

Semantic Approximation for Reducing Code Bloat in Genetic Programming

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Table 2: 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	<u>0.41</u>	0.95	1.16
F2	1.91	1.11	2.27	4.25	<u>1.03</u>	2.33	3.54
F3	0.10	0.11	0.13	0.12	<u>0.10</u>	0.12	0.11
F4	0.51	0.19	0.43	1.98	<u>0.17</u>	0.35	1.28
F5	1.13	0.95	1.62	2.68	<u>0.88</u>	1.54	2.40
F6	0.26	0.25	0.25	0.25	<u>0.25</u>	0.25	0.25
F7	0.03	0.03	0.03	0.03	<u>0.03</u>	0.03	0.03
F8	<u>9.90</u>	11.58	24.61	41.36	10.56	23.17	30.25
F9	0.38	0.37	0.49	0.49	<u>0.32</u>	0.47	0.48
F10	0.41	0.17	0.23	0.23	<u>0.14</u>	0.17	0.18
B. UCI Problems							
F11	0.47	0.48	0.52	0.53	<u>0.46</u>	0.50	0.51
F12	0.40	0.19	0.26	0.31	<u>0.15</u>	0.16	0.17
F13	3.28	3.33	3.41	3.44	<u>3.08</u>	3.28	3.29
F14	0.17	0.17	0.18	0.18	<u>0.17</u>	0.17	0.17
F15	0.82	0.54	0.80	0.87	<u>0.45</u>	0.54	0.58
F16	1.68	1.70	2.01	2.05	<u>1.61</u>	1.84	1.93
F17	0.91	0.94	1.11	1.11	<u>0.83</u>	1.00	1.03
F18	0.53	0.49	0.64	0.66	<u>0.42</u>	0.55	0.60

Table 3: 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	<u>0.93</u>	1.38	0.98	1.83	2.01
F2	10.17	4.77	5.10	5.61	<u>4.41</u>	4.63	5.66
F3	0.06	0.05	0.06	0.06	0.05	0.05	<u>0.05</u>
F4	0.31	0.16	0.25	3.52	<u>0.01</u>	<u>0.01</u>	2.94
F5	33.01	12.72	6.55	19.39	14.87	<u>3.56</u>	8.87
F6	0.26	0.25	0.25	<u>0.25</u>	0.25	0.25	0.25
F7	0.03	0.03	0.03	0.03	0.03	0.03	<u>0.03</u>
F8	45.88	44.21	44.63	44.23	44.94	44.25	<u>43.90</u>
F9	2.19	2.18	2.18	<u>2.18</u>	2.19	2.18	2.18
B. UCI Problems							
F10	0.75	0.27	0.27	0.27	<u>0.24</u>	0.25	0.25
F11	0.61	0.59	0.58	0.58	0.59	0.58	<u>0.58</u>
F12	0.36	0.20	0.29	0.32	<u>0.16</u>	0.17	0.18
F13	5.18	3.87	3.84	3.90	4.00	3.77	<u>3.74</u>
F14	0.18	0.17	0.18	0.18	<u>0.17</u>	0.17	0.17
F15	1.44	0.55	0.65	0.86	<u>0.52</u>	0.53	0.53
F16	2.69	2.40	2.09	2.04	2.23	<u>2.04</u>	2.07
F17	1.77	1.31	1.14	<u>1.12</u>	1.54	1.30	1.32
F18	0.73	0.60	0.68	0.67	<u>0.55</u>	0.62	0.62

Table 4: 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	<u>17.1</u>
F2	228.3	81.5	22.8	13.5	77.2	27.1	<u>12.7</u>
F3	180.9	64.6	43.5	<u>31.6</u>	63.5	43.8	36.0
F4	187.3	75.5	24.2	14.9	44.2	<u>11.3</u>	11.9
F5	162.5	59.1	12.8	<u>11.2</u>	57.6	12.3	12.5
F6	216.9	84.0	24.3	<u>10.6</u>	68.2	21.6	16.7
F7	153.6	68.8	22.5	23.4	72.3	<u>17.5</u>	20.9
F8	161.0	60.1	<u>14.1</u>	20.2	62.3	17.7	17.6
F9	237.8	79.2	12.1	<u>10.5</u>	73.6	11.8	11.9
B. UCI Problems							
F10	196.4	55.7	10.9	<u>9.6</u>	58.5	15.7	11.4
F11	192.0	62.8	10.6	<u>6.7</u>	82.0	19.2	16.5
F12	151.7	65.5	21.2	<u>12.4</u>	72.7	21.1	15.3
F13	200.8	24.8	7.9	<u>6.7</u>	70.6	11.9	7.2
F14	170.5	58.0	10.1	<u>7.3</u>	62.3	11.7	10.8
F15	187.4	58.3	9.9	<u>7.7</u>	68.9	13.8	8.8
F16	192.6	60.1	9.7	<u>9.1</u>	72.4	19.2	14.9
F17	177.5	63.5	10.7	<u>8.5</u>	84.3	17.6	12.5
F18	181.8	50.6	8.7	<u>7.2</u>	61.3	16.5	11.4

Table 5: Average running time in seconds 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	3.6	2.3	<u>0.8</u>	1.8	2.1	1.5	1.9
F2	2.7	2.2	<u>1.3</u>	1.4	2.6	2.0	1.6
F3	4.3	3.5	<u>3.2</u>	7.0	5.9	5.3	6.7
F4	63.2	34.7	<u>14.2</u>	15.3	48.3	31.4	57.6
F5	64.9	33.8	<u>11.9</u>	15.9	43.8	39.0	88.0
F6	96.0	66.3	28.3	<u>17.7</u>	66.7	47.4	81.2
F7	77.7	60.0	<u>25.1</u>	26.8	79.3	50.2	214.5
F8	79.7	44.0	<u>13.9</u>	18.0	62.6	45.9	136.9
F9	82.7	46.6	16.0	<u>14.4</u>	66.6	44.7	62.4
B. UCI Problems							
F10	46.0	16.8	<u>8.1</u>	14.8	31.2	25.4	47.6
F11	8.4	6.0	<u>2.3</u>	4.7	9.0	3.8	36.8
F12	43.8	31.2	<u>11.9</u>	14.6	49.4	31.3	36.9
F13	7.2	2.6	<u>2.6</u>	5.6	7.3	5.6	37.1
F14	63.1	40.4	<u>11.9</u>	36.8	48.3	30.1	251.8
F15	4.1	1.9	<u>1.3</u>	3.1	3.7	1.6	14.4
F16	4.0	2.1	<u>0.9</u>	3.4	4.3	1.8	17.8
F17	4.0	2.1	<u>1.1</u>	3.4	5.0	1.8	17.8
F18	27.4	11.2	<u>5.9</u>	18.6	23.3	15.6	145.7

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	<u>0.47</u>	0.51	1.00	1.36	0.49	0.95	1.16
F2	1.91	1.18	2.54	4.20	<u>0.95</u>	2.20	3.39
F3	0.10	0.10	0.12	0.12	<u>0.09</u>	0.12	0.11
F4	0.51	0.23	0.72	1.91	<u>0.08</u>	0.31	0.53
F5	1.13	0.99	1.56	2.75	<u>0.83</u>	1.49	2.66
F6	0.26	0.25	0.25	0.26	<u>0.25</u>	0.25	0.25
F7	0.03	0.03	0.03	0.03	<u>0.03</u>	0.03	0.03
F8	9.90	11.28	20.92	37.54	<u>7.56</u>	15.66	21.01
F9	0.38	0.38	0.48	0.49	<u>0.36</u>	0.46	0.48
B. UCI Problems							
F10	0.41	0.16	0.22	0.22	<u>0.14</u>	0.17	0.18
F11	0.47	0.48	0.52	0.53	<u>0.47</u>	0.50	0.51
F12	0.40	0.20	0.26	0.32	<u>0.16</u>	0.16	0.17
F13	3.28	3.31	3.43	3.44	<u>3.07</u>	3.26	3.28
F14	0.17	0.17	0.18	0.18	<u>0.17</u>	0.17	0.17
F15	0.82	0.54	0.89	0.93	<u>0.49</u>	0.52	0.56
F16	1.68	1.72	2.01	2.06	<u>1.56</u>	1.80	1.94
F17	0.91	0.91	1.10	1.12	<u>0.87</u>	1.01	1.04
F18	0.53	0.50	0.65	0.66	<u>0.42</u>	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	<u>1.11</u>	1.52	1.54	1.33	2.08
F2	10.17	5.37	4.83	5.19	<u>4.26</u>	4.27	5.68
F3	0.06	<u>0.05</u>	0.05	0.05	0.05	0.05	0.05
F4	0.31	0.08	0.57	3.31	<u>0.00</u>	0.01	0.02
F5	33.01	24.12	6.56	23.32	10.36	<u>5.08</u>	19.74
F6	0.26	0.25	0.25	<u>0.25</u>	0.25	0.25	0.25
F7	0.03	0.03	0.03	<u>0.03</u>	0.03	0.03	0.03
F8	45.88	45.05	45.05	<u>44.29</u>	45.97	45.58	44.60
F9	2.19	2.18	2.18	<u>2.18</u>	2.20	2.18	2.18
B. UCI Problems							
F10	0.75	0.27	0.28	0.26	<u>0.24</u>	0.25	0.25
F11	0.61	0.58	0.57	0.58	0.58	<u>0.57</u>	0.57
F12	0.36	0.20	0.27	0.33	<u>0.16</u>	0.17	0.18
F13	5.18	3.86	3.90	3.97	3.99	<u>3.73</u>	3.75
F14	0.18	0.17	0.18	0.18	0.17	<u>0.17</u>	0.17
F15	1.44	0.56	0.89	0.94	0.56	<u>0.51</u>	0.54
F16	2.69	2.31	2.10	2.06	2.17	2.10	<u>1.97</u>
F17	1.77	1.28	1.16	<u>1.13</u>	1.29	1.29	1.31
F18	0.73	0.59	0.69	0.69	<u>0.53</u>	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	<u>15.2</u>	75.9	21.8	15.8
F2	228.3	81.5	20.4	20.9	76.1	25.4	<u>15.4</u>
F3	180.9	67.3	42.4	30.9	76.6	43.7	<u>28.4</u>
F4	187.3	66.4	20.5	11.9	54.3	13.3	<u>9.5</u>
F5	162.5	59.1	16.1	<u>11.4</u>	54.6	13.4	12.3
F6	216.9	79.1	21.9	<u>11.0</u>	65.6	21.7	16.8
F7	153.6	69.6	21.8	21.5	63.9	<u>20.5</u>	24.8
F8	161.0	61.3	15.6	24.6	63.3	16.7	<u>11.6</u>
F9	237.8	85.0	16.3	<u>7.8</u>	60.3	15.9	11.3
B. UCI Problems							
F10	196.4	58.5	<u>8.6</u>	12.0	70.7	16.5	15.5
F11	192.0	66.1	10.8	<u>8.1</u>	75.0	17.3	12.8
F12	151.7	57.5	16.9	<u>12.4</u>	74.0	21.1	13.6
F13	200.8	26.9	7.9	<u>7.7</u>	55.7	13.1	8.1
F14	170.5	52.9	8.5	<u>6.7</u>	65.4	12.8	9.9
F15	187.4	51.6	10.8	<u>8.7</u>	68.9	15.9	9.2
F16	192.6	61.1	10.0	<u>8.4</u>	74.3	20.3	13.7
F17	177.5	68.0	8.8	<u>7.6</u>	76.0	16.3	13.5
F18	181.8	46.0	9.2	<u>8.1</u>	61.3	17.1	15.5

Table 9: Average running time in seconds 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	3.6	2.7	<u>0.8</u>	1.7	2.9	1.1	2.6
F2	2.7	2.3	<u>0.6</u>	1.7	2.6	1.2	2.5
F3	4.3	3.7	<u>2.9</u>	6.3	6.7	5.8	6.0
F4	63.2	39.4	<u>13.6</u>	13.7	45.0	25.9	83.1
F5	64.9	34.7	<u>12.2</u>	20.6	49.4	29.3	115.6
F6	96.0	67.9	<u>19.9</u>	23.8	70.3	33.2	116.3
F7	77.7	60.9	<u>20.9</u>	34.3	82.8	36.0	224.2
F8	79.7	51.6	<u>13.0</u>	24.0	67.8	31.7	124.5
F9	82.7	52.7	<u>15.4</u>	22.9	61.4	36.4	74.6
B. UCI Problems							
F10	46.0	19.7	<u>14.0</u>	15.6	36.1	23.5	54.3
F11	8.4	4.9	<u>2.2</u>	5.8	9.9	4.3	47.2
F12	43.8	26.0	17.0	<u>13.7</u>	46.6	30.6	43.8
F13	7.2	2.5	<u>2.3</u>	5.7	7.7	5.1	26.1
F14	63.1	36.6	<u>20.1</u>	43.3	50.2	28.7	333.8
F15	4.1	1.5	<u>1.4</u>	3.2	3.3	2.0	10.2
F16	4.0	1.7	<u>1.3</u>	3.5	3.7	1.9	13.0
F17	4.0	1.8	<u>0.7</u>	3.5	4.0	1.9	10.7
F18	27.4	11.2	<u>7.2</u>	17.9	21.5	9.9	164.5

Table 10: 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	<u>0.43</u>	0.90	1.17
F2	1.91	1.17	2.35	4.18	<u>0.99</u>	2.24	3.51
F3	0.10	0.10	0.13	0.14	<u>0.10</u>	0.12	0.12
F4	0.51	0.16	0.52	1.94	<u>0.07</u>	0.10	1.41
F5	1.13	1.07	1.61	2.85	<u>1.01</u>	1.42	2.79
F6	0.26	0.25	0.25	0.26	<u>0.25</u>	0.25	0.25
F7	0.03	<u>0.03</u>	0.03	0.03	0.03	0.03	0.03
F8	9.90	9.72	22.97	36.76	<u>8.84</u>	15.01	22.07
F9	0.38	0.38	0.48	0.50	<u>0.32</u>	0.45	0.48
B. UCI Problems							
F10	0.41	0.16	0.23	0.23	<u>0.14</u>	0.16	0.18
F11	0.47	0.48	0.52	0.53	<u>0.46</u>	0.50	0.51
F12	0.40	0.18	0.27	0.30	<u>0.16</u>	0.16	0.17
F13	3.28	3.31	3.42	3.44	<u>3.10</u>	3.27	3.27
F14	0.17	0.17	0.18	0.18	<u>0.17</u>	0.17	0.17
F15	0.82	0.58	0.81	0.89	<u>0.50</u>	0.53	0.58
F16	1.68	1.64	2.01	2.06	<u>1.55</u>	1.80	1.92
F17	0.91	0.94	1.10	1.11	<u>0.85</u>	1.01	1.04
F18	0.53	0.48	0.65	0.66	<u>0.41</u>	0.54	0.60

Table 11: 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	<u>0.99</u>	1.51	1.34	1.34	1.99
F2	10.17	4.72	<u>3.86</u>	5.74	4.44	4.34	5.70
F3	0.06	0.05	0.05	0.06	<u>0.05</u>	0.05	0.05
F4	0.31	0.14	0.21	3.99	0.01	<u>0.01</u>	3.02
F5	33.01	25.47	7.35	25.48	10.87	<u>6.77</u>	24.63
F6	0.26	0.26	0.25	<u>0.25</u>	0.25	0.25	0.25
F7	0.03	0.03	0.03	0.03	0.03	0.03	<u>0.03</u>
F8	45.88	45.59	45.51	<u>44.30</u>	46.74	45.37	45.11
F9	2.19	2.19	2.18	<u>2.18</u>	2.19	2.18	2.18
B. UCI Problems							
F10	0.75	0.26	0.28	0.28	0.24	<u>0.23</u>	0.25
F11	0.61	0.59	0.57	0.58	0.59	<u>0.57</u>	0.57
F12	0.36	0.19	0.26	0.32	<u>0.17</u>	0.17	0.18
F13	5.18	3.85	3.82	3.82	3.92	<u>3.72</u>	3.77
F14	0.18	0.17	0.18	0.18	<u>0.17</u>	0.17	0.17
F15	1.44	0.61	0.88	0.94	0.59	<u>0.51</u>	0.53
F16	2.69	2.17	2.05	2.04	2.43	2.04	<u>1.99</u>
F17	1.77	1.31	1.15	<u>1.13</u>	1.32	1.29	1.33
F18	0.73	0.60	0.65	0.69	<u>0.55</u>	0.59	0.60

Table 12: 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	<u>14.4</u>
F2	228.3	77.4	21.6	<u>18.7</u>	79.5	27.6	18.9
F3	180.9	67.3	29.5	28.5	65.1	39.6	<u>28.4</u>
F4	187.3	65.4	19.0	<u>10.5</u>	51.3	12.2	12.1
F5	162.5	61.6	13.5	<u>10.4</u>	58.2	13.2	13.0
F6	216.9	77.1	17.7	<u>8.9</u>	66.5	18.4	20.7
F7	153.6	75.1	20.9	19.9	69.6	<u>18.5</u>	18.8
F8	161.0	67.4	15.7	21.9	57.6	15.8	<u>13.8</u>
F9	237.8	74.1	13.8	<u>10.6</u>	63.4	17.0	10.7
B. UCI Problems							
F10	196.4	60.1	<u>7.8</u>	9.6	65.7	15.9	15.8
F11	192.0	55.8	10.3	<u>7.2</u>	77.1	18.3	11.3
F12	151.7	55.7	14.0	<u>11.3</u>	71.4	21.0	12.4
F13	200.8	22.6	<u>7.2</u>	8.4	64.0	13.8	7.9
F14	170.5	48.3	8.9	<u>6.9</u>	65.7	15.5	9.9
F15	187.4	67.2	9.9	<u>7.7</u>	73.5	17.2	9.5
F16	192.6	63.2	9.2	<u>7.6</u>	75.7	19.5	15.3
F17	177.5	60.1	9.9	<u>8.3</u>	75.8	16.7	14.5
F18	181.8	58.7	8.4	<u>7.0</u>	66.6	18.6	14.8

Table 13: Average running time in seconds 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	3.6	2.6	<u>0.8</u>	2.0	3.0	1.2	2.8
F2	2.7	2.1	<u>0.6</u>	2.0	2.7	1.3	2.7
F3	4.3	4.9	<u>2.6</u>	5.2	6.2	5.1	6.0
F4	63.2	39.3	<u>13.0</u>	17.7	38.3	44.3	67.7
F5	64.9	38.6	<u>13.1</u>	21.7	46.5	42.0	92.1
F6	96.0	68.8	24.1	<u>22.0</u>	66.5	41.9	83.6
F7	77.7	67.2	<u>22.0</u>	41.8	72.8	46.3	156.5
F8	79.7	51.9	<u>13.9</u>	21.4	56.6	33.0	107.5
F9	82.7	51.0	<u>17.0</u>	21.3	57.0	33.5	77.4
B. UCI Problems							
F10	46.0	18.2	<u>15.9</u>	20.2	37.0	23.4	43.5
F11	8.4	5.9	<u>2.6</u>	6.9	10.4	4.7	37.0
F12	43.8	30.5	<u>15.4</u>	15.7	41.6	37.9	46.6
F13	7.2	<u>2.7</u>	2.7	6.2	7.8	6.6	35.5
F14	63.1	36.3	<u>18.8</u>	42.0	42.8	38.0	369.8
F15	4.1	3.1	<u>1.2</u>	3.0	5.0	3.3	12.2
F16	4.0	2.7	<u>1.1</u>	3.0	5.4	2.8	18.1
F17	4.0	2.8	<u>1.1</u>	3.0	5.1	2.7	18.2
F18	27.4	12.6	<u>7.5</u>	17.4	18.5	12.1	136.2