

TABLE I

DM RESULTS OF SEVEN CMOEAs ON LIRCMOP TEST SUITE. “+”, “-”, OR “≈” INDICATES THAT THE CORRESPONDING ALGORITHM IS SIGNIFICANTLY BETTER THAN, WORSE THAN, OR COMPARABLE TO DPPCMO. THE BEST AVERAGE DM VALUE ON EACH TEST PROBLEM IS HIGHLIGHTED IN GRAY.

Problem	dpACS	PPS	CMOES	ToP	BiCo	CCMO	DPPCMO
MW1	9.7643e-1 (1.24e-2) -	8.5643e-1 (1.99e-1) -	1.0000e+0 (0.00e+0) ≈	7.7250e-1 (0.00e+0) -	9.9881e-1 (6.53e-3) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0)
MW2	8.4361e-1 (1.71e-1) +	3.9292e-1 (1.29e-1) -	7.2176e-1 (1.20e-1) +	1.0000e+0 (0.00e+0) ≈	7.0039e-1 (1.11e-1) ≈	6.4546e-1 (6.11e-2) ≈	6.6084e-1 (8.07e-2)
MW3	8.1516e-1 (2.45e-2) -	7.7613e-1 (1.87e-2) -	8.4628e-1 (1.87e-2) ≈	7.1592e-1 (3.20e-1) ≈	8.4870e-1 (1.90e-2) ≈	8.5123e-1 (1.95e-2) ≈	8.5323e-1 (1.63e-2)
MW4	2.9957e-1 (1.25e-2) -	7.3765e-1 (1.74e-2) +	6.3519e-1 (2.28e-2) +	3.4758e-1 (2.87e-2) -	6.3203e-1 (2.24e-2) +	6.1553e-1 (2.34e-2) ≈	6.1709e-1 (2.57e-2)
MW5	8.7982e-1 (8.02e-2) -	1.8106e-1 (1.08e-1) -	9.3032e-1 (3.85e-2) ≈	6.5333e-1 (3.78e-1) ≈	8.9923e-1 (1.49e-1) ≈	8.9770e-1 (1.32e-1) ≈	9.2610e-1 (3.36e-2)
MW6	9.2101e-1 (2.34e-2) ≈	2.9618e-1 (1.22e-1) -	9.2990e-1 (7.13e-2) ≈	3.7859e-1 (1.15e-1) -	9.6781e-1 (2.78e-2) +	8.6211e-1 (8.04e-2) -	9.2010e-1 (5.69e-2)
MW7	7.8623e-1 (2.31e-2) -	8.3515e-1 (2.25e-2) -	9.1271e-1 (1.20e-2) -	6.3024e-1 (1.67e-1) -	9.0621e-1 (2.06e-2) -	9.0706e-1 (1.79e-2) -	9.2262e-1 (1.22e-2)
MW8	6.1690e-1 (1.45e-2) -	7.4672e-1 (3.79e-2) +	6.9643e-1 (1.85e-2) ≈	3.9628e-1 (3.25e-1) -	7.0032e-1 (1.84e-2) ≈	6.8461e-1 (1.95e-2) -	6.9562e-1 (1.94e-2)
MW9	7.6211e-1 (2.37e-2) -	5.4309e-1 (2.00e-1) -	8.3151e-1 (9.85e-2) ≈	5.2141e-1 (1.25e-1) -	8.3601e-1 (1.54e-2) -	8.4675e-1 (1.56e-2) ≈	8.4858e-1 (1.15e-2)
MW10	9.0404e-1 (5.62e-2) +	3.7278e-1 (1.83e-1) -	8.6687e-1 (3.90e-2) ≈	NaN (NaN)	8.5521e-1 (6.59e-2) ≈	8.3275e-1 (7.91e-2) ≈	8.6430e-1 (5.00e-2)
MW11	7.4711e-1 (3.07e-2) -	8.0338e-1 (2.11e-2) -	8.3745e-1 (1.26e-2) ≈	4.1009e-1 (6.20e-2) -	8.4660e-1 (1.53e-2) ≈	8.3754e-1 (1.94e-2) ≈	8.3881e-1 (1.54e-2)
MW12	8.2739e-1 (1.50e-2) -	6.4307e-1 (1.69e-1) -	8.7028e-1 (1.84e-2) ≈	4.1661e-1 (7.04e-2) -	8.6340e-1 (1.31e-2) -	8.7134e-1 (1.13e-2) ≈	8.7581e-1 (1.00e-2)
MW13	8.9659e-1 (8.67e-2) +	3.4172e-1 (1.53e-1) -	7.9661e-1 (1.08e-1) ≈	2.0910e-1 (1.57e-1) -	9.2575e-1 (8.44e-2) +	7.6605e-1 (1.35e-1) ≈	7.9163e-1 (8.84e-2)
MW14	5.7567e-1 (4.05e-2) -	8.5821e-1 (2.90e-2) +	6.3126e-1 (2.87e-2) ≈	6.6487e-1 (3.15e-1) ≈	7.1466e-1 (3.04e-2) +	6.3696e-1 (2.97e-2) ≈	6.2035e-1 (2.92e-2)
LIRCMOP1	4.3496e-1 (4.65e-2) -	7.8316e-1 (3.73e-2) +	6.2203e-1 (9.20e-2) -	5.1878e-1 (2.19e-1) -	7.2355e-1 (4.68e-2) ≈	5.8664e-1 (8.95e-2) -	7.2303e-1 (6.18e-2)
LIRCMOP2	5.4763e-1 (1.30e-1) -	8.0646e-1 (1.97e-2) +	5.8980e-1 (7.83e-2) -	5.5518e-1 (2.24e-1) -	7.8557e-1 (3.08e-2) +	5.1432e-1 (1.15e-1) -	7.5826e-1 (6.69e-2)
LIRCMOP3	4.4984e-1 (9.85e-2) -	8.8703e-1 (4.35e-2) +	5.4740e-1 (6.82e-2) -	1.5103e-1 (5.76e-2) -	7.8708e-1 (6.44e-2) +	4.4656e-1 (1.03e-1) -	7.4361e-1 (7.88e-2)
LIRCMOP4	4.7953e-1 (1.03e-1) -	9.5403e-1 (1.97e-2) +	5.7458e-1 (1.01e-1) -	1.3849e-1 (4.37e-2) -	8.0135e-1 (7.64e-2) ≈	4.5914e-1 (8.55e-2) -	7.6543e-1 (9.38e-2)
LIRCMOP5	8.9218e-1 (1.40e-2) +	7.3792e-1 (2.07e-2) -	8.3786e-1 (1.57e-2) -	7.4980e-1 (1.27e-1) -	4.2333e-1 (1.77e-1) -	8.4920e-1 (1.61e-2) ≈	8.4905e-1 (1.30e-2)
LIRCMOP6	8.6271e-1 (1.54e-2) ≈	7.1590e-1 (2.41e-2) -	8.6207e-1 (1.22e-2) -	7.9422e-1 (1.23e-1) -	6.2729e-1 (1.54e-1) -	8.6322e-1 (1.35e-2) -	8.7106e-1 (1.27e-2)
LIRCMOP7	8.5155e-1 (2.91e-2) -	7.8351e-1 (2.00e-2) -	8.9791e-1 (1.69e-2) ≈	8.4076e-1 (2.29e-2) -	8.6599e-1 (2.89e-2) -	8.9906e-1 (1.44e-2) ≈	8.9937e-1 (1.64e-2)
LIRCMOP8	8.6256e-1 (2.51e-2) -	7.8028e-1 (2.08e-2) -	8.9609e-1 (1.78e-2) ≈	8.3321e-1 (2.70e-2) -	8.8269e-1 (2.88e-2) -	9.0052e-1 (1.48e-2) ≈	9.0420e-1 (1.99e-2)
LIRCMOP9	9.8197e-1 (1.17e-2) -	9.9460e-1 (1.10e-2) -	1.0000e+0 (0.00e+0) ≈	6.4165e-1 (2.75e-1) -	7.3401e-1 (1.08e-1) -	9.9852e-1 (4.53e-3) ≈	1.0000e+0 (0.00e+0)
LIRCMOP10	9.4812e-1 (1.59e-2) -	9.2940e-1 (1.80e-2) -	9.8844e-1 (3.53e-3) ≈	9.6992e-1 (1.74e-2) -	8.2785e-1 (1.91e-1) -	9.8822e-1 (4.98e-3) ≈	9.8850e-1 (4.16e-3)
LIRCMOP11	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	7.0046e-1 (1.19e-1) -	9.8848e-1 (4.38e-2) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0)
LIRCMOP12	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	9.2723e-1 (1.25e-1) -	9.6575e-1 (5.78e-2) -	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0)
LIRCMOP13	5.3716e-1 (9.45e-3) -	7.5805e-1 (1.93e-2) +	6.8548e-1 (1.95e-2) ≈	7.8837e-1 (1.22e-2) +	6.9438e-1 (1.93e-2) ≈	6.7570e-1 (1.56e-2) -	6.9152e-1 (1.85e-2)
LIRCMOP14	5.8132e-1 (1.44e-2) -	7.9012e-1 (1.41e-2) +	6.8542e-1 (1.49e-2) ≈	7.8557e-1 (1.17e-2) +	6.8936e-1 (1.77e-2) ≈	6.8737e-1 (1.87e-2) ≈	6.8466e-1 (1.77e-2)
DASCMP1	8.6029e-1 (4.07e-2) -	7.0610e-1 (2.10e-1) -	9.3287e-1 (1.72e-2) ≈	2.1499e-1 (1.44e-1) -	3.4019e-1 (6.45e-2) -	9.2466e-1 (1.91e-2) -	9.4489e-1 (1.99e-2)
DASCMP2	8.2753e-1 (2.63e-2) -	8.0158e-1 (1.57e-2) -	8.6968e-1 (1.96e-2) ≈	2.2270e-1 (1.84e-1) -	2.4974e-1 (3.52e-2) -	8.6848e-1 (1.24e-2) ≈	8.7222e-1 (1.85e-2)
DASCMP3	8.5047e-1 (3.05e-2) -	5.0556e-1 (1.99e-1) -	8.7263e-1 (3.61e-2) ≈	3.4445e-1 (2.02e-1) -	3.7652e-1 (5.73e-2) -	8.6457e-1 (3.01e-2) ≈	8.7313e-1 (3.43e-2)
DASCMP4	8.9863e-1 (7.92e-2) -	6.6614e-1 (1.11e-1) -	9.3797e-1 (1.30e-1) -	NaN (NaN)	9.9075e-1 (7.97e-3) ≈	9.9168e-1 (5.84e-3) ≈	9.9275e-1 (0.00e+0)
DASCMP5	8.0490e-1 (6.92e-2) -	8.8687e-1 (2.96e-2) -	9.4383e-1 (2.19e-2) -	NaN (NaN)	9.6195e-1 (9.16e-3) ≈	9.6231e-1 (5.32e-3) ≈	9.6406e-1 (2.68e-3)
DASCMP6	7.9253e-1 (1.11e-1) -	7.4030e-1 (1.72e-1) -	8.3793e-1 (6.52e-2) -	NaN (NaN)	8.2351e-1 (1.45e-1) ≈	8.5377e-1 (4.64e-2) ≈	8.7767e-1 (2.57e-2)
DASCMP7	6.1875e-1 (3.21e-2) -	7.4374e-1 (1.59e-2) +	6.3735e-1 (1.27e-1) -	NaN (NaN)	6.8900e-1 (1.70e-2) ≈	6.8588e-1 (1.74e-2) ≈	6.8959e-1 (1.31e-2)
DASCMP8	6.1632e-1 (3.54e-2) -	7.2968e-1 (3.46e-2) +	6.7832e-1 (8.21e-2) ≈	NaN (NaN)	6.9279e-1 (1.70e-2) ≈	6.8744e-1 (1.81e-2) -	6.9566e-1 (1.49e-2)
DASCMP9	6.6279e-1 (2.01e-2) -	7.1012e-1 (3.05e-2) ≈	6.9619e-1 (1.37e-2) ≈	3.0546e-1 (2.22e-1) -	5.6670e-1 (3.29e-2) -	6.9384e-1 (1.50e-2) ≈	6.9453e-1 (1.59e-2)
DOC1	7.4304e-1 (3.03e-2) -	4.1967e-1 (1.07e-1) -	7.4640e-1 (1.08e-1) -	7.8851e-1 (1.59e-2) -	8.6012e-1 (3.13e-2) +	8.1415e-1 (1.62e-2) -	8.3447e-1 (1.28e-2)
DOC2	3.5177e-1 (1.44e-1) -	1.1368e-1 (8.63e-2) -	NaN (NaN)	2.8298e-1 (5.53e-2) -	NaN (NaN)	9.2482e-1 (1.39e-1) ≈	9.5647e-1 (2.07e-2)
DOC3	4.9009e-1 (3.47e-1) -	3.5068e-1 (1.69e-1) -	8.7542e-1 (1.01e-1) -	7.3449e-1 (6.28e-2) -	9.4518e-1 (2.59e-2) +	9.0652e-1 (6.68e-2) ≈	9.2042e-1 (3.11e-2)
DOC4	4.1444e-1 (1.90e-1) +	2.2031e-1 (6.90e-2) +	1.2074e-1 (3.70e-2) +	2.7778e-1 (3.22e-1) ≈	3.6186e-1 (1.54e-1) +	1.4210e-1 (9.21e-2) +	7.7592e-2 (4.69e-3)
DOC5	7.1059e-1 (1.44e-1) +	3.3926e-1 (1.44e-1) +	2.1880e-1 (1.82e-1) ≈	7.7425e-1 (9.44e-2) +	NaN (NaN)	2.4919e-1 (1.76e-1) ≈	1.7892e-1 (1.57e-1)
DOC6	1.0947e-1 (5.56e-2) -	5.8646e-2 (3.16e-2) -	6.1766e-1 (3.41e-1) -	1.0448e-1 (5.67e-2) -	5.1164e-1 (3.29e-1) -	8.3776e-1 (9.50e-2) -	8.9014e-1 (8.38e-3)
DOC7	6.7790e-1 (1.06e-1) -	1.2768e-1 (1.15e-1) -	8.3719e-1 (1.42e-1) ≈	6.3033e-1 (1.82e-1) -	1.5204e-1 (8.47e-17) -	8.7381e-1 (3.52e-2) ≈	8.7965e-1 (9.89e-3)
DOC8	3.5125e-1 (8.46e-2) -	3.0864e-2 (1.56e-2) -	6.6149e-1 (1.82e-2) ≈	9.8077e-2 (4.78e-2) -	9.5957e-2 (7.07e-2) -	6.6634e-1 (1.91e-2) ≈	6.7070e-1 (1.89e-2)
DOC9	5.9990e-1 (2.41e-2) -	5.1798e-1 (4.81e-2) -	6.4573e-1 (2.03e-2) -	6.9902e-1 (2.03e-2) +	6.5203e-1 (3.56e-2) ≈	6.4264e-1 (1.64e-2) -	6.5514e-1 (1.47e-2)
+ / - / ≈	6/36/4	13/30/3	3/15/27	4/31/5	9/17/18	1/14/31	