Semantic Approximation for Reducing Code Bloat in Genetic Programming

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Table 2: Average of the population size with the maximum depth of $sTree$= 2.

Pro	GP	RDO	PP	TS-S	SA10	SA20	SAD	DA10	DA20	DAD
A. **Benchmarking Problems**										
F1	190.6	99.5	18.5	44.8	60.3	17.2	7.3	50.5	12.9	7.0
F2	149.3	70.3	13.3	60.3	59.8	18.3	7.4	56.0	18.7	7.4
F3	114.2	54.3	46.1	24.9	46.7	35.6	25.6	47.6	40.2	29.1
F4	113.6	45.3	9.3	30.8	47.0	12.9	7.1	42.6	10.8	7.4
F5	101.1	58.9	9.7	53.5	37.3	10.6	7.1	37.4	10.5	7.4
F6	137.9	43.2	12.8	60.4	58.9	18.9	6.1	49.7	11.7	6.0
F7	105.9	28.7	12.6	39.0	51.6	18.1	6.0	49.8	13.7	6.1
F8	102.1	69.0	9.6	73.6	38.4	10.4	7.0	39.7	11.3	7.1
F9	139.3	51.4	10.7	78.2	51.5	12.4	6.4	49.6	12.0	6.7
B. **UCI Problems**										
F10	108.5	77.5	9.3	83.2	25.6	6.3	5.5	46.0	11.4	6.5
F11	111.0	71.5	7.4	29.7	37.0	8.4	5.7	49.1	10.2	7.0
F12	96.3	84.9	12.0	66.6	40.6	12.6	10.2	53.4	19.0	11.7
F13	101.2	31.9	6.0	5.0	14.0	5.0	4.8	41.2	9.7	6.7
F14	107.3	45.0	7.8	42.5	36.8	8.7	5.5	43.1	9.8	6.9
F15	102.2	78.7	6.5	17.1	34.8	7.4	5.5	50.6	12.3	6.9
F16	98.5	79.6	7.0	15.4	34.4	8.1	6.2	51.1	11.7	7.3
F17	105.0	69.5	6.8	15.3	35.5	7.2	6.0	48.4	11.2	7.3
F18	100.0	81.6	7.2	59.0	28.9	7.4	5.6	45.7	11.2	7.1

Table 3: Mean of the best fitness with the maximum depth of $sTree$= 1: bold face is better than GP, underline is the best result.

Pro	GP	SA10	SA20	SAD	DA10	DA20	DAD
A. **Benchmarking Problems**							
F1	0.47	0.52	0.85	1.34	**0.41**	0.95	1.16
F2	1.91	**1.11**	2.27	4.25	**1.03**	2.33	3.54
F3	0.10	0.11	0.13	0.12	**0.10**	0.12	0.11
F4	0.51	**0.19**	**0.43**	1.98	**0.17**	**0.35**	1.28
F5	1.13	**0.95**	1.62	2.68	**0.88**	1.54	2.40
F6	0.26	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**
F7	0.03	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**
F8	9.90	11.58	24.61	41.36	10.56	23.17	30.25
F9	0.38	**0.37**	0.49	0.49	**0.32**	0.47	0.48
F10	0.41	**0.17**	**0.23**	**0.23**	**0.14**	**0.17**	**0.18**
B. **UCI Problems**							
F11	0.47	0.48	0.52	0.53	**0.46**	0.50	0.51
F12	0.40	**0.19**	**0.26**	**0.31**	**0.15**	**0.16**	**0.17**
F13	3.28	3.33	3.41	3.44	**3.08**	**3.28**	3.29
F14	0.17	**0.17**	0.18	0.18	**0.17**	**0.17**	0.17
F15	0.82	**0.54**	**0.80**	0.87	**0.45**	**0.54**	**0.58**
F16	1.68	1.70	2.01	2.05	**1.61**	1.84	1.93
F17	0.91	0.94	1.11	1.11	**0.83**	1.00	1.03
F18	0.53	**0.49**	0.64	0.66	**0.42**	0.55	0.60

Table 4: Median of testing error with the maximum depth of $sTree$= 1: bold face is better than GP, underline is the best result.

Pro	GP	SA10	SA20	SAD	DA10	DA20	DAD
A. **Benchmarking Problems**							
F1	1.69	**1.17**	**0.93**	**1.38**	**0.98**	1.83	2.01
F2	10.17	**4.77**	**5.10**	**5.61**	**4.41**	**4.63**	**5.66**
F3	0.06	**0.05**	**0.06**	0.06	**0.05**	**0.05**	**0.05**
F4	0.31	**0.16**	**0.25**	3.52	**0.01**	**0.01**	2.94
F5	33.01	**12.72**	**6.55**	**19.39**	**14.87**	**3.56**	**8.87**
F6	0.26	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**
F7	0.03	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**
F8	45.88	**44.21**	**44.63**	**44.23**	**44.94**	**44.25**	**43.90**
F9	2.19	**2.18**	**2.18**	**2.18**	2.19	**2.18**	**2.18**
B. **UCI Problems**							
F10	0.75	**0.27**	**0.27**	**0.27**	**0.24**	**0.25**	**0.25**
F11	0.61	**0.59**	**0.58**	**0.58**	**0.59**	**0.58**	**0.58**
F12	0.36	**0.20**	**0.29**	**0.32**	**0.16**	**0.17**	**0.18**
F13	5.18	**3.87**	**3.84**	**3.90**	**4.00**	**3.77**	**3.74**
F14	0.18	**0.17**	0.18	0.18	**0.17**	**0.17**	**0.17**
F15	1.44	**0.55**	**0.65**	**0.86**	**0.52**	**0.53**	**0.53**
F16	2.69	**2.40**	**2.09**	**2.04**	**2.23**	**2.04**	**2.07**
F17	1.77	**1.31**	**1.14**	**1.12**	**1.54**	**1.30**	**1.32**
F18	0.73	**0.60**	**0.68**	**0.67**	**0.55**	**0.62**	**0.62**

Table 5: Average size of solutions with the maximum depth of $sTree$= 1: bold face is better than GP, underline is the best result.

Pro	GP	SA10	SA20	SAD	DA10	DA20	DAD
A. **Benchmarking Problems**							
F1	295.5	**93.2**	**26.8**	**23.4**	**78.2**	**19.6**	**17.1**
F2	228.3	**81.5**	**22.8**	**13.5**	**77.2**	**27.1**	**12.7**
F3	180.9	**64.6**	**43.5**	**31.6**	**63.5**	**43.8**	**36.0**
F4	187.3	**75.5**	**24.2**	**14.9**	**44.2**	**11.3**	**11.9**
F5	162.5	**59.1**	**12.8**	**11.2**	**57.6**	**12.3**	**12.5**
F6	216.9	**84.0**	**24.3**	**10.6**	**68.2**	**21.6**	**16.7**
F7	153.6	**68.8**	**22.5**	**23.4**	**72.3**	**17.5**	**20.9**
F8	161.0	**60.1**	**14.1**	**20.2**	**62.3**	**17.7**	**17.6**
F9	237.8	**79.2**	**12.1**	**10.5**	**73.6**	**11.8**	**11.9**
B. **UCI Problems**							
F10	196.4	**55.7**	**10.9**	**9.6**	**58.5**	**15.7**	**11.4**
F11	192.0	**62.8**	**10.6**	**6.7**	**82.0**	**19.2**	**16.5**
F12	151.7	**65.5**	**21.2**	**12.4**	**72.7**	**21.1**	**15.3**
F13	200.8	**24.8**	**7.9**	**6.7**	**70.6**	**11.9**	**7.2**
F14	170.5	**58.0**	**10.1**	**7.3**	**62.3**	**11.7**	**10.8**
F15	187.4	**58.3**	**9.9**	**7.7**	**68.9**	**13.8**	**8.8**
F16	192.6	**60.1**	**9.7**	**9.1**	**72.4**	**19.2**	**14.9**
F17	177.5	**63.5**	**10.7**	**8.5**	**84.3**	**17.6**	**12.5**
F18	181.8	**50.6**	**8.7**	**7.2**	**61.3**	**16.5**	**11.4**

Table 6: Mean of the best fitness with the maximum depth of $sTree$= 3: bold face is better than GP, underline is the best result.

Pro	GP	SA10	SA20	SAD	DA10	DA20	DAD
A. **Benchmarking Problems**							
F1	0.47	0.51	1.00	1.36	0.49	0.95	1.16
F2	1.91	**1.18**	2.54	4.20	**0.95**	2.20	3.39
F3	0.10	0.10	0.12	0.12	**0.09**	0.12	0.11
F4	0.51	**0.23**	0.72	1.91	**0.08**	**0.31**	0.53
F5	1.13	**0.99**	1.56	2.75	**0.83**	1.49	2.66
F6	0.26	**0.25**	**0.25**	**0.26**	**0.25**	**0.25**	**0.25**
F7	0.03	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**
F8	9.90	11.28	20.92	37.54	**7.56**	15.66	21.01
F9	0.38	**0.38**	0.48	0.49	**0.36**	0.46	0.48
B. **UCI Problems**							
F10	0.41	**0.16**	**0.22**	**0.22**	**0.14**	**0.17**	**0.18**
F11	0.47	0.48	0.52	0.53	**0.47**	0.50	0.51
F12	0.40	**0.20**	**0.26**	**0.32**	**0.16**	**0.16**	**0.17**
F13	3.28	3.31	3.43	3.44	**3.07**	**3.26**	3.28
F14	0.17	**0.17**	0.18	0.18	**0.17**	**0.17**	0.17
F15	0.82	**0.54**	0.89	0.93	**0.49**	**0.52**	**0.56**
F16	1.68	1.72	2.01	2.06	**1.56**	1.80	1.94
F17	0.91	0.91	1.10	1.12	**0.87**	1.01	1.04
F18	0.53	**0.50**	0.65	0.66	**0.42**	0.55	0.60

Table 7: Median of testing error with the maximum depth of $sTree$= 3: bold face is better than GP, underline is the best result

Pro	GP	SA10	SA20	SAD	DA10	DA20	DAD
A. **Benchmarking Problems**							
F1	1.69	**1.19**	**1.11**	**1.52**	**1.54**	**1.33**	2.08
F2	10.17	**5.37**	**4.83**	**5.19**	**4.26**	**4.27**	**5.68**
F3	0.06	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
F4	0.31	**0.08**	0.57	3.31	**0.00**	**0.01**	**0.02**
F5	33.01	**24.12**	**6.56**	**23.32**	**10.36**	**5.08**	**19.74**
F6	0.26	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**
F7	0.03	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**
F8	45.88	**45.05**	**45.05**	**44.29**	45.97	**45.58**	**44.60**
F9	2.19	**2.18**	**2.18**	**2.18**	2.20	**2.18**	**2.18**
B. **UCI Problems**							
F10	0.75	**0.27**	**0.28**	**0.26**	**0.24**	**0.25**	**0.25**
F11	0.61	**0.58**	**0.57**	**0.58**	**0.58**	**0.57**	**0.57**
F12	0.36	**0.20**	**0.27**	**0.33**	**0.16**	**0.17**	**0.18**
F13	5.18	**3.86**	**3.90**	**3.97**	**3.99**	**3.73**	**3.75**
F14	0.18	**0.17**	**0.18**	0.18	**0.17**	**0.17**	**0.17**
F15	1.44	**0.56**	**0.89**	**0.94**	**0.56**	**0.51**	**0.54**
F16	2.69	**2.31**	**2.10**	**2.06**	**2.17**	**2.10**	**1.97**
F17	1.77	**1.28**	**1.16**	**1.13**	**1.29**	**1.29**	**1.31**
F18	0.73	**0.59**	**0.69**	**0.69**	**0.53**	**0.57**	**0.64**

Table 8: Average size of solutions with the maximum depth of $sTree$= 3: bold face is better than GP, underline is the best result

Pro	GP	SA10	SA20	SAD	DA10	DA20	DAD
A. **Benchmarking Problems**							
F1	295.5	**97.2**	**18.7**	**15.2**	**75.9**	**21.8**	**15.8**
F2	228.3	**81.5**	**20.4**	**20.9**	**76.1**	**25.4**	**15.4**
F3	180.9	**67.3**	**42.4**	**30.9**	**76.6**	**43.7**	**28.4**
F4	187.3	**66.4**	**20.5**	**11.9**	**54.3**	**13.3**	**9.5**
F5	162.5	**59.1**	**16.1**	**11.4**	**54.6**	**13.4**	**12.3**
F6	216.9	**79.1**	**21.9**	**11.0**	**65.6**	**21.7**	**16.8**
F7	153.6	**69.6**	**21.8**	**21.5**	**63.9**	**20.5**	**24.8**
F8	161.0	**61.3**	**15.6**	**24.6**	**63.3**	**16.7**	**11.6**
F9	237.8	**85.0**	**16.3**	**7.8**	**60.3**	**15.9**	**11.3**
B. **UCI Problems**							
F10	196.4	**58.5**	**8.6**	**12.0**	**70.7**	**16.5**	**15.5**
F11	192.0	**66.1**	**10.8**	**8.1**	**75.0**	**17.3**	**12.8**
F12	151.7	**57.5**	**16.9**	**12.4**	**74.0**	**21.1**	**13.6**
F13	200.8	**26.9**	**7.9**	**7.7**	**55.7**	**13.1**	**8.1**
F14	170.5	**52.9**	**8.5**	**6.7**	**65.4**	**12.8**	**9.9**
F15	187.4	**51.6**	**10.8**	**8.7**	**68.9**	**15.9**	**9.2**
F16	192.6	**61.1**	**10.0**	**8.4**	**74.3**	**20.3**	**13.7**
F17	177.5	**68.0**	**8.8**	**7.6**	**76.0**	**16.3**	**13.5**
F18	181.8	**46.0**	**9.2**	**8.1**	**61.3**	**17.1**	**15.5**

Table 9: Mean of the best fitness with the maximum depth of $sTree$= 4: bold face is better than GP, underline is the best result

Pro	GP	SA10	SA20	SAD	DA10	DA20	DAD
A. **Benchmarking Problems**							
F1	0.47	0.48	0.89	1.34	**0.43**	0.90	1.17
F2	1.91	**1.17**	2.35	4.18	**0.99**	2.24	3.51
F3	0.10	**0.10**	0.13	0.14	**0.10**	0.12	0.12
F4	0.51	**0.16**	0.52	1.94	**0.07**	**0.10**	1.41
F5	1.13	**1.07**	1.61	2.85	**1.01**	1.42	2.79
F6	0.26	**0.25**	**0.25**	**0.26**	**0.25**	**0.25**	**0.25**
F7	0.03	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**
F8	9.90	**9.72**	22.97	36.76	**8.84**	15.01	22.07
F9	0.38	0.38	0.48	0.50	**0.32**	0.45	0.48
B. **UCI Problems**							
F10	0.41	**0.16**	**0.23**	**0.23**	**0.14**	**0.16**	**0.18**
F11	0.47	0.48	0.52	0.53	**0.46**	0.50	0.51
F12	0.40	**0.18**	**0.27**	**0.30**	**0.16**	**0.16**	**0.17**
F13	3.28	3.31	3.42	3.44	**3.10**	**3.27**	**3.27**
F14	0.17	**0.17**	0.18	0.18	**0.17**	**0.17**	0.17
F15	0.82	**0.58**	**0.81**	0.89	**0.50**	**0.53**	**0.58**
F16	1.68	**1.64**	2.01	2.06	**1.55**	1.80	1.92
F17	0.91	0.94	1.10	1.11	**0.85**	1.01	1.04
F18	0.53	**0.48**	0.65	0.66	**0.41**	0.54	0.60

Table 10: Median of testing error with the maximum depth of $sTree$= 4: bold face is better than GP, underline is the best result

Pro	GP	SA10	SA20	SAD	DA10	DA20	DAD
A. **Benchmarking Problems**							
F1	1.69	**1.14**	**0.99**	**1.51**	**1.34**	**1.34**	1.99
F2	10.17	**4.72**	**3.86**	**5.74**	**4.44**	**4.34**	**5.70**
F3	0.06	**0.05**	**0.05**	0.06	**0.05**	**0.05**	**0.05**
F4	0.31	**0.14**	**0.21**	3.99	**0.01**	**0.01**	3.02
F5	33.01	**25.47**	**7.35**	**25.48**	**10.87**	**6.77**	**24.63**
F6	0.26	**0.26**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**
F7	0.03	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**
F8	45.88	**45.59**	**45.51**	**44.30**	46.74	**45.37**	**45.11**
F9	2.19	**2.19**	**2.18**	**2.18**	**2.19**	**2.18**	**2.18**
B. **UCI Problems**							
F10	0.75	**0.26**	**0.28**	**0.28**	**0.24**	**0.23**	**0.25**
F11	0.61	**0.59**	**0.57**	**0.58**	**0.59**	**0.57**	**0.57**
F12	0.36	**0.19**	**0.26**	**0.32**	**0.17**	**0.17**	**0.18**
F13	5.18	**3.85**	**3.82**	**3.82**	**3.92**	**3.72**	**3.77**
F14	0.18	**0.17**	0.18	0.18	**0.17**	**0.17**	**0.17**
F15	1.44	**0.61**	**0.88**	**0.94**	**0.59**	**0.51**	**0.53**
F16	2.69	**2.17**	**2.05**	**2.04**	**2.43**	**2.04**	**1.99**
F17	1.77	**1.31**	**1.15**	**1.13**	**1.32**	**1.29**	**1.33**
F18	0.73	**0.60**	**0.65**	**0.69**	**0.55**	**0.59**	**0.60**

Table 11: Average size of solutions with the maximum depth of $sTree$= 4: bold face is better than GP, underline is the best result

Pro	GP	SA10	SA20	SAD	DA10	DA20	DAD
A. **Benchmarking Problems**							
F1	295.5	**93.8**	**23.1**	**14.8**	**75.8**	**21.7**	**14.4**
F2	228.3	**77.4**	**21.6**	**18.7**	**79.5**	**27.6**	**18.9**
F3	180.9	**67.3**	**29.5**	**28.5**	**65.1**	**39.6**	**28.4**
F4	187.3	**65.4**	**19.0**	**10.5**	**51.3**	**12.2**	**12.1**
F5	162.5	**61.6**	**13.5**	**10.4**	**58.2**	**13.2**	**13.0**
F6	216.9	**77.1**	**17.7**	**8.9**	**66.5**	**18.4**	**20.7**
F7	153.6	**75.1**	**20.9**	**19.9**	**69.6**	**18.5**	**18.8**
F8	161.0	**67.4**	**15.7**	**21.9**	**57.6**	**15.8**	**13.8**
F9	237.8	**74.1**	**13.8**	**10.6**	**63.4**	**17.0**	**10.7**
B. **UCI Problems**							
F10	196.4	**60.1**	**7.8**	**9.6**	**65.7**	**15.9**	**15.8**
F11	192.0	**55.8**	**10.3**	**7.2**	**77.1**	**18.3**	**11.3**
F12	151.7	**55.7**	**14.0**	**11.3**	**71.4**	**21.0**	**12.4**
F13	200.8	**22.6**	**7.2**	**8.4**	**64.0**	**13.8**	**7.9**
F14	170.5	**48.3**	**8.9**	**6.9**	**65.7**	**15.5**	**9.9**
F15	187.4	**67.2**	**9.9**	**7.7**	**73.5**	**17.2**	**9.5**
F16	192.6	**63.2**	**9.2**	**7.6**	**75.7**	**19.5**	**15.3**
F17	177.5	**60.1**	**9.9**	**8.3**	**75.8**	**16.7**	**14.5**
F18	181.8	**58.7**	**8.4**	**7.0**	**66.6**	**18.6**	**14.8**

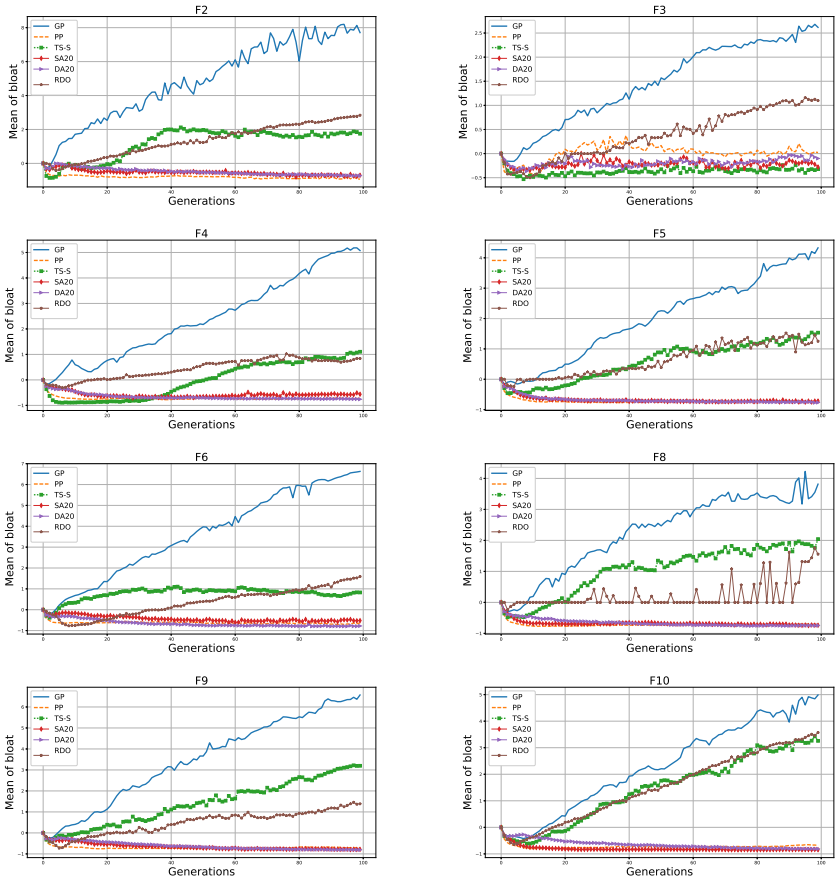

Figure 1: Average bloat over generations on problems F2, F3, F4, F5, F6, F8,F9 and F10.

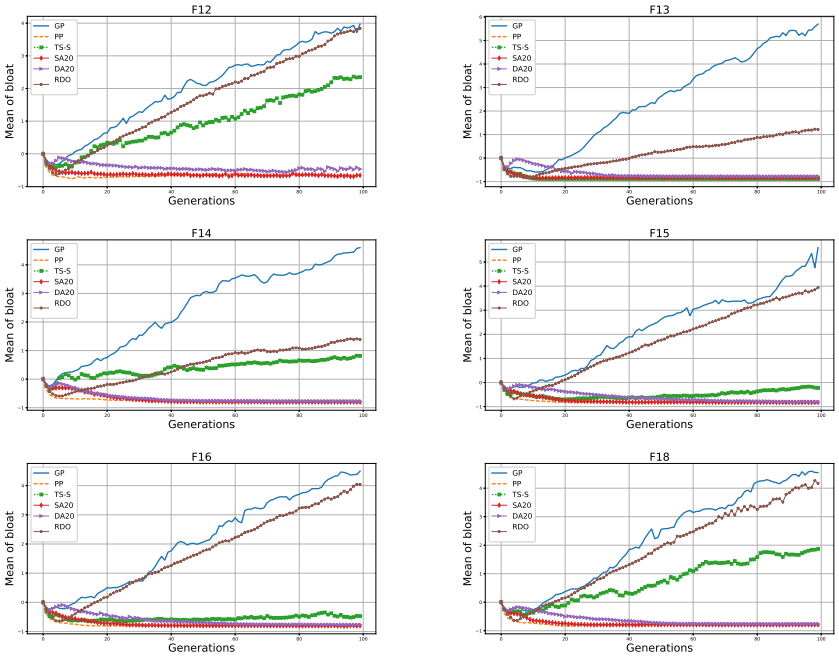

Figure 2: Average bloat over generations on problems F12, F13, F14, F15, F16 and F18.

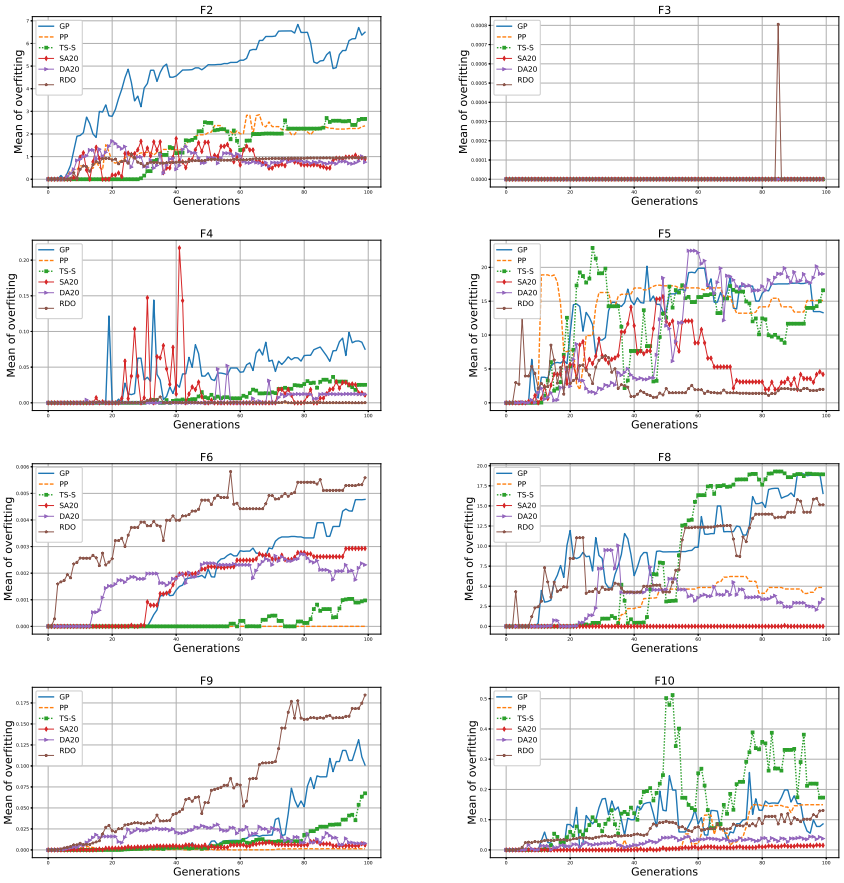

Figure 3: Average overfitting over the generations on problems F2, F3, F4, F5, F6, F8, F9 and F10.

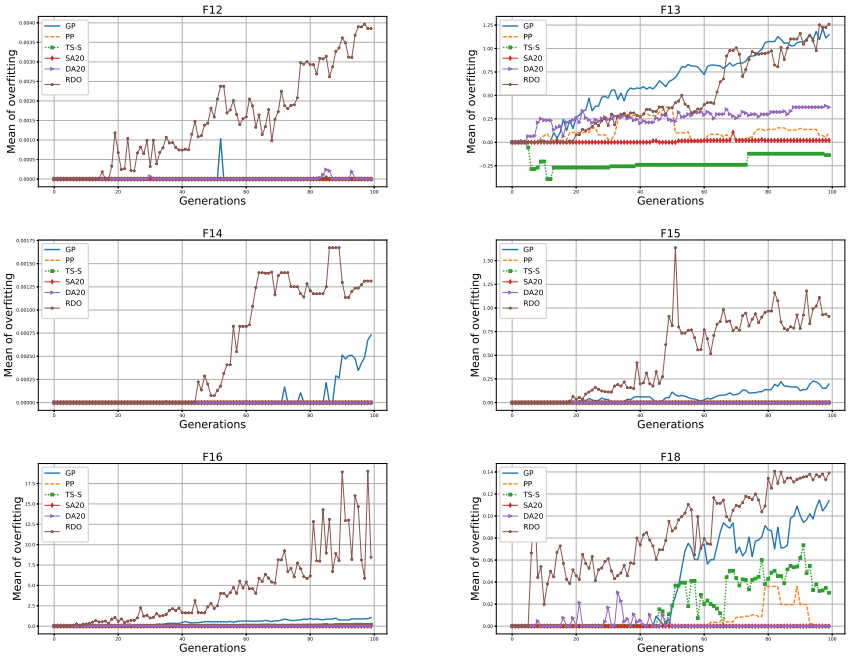

Figure 4: Average overfitting over the generations on problems F12, F13, F14, F15, F16 and F18.

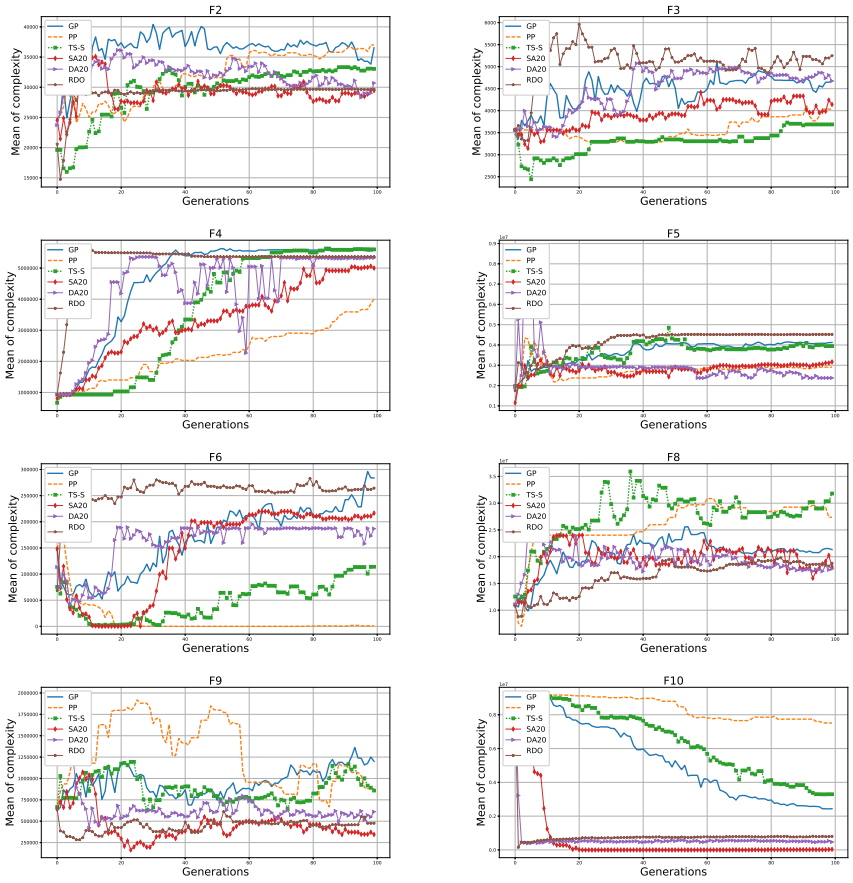

Figure 5: Average complexity of the best individual over the generations on problems F2, F3, F4, F5, F6, F8, F9 and F10.

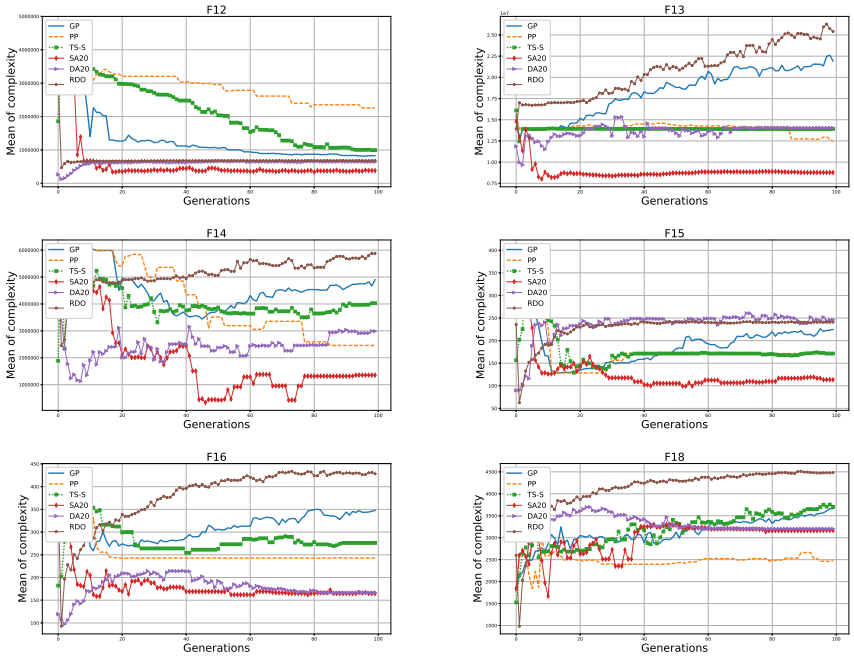

Figure 6: Average complexity of the best individual over the generations on problems F12, F13, F14, F15, F16 and F18.