A Comparative study of MOEAs

This appendix presents a comparative study of the algorithms MOMBI, MOEA/D and SMS-EMOA for the so-called DTLZ (Deb-Thiele-Laumanns-Zitzler) and the WFG (Walking-Fish-Group) test problems, scaled up to 8 objectives.

In all the tables, the best results are shown in **boldface** and the second best ones in *italics*. The following notation is used:

avg: Average or mean

med: Median

worst: Worst value

best: Best value

var: Variance

std: Standard deviation

m : Number of objective functions

The source code of MOMBI is available for download at:

`http://computacion.cs.cinvestav.mx/~rhernandez/mombi`

Table 1: Comparison of results for the DTLZ1-3. Average and median hypervolume.

m	**MOMBI**		**MOEA/D**		**SMS-EMOA**	
	avg	med	avg	med	avg	med
DTLZ1						
2	**8.737838e-01**	**8.738272e-01**	*8.737470e-01*	*8.737779e-01*	8.735790e-01	8.735806e-01
3	*9.693597e-01*	*9.694435e-01*	9.689446e-01	9.689222e-01	**9.738787e-01**	**9.740816e-01**
4	9.854892e-01	9.860312e-01	*9.884462e-01*	*9.884473e-01*	**9.924153e-01**	**9.941116e-01**
5	*9.919373e-01*	*9.924734e-01*	**9.932330e-01**	**9.966979e-01**	9.878291e-01	9.915189e-01
6	*9.944634e-01*	*9.942771e-01*	**9.955037e-01**	**9.965058e-01**	9.656273e-01	9.920703e-01
7	*9.752993e-01*	9.748683e-01	**9.865474e-01**	*9.887172e-01*	9.533103e-01	**9.962981e-01**
8	**9.845829e-01**	9.853806e-01	*9.805640e-01*	*9.855604e-01*	9.354406e-01	**9.935489e-01**
DTLZ2						
2	*3.210785e+00*	*3.210796e+00*	**3.210866e+00**	**3.210866e+00**	3.210667e+00	3.210664e+00
3	*7.388812e+00*	*7.388791e+00*	7.383274e+00	7.383043e+00	**7.427998e+00**	**7.428039e+00**
4	1.542186e+01	1.542176e+01	*1.542219e+01*	*1.542203e+01*	**1.558163e+01**	**1.558159e+01**
5	*3.153492e+01*	*3.153469e+01*	3.153351e+01	3.153369e+01	**3.168830e+01**	**3.168853e+01**
6	*6.299770e+01*	*6.300968e+01*	6.287641e+01	6.283400e+01	**6.375897e+01**	**6.375919e+01**
7	*1.226035e+02*	*1.229920e+02*	1.219099e+02	1.222005e+02	**1.277801e+02**	**1.277806e+02**
8	*2.453361e+02*	*2.458807e+02*	2.438129e+02	2.445200e+02	**2.558339e+02**	**2.558344e+02**
DTLZ3						
2	**4.820292e+01**	**4.820398e+01**	*4.820122e+01*	*4.820174e+01*	4.819756e+01	4.820018e+01
3	*3.423640e+02*	*3.423676e+02*	**3.423744e+02**	**3.423740e+02**	3.391415e+02	3.419464e+02
4	**2.400275e+03**	*2.400304e+03*	*2.400109e+03*	**2.400407e+03**	1.524083e+03	1.785140e+03
5	**1.680506e+04**	*1.680599e+04*	*1.680405e+04*	**1.680650e+04**	2.303193e+03	0.000000e+00
6	*1.175943e+05*	**1.176418e+05**	**1.176068e+05**	*1.176351e+05*	4.276067e+03	0.000000e+00
7	**8.228736e+05**	**8.231896e+05**	*8.224488e+05*	*8.231023e+05*	4.508892e+04	0.000000e+00
8	*5.752984e+06*	**5.762455e+06**	**5.756130e+06**	*5.757882e+06*	9.710261e+04	0.000000e+00

Table 2: Comparison of results for the DTLZ1-3. The worst and best hypervolume values.

m	**MOMBI**		**MOEA/D**		**SMS-EMOA**	
	worst	best	worst	best	worst	best
DTLZ1						
2	*8.733190e-01*	*8.738930e-01*	**8.734058e-01**	**8.739416e-01**	8.731759e-01	8.737237e-01
3	9.667351e-01	*9.709102e-01*	*9.687122e-01*	9.691861e-01	**9.709828e-01**	**9.742155e-01**
4	*9.782559e-01*	*9.891786e-01*	**9.882444e-01**	9.885390e-01	9.770578e-01	**9.943260e-01**
5	**9.842134e-01**	9.958678e-01	8.975375e-01	*9.968151e-01*	*9.063102e-01*	**9.986221e-01**
6	*9.875859e-01*	9.978102e-01	**9.904039e-01**	*9.979095e-01*	6.540521e-01	**9.996050e-01**
7	**9.624802e-01**	9.887261e-01	*9.596363e-01*	*9.957675e-01*	2.973475e-01	**9.997679e-01**
8	**9.745476e-01**	9.909587e-01	*9.526351e-01*	*9.945560e-01*	5.532846e-01	**9.995879e-01**
DTLZ2						
2	*3.210539e+00*	3.210810e+00	**3.210850e+00**	*3.210874e+00*	3.210381e+00	**3.210903e+00**
3	*7.383491e+00*	*7.394204e+00*	7.382361e+00	7.384527e+00	**7.427345e+00**	**7.428834e+00**
4	1.542022e+01	*1.542350e+01*	*1.542127e+01*	1.542327e+01	**1.557930e+01**	**1.558298e+01**
5	*3.153380e+01*	*3.153708e+01*	3.153136e+01	3.153412e+01	**3.168494e+01**	**3.168969e+01**
6	*6.286845e+01*	*6.308026e+01*	6.277073e+01	6.303191e+01	**6.375517e+01**	**6.376203e+01**
7	*1.206289e+02*	1.231135e+02	1.198549e+02	*1.231595e+02*	**1.277760e+02**	**1.277839e+02**
8	*2.410877e+02*	*2.465602e+02*	2.365561e+02	2.462847e+02	**2.558220e+02**	**2.558403e+02**
DTLZ3						
2	**4.818106e+01**	**4.820967e+01**	*4.817882e+01*	*4.820900e+01*	4.816393e+01	4.820799e+01
3	*3.423210e+02*	3.423830e+02	**3.423626e+02**	*3.423843e+02*	3.258967e+02	**3.424030e+02**
4	**2.399323e+03**	*2.400391e+03*	*2.391518e+03*	**2.400423e+03**	0.000000e+00	2.399561e+03
5	**1.677934e+04**	*1.680616e+04*	*1.675689e+04*	**1.680653e+04**	0.000000e+00	1.642005e+04
6	*1.164424e+05*	*1.176435e+05*	**1.173921e+05**	**1.176451e+05**	0.000000e+00	5.472079e+04
7	**8.183400e+05**	*8.232538e+05*	*8.087476e+05*	**8.233468e+05**	0.000000e+00	6.472830e+05
8	*5.548677e+06*	*5.762705e+06*	**5.707150e+06**	**5.763270e+06**	0.000000e+00	1.929852e+06

Table 3: Comparison of results for the DTLZ1-3. Variance and standard deviation of the hypervolume.

m	**MOMBI**		**MOEA/D**		**SMS-EMOA**	
	var	std	var	std	var	std
DTLZ1						
2	**1.459811e-08**	1.208226e-04	2.294091e-08	1.514626e-04	*1.501822e-08*	1.225488e-04
3	1.059556e-06	1.029347e-03	**1.163207e-08**	1.078521e-04	*4.506492e-07*	6.713041e-04
4	*6.649098e-06*	2.578585e-03	**4.086904e-09**	6.392890e-05	1.246312e-05	3.530314e-03
5	**7.402363e-06**	2.720728e-03	3.166095e-04	1.779352e-02	*2.875938e-04*	1.695859e-02
6	*4.917218e-06*	2.217480e-03	**4.753888e-06**	2.180341e-03	7.237671e-03	8.507450e-02
7	**4.623612e-05**	6.799715e-03	*7.814122e-05*	8.839753e-03	1.838327e-02	1.355849e-01
8	**1.173196e-05**	3.425195e-03	*1.390863e-04*	1.179349e-02	1.535658e-02	1.239217e-01
DTLZ2						
2	*2.206587e-09*	4.697432e-05	**2.842526e-11**	5.331535e-06	1.791364e-08	1.338418e-04
3	6.198492e-06	2.489677e-03	*4.113619e-07*	6.413750e-04	**1.235401e-07**	3.514827e-04
4	*4.582699e-07*	6.769564e-04	**2.966405e-07**	5.446471e-04	5.400805e-07	7.349017e-04
5	*3.870119e-07*	6.221028e-04	**3.461378e-07**	5.883347e-04	1.326909e-06	1.151915e-03
6	*4.129402e-03*	6.426043e-02	5.213918e-03	7.220747e-02	**2.168917e-06**	1.472724e-03
7	*3.494065e-01*	5.911061e-01	8.591921e-01	9.269262e-01	**5.006217e-06**	2.237458e-03
8	*1.458295e+00*	1.207599e+00	5.579613e+00	2.362120e+00	**1.869281e-05**	4.323518e-03
DTLZ3						
2	**3.529584e-05**	5.941030e-03	*3.784527e-05*	6.151851e-03	1.287662e-04	1.134752e-02
3	*1.943689e-04*	1.394163e-02	**3.316248e-05**	5.758687e-03	1.757312e+01	4.192030e+00
4	**3.426462e-02**	1.851071e-01	*2.545110e+00*	1.595340e+00	7.845500e+05	8.857483e+02
5	**2.288445e+01**	4.783769e+00	*8.582766e+01*	9.264322e+00	2.655732e+07	5.153380e+03
6	*4.735598e+04*	2.176143e+02	**4.843328e+03**	6.959402e+01	1.527236e+08	1.235814e+04
7	**1.363299e+06**	1.167604e+03	*6.725919e+06*	2.593438e+03	1.747927e+10	1.322092e+05
8	*1.517234e+09*	3.895169e+04	**1.092395e+08**	1.045177e+04	1.469398e+11	3.833273e+05

Table 4: Comparison of results for the DTLZ4-6. Average and median hypervolume.

m	**MOMBI**		**MOEA/D**		**SMS-EMOA**	
	avg	med	avg	med	avg	med
DTLZ4						
2	**3.089723e+00**	**3.210805e+00**	2.565073e+00	2.000000e+00	*3.008898e+00*	*3.210623e+00*
3	**7.292802e+00**	*7.390455e+00*	6.479912e+00	6.411924e+00	*7.126184e+00*	**7.428099e+00**
4	**1.518143e+01**	*1.542176e+01*	1.420544e+01	1.465531e+01	*1.509114e+01*	**1.558281e+01**
5	**3.128310e+01**	**3.151300e+01**	2.868783e+01	2.913078e+01	*3.076816e+01*	*3.117124e+01*
6	*6.278644e+01*	*6.289587e+01*	6.022725e+01	6.142748e+01	**6.337518e+01**	**6.376357e+01**
7	*1.221849e+02*	1.222819e+02	1.171185e+02	*1.225496e+02*	**1.272727e+02**	**1.274773e+02**
8	*2.443096e+02*	2.443970e+02	2.419017e+02	*2.451337e+02*	**2.554984e+02**	**2.558241e+02**
DTLZ5						
2	*1.521078e+01*	*1.521079e+01*	**1.521085e+01**	**1.521085e+01**	1.521065e+01	1.521064e+01
3	*5.984359e+01*	*5.984314e+01*	5.984289e+01	5.984300e+01	**5.986865e+01**	**5.986890e+01**
4	*2.392736e+02*	**2.393134e+02**	2.387649e+02	2.388609e+02	**2.392747e+02**	*2.392738e+02*
5	*9.494039e+02*	*9.494269e+02*	9.452332e+02	9.456087e+02	**9.579889e+02**	**9.580378e+02**
6	*3.768958e+03*	*3.771098e+03*	3.746660e+03	3.752986e+03	**3.834024e+03**	**3.834075e+03**
7	*1.494773e+04*	*1.494851e+04*	1.492053e+04	1.492046e+04	**1.529317e+04**	**1.529217e+04**
8	*5.983042e+04*	*5.978726e+04*	5.946643e+04	5.954670e+04	**6.129900e+04**	**6.130386e+04**
DTLZ6						
2	*1.201014e+02*	*1.200988e+02*	1.200361e+02	1.200263e+02	**1.201015e+02**	**1.201069e+02**
3	*1.317979e+03*	*1.317907e+03*	1.316642e+03	1.316558e+03	**1.318087e+03**	**1.318069e+03**
4	*1.447895e+04*	*1.448000e+04*	**1.448415e+04**	**1.448493e+04**	1.447694e+04	1.447656e+04
5	1.559276e+05	1.560669e+05	*1.582229e+05*	*1.582452e+05*	**1.592911e+05**	**1.592990e+05**
6	1.697309e+06	1.699201e+06	*1.732222e+06*	*1.731748e+06*	**1.752823e+06**	**1.752826e+06**
7	1.869272e+07	1.869916e+07	*1.907810e+07*	*1.909405e+07*	**1.932404e+07**	**1.932463e+07**
8	2.037302e+08	2.040410e+08	*2.099493e+08*	*2.099767e+08*	**2.121759e+08**	**2.121788e+08**

Table 5: Comparison of results for the DTLZ4-6. The worst and best hypervolume values.

m	**MOMBI**		**MOEA/D**		**SMS-EMOA**	
	worst	best	worst	best	worst	best
DTLZ4						
2	**2.000000e+00**	3.210826e+00	**2.000000e+00**	**3.210875e+00**	**2.000000e+00**	*3.210838e+00*
3	*6.408235e+00*	*7.395256e+00*	4.000000e+00	7.392313e+00	**6.420637e+00**	**7.428791e+00**
4	**1.462969e+01**	1.542828e+01	8.000000e+00	*1.543174e+01*	*1.284269e+01*	**1.558433e+01**
5	**2.996869e+01**	*3.153904e+01*	1.600000e+01	3.153382e+01	*2.568321e+01*	**3.169264e+01**
6	**6.140849e+01**	*6.310301e+01*	5.046536e+01	6.306855e+01	*5.943386e+01*	**6.376570e+01**
7	*1.199916e+02*	*1.234131e+02*	6.400000e+01	1.232026e+02	**1.245053e+02**	**1.277884e+02**
8	*2.409677e+02*	*2.471436e+02*	2.010005e+02	2.464040e+02	**2.533435e+02**	**2.558493e+02**
DTLZ5						
2	*1.521069e+01*	1.521081e+01	**1.521080e+01**	*1.521087e+01*	1.521018e+01	**1.521093e+01**
3	5.983688e+01	*5.985228e+01*	*5.984179e+01*	5.984312e+01	**5.986334e+01**	**5.987059e+01**
4	*2.388601e+02*	**2.394522e+02**	2.372344e+02	2.391232e+02	**2.389941e+02**	*2.394274e+02*
5	*9.462922e+02*	*9.528128e+02*	9.405529e+02	9.469182e+02	**9.572203e+02**	**9.585363e+02**
6	*3.745145e+03*	*3.796591e+03*	3.685495e+03	3.754181e+03	**3.828997e+03**	**3.837509e+03**
7	1.479799e+04	*1.505278e+04*	*1.488577e+04*	1.495100e+04	**1.527304e+04**	**1.531982e+04**
8	*5.946667e+04*	*6.025458e+04*	5.897761e+04	5.961061e+04	**6.120124e+04**	**6.136996e+04**
DTLZ6						
2	**1.200254e+02**	*1.201725e+02*	1.199395e+02	1.201432e+02	*1.199930e+02*	**1.201745e+02**
3	*1.317240e+03*	*1.318937e+03*	1.315046e+03	1.317571e+03	**1.317264e+03**	**1.319034e+03**
4	1.445592e+04	*1.449446e+04*	**1.447070e+04**	**1.450287e+04**	*1.446564e+04*	1.448634e+04
5	1.537251e+05	1.570948e+05	*1.573286e+05*	*1.589276e+05*	**1.591933e+05**	**1.593868e+05**
6	1.665978e+06	1.714947e+06	*1.725615e+06*	*1.740175e+06*	**1.752010e+06**	**1.753679e+06**
7	1.840819e+07	1.890470e+07	*1.888998e+07*	*1.914071e+07*	**1.930991e+07**	**1.933356e+07**
8	1.997738e+08	2.064967e+08	*2.087144e+08*	*2.107991e+08*	**2.119580e+08**	**2.123135e+08**

Table 6: Comparison of results for the DTLZ4-6. Variance and standard deviation of the hypervolume.

m	**MOMBI**		**MOEA/D**		**SMS-EMOA**	
	var	std	var	std	var	std
DTLZ4						
2	**1.319440e-01**	3.632409e-01	3.649225e-01	6.040881e-01	*2.035752e-01*	4.511931e-01
3	**8.669599e-02**	2.944418e-01	1.150576e+00	1.072649e+00	*2.129874e-01*	4.615056e-01
4	**1.231362e-01**	3.509076e-01	3.284656e+00	1.812362e+00	*6.673058e-01*	8.168878e-01
5	**1.543006e-01**	3.928111e-01	1.427819e+01	3.778649e+00	*3.114470e+00*	1.764786e+00
6	**1.673714e-01**	4.091105e-01	8.630370e+00	2.937749e+00	*7.161790e-01*	8.462736e-01
7	*6.682623e-01*	8.174731e-01	2.297692e+02	1.515814e+01	**6.624556e-01**	8.139137e-01
8	*1.913835e+00*	1.383414e+00	7.854372e+01	8.862490e+00	**3.991870e-01**	6.318125e-01
DTLZ5						
2	*8.539871e-10*	2.922306e-05	**2.558522e-10**	1.599538e-05	2.803563e-08	1.674384e-04
3	1.350014e-05	3.674254e-03	**8.175721e-08**	2.859322e-04	*2.171678e-06*	1.473661e-03
4	*2.248387e-02*	1.499462e-01	1.397225e-01	3.737947e-01	**7.546374e-03**	8.686987e-02
5	3.697980e+00	1.923013e+00	*1.848924e+00*	1.359752e+00	**1.374457e-01**	3.707367e-01
6	*1.087160e+02*	1.042670e+01	2.145042e+02	1.464596e+01	**3.759553e+00**	1.938957e+00
7	2.723981e+03	5.219177e+01	**7.759201e+01**	8.808633e+00	*1.689735e+02*	1.299898e+01
8	3.629716e+04	1.905181e+02	*3.172888e+04*	1.781260e+02	**1.854971e+03**	4.306937e+01
DTLZ6						
2	**1.650838e-03**	4.063050e-02	*2.505946e-03*	5.005943e-02	2.903787e-03	5.388680e-02
3	*1.667936e-01*	4.084037e-01	2.954994e-01	5.435986e-01	**1.658808e-01**	4.072846e-01
4	8.780643e+01	9.370509e+00	*8.545985e+01*	9.244450e+00	**2.434329e+01**	4.933892e+00
5	7.542864e+05	8.684967e+02	*8.902333e+04*	2.983678e+02	**1.517074e+03**	3.894964e+01
6	1.067347e+08	1.033125e+04	*1.382287e+07*	3.717912e+03	**2.489803e+05**	4.989793e+02
7	1.691323e+10	1.300509e+05	*2.997626e+09*	5.475058e+04	**3.289251e+07**	5.735199e+03
8	2.451991e+12	1.565883e+06	*2.850958e+11*	5.339436e+05	**4.983986e+09**	7.059735e+04

Table 7: Comparison of results for the DTLZ7. Average and median hypervolume.

m	**MOMBI**		**MOEA/D**		**SMS-EMOA**	
	avg	med	avg	med	avg	med
DTLZ7						
2	**3.915723e+02**	3.915723e+02	3.872996e+02	*3.915769e+02*	*3.915701e+02*	**3.915812e+02**
3	**8.029312e+03**	8.065059e+03	7.796863e+03	**8.065685e+03**	*7.975963e+03*	*8.065684e+03*
4	**1.647751e+05**	1.658869e+05	1.592594e+05	**1.660293e+05**	*1.622055e+05*	*1.659562e+05*
5	**3.368343e+06**	**3.406735e+06**	*3.139535e+06*	*3.178907e+06*	3.093805e+06	3.170281e+06
6	**6.683026e+07**	**6.990758e+07**	*6.276078e+07*	*6.522038e+07*	5.937294e+07	5.980248e+07
7	**1.197319e+09**	**1.227703e+09**	*1.177091e+09*	*1.129458e+09*	1.107867e+09	1.021514e+09
8	**2.461092e+10**	**2.503113e+10**	*2.314593e+10*	*2.301334e+10*	2.007093e+10	1.937868e+10

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Table 8: Comparison of results for the DTLZ7. The worst and best hypervolume values.

m	**MOMBI**		**MOEA/D**		**SMS-EMOA**	
	worst	best	worst	best	worst	best
DTLZ7						
2	**3.915723e+02**	3.915724e+02	3.659104e+02	*3.915806e+02*	*3.914975e+02*	**3.915837e+02**
3	**7.527331e+03**	8.065981e+03	6.989159e+03	**8.066212e+03**	*7.527040e+03*	*8.066048e+03*
4	**1.546837e+05**	1.659524e+05	*1.434535e+05*	**1.660360e+05**	1.434126e+05	*1.660038e+05*
5	**3.173894e+06**	3.408816e+06	*2.942144e+06*	**3.415496e+06**	2.699308e+06	*3.410325e+06*
6	*5.032384e+07*	*6.996543e+07*	**5.035451e+07**	**7.019573e+07**	5.005772e+07	6.987435e+07
7	*9.206302e+08*	1.431741e+09	**9.212080e+08**	*1.438965e+09*	8.104920e+08	**1.440028e+09**
8	**1.859871e+10**	*2.931536e+10*	*1.649254e+10*	**2.949674e+10**	1.350630e+10	2.715899e+10

Table 9: Comparison of results for the DTLZ7. Variance and standard deviation of the hypervolume.

m	**MOMBI**		**MOEA/D**		**SMS-EMOA**	
	var	std	var	std	var	std
DTLZ7						
2	**3.492460e-10**	1.868812e-05	9.148735e+01	9.564902e+00	*5.454909e-04*	2.335575e-02
3	**1.799063e+04**	1.341292e+02	9.177512e+04	3.029441e+02	*4.027571e+04*	2.006881e+02
4	**1.131121e+07**	3.363214e+03	9.004804e+07	9.489365e+03	*3.679653e+07*	6.066015e+03
5	**7.528176e+09**	8.676506e+04	*3.387848e+10*	1.840611e+05	6.074417e+10	2.464633e+05
6	*2.313795e+13*	4.810193e+06	**2.247410e+13**	4.740685e+06	2.973570e+13	5.453045e+06
7	**1.820458e+16**	1.349244e+08	*1.842518e+16*	1.357394e+08	4.073945e+16	2.018402e+08
8	*9.525246e+18*	3.086300e+09	**8.698286e+18**	2.949286e+09	1.751288e+19	4.184839e+09

Table 10: Comparison of results for the WFG1-3. Average and median hypervolume.

m	**MOMBI**		**MOEA/D**		**SMS-EMOA**	
	avg	med	avg	med	avg	med
WFG1						
2	**6.294468e+00**	*6.107804e+00*	5.836052e+00	5.623144e+00	*6.253419e+00*	**6.206816e+00**
3	**5.494206e+01**	**5.511991e+01**	*5.169631e+01*	*5.278313e+01*	5.069579e+01	4.924417e+01
4	**4.700020e+02**	**4.674168e+02**	*4.565852e+02*	*4.566560e+02*	4.153136e+02	4.108954e+02
5	**4.992548e+03**	**4.999649e+03**	*4.665130e+03*	*4.666981e+03*	4.247997e+03	4.254084e+03
6	**6.546410e+04**	**6.485968e+04**	*5.654459e+04*	*5.638409e+04*	5.448022e+04	5.397501e+04
7	**1.050149e+06**	**1.045557e+06**	8.222872e+05	8.193762e+05	*8.667918e+05*	*8.580455e+05*
8	**2.027665e+07**	**2.013310e+07**	1.353975e+07	1.347821e+07	*1.509819e+07*	*1.497620e+07*
WFG2						
2	*1.096112e+01*	*1.059415e+01*	1.045158e+01	1.054469e+01	**1.099152e+01**	**1.060150e+01**
3	**9.377662e+01**	**9.875486e+01**	8.526391e+01	8.330335e+01	*9.242151e+01*	*8.505406e+01*
4	**9.023867e+02**	**9.225394e+02**	7.729761e+02	7.600906e+02	*8.664688e+02*	*9.212402e+02*
5	**9.927867e+03**	**1.027907e+04**	8.599778e+03	8.438210e+03	*9.685033e+03*	*1.016433e+04*
6	*1.292477e+05*	**1.340007e+05**	1.104339e+05	1.089187e+05	**1.293052e+05**	*1.324413e+05*
7	*1.798632e+06*	*1.639355e+06*	1.550014e+06	1.604416e+06	**1.826704e+06**	**1.962619e+06**
8	*3.115276e+07*	*3.341779e+07*	2.824171e+07	2.754389e+07	**3.206849e+07**	**3.391995e+07**
WFG3						
2	**1.090903e+01**	**1.090808e+01**	1.084768e+01	1.085838e+01	*1.088469e+01*	*1.089689e+01*
3	**7.533956e+01**	**7.538996e+01**	7.343757e+01	7.368656e+01	*7.521931e+01*	*7.519423e+01*
4	*6.521278e+02*	*6.519441e+02*	5.922803e+02	5.853244e+02	**6.725993e+02**	**6.730937e+02**
5	*6.536085e+03*	*6.522666e+03*	5.868854e+03	5.880785e+03	**7.388436e+03**	**7.389497e+03**
6	*8.169419e+04*	*8.154143e+04*	7.015066e+04	7.024789e+04	**9.622059e+04**	**9.622967e+04**
7	**1.139849e+06**	**1.139788e+06**	9.341369e+05	9.372006e+05	*1.106727e+06*	*1.134952e+06*
8	*1.919048e+07*	*1.920481e+07*	1.571596e+07	1.569742e+07	**2.346759e+07**	**2.456368e+07**

Table 11: Comparison of results for the WFG1-3. The worst and best hypervolume values.

m	**MOMBI**		**MOEA/D**		**SMS-EMOA**	
	worst	best	worst	best	worst	best
WFG1						
2	*5.637208e+00*	**7.866950e+00**	5.076072e+00	*6.779098e+00*	**5.803674e+00**	6.739641e+00
3	**5.157556e+01**	**5.737840e+01**	*4.803850e+01*	5.450215e+01	4.537526e+01	*5.580604e+01*
4	**4.562475e+02**	**4.912421e+02**	*4.269373e+02*	*4.775343e+02*	3.942597e+02	4.577706e+02
5	**4.752935e+03**	**5.268082e+03**	*4.388175e+03*	*4.986494e+03*	4.101187e+03	4.464162e+03
6	**6.132573e+04**	**7.020778e+04**	*5.341807e+04*	5.928865e+04	5.008139e+04	*5.977902e+04*
7	**9.109255e+05**	**1.172520e+06**	7.547331e+05	8.766126e+05	*7.827669e+05*	*9.921911e+05*
8	**1.610232e+07**	**2.407239e+07**	1.246860e+07	1.450365e+07	*1.300042e+07*	*1.727931e+07*
WFG2						
2	*1.053196e+01*	*1.142289e+01*	9.118714e+00	1.132250e+01	**1.056421e+01**	**1.142913e+01**
3	**8.423454e+01**	*9.957126e+01*	7.991810e+01	9.775673e+01	*8.393111e+01*	**1.005804e+02**
4	**7.683686e+02**	*9.274479e+02*	7.201266e+02	8.980913e+02	*7.589757e+02*	**9.314014e+02**
5	**8.466960e+03**	**1.033257e+04**	7.679835e+03	1.017610e+04	*8.275415e+03*	*1.023587e+04*
6	**1.097193e+05**	**1.345474e+05**	9.905465e+04	*1.339617e+05*	*1.078511e+05*	1.334441e+05
7	**1.627343e+06**	*2.007568e+06*	1.165282e+06	1.923502e+06	*1.602134e+06*	**2.013475e+06**
8	**2.756510e+07**	**3.424305e+07**	2.516191e+07	3.310033e+07	*2.739071e+07*	*3.415576e+07*
WFG3						
2	**1.087779e+01**	**1.092977e+01**	1.068306e+01	1.090382e+01	*1.083853e+01*	*1.091308e+01*
3	**7.488922e+01**	*7.570807e+01*	6.944645e+01	7.462050e+01	*7.459469e+01*	**7.580499e+01**
4	*6.426518e+02*	*6.599835e+02*	5.629729e+02	6.253038e+02	**6.679992e+02**	**6.759091e+02**
5	*6.429755e+03*	*6.847143e+03*	5.529686e+03	6.099138e+03	**7.329846e+03**	**7.432707e+03**
6	*8.010870e+04*	*8.468889e+04*	6.495207e+04	7.302943e+04	**9.548822e+04**	**9.676199e+04**
7	**1.115387e+06**	*1.180677e+06*	*8.671150e+05*	9.759342e+05	6.903841e+05	**1.439588e+06**
8	*1.821724e+07*	*2.029872e+07*	1.435545e+07	1.682801e+07	**1.994467e+07**	**2.473591e+07**

Table 12: Comparison of results for the WFG1-3. Variance and standard deviation of the hypervolume.

m	**MOMBI**		**MOEA/D**		**SMS-EMOA**	
	var	std	var	std	var	std
WFG1						
2	2.656288e-01	5.153919e-01	*2.509922e-01*	5.009912e-01	**5.825781e-02**	2.413666e-01
3	**1.698476e+00**	1.303256e+00	*4.828570e+00*	2.197401e+00	1.092292e+01	3.304985e+00
4	**6.627184e+01**	8.140752e+00	*1.512518e+02*	1.229845e+01	2.553138e+02	1.597854e+01
5	1.860002e+04	1.363819e+02	*1.856560e+04*	1.362557e+02	**8.191545e+03**	9.050716e+01
6	6.376797e+06	2.525232e+03	**2.160650e+06**	1.469915e+03	*5.919072e+06*	2.432914e+03
7	4.073317e+09	6.382254e+04	**6.556956e+08**	2.560655e+04	*2.562283e+09*	5.061900e+04
8	2.738142e+12	1.654733e+06	**2.126086e+11**	4.610950e+05	*1.539374e+12*	1.240715e+06
WFG2						
2	*1.696206e-01*	4.118502e-01	2.330801e-01	4.827837e-01	**1.689931e-01**	4.110878e-01
3	*4.919503e+01*	7.013917e+00	**2.714574e+01**	5.210158e+00	5.979845e+01	7.732946e+00
4	*2.721618e+03*	5.216913e+01	**2.296585e+03**	4.792270e+01	6.013527e+03	7.754693e+01
5	*5.242675e+05*	7.240632e+02	**3.433979e+05**	5.860016e+02	6.555992e+05	8.096908e+02
6	9.332699e+07	9.660590e+03	*7.364117e+07*	8.581443e+03	**6.640878e+07**	8.149158e+03
7	*3.122648e+10*	1.767102e+05	**2.667720e+10**	1.633316e+05	3.496147e+10	1.869799e+05
8	9.021949e+12	3.003656e+06	**4.416845e+12**	2.101629e+06	*8.639182e+12*	2.939249e+06
WFG3						
2	**1.829441e-04**	1.352568e-02	2.658475e-03	5.156041e-02	*5.096413e-04*	2.257524e-02
3	**3.138722e-02**	1.771644e-01	1.120582e+00	1.058576e+00	*6.118869e-02*	2.473635e-01
4	*1.601536e+01*	4.001920e+00	3.847746e+02	1.961567e+01	**3.980512e+00**	1.995122e+00
5	*5.490677e+03*	7.409910e+01	2.041270e+04	1.428730e+02	**4.390543e+02**	2.095362e+01
6	*1.073576e+06*	1.036135e+03	4.165475e+06	2.040950e+03	**8.548721e+04**	2.923820e+02
7	**1.964740e+08**	1.401692e+04	*6.180854e+08*	2.486132e+04	3.820164e+10	1.954524e+05
8	**2.214949e+11**	4.706324e+05	*2.272786e+11*	4.767374e+05	3.301181e+12	1.816915e+06

Table 13: Comparison of results for the WFG4-6. Average and median hypervolume.

m	**MOMBI**		**MOEA/D**		**SMS-EMOA**	
	avg	med	avg	med	avg	med
WFG4						
2	**8.663414e+00**	**8.664239e+00**	*8.638790e+00*	*8.642514e+00*	8.622096e+00	8.634763e+00
3	*7.428724e+01*	*7.424625e+01*	7.367783e+01	7.364434e+01	**7.655320e+01**	**7.657281e+01**
4	*6.899212e+02*	*6.894172e+02*	6.683063e+02	6.696255e+02	**7.565462e+02**	**7.558798e+02**
5	*7.963947e+03*	*7.985952e+03*	7.477385e+03	7.572611e+03	**8.613500e+03**	**8.605580e+03**
6	*9.172554e+04*	*9.170785e+04*	8.358673e+04	8.207561e+04	**1.116341e+05**	**1.106565e+05**
7	*1.114922e+06*	*1.124891e+06*	9.895873e+05	1.004345e+06	**1.551352e+06**	**1.561639e+06**
8	*1.840730e+07*	*1.858595e+07*	1.563104e+07	1.555789e+07	**2.832567e+07**	**2.811750e+07**
WFG5						
2	**8.208059e+00**	**8.209282e+00**	8.135799e+00	8.135080e+00	*8.165422e+00*	*8.135201e+00*
3	*7.111670e+01*	*7.109666e+01*	6.980779e+01	6.972882e+01	**7.337062e+01**	**7.348882e+01**
4	*6.676905e+02*	*6.667779e+02*	6.374582e+02	6.380494e+02	**7.323117e+02**	**7.331040e+02**
5	*7.690169e+03*	*7.670103e+03*	7.402440e+03	7.483427e+03	**8.421103e+03**	**8.434544e+03**
6	*9.592303e+04*	*9.557708e+04*	9.477511e+04	9.521213e+04	**1.097473e+05**	**1.099307e+05**
7	1.061202e+06	*1.059558e+06*	*1.085262e+06*	1.058222e+06	**1.576659e+06**	**1.570270e+06**
8	*1.742656e+07*	*1.747336e+07*	1.720052e+07	1.680415e+07	**2.749614e+07**	**2.728534e+07**
WFG6						
2	**8.366185e+00**	**8.353960e+00**	*8.339773e+00*	8.335431e+00	8.335931e+00	*8.335526e+00*
3	*7.180386e+01*	*7.176551e+01*	7.090983e+01	7.102731e+01	**7.396142e+01**	**7.395474e+01**
4	*6.905283e+02*	*6.906542e+02*	6.335617e+02	6.296149e+02	**7.273866e+02**	**7.258445e+02**
5	*7.992895e+03*	*8.039336e+03*	7.166289e+03	7.167311e+03	**8.453112e+03**	**8.468658e+03**
6	*9.657006e+04*	*9.661895e+04*	8.711648e+04	8.658572e+04	**1.114382e+05**	**1.114669e+05**
7	1.069256e+06	1.060981e+06	*1.094029e+06*	*1.087937e+06*	**1.484532e+06**	**1.505427e+06**
8	*1.720793e+07*	*1.708134e+07*	1.568331e+07	1.567155e+07	**2.804717e+07**	**2.824907e+07**

Table 14: Comparison of results for the WFG4-6. The worst and best hypervolume values.

m	**MOMBI**		**MOEA/D**		**SMS-EMOA**	
	worst	best	worst	best	worst	best
WFG4						
2	**8.653297e+00**	**8.669491e+00**	*8.554263e+00*	*8.655330e+00*	8.476408e+00	8.648468e+00
3	*7.392850e+01*	*7.471565e+01*	7.329301e+01	7.457938e+01	**7.607803e+01**	**7.688551e+01**
4	*6.651817e+02*	*7.222442e+02*	6.486870e+02	6.872723e+02	**7.454220e+02**	**7.701649e+02**
5	*7.566543e+03*	*8.369514e+03*	6.798814e+03	7.849343e+03	**8.324993e+03**	**8.810746e+03**
6	*8.415451e+04*	*1.006265e+05*	7.557633e+04	9.685107e+04	**1.085453e+05**	**1.163667e+05**
7	*9.808105e+05*	*1.184443e+06*	8.298196e+05	1.115010e+06	**1.407137e+06**	**1.694929e+06**
8	*1.647756e+07*	*1.975351e+07*	1.323297e+07	1.880679e+07	**2.716591e+07**	**2.987684e+07**
WFG5						
2	**8.133671e+00**	**8.283621e+00**	*8.128684e+00*	8.153429e+00	8.121776e+00	*8.248063e+00*
3	*7.056279e+01*	*7.162665e+01*	6.940872e+01	7.098109e+01	**7.277084e+01**	**7.375126e+01**
4	*6.603593e+02*	*6.804061e+02*	6.070971e+02	6.772041e+02	**7.134773e+02**	**7.402836e+02**
5	*7.447735e+03*	*7.874282e+03*	6.504050e+03	7.827082e+03	**8.208465e+03**	**8.515084e+03**
6	*9.040155e+04*	*1.021348e+05*	8.011804e+04	1.015838e+05	**1.047141e+05**	**1.141294e+05**
7	*9.557849e+05*	1.193413e+06	9.264838e+05	*1.385283e+06*	**1.517288e+06**	**1.630618e+06**
8	*1.538803e+07*	1.950280e+07	1.485926e+07	*2.040902e+07*	**2.653732e+07**	**2.874369e+07**
WFG6						
2	**8.268723e+00**	**8.487088e+00**	8.220565e+00	*8.445417e+00*	*8.243149e+00*	8.432501e+00
3	*7.096498e+01*	*7.299455e+01*	6.913511e+01	7.244649e+01	**7.295067e+01**	**7.495813e+01**
4	*6.665644e+02*	*7.054710e+02*	6.059004e+02	6.644238e+02	**7.120393e+02**	**7.455583e+02**
5	*6.702205e+03*	*8.441905e+03*	6.482420e+03	7.699734e+03	**8.100903e+03**	**8.603545e+03**
6	*9.025205e+04*	*1.030589e+05*	7.999922e+04	9.554142e+04	**1.075010e+05**	**1.153342e+05**
7	*9.585324e+05*	1.229736e+06	8.979160e+05	*1.340084e+06*	**1.251546e+06**	**1.753912e+06**
8	*1.576403e+07*	*1.966619e+07*	1.263717e+07	1.848525e+07	**2.492906e+07**	**3.015494e+07**

Table 15: Comparison of results for the WFG4-6. Variance and standard deviation of the hypervolume.

m	**MOMBI**		**MOEA/D**		**SMS-EMOA**	
	var	std	var	std	var	std
WFG4						
2	**2.072747e-05**	4.552744e-03	*3.631297e-04*	1.905596e-02	1.655572e-03	4.068872e-02
3	*4.275291e-02*	2.067678e-01	5.574266e-02	2.360988e-01	**2.774898e-02**	1.665802e-01
4	1.228001e+02	1.108152e+01	*9.987828e+01*	9.993912e+00	**5.185863e+01**	7.201294e+00
5	*4.218705e+04*	2.053949e+02	7.205865e+04	2.684374e+02	**1.720060e+04**	1.311511e+02
6	*1.333393e+07*	3.651565e+03	2.623089e+07	5.121610e+03	**4.967909e+06**	2.228881e+03
7	**2.641785e+09**	5.139830e+04	6.138024e+09	7.834554e+04	*4.117288e+09*	6.416610e+04
8	*6.953531e+11*	8.338783e+05	1.805313e+12	1.343619e+06	**3.207753e+11**	5.663702e+05
WFG5						
2	2.018775e-03	4.493078e-02	**2.694075e-05**	5.190448e-03	*1.395446e-03*	3.735567e-02
3	**4.308293e-02**	2.075643e-01	1.113183e-01	3.336439e-01	*9.331138e-02*	3.054691e-01
4	**2.947578e+01**	5.429160e+00	3.113916e+02	1.764629e+01	*3.866135e+01*	6.217825e+00
5	*1.379128e+04*	1.174363e+02	1.086555e+05	3.296293e+02	**4.219306e+03**	6.495618e+01
6	*8.608713e+06*	2.934061e+03	1.743424e+07	4.175433e+03	**4.873425e+06**	2.207583e+03
7	*2.615609e+09*	5.114303e+04	1.077582e+10	1.038067e+05	**9.526184e+08**	3.086452e+04
8	*8.246040e+11*	9.080771e+05	2.229400e+12	1.493118e+06	**3.804264e+11**	6.167872e+05
WFG6						
2	*2.946331e-03*	5.428011e-02	3.621172e-03	6.017617e-02	**2.083195e-03**	4.564203e-02
3	*2.914049e-01*	5.398194e-01	6.960060e-01	8.342698e-01	**1.961426e-01**	4.428799e-01
4	*8.027037e+01*	8.959373e+00	2.334101e+02	1.527776e+01	**6.222127e+01**	7.888046e+00
5	9.012650e+04	3.002108e+02	*7.887597e+04*	2.808487e+02	**1.110037e+04**	1.053583e+02
6	*1.023919e+07*	3.199873e+03	1.388366e+07	3.726078e+03	**3.166955e+06**	1.779594e+03
7	**3.483839e+09**	5.902405e+04	*1.190948e+10*	1.091306e+05	2.045762e+10	1.430301e+05
8	**9.359717e+11**	9.674563e+05	2.910100e+12	1.705901e+06	*1.328196e+12*	1.152474e+06

Table 16: Comparison of results for the WFG7-9. Average and median hypervolume.

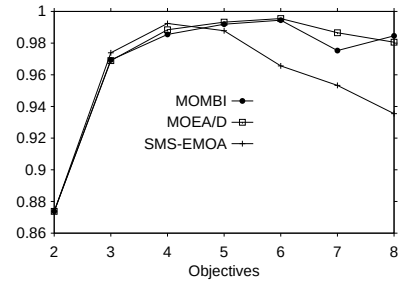
m	**MOMBI**		**MOEA/D**		**SMS-EMOA**	
	avg	med	avg	med	avg	med
WFG7						
2	**8.676485e+00**	**8.676518e+00**	*8.665153e+00*	*8.665648e+00*	8.659994e+00	8.659259e+00
3	*7.495940e+01*	*7.498835e+01*	7.376198e+01	7.369063e+01	**7.689421e+01**	**7.690586e+01**
4	*7.207621e+02*	*7.230443e+02*	6.801568e+02	6.791577e+02	**7.626003e+02**	**7.640795e+02**
5	*8.374343e+03*	*8.316058e+03*	7.683882e+03	7.652834e+03	**8.907564e+03**	**8.939871e+03**
6	*1.013138e+05*	*1.014038e+05*	9.488079e+04	9.454881e+04	**1.156273e+05**	**1.159146e+05**
7	*1.126400e+06*	*1.121803e+06*	1.011440e+06	1.000954e+06	**1.653699e+06**	**1.649727e+06**
8	*1.844738e+07*	*1.867711e+07*	1.533142e+07	1.528356e+07	**2.943970e+07**	**2.930634e+07**
WFG8						
2	**8.081846e+00**	**8.086566e+00**	*8.070813e+00*	*8.066183e+00*	8.058860e+00	8.062979e+00
3	*6.842167e+01*	*6.840637e+01*	6.806646e+01	6.813463e+01	**7.021008e+01**	**7.024693e+01**
4	*5.851432e+02*	*5.815902e+02*	5.489519e+02	5.513801e+02	**6.862165e+02**	**6.860724e+02**
5	*5.010892e+03*	*5.059005e+03*	4.748502e+03	4.781713e+03	**7.782572e+03**	**7.774735e+03**
6	*5.680393e+04*	*5.675592e+04*	4.633819e+04	4.579509e+04	**9.848530e+04**	**9.812310e+04**
7	*7.871659e+05*	*7.885645e+05*	5.748249e+05	5.519519e+05	**1.318850e+06**	**1.313620e+06**
8	*1.299050e+07*	*1.270383e+07*	9.495123e+06	9.517506e+06	**2.461203e+07**	**2.449031e+07**
WFG9						
2	*8.234320e+00*	**8.414378e+00**	8.065763e+00	8.134326e+00	**8.252136e+00**	*8.363687e+00*
3	6.712947e+01	6.643640e+01	*6.785035e+01*	*6.838442e+01*	**7.108843e+01**	**7.276675e+01**
4	*5.889761e+02*	*5.837546e+02*	5.654998e+02	5.529761e+02	**6.930176e+02**	**6.683059e+02**
5	*5.852350e+03*	*5.834201e+03*	5.585894e+03	5.483850e+03	**7.684327e+03**	**7.524648e+03**
6	*6.393249e+04*	*6.345775e+04*	5.933684e+04	5.965160e+04	**1.017342e+05**	**9.702094e+04**
7	*6.670261e+05*	*6.571498e+05*	6.585370e+05	6.377819e+05	**1.519268e+06**	**1.429894e+06**
8	*1.078788e+07*	*1.046829e+07*	1.002607e+07	9.815105e+06	**2.583169e+07**	**2.724997e+07**

Table 17: Comparison of results for the WFG7-9. The worst and best hypervolume values.

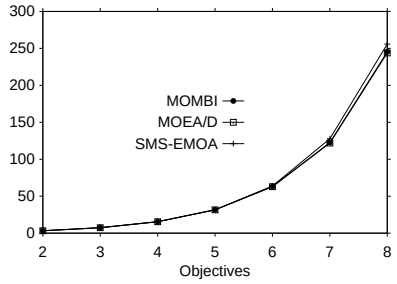
m	**MOMBI**		**MOEA/D**		**SMS-EMOA**	
	worst	best	worst	best	worst	best
WFG7						
2	**8.674400e+00**	**8.679696e+00**	*8.656101e+00*	*8.671756e+00*	8.649117e+00	8.670178e+00
3	*7.431384e+01*	*7.538629e+01*	7.352663e+01	7.441844e+01	**7.660681e+01**	**7.702542e+01**
4	*7.079482e+02*	*7.328240e+02*	6.728069e+02	6.927879e+02	**7.491502e+02**	**7.726754e+02**
5	*8.285495e+03*	*8.686923e+03*	7.393535e+03	8.137183e+03	**8.522229e+03**	**8.983413e+03**
6	*9.563535e+04*	*1.042406e+05*	8.824882e+04	1.021421e+05	**1.101541e+05**	**1.196610e+05**
7	*1.083337e+06*	1.169596e+06	9.063962e+05	*1.180232e+06*	**1.589925e+06**	**1.738135e+06**
8	*1.694039e+07*	*2.007593e+07*	1.310813e+07	1.734283e+07	**2.827480e+07**	**3.101199e+07**
WFG8						
2	**8.014817e+00**	*8.104072e+00*	*8.003224e+00*	**8.142331e+00**	8.001549e+00	8.093368e+00
3	*6.799182e+01*	*6.889378e+01*	6.675114e+01	6.867608e+01	**6.969866e+01**	**7.057996e+01**
4	*5.754633e+02*	*6.096155e+02*	4.943815e+02	5.665686e+02	**6.656405e+02**	**6.957147e+02**
5	*4.578294e+03*	*5.506780e+03*	4.452659e+03	4.955060e+03	**7.703600e+03**	**7.941152e+03**
6	*4.947406e+04*	*6.419914e+04*	3.616628e+04	5.384431e+04	**9.573853e+04**	**1.015724e+05**
7	*7.031737e+05*	*9.121368e+05*	4.309378e+05	7.650517e+05	**1.245281e+06**	**1.402420e+06**
8	*1.006059e+07*	*1.640973e+07*	7.119409e+06	1.201658e+07	**2.297994e+07**	**2.690072e+07**
WFG9						
2	**7.802318e+00**	*8.439521e+00*	7.793685e+00	8.404166e+00	*7.797756e+00*	**8.439891e+00**
3	*6.616499e+01*	*7.211229e+01*	6.481349e+01	7.034014e+01	**6.794289e+01**	**7.370042e+01**
4	*5.774342e+02*	*6.500268e+02*	4.876399e+02	6.165813e+02	**6.595483e+02**	**7.285293e+02**
5	*5.586043e+03*	6.167515e+03	4.329462e+03	*6.580874e+03*	**7.481368e+03**	**8.289958e+03**
6	*4.968587e+04*	*7.691654e+04*	4.189768e+04	7.033754e+04	**9.564301e+04**	**1.102383e+05**
7	*5.501241e+05*	7.871205e+05	5.305750e+05	*8.830376e+05*	**1.350620e+06**	**1.670318e+06**
8	*8.561758e+06*	*1.338562e+07*	7.541152e+06	1.233336e+07	**2.278066e+07**	**2.830437e+07**

Table 18: Comparison of results for the WFG7-9. Variance and standard deviation of the hypervolume.

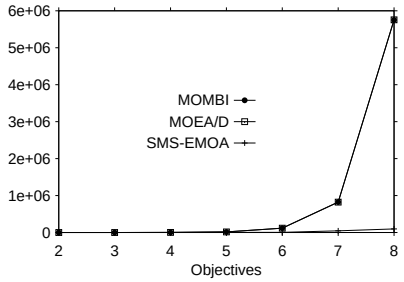
m	**MOMBI**		**MOEA/D**		**SMS-EMOA**	
	var	std	var	std	var	std
WFG7						
2	**1.737473e-06**	1.318132e-03	*1.348138e-05*	3.671700e-03	2.880951e-05	5.367449e-03
3	*4.955661e-02*	2.226131e-01	5.075830e-02	2.252960e-01	**1.134543e-02**	1.065149e-01
4	*5.275802e+01*	7.263471e+00	**2.122040e+01**	4.606561e+00	5.421037e+01	7.362769e+00
5	**1.213241e+04**	1.101472e+02	3.522759e+04	1.876902e+02	*1.223224e+04*	1.105995e+02
6	**4.201200e+06**	2.049683e+03	*1.173583e+07*	3.425760e+03	1.189716e+07	3.449226e+03
7	**4.807607e+08**	2.192626e+04	5.259325e+09	7.252120e+04	*1.237686e+09*	3.518076e+04
8	**5.955341e+11**	7.717086e+05	8.513782e+11	9.227016e+05	*5.961854e+11*	7.721304e+05
WFG8						
2	*5.174806e-04*	2.274820e-02	9.992488e-04	3.161090e-02	**4.583703e-04**	2.140958e-02
3	**3.876594e-02**	1.968907e-01	1.703333e-01	4.127146e-01	*5.223735e-02*	2.285549e-01
4	*8.165448e+01*	9.036287e+00	1.576507e+02	1.255590e+01	**5.422862e+01**	7.364008e+00
5	6.548716e+04	2.559046e+02	*1.946707e+04*	1.395244e+02	**2.321397e+03**	4.818088e+01
6	1.763930e+07	4.199917e+03	*1.002646e+07*	3.166459e+03	**3.116205e+06**	1.765278e+03
7	*2.704611e+09*	5.200587e+04	6.450135e+09	8.031274e+04	**1.844372e+09**	4.294615e+04
8	2.776016e+12	1.666138e+06	*1.569843e+12*	1.252934e+06	**1.010850e+12**	1.005410e+06
WFG9						
2	7.995422e-02	2.827618e-01	**4.680322e-02**	2.163405e-01	*5.216009e-02*	2.283858e-01
3	**3.157739e+00**	1.777003e+00	*4.367619e+00*	2.089885e+00	6.235799e+00	2.497158e+00
4	**2.781273e+02**	1.667715e+01	8.733009e+02	2.955166e+01	*7.969002e+02*	2.822942e+01
5	**2.019189e+04**	1.420982e+02	2.276409e+05	4.771172e+02	*9.571754e+04*	3.093825e+02
6	**3.620832e+07**	6.017335e+03	5.271518e+07	7.260522e+03	*3.871613e+07*	6.222229e+03
7	**4.392859e+09**	6.627865e+04	*5.855718e+09*	7.652267e+04	1.537770e+10	1.240069e+05
8	*2.045994e+12*	1.430383e+06	**1.201991e+12**	1.096353e+06	5.822228e+12	2.412929e+06



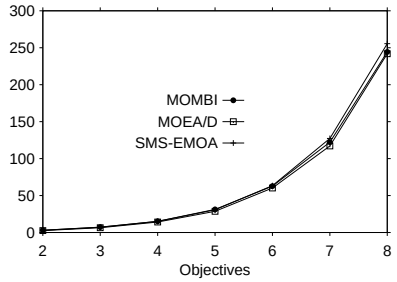
DTLZ1



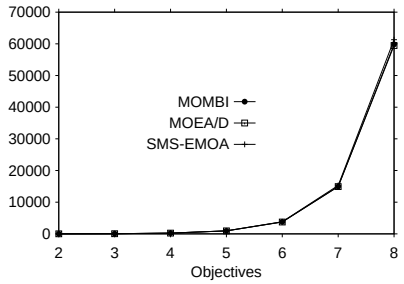
DTLZ2



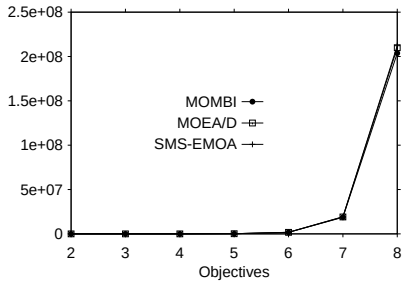
DTLZ3



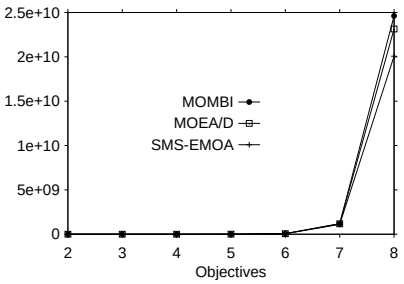
DTLZ4



DTLZ5

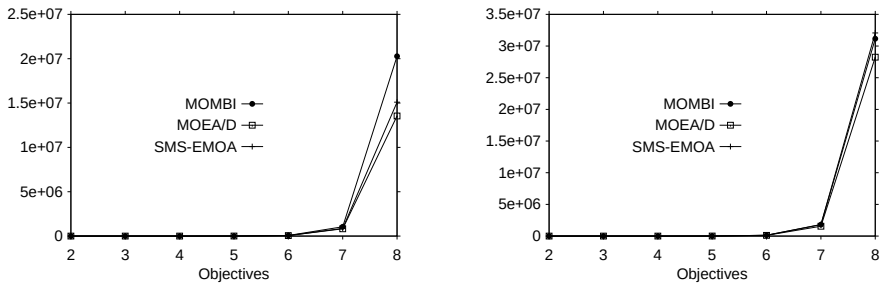


DTLZ6



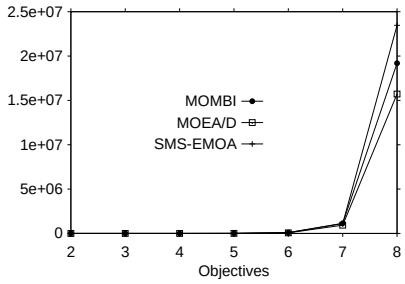
DTLZ7

Figure 1: Average hypervolume for the DTLZ test problems.

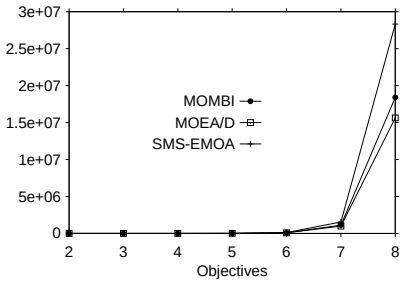


WFG1

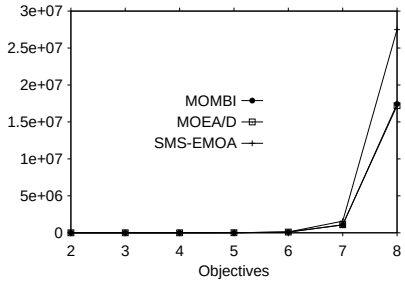
WFG2



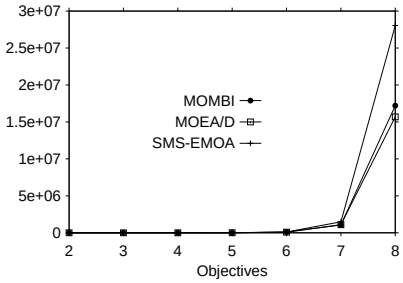
WFG3



WFG4

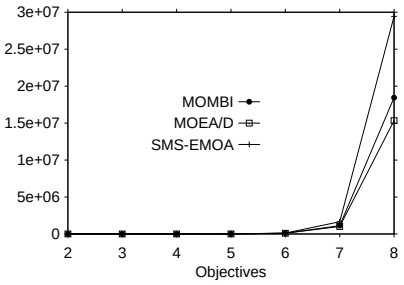


WFG5

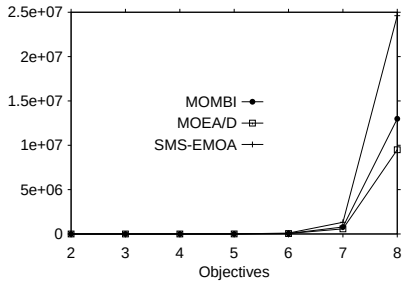


WFG6

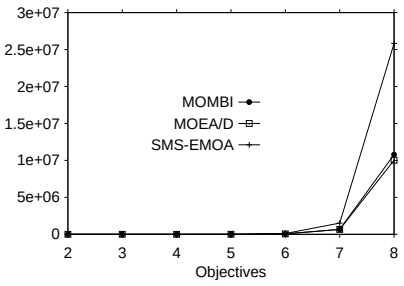
Figure 2: Average hypervolume for the WFG1-6 test problems.



WFG7

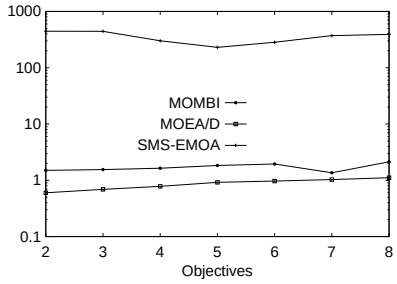


WFG8

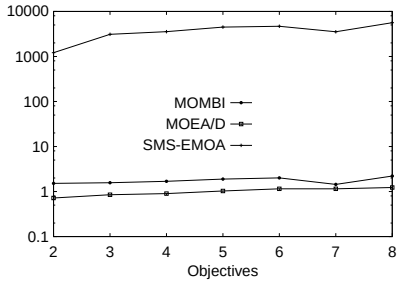


WFG9

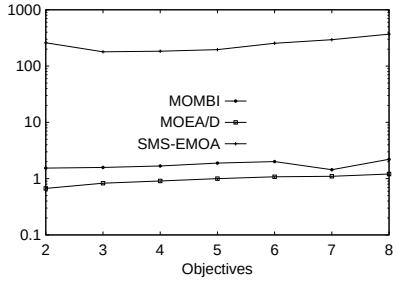
Figure 3: Average hypervolume for the WFG7-9 test problems.



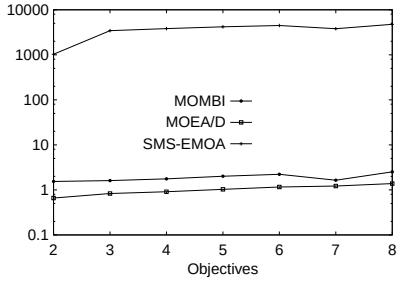
DTLZ1



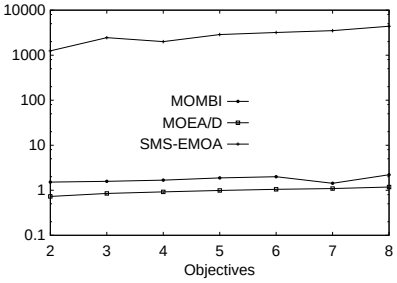
DTLZ2



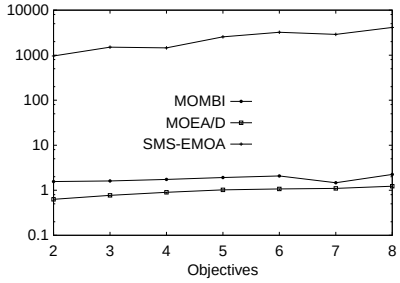
DTLZ3



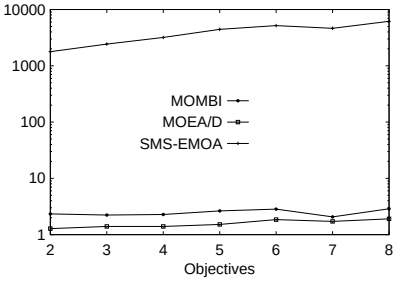
DTLZ4



DTLZ5

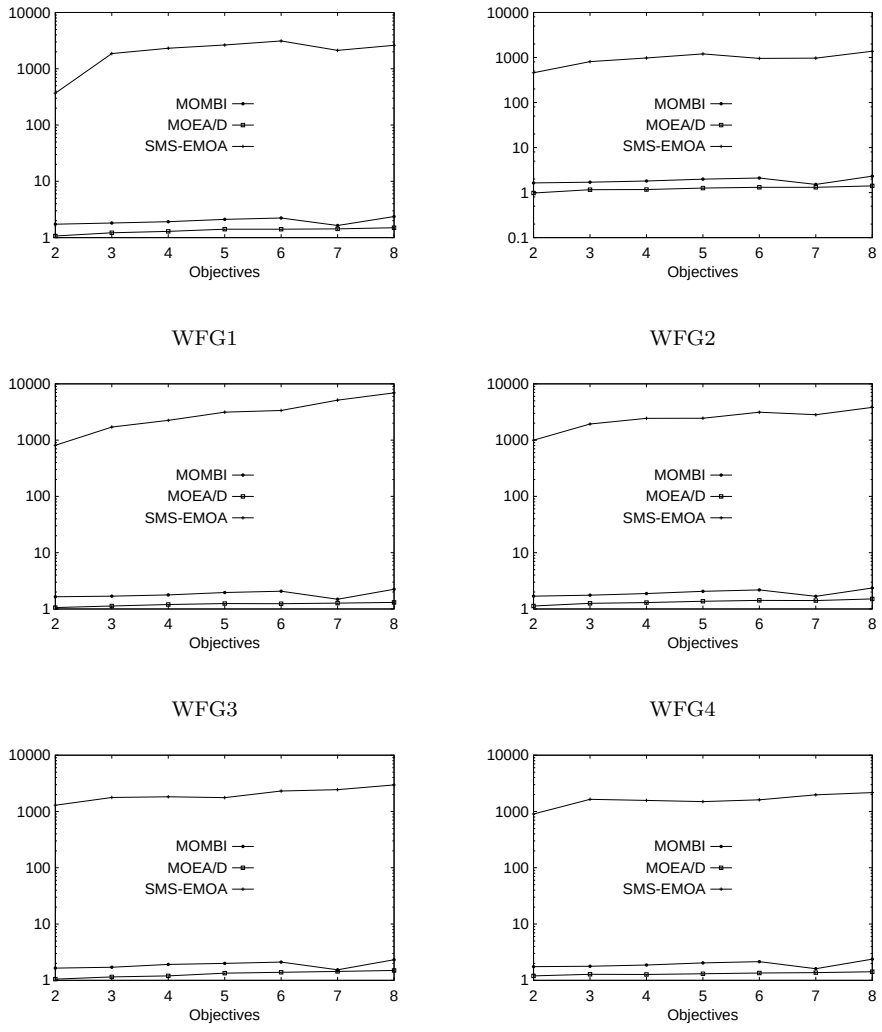


DTLZ6



DTLZ7

Figure 4: Average time (in seconds) on a logarithmic scale for the DTLZ test problems.

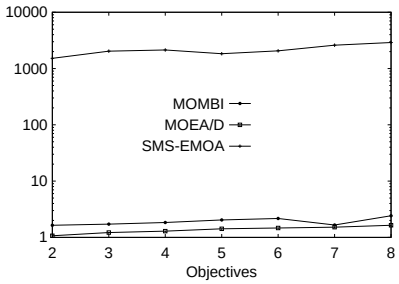


WFG1 WFG2

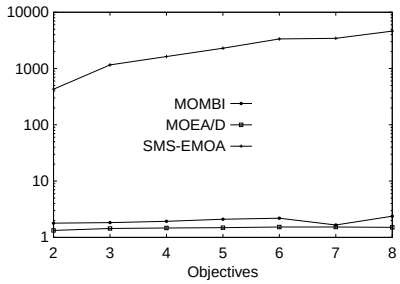
WFG3 WFG4

WFG5 WFG6

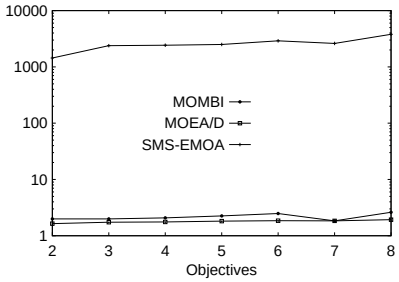
Figure 5: Average time (in seconds) on a logarithmic scale for the WFG1-6 test problems.



WFG7

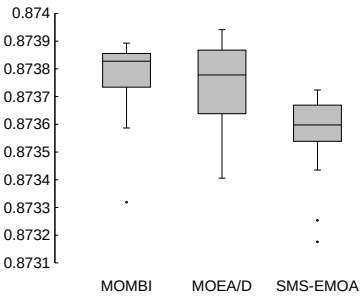


WFG8

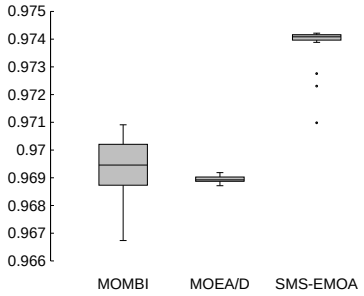


WFG9

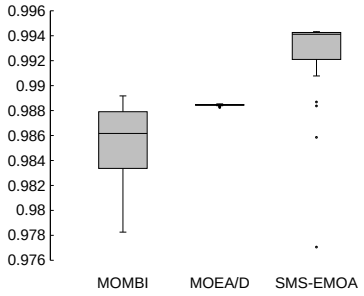
Figure 6: Average time (in seconds) on a logarithmic scale for the WFG7-9 test problems.



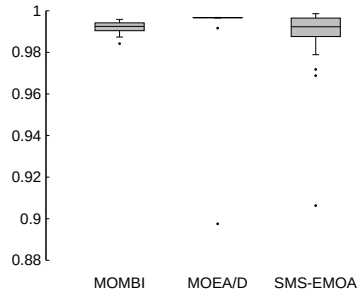
2D



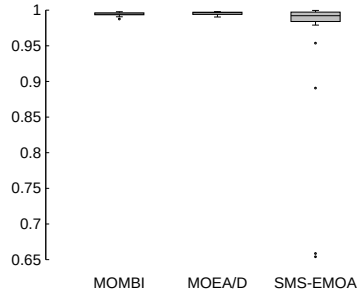
3D



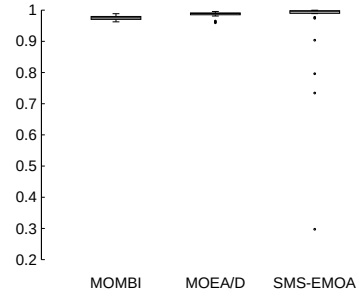
4D



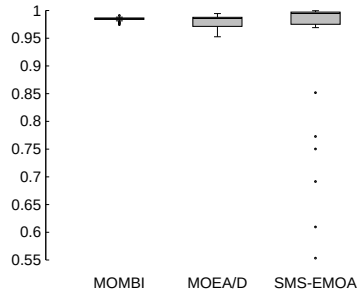
5D



6D

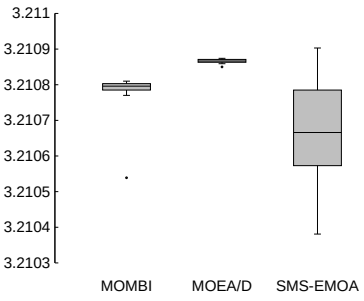


7D

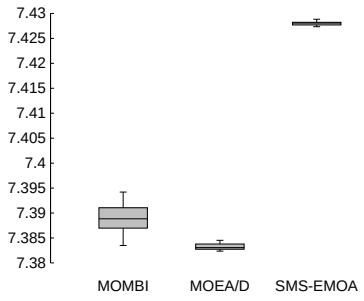


8D

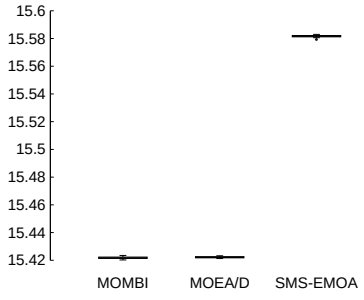
Figure 7: Boxplot of the hypervolume for the DTLZ1 test problem.



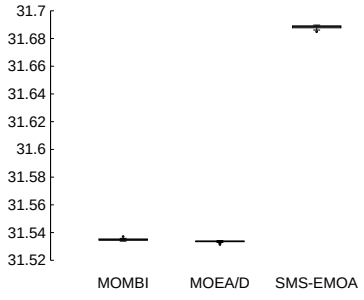
2D



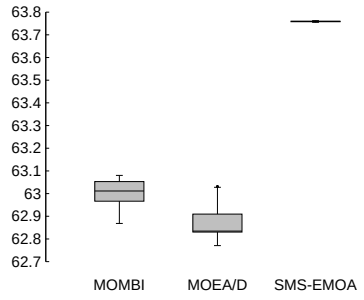
3D



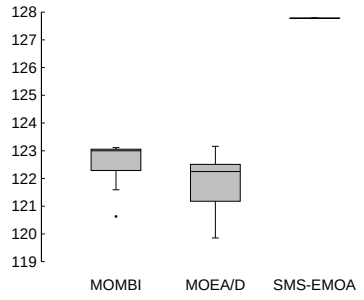
4D



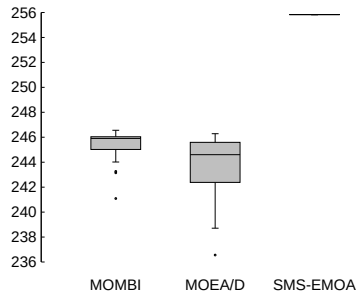
5D



6D

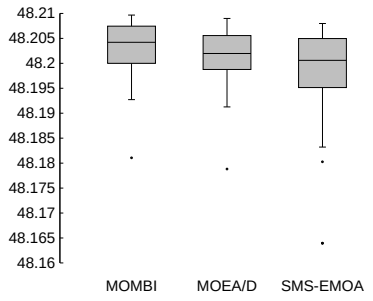


7D

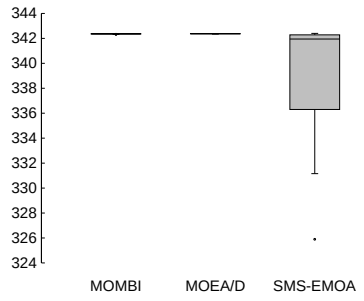


8D

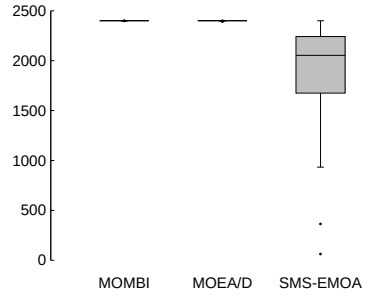
Figure 8: Boxplot of the hypervolume for the DTLZ2 test problem.



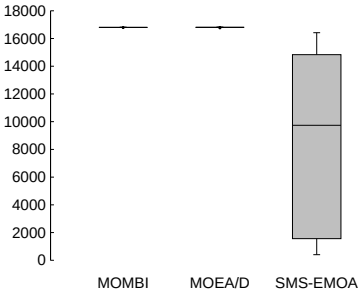
2D



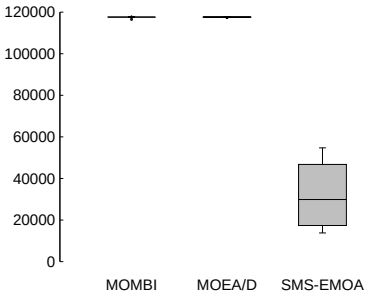
3D



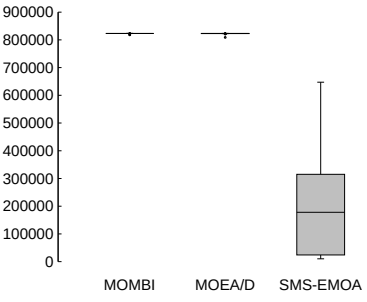
4D



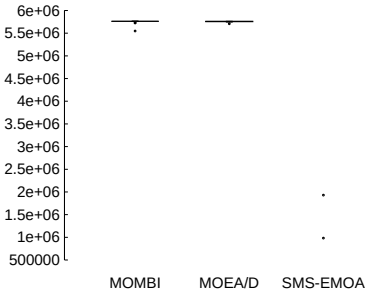
5D



6D



7D



8D

Figure 9: Boxplot of the hypervolume for the DTLZ3 test problem.

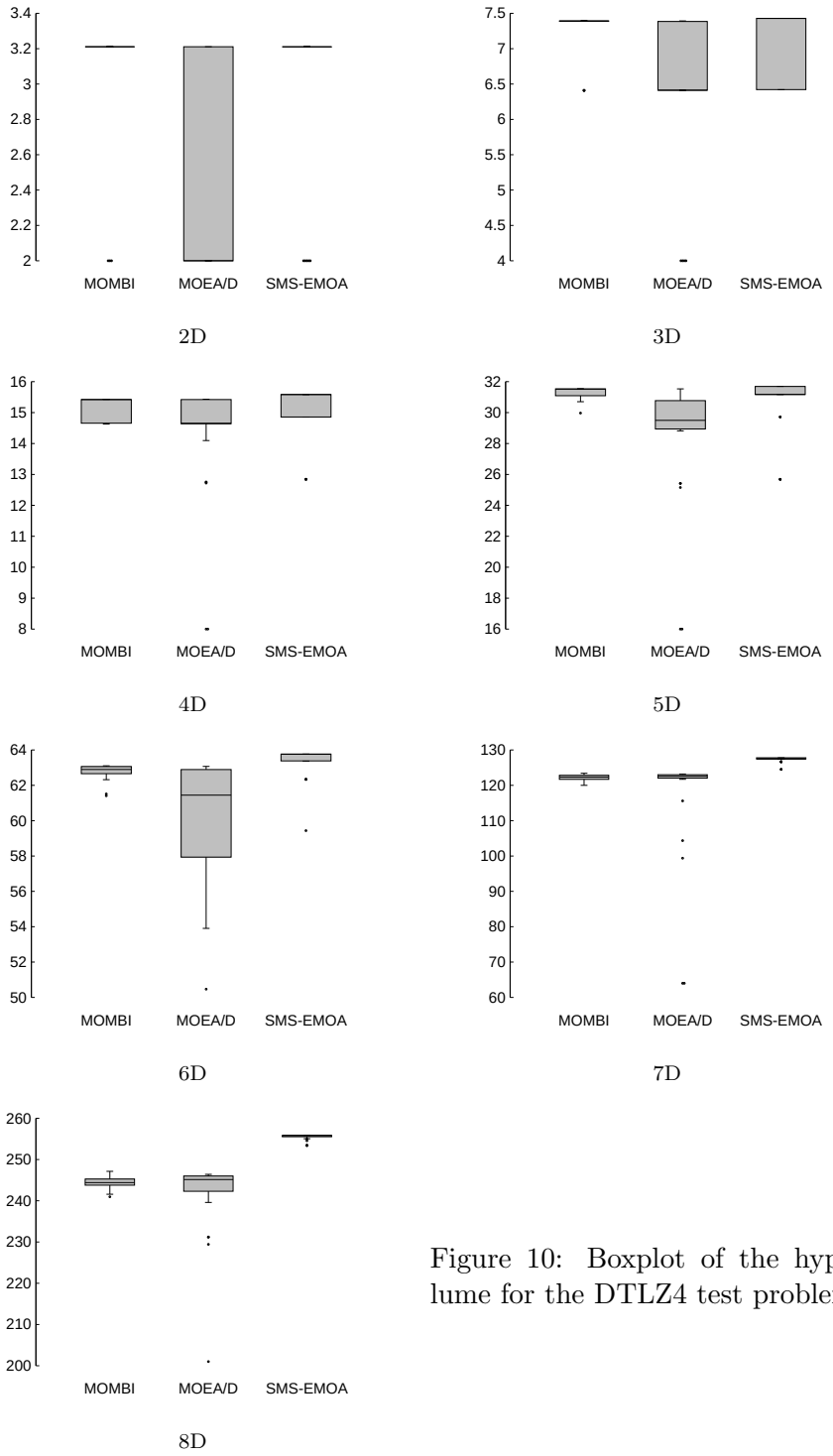
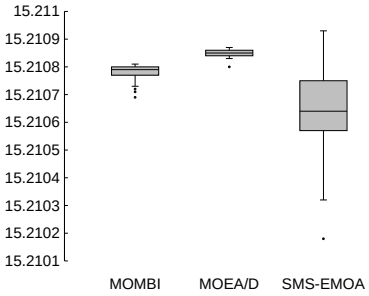
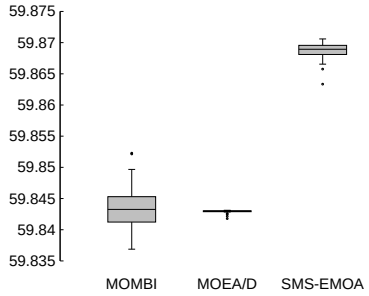


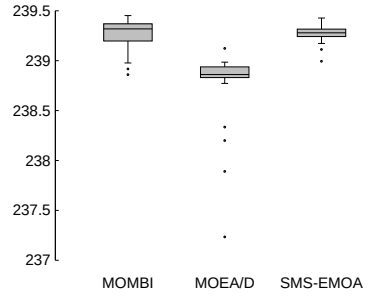
Figure 10: Boxplot of the hypervolume for the DTLZ4 test problem.



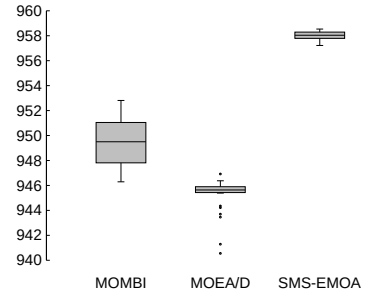
2D



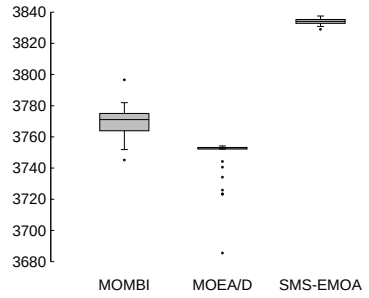
3D



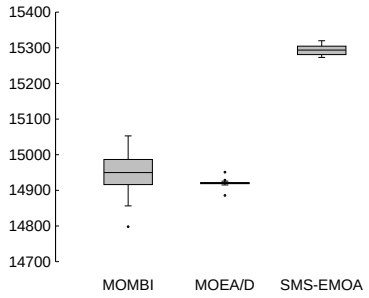
4D



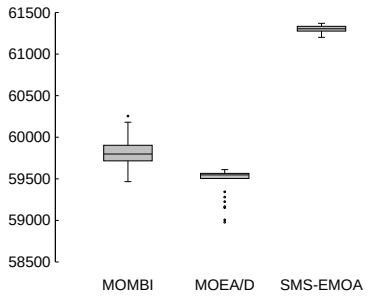
5D



6D

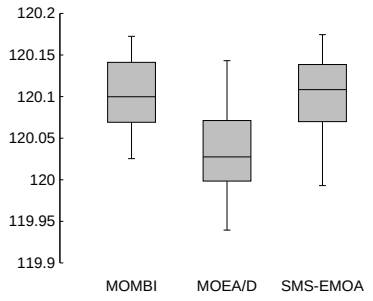


7D

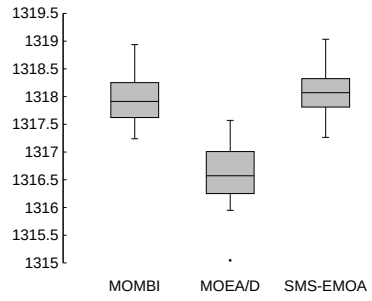


8D

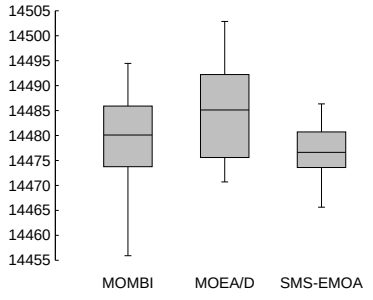
Figure 11: Boxplot of the hypervolume for the DTLZ5 test problem.



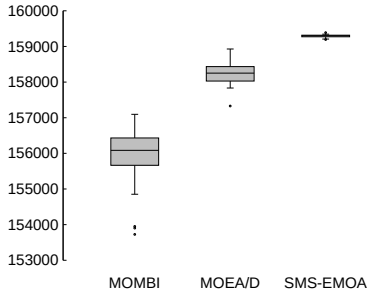
2D



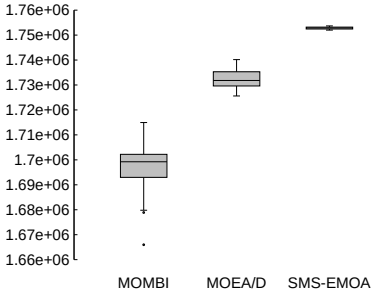
3D



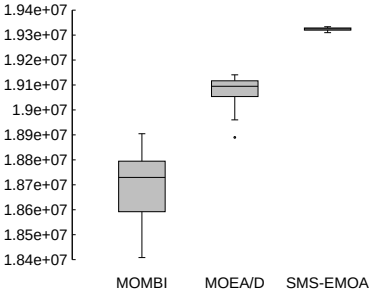
4D



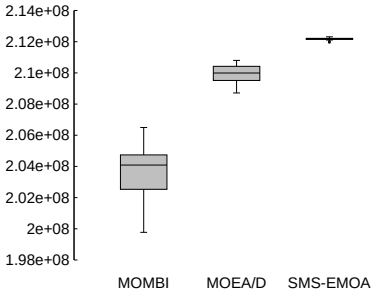
5D



6D

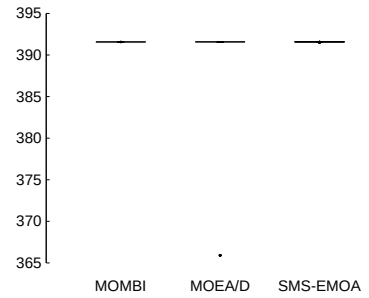


7D

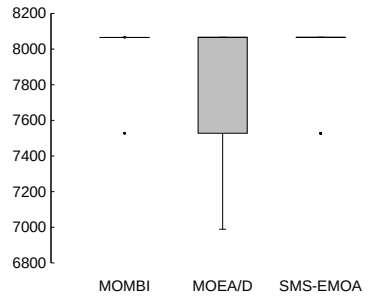


8D

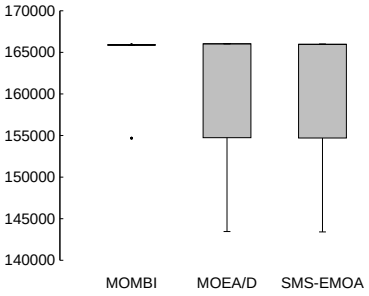
Figure 12: Boxplot of the hypervolume for the DTLZ6 test problem.



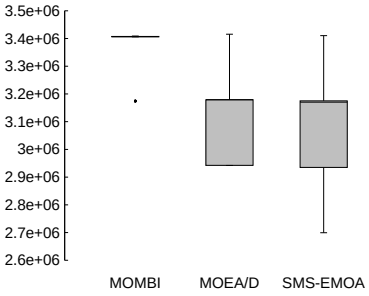
2D



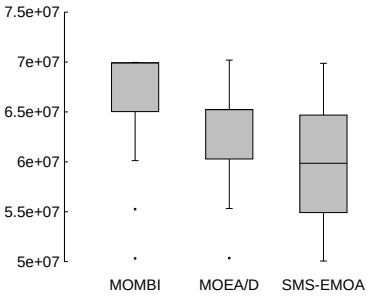
3D



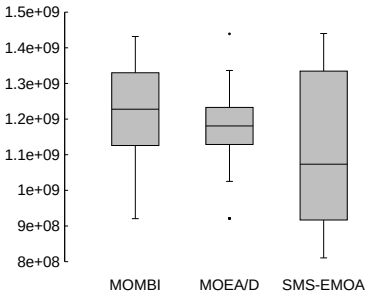
4D



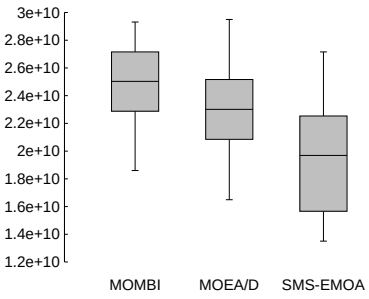
5D



6D

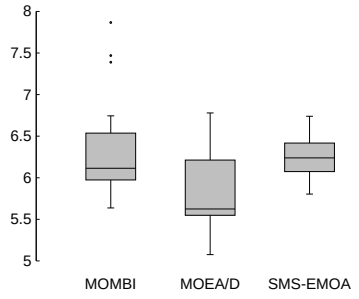


7D

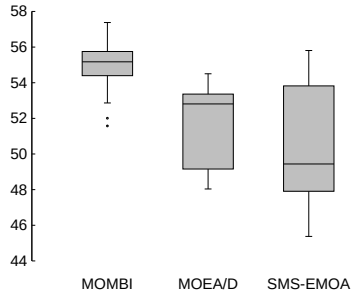


8D

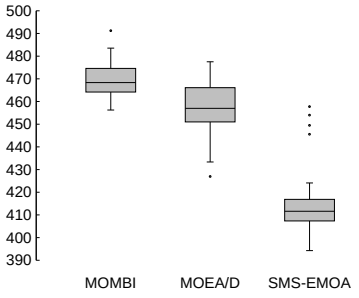
Figure 13: Boxplot of the hypervolume for the DTLZ7 test problem.



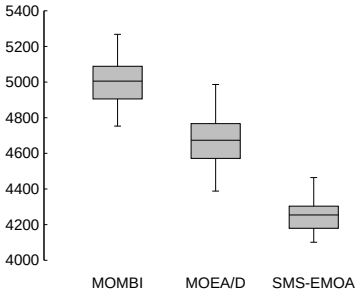
2D



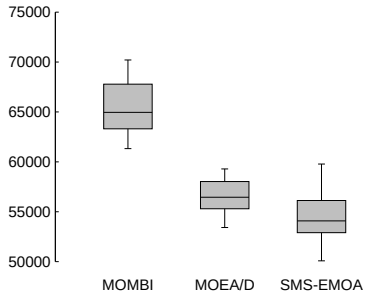
3D



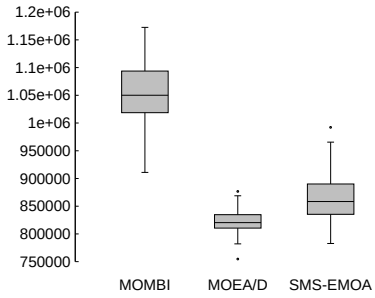
4D



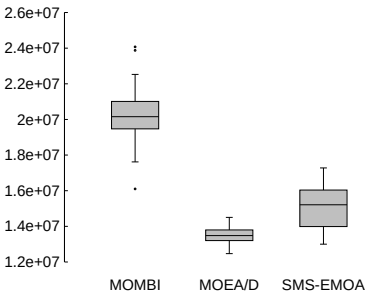
5D



6D

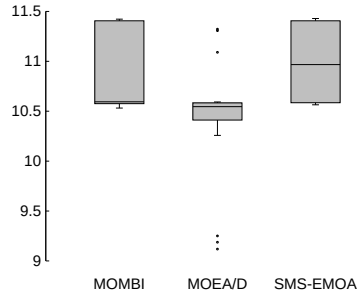


7D

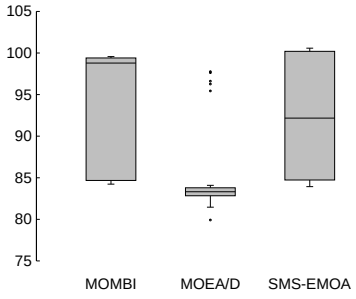


8D

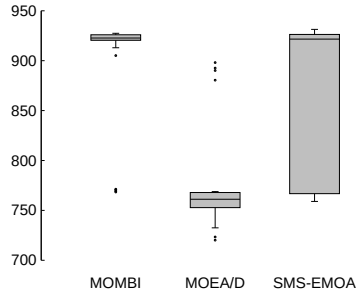
Figure 14: Boxplot of the hypervolume for the WFG1 test problem.



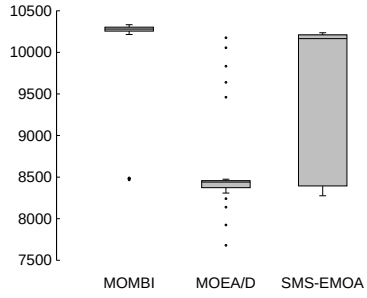
2D



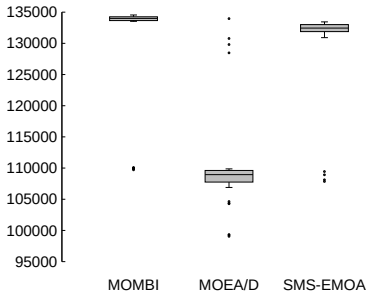
3D



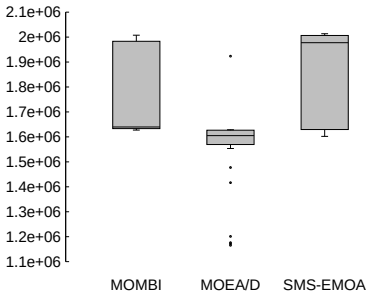
4D



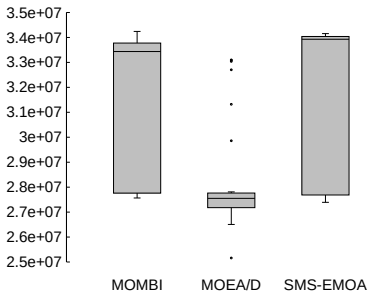
5D



6D

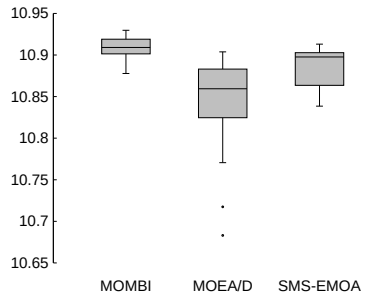


7D

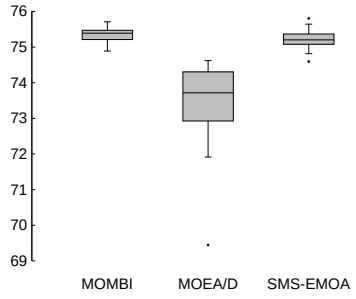


8D

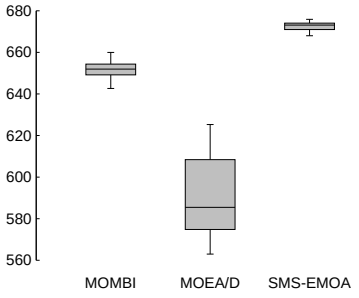
Figure 15: Boxplot of the hypervolume for the WFG2 test problem.



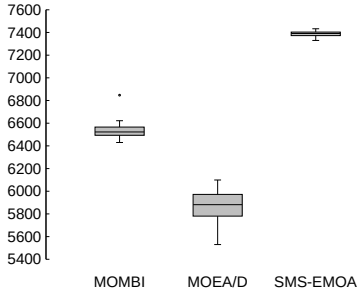
2D



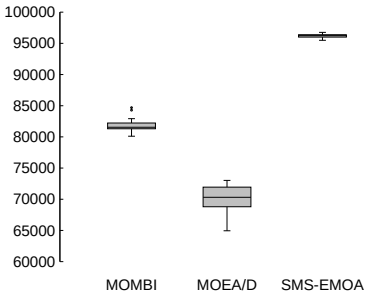
3D



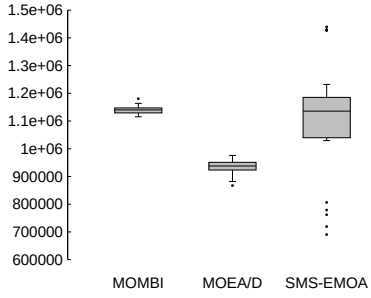
4D



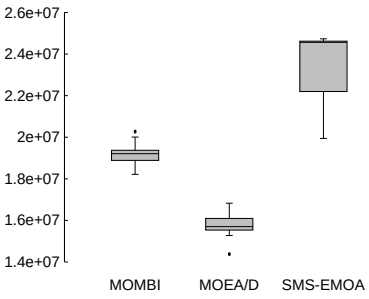
5D



6D

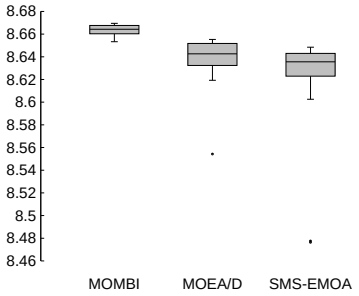


7D

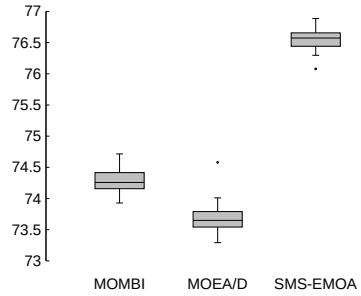


8D

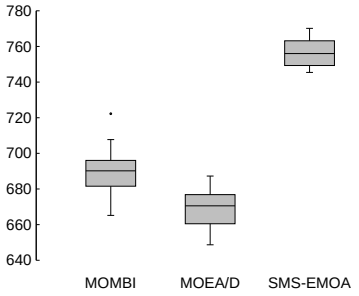
Figure 16: Boxplot of the hypervolume for the WFG3 test problem.



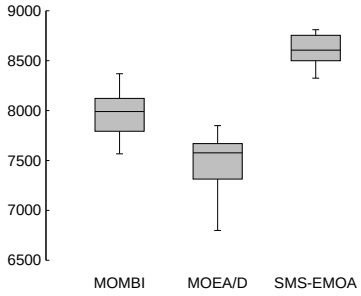
2D



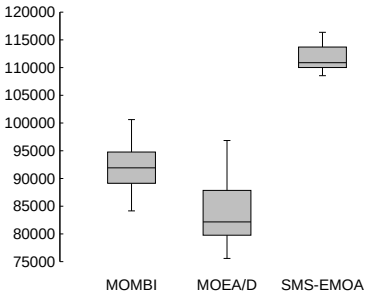
3D



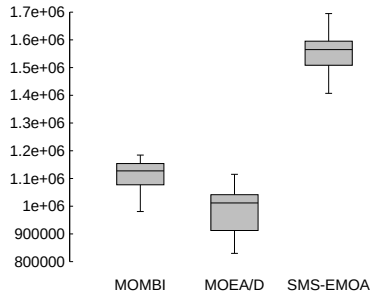
4D



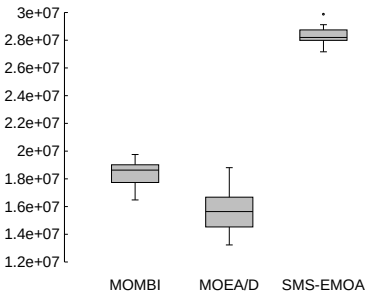
5D



6D

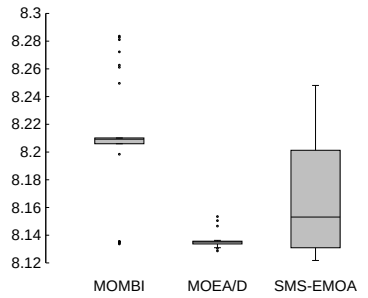


7D

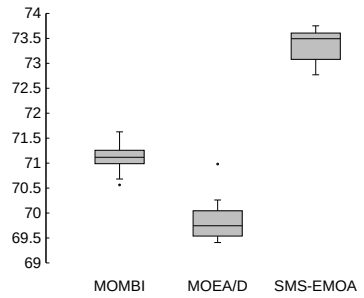


8D

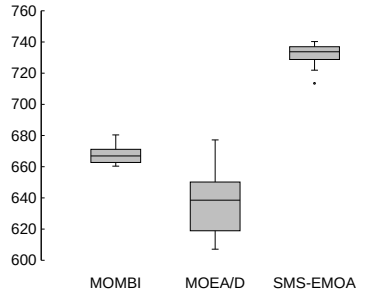
Figure 17: Boxplot of the hypervolume for the WFG4 test problem.



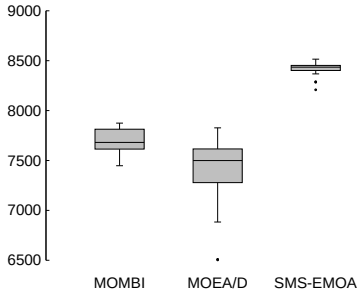
2D



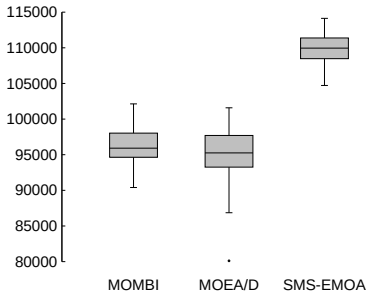
3D



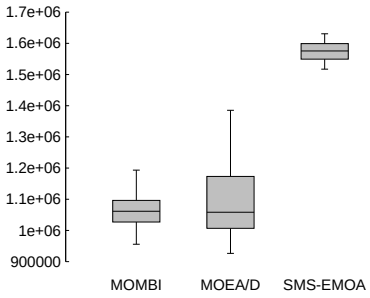
4D



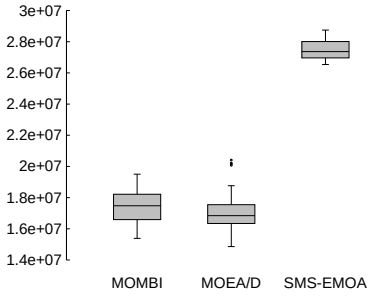
5D



6D

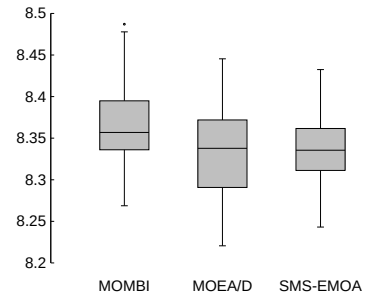


7D

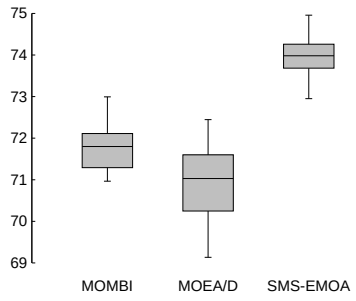


8D

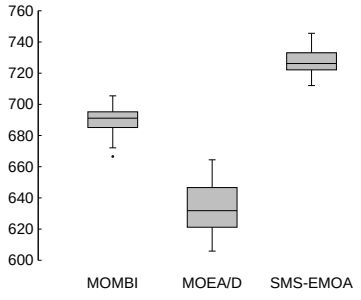
Figure 18: Boxplot of the hypervolume for the WFG5 test problem.



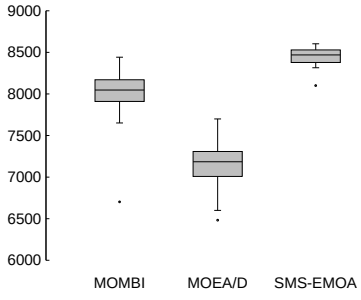
2D



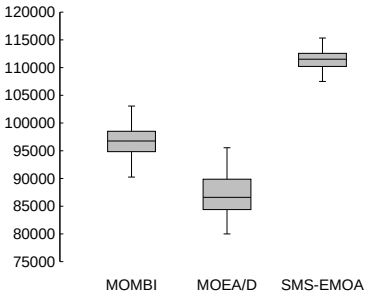
3D



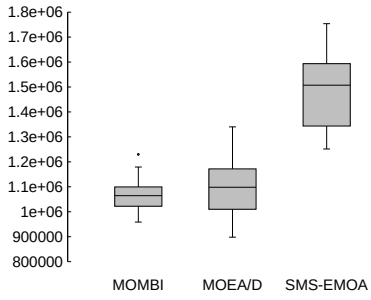
4D



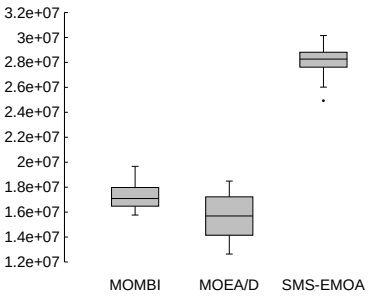
5D



6D

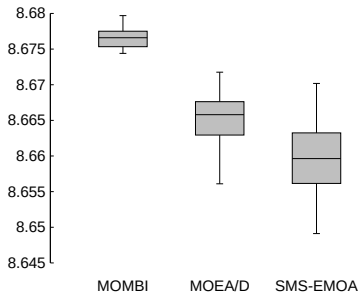


7D

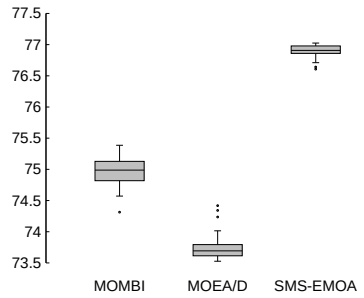


8D

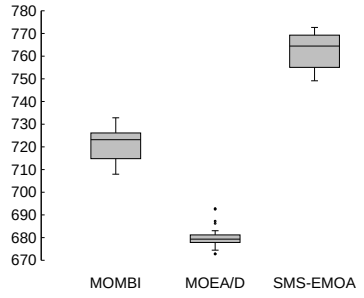
Figure 19: Boxplot of the hypervolume for the WFG6 test problem.



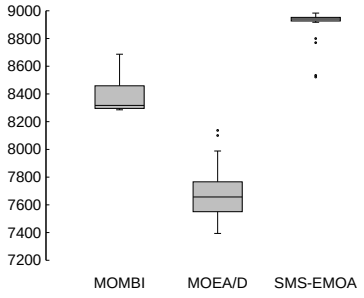
2D



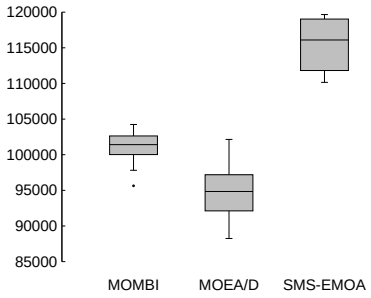
3D



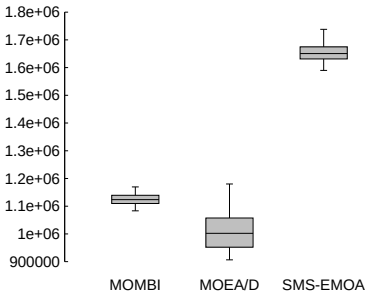
4D



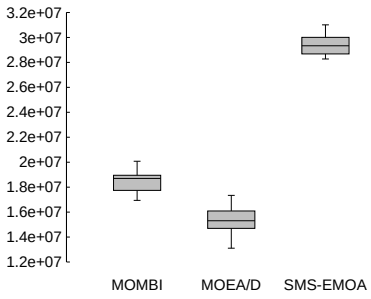
5D



6D

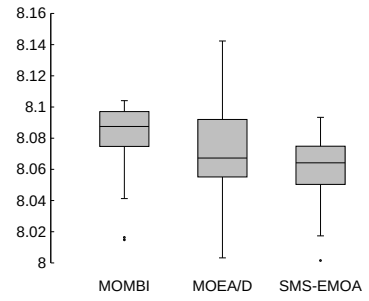


7D

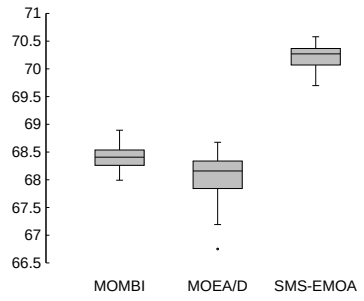


8D

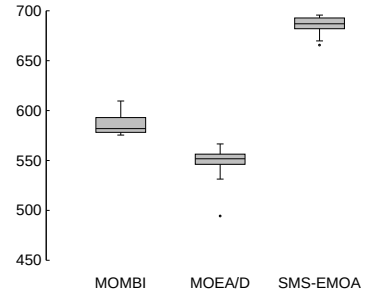
Figure 20: Boxplot of the hypervolume for the WFG7 test problem.



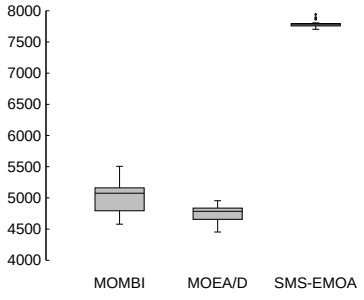
2D



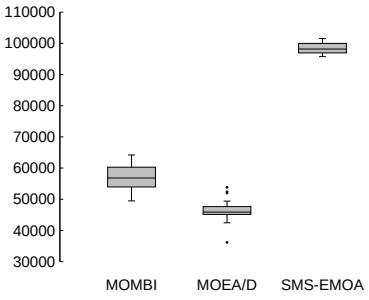
3D



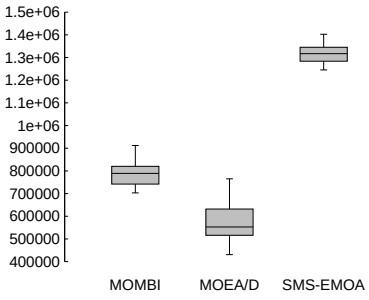
4D



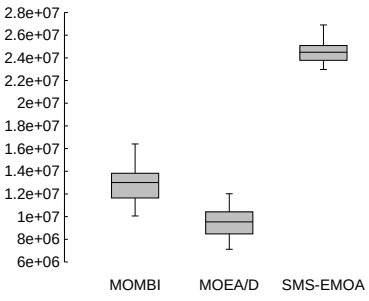
5D



6D

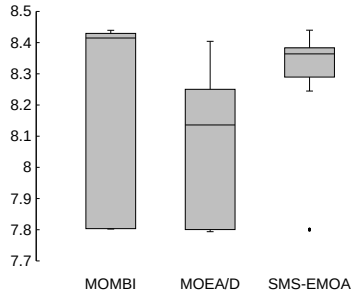


7D

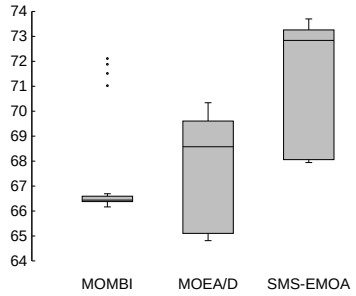


8D

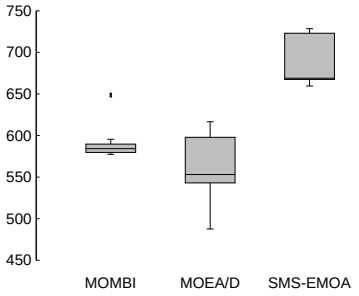
Figure 21: Boxplot of the hypervolume for the WFG8 test problem.



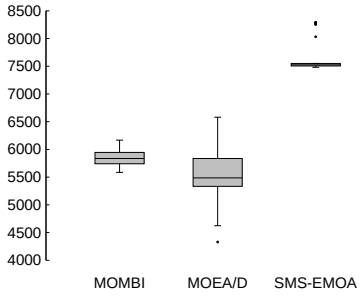
2D



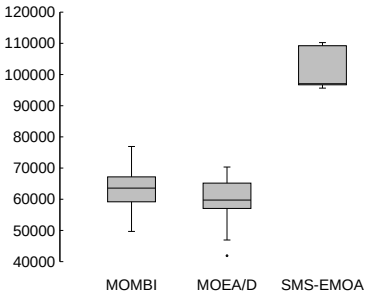
3D



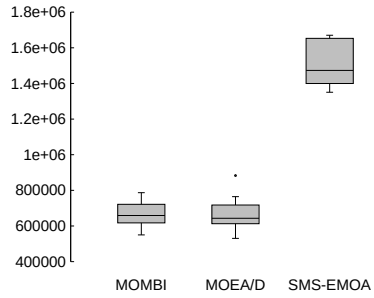
4D



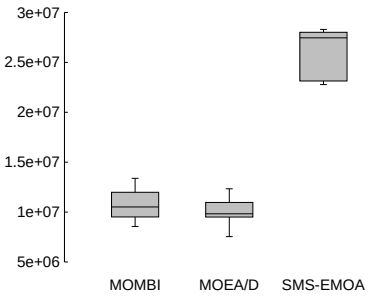
5D



6D



7D



8D

Figure 22: Boxplot of the hypervolume for the WFG9 test problem.