	5.8209	0.8492	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Welded Beam	IDEA	Feasible	2.4873	3.4234	3.2579	6.0964	0.8510	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	mNSGA-II	Feasible	2.5981	3.7933	3.5483	5.8166	0.8523	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	NSGA-II	Feasible	2.5273	3.8105	3.6139	5.7451	0.8503	30.0000
		Infeasible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

2 Convergence plots

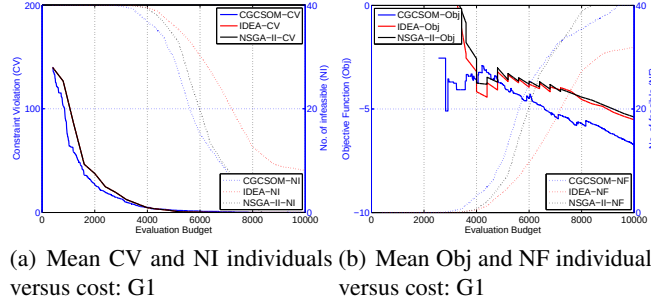


Fig. 1. Convergence plots: G1

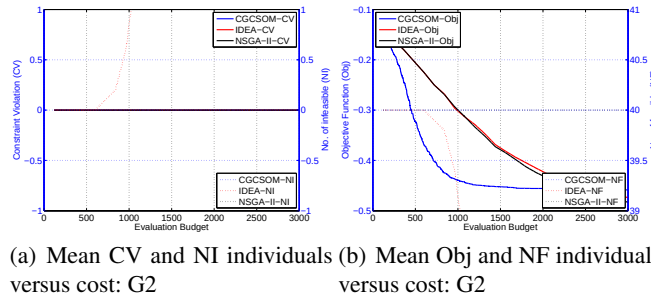


Fig. 2. Convergence plots: G2

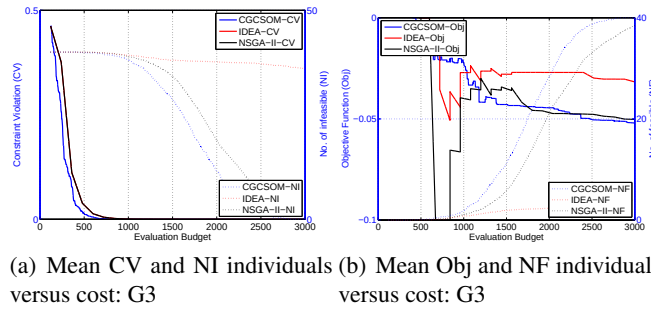
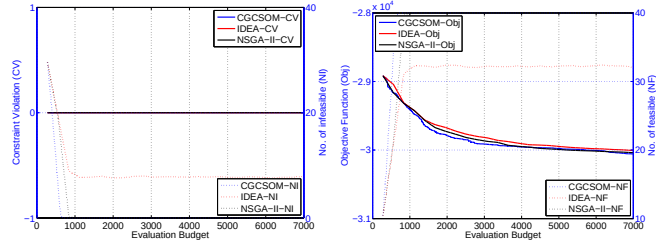
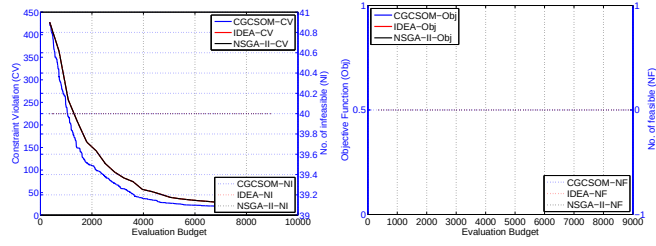


Fig. 3. Convergence plots: G3



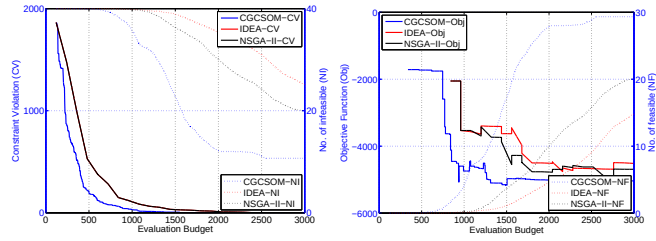
(a) Mean CV and NI individuals (b) Mean Obj and NF individuals
versus cost: G4

Fig. 4. Convergence plots: G4



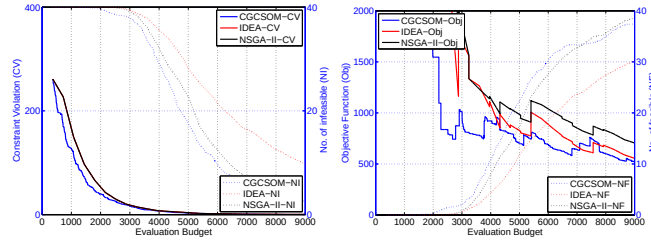
(a) Mean CV and NI individuals (b) Mean Obj and NF individuals
versus cost: G5

Fig. 5. Convergence plots: G5



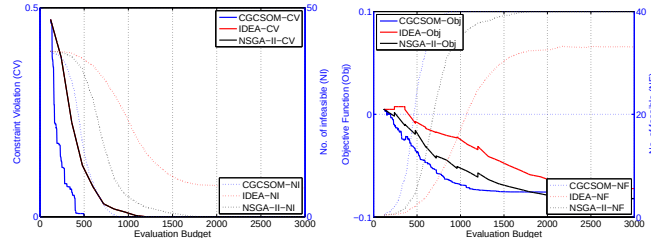
(a) Mean CV and NI individuals (b) Mean Obj and NF individuals
versus cost: G6

Fig. 6. Convergence plots: G6



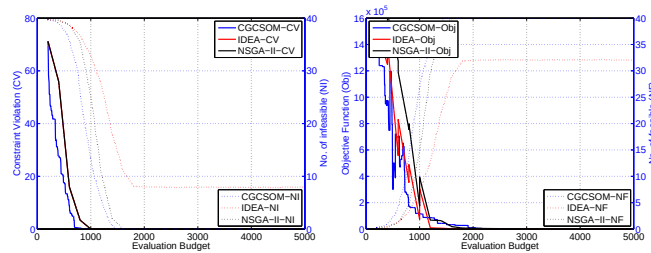
(a) Mean CV and NI individuals versus cost: G7 (b) Mean Obj and NF individuals versus cost: G7

Fig. 7. Convergence plots: G7



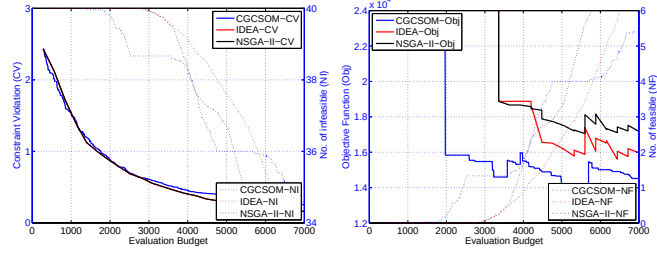
(a) Mean CV and NI individuals versus cost: G8 (b) Mean Obj and NF individuals versus cost: G8

Fig. 8. Convergence plots: G8



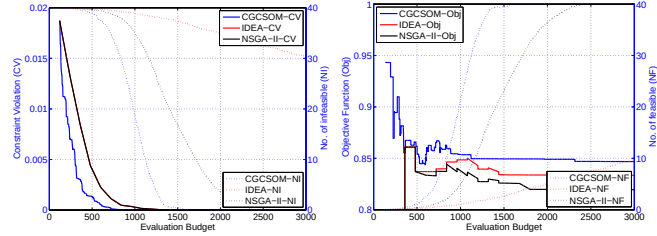
(a) Mean CV and NI individuals versus cost: G9 (b) Mean Obj and NF individuals versus cost: G9

Fig. 9. Convergence plots: G9



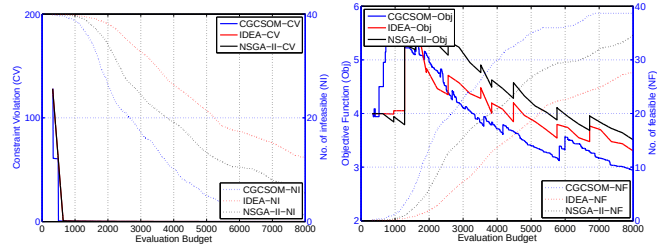
(a) Mean CV and NI individuals (b) Mean Obj and NF individuals versus cost: G10

Fig. 10. Convergence plots: G10



(a) Mean CV and NI individuals (b) Mean Obj and NF individuals versus cost: G11

Fig. 11. Convergence plots: G11



(a) Mean CV and NI individuals (b) Mean Obj and NF individuals versus cost: Belleville Spring

Fig. 12. Convergence plots: Belleville Spring

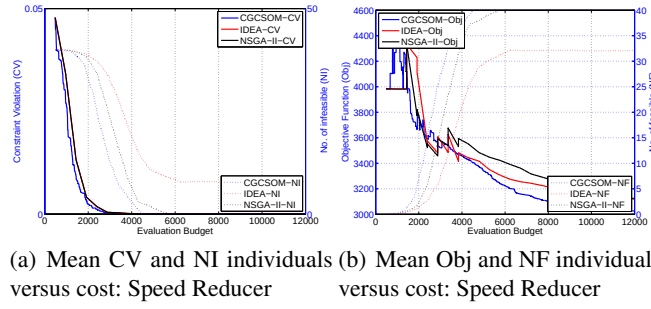


Fig. 13. Convergence plots: Speed Reducer

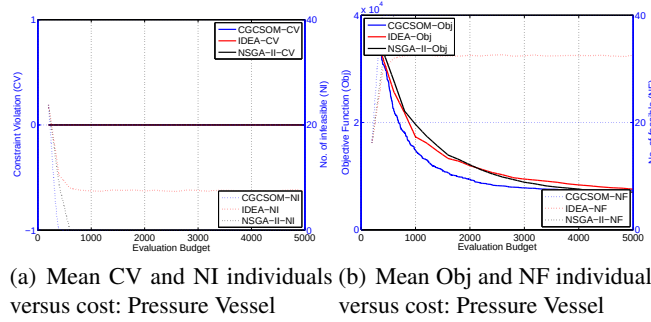


Fig. 14. Convergence plots: Pressure Vessel

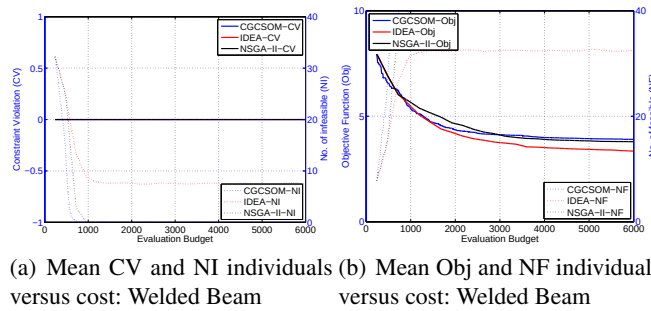


Fig. 15. Convergence plots: Welded Beam