Semantic Approximation Based Operator for Reducing Code Bloat in Genetic Programming

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Supplement 1: The results of Kruskal-Wallis test and post hoc analysis using Dunns Test with Benjamini Hochberg procedure.

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Table 2: Post-hoc analysis of Kruskal Wallis test using Dunns Test with Benjamini Hochberg procedure conducted on training errors. If the result of the method in the first column is better than that of the method in the second column, p-value of this post-hoc test is printed in bold face. Significant results marked in italic face ($\alpha = 0.05$).

Problems		F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15
Kruskal Wallis		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
neatGP	GP	*.013*	*.000*	*.004*	*.000*	*.000*	*.000*	*.000*	*.001*	*.031*	*.000*	*.000*	*.000*	*.000*	*.000*	*.001*
PP	GP	.241	*.037*	.338	*.000*	***.000***	*.000*	*.002*	.099	*.022*	*.000*	*.000*	*.006*	*.000*	*.000*	*.001*
SAT-GP	GP	***.000***	***.000***	***.000***	***.001***	**.097**	**.585**	**.556**	***.000***	***.002***	*.000*	.331	**.220**	*.001*	*.008*	**.546**
PP-AT0.1	GP	***.000***	.060	***.044***	*.043*	**.885**	**.576**	**.446**	***.000***	***.000***	**.827**	**.719**	**.558**	.684	**.879**	***.011***
PP-AT0.2	GP	***.000***	***.005***	***.003***	.306	**.539**	.568	**.149**	***.000***	***.000***	.450	**.896**	**.333**	.843	.714	***.003***
PP-AT0.5	GP	***.001***	**.081**	**.212**	*.000*	***.000***	*.002*	.144	***.000***	***.046***	*.000*	*.000*	*.035*	*.000*	*.000*	.123
PP	neatGP	**.205**	***.022***	**.059**	***.001***	**.174**	***.032***	***.012***	**.135**	**.873**	*.008*	**.712**	**.139**	**.368**	.138	**.971**
SAT-GP	neatGP	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	.304	***.000***	***.000***	***.021***	***.006***	***.000***
PP-AT0.1	neatGP	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***
PP-AT0.2	neatGP	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***
PP-AT0.5	neatGP	***.000***	***.000***	***.000***	***.001***	***.024***	***.002***	***.000***	***.000***	***.000***	.360	**.694**	***.031***	**.932**	**.905**	**.054**
SAT-GP	PP	***.000***	***.000***	***.000***	**.065**	***.000***	***.001***	***.000***	***.000***	***.000***	**.149**	***.003***	***.000***	***.001***	***.000***	***.000***
PP-AT0.1	PP	***.000***	***.000***	***.003***	***.002***	***.000***	***.001***	***.000***	***.000***	***.000***	***.000***	***.000***	***.001***	***.000***	***.000***	***.000***
PP-AT0.2	PP	***.000***	***.000***	***.000***	***.000***	***.000***	***.001***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***
PP-AT0.5	PP	***.000***	***.000***	***.029***	**.835**	**.409**	**.418**	**.127**	***.000***	***.000***	**.109**	**.944**	**.575**	**.341**	**.115**	**.052**
PP-AT0.1	SAT-GP	.978	*.009*	*.002*	.225	**.074**	**1**	**.807**	.642	**.534**	***.000***	**.120**	.562	***.007***	***.013***	**.054**
PP-AT0.2	SAT-GP	.954	.087	*.035*	*.026*	**.302**	.981	**.401**	**.097**	**.440**	***.000***	**.257**	.784	***.003***	***.027***	***.021***
PP-AT0.5	SAT-GP	*.040*	*.006*	*.000*	.098	*.008*	*.019*	*.042*	**.694**	.355	**.858**	*.003*	*.001*	*.025*	*.007*	*.032*
PP-AT0.2	PP-AT0.1	.976	**.337**	**.322**	**.296**	.469	1	**.507**	**.222**	**.898**	.336	.748	**.667**	**.849**	.843	**.691**
PP-AT0.5	PP-AT0.1	*.032*	**.880**	.415	***.004***	*.000*	*.018*	*.023*	**.406**	.102	*.000*	*.000*	*.006*	*.000*	*.000*	*.000*
PP-AT0.5	PP-AT0.2	*.032*	**.280**	.082	*.000*	*.000*	*.020*	*.003*	*.041*	.072	*.000*	*.000*	*.001*	*.000*	*.000*	*.000*

Table 3: Summary of the post hoc analysis of the Kruskal-Wallis test on training error. Each cell presents the number of problems that the method in a column is significantly better than the method in a row.

	neatGP	PP	SAT-GP	PP-AT0.1	PP-AT0.2	PP-AT0.5
neatGP		4	14	15	15	10
PP	1		13	15	15	5
SAT	0			3	4	0
PP-AT0.1	0	0	2		0	1
PP-AT0.2	0	0	2	0		0
$PP_AP0.5$	0	0	11	10	12	

Table 4: Post-hoc analysis of Kruskal Wallis test using Dunns Test with Benjamini Hochberg procedure conducted on testing errors. If the result of the method in the first column is better than that of the method in the second column, p-value of this post-hoc test is printed in bold face. Significant results marked in italic face ($\alpha = 0.05$).

Problems		F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15
Kruskal Wallis		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
neatGP	GP	.052	.931	*.020*	***.000***	***.021***	.748	***.040***	.534	.204	**.325**	*.031*	**.791**	**.349**	.791	.491
PP	GP	.376	**.907**	.294	***.021***	**.076**	**.875**	**.715**	.863	.258	**.196**	.823	.929	**.497**	**.396**	.543
SAT-GP	GP	***.000***	***.000***	***.000***	**.322**	.972	**.958**	.528	***.000***	***.001***	***.000***	***.025***	***.000***	***.010***	***.022***	***.001***
PP-AT0.1	GP	***.000***	***.002***	**.116**	.700	1.000	.185	**.183**	***.001***	***.001***	***.000***	***.033***	***.010***	**.228**	**.109**	***.001***
PP-AT0.2	GP	***.000***	***.000***	***.004***	.902	**1.000**	**.386**	***.045***	***.000***	***.001***	***.000***	***.050***	***.038***	**.193**	***.021***	***.000***
PP-AT0.5	GP	***.000***	***.001***	**.177**	***.009***	**.262**	**.123**	**.115**	***.000***	**.083**	***.000***	**.853**	***.021***	***.001***	***.003***	***.001***
PP	neatGP	**.351**	**.879**	**.183**	.087	.690	**.614**	.089	.446	**.960**	**.781**	***.044***	.848	**.830**	**.246**	**.952**
SAT-GP	neatGP	***.000***	***.000***	***.000***	*.003*	*.021*	**.750**	.133	***.000***	***.000***	***.000***	***.000***	***.000***	**.104**	***.013***	***.000***
PP-AT0.1	neatGP	***.000***	***.002***	***.000***	*.000*	*.022*	.375	.453	***.000***	***.000***	***.003***	***.001***	***.004***	**.865**	**.056**	***.000***
PP-AT0.2	neatGP	***.000***	***.000***	***.000***	*.000*	***.036***	**.190**	**.858**	***.000***	***.000***	***.003***	***.000***	***.021***	.763	***.011***	***.000***
PP-AT0.5	neatGP	***.000***	***.000***	***.000***	.157	.246	***.049***	.608	***.000***	***.001***	***.000***	***.021***	***.010***	***.018***	***.001***	***.000***
SAT-GP	PP	***.000***	***.000***	***.000***	.206	.068	**.876**	.741	***.000***	***.000***	***.000***	***.019***	***.000***	**.060**	**.196**	***.000***
PP-AT0.1	PP	***.000***	***.003***	***.010***	*.007*	.060	.152	**.364**	***.001***	***.000***	***.008***	**.254**	***.010***	.726	**.504**	***.000***
PP-AT0.2	PP	***.000***	***.000***	***.000***	*.016*	**.060**	**.467**	**.072**	***.000***	***.000***	***.006***	**.174**	***.045***	.624	**.180**	***.000***
PP-AT0.5	PP	***.000***	***.001***	***.021***	**.772**	.646	**.147**	**.207**	***.000***	***.002***	***.000***	**.752**	***.021***	***.010***	***.033***	***.000***
PP-AT0.1	SAT-GP	**1.000**	*.001*	*.001*	.149	1.000	.185	**.528**	*.013*	**.922**	.055	.234	.150	.174	**.489**	**1.000**
PP-AT0.2	SAT-GP	1.000	*.009*	**.051**	.279	**1.000**	**.383**	***.049***	.051	**.920**	.059	.312	.056	.205	**.963**	.989
PP-AT0.5	SAT-GP	.058	*.003*	*.000*	**.129**	**.259**	**.134**	**.390**	.420	.200	**.457**	.057	.072	**.539**	**.475**	1.000
PP-AT0.2	PP-AT0.1	1.000	**.541**	**.177**	**.760**	**.949**	***.030***	**.365**	**.619**	.912	**.936**	**.829**	.608	.863	**.494**	.909
PP-AT0.5	PP-AT0.1	.054	**.791**	.763	***.002***	**.232**	***.001***	**.767**	**.123**	.135	***.003***	.420	**.832**	***.034***	**.179**	.982
PP-AT0.5	PP-AT0.2	.054	**.845**	.116	***.007***	.226	**.474**	.508	**.318**	.176	***.003***	.305	**.790**	***.046***	**.504**	**.930**

Table 5: Post-hoc analysis of Kruskal Wallis test using Dunns Test with Benjamini Hochberg procedure conducted on solution size. If the result of the method in the first column is better than that of the method in the second column, p-value of this post-hoc test is printed in bold face. Significant results marked in italic face ($\alpha = 0.05$).

Problems		F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15
Kruskal Wallis		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
neatGP	GP	***.002***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***
PP	GP	***.003***	***.000***	***.040***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***
SAT-GP	GP	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***
PP-AT0.1	GP	***.001***	**.349**	**.422**	**.602**	**.792**	.901	**.416**	**.854**	***.003***	**.178**	***.049***	***.044***	**.196**	**.306**	***.028***
PP-AT0.2	GP	***.000***	**.135**	**.824**	**.440**	**.582**	**.433**	***.048***	***.024***	***.000***	***.033***	***.045***	***.048***	**.320**	**.178**	***.021***
PP-AT0.5	GP	***.000***	***.000***	***.001***	***.000***	***.001***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***
PP	neatGP	**.895**	*.009*	*.000*	*.000*	*.007*	.072	*.000*	**.413**	**.236**	**.272**	**.340**	.291	.499	**.372**	.577
SAT-GP	neatGP	***.000***	**.491**	.107	.448	.784	.904	**.416**	***.000***	***.002***	***.000***	***.001***	***.009***	***.013***	***.008***	***.000***
PP-AT0.1	neatGP	**.858**	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	.082	*.029*	*.004*	*.000*	*.000*	*.000*	*.007*
PP-AT0.2	neatGP	**.205**	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	.071	.244	.163	*.005*	*.000*	*.000*	*.000*	*.010*
PP-AT0.5	neatGP	***.000***	*.007*	*.001*	*.001*	*.000*	.062	*.007*	**.077**	**.051**	***.002***	**.360**	**.079**	**.615**	**.208**	***.018***
SAT-GP	PP	***.000***	***.001***	***.004***	***.002***	***.016***	**.088**	***.003***	***.002***	**.053**	***.000***	***.022***	***.000***	***.001***	**.100**	***.000***
PP-AT0.1	PP	**.790**	*.000*	*.004*	*.000*	*.000*	*.000*	*.001*	*.000*	*.003*	*.001*	*.000*	*.008*	*.000*	*.000*	*.029*
PP-AT0.2	PP	**.152**	*.002*	.065	*.001*	*.000*	*.000*	*.018*	*.010*	*.018*	*.015*	*.000*	*.007*	*.000*	*.000*	*.037*
PP-AT0.5	PP	***.000***	.931	**.244**	**.550**	.173	.947	**.293**	**.360**	**.415**	***.036***	.990	***.006***	**.240**	**.710**	***.004***
PP-AT0.1	SAT-GP	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*
PP-AT0.2	SAT-GP	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*
PP-AT0.5	SAT-GP	.210	*.001*	.102	*.017*	*.000*	.076	.065	*.030*	.246	*.025*	*.019*	.393	.051	.206	.211
PP-AT0.2	PP-AT0.1	**.251**	**.601**	**.319**	**.719**	**.401**	**.320**	**.328**	***.034***	**.566**	**.404**	**.947**	.990	.728	**.686**	**.884**
PP-AT0.5	PP-AT0.1	***.000***	***.001***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***
PP-AT0.5	PP-AT0.2	***.004***	***.003***	***.002***	***.000***	***.007***	***.000***	***.001***	***.000***	***.002***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***

Table 6: Post-hoc analysis of Kruskal Wallis test using Dunns Test with Benjamini Hochberg procedure conducted on running time. If the result of the method in the first column is better than that of the method in the second column, p-value of this post-hoc test is printed in bold face. Significant results marked in italic face ($\alpha = 0.05$).

Problems		F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15
Kruskal Wallis		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
neatGP	GP	*.049*	*.043*	.418	*.045*	.133	*.044*	.149	*.041*	*.050*	*.045*	*.036*	*.045*	*.042*	*.045*	*.042*
PP	GP	***.013***	***.003***	***.002***	***.002***	***.000***	***.000***	***.000***	***.007***	***.003***	***.000***	***.000***	***.000***	***.000***	***.000***	***.001***
SAT-GP	GP	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***
PP-AT0.1	GP	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.005***	***.000***	***.016***	***.007***	***.005***	***.000***
PP-AT0.2	GP	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.001***	***.001***	***.000***	***.001***	***.000***	***.000***
PP-AT0.5	GP	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***
PP	neatGP	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***
SAT-GP	neatGP	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***
PP-AT0.1	neatGP	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***
PP-AT0.2	neatGP	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***
PP-AT0.5	neatGP	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***
SAT-GP	PP	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.001***	***.000***	***.003***	***.022***	***.005***	***.000***
PP-AT0.1	PP	**.075**	**.636**	**.144**	**.231**	.882	.484	**.571**	**.152**	**.190**	*.010*	.860	*.012*	*.005*	*.046*	**.562**
PP-AT0.2	PP	***.015***	***.047***	***.003***	**.160**	.714	.313	**.992**	**.057**	**.308**	*.043*	.820	.405	*.034*	.483	**.558**
PP-AT0.5	PP	***.000***	***.000***	***.000***	***.000***	***.000***	***.009***	***.000***	***.000***	***.000***	**.063**	***.000***	***.000***	***.006***	***.000***	***.000***
PP-AT0.1	SAT-GP	*.000*	*.000*	*.003*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*
PP-AT0.2	SAT-GP	*.000*	*.000*	.137	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*
PP-AT0.5	SAT-GP	.078	.209	**.444**	.533	.217	.120	.314	.058	.355	.105	.343	**.575**	**.606**	**.467**	.396
PP-AT0.2	PP-AT0.1	**.464**	**.121**	**.147**	**.819**	.794	.737	**.593**	**.610**	.755	**.569**	.718	**.089**	**.491**	**.183**	**.963**
PP-AT0.5	PP-AT0.1	***.006***	***.000***	***.000***	***.001***	***.000***	***.001***	***.001***	***.003***	***.001***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***
PP-AT0.5	PP-AT0.2	***.042***	***.016***	***.024***	***.002***	***.000***	***.000***	***.000***	***.013***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***	***.000***