

jGE Experiments

Grammatical Evolution – Trigonometric Identity Experiments

Experiment 1 – Max Generations 100 and Population 500 (12/06/2006)

Trigonometric Identity Tableau for GE (O'Neill-style)

Objective:	Find a new mathematical expression, in symbolic form that equals a given mathematical expression, for all values of its independent variables. Examined Function: $\text{Math.cos}(2 * x)$ Desired Trigonometric Identity: $1-2\text{Sin}^2x$.
Terminal Operands:	x, the constant 1.0
Terminal Operators:	The binary operators +, -, /, *, and - The unary operator Math.sin
Fitness cases:	The given sample of the pairs (x_i, y_i) of 20 data points in the interval $[0, 2\pi]$. The input data points (x_i) are randomly created and their corresponding output points (y_i) are automatically created by the expression $\text{Math.cos}(2 * x)$
Raw Fitness:	The sum, of the absolute values of errors taken over the fitness cases (x_i, y_i) . With the above Raw Fitness the best individuals have lower values. For this reason a kind of Adjusted Fitness will be used and assigned to each individual. Adjusted Fitness of an individual i is typically defined as following: $Fa(i) = 1 / (1 + Fs(i))$ where Fs the Standardised Fitness of i. In this case the Adjusted Fitness of an individual i is calculated as following: $Fa(i) = 1 / (1 + Fr(i))$ where Fr the Raw Fitness of i. The fitness value varies from 0 to 1 and Invalid individuals will have Raw Fitness Value 0.
Standardised Fitness:	Same as raw fitness.
Wrapper:	Standard productions to generate a Java Class with a main() method which prints the fitness values in the standard output
Parameters:	Population Size (M) = 500, Maximum Generations (G) = 100, Prob. Mutation (Pm) = 0.01, Prob. Crossover (Pc) = 0.9, Prob. Duplication (Pd) = 0.01, Prob. Pruning (Pp) = 0.01, Codon Size = 8, Selection Mechanism: Steady State GA with Generation Gap (G) = 0.9 Initial Population: Min Codons = 20, Max Codons = 30

BNF Grammar

```
<expr> ::= <expr> <op> <expr> | ( <expr> <op> <expr> ) | <pre-op> ( <var> ) | <pre-op> ( <var> ) | <var> | <var> | <var> | <var> | <var>
<op> ::= + | - | / | *
<pre-op> ::= Math.sin
<var> ::= x | 1.0
```

Trigonometric Identity Results

Run	Generations	Phenotype	Raw Fitness
1	100	$((\text{Math.sin}(1.0) * \text{Math.sin}(1.0)) - \text{Math.sin}(x) * \text{Math.sin}(x) / \text{Math.sin}(1.0))$	0.17683099478389447
2	100	$(1.0 - \text{Math.sin}(x) * (1.0 + 1.0) * \text{Math.sin}(x))$	0.9999999999999998
3	100	$1.0 - (\text{Math.sin}(x) + \text{Math.sin}(x)) *$	0.9999999999999982

		Math.sin (x)	
4	100	1.0 / (Math.sin (1.0) - x + x + Math.sin (1.0) / 1.0) - (Math.sin (x) / Math.sin (1.0) * Math.sin (x) / Math.sin (1.0) * 1.0)	0.2224573457715675
5	100	(1.0 - (1.0 * ((Math.sin (x) * Math.sin (1.0)) + Math.sin (x)))) / Math.sin (1.0))	0.1440742539861499
6	100	((Math.sin (1.0) / Math.sin (1.0) / Math.sin (x) - (Math.sin (x) + Math.sin (x))) * (Math.sin (x) * x / x))	0.9999999999999989
7	100	(((1.0 - Math.sin (x) - Math.sin (x)) * Math.sin (x)) - (Math.sin (x) - 1.0))	0.9999999999999984
8	100	(1.0 - (Math.sin (x) * (Math.sin (x) + Math.sin (x))))	0.9999999999999991
9	100	(Math.sin (1.0) - Math.sin (x) / Math.sin (1.0) / (Math.sin (1.0) / (Math.sin (x) / Math.sin (1.0))))	0.31883963323628783
10	100	1.0 - (Math.sin (x) * Math.sin (x) / x * (x + x))	0.9999999999999984
Avg	100		0.686220222777789

Experiment 2 – Using Families (x10) with Max Generations 10 and Population 500 (12/06/2006)

Trigonometric Identity Tableau for GE (O'Neill-style)

Objective:	Find a new mathematical expression, in symbolic form that equals a given mathematical expression, for all values of its independent variables. Examined Function: Math.cos(2 * x) Desired Trigonometric Identity: 1-2Sin ² x.
Terminal Operands:	x, the constant 1.0
Terminal Operators:	The binary operators +, -, /, *, and - The unary operator Math.sin
Fitness cases:	The given sample of the pairs (x _i , y _i) of 20 data points in the interval [0, 2π]. The input data points (x _i) are randomly created and their corresponding output points (y _i) are automatically created by the expression Math.cos(2 * x)
Raw Fitness:	The sum, of the absolute values of errors taken over the fitness cases (x _i , y _i). With the above Raw Fitness the best individuals have lower values. For this reason a kind of Adjusted Fitness will be used and assigned to each individual. Adjusted Fitness of an individual i is typically defined as following: Fa(i) = 1 / (1 + Fs(i)) where Fs the Standardised Fitness of i. In this case the Adjusted Fitness of an individual i is calculated as following: Fa(i) = 1 / (1 + Fr(i)) where Fr the Raw Fitness of i. The fitness value varies from 0 to 1 and Invalid individuals will have Raw Fitness Value 0.
Standardised Fitness:	Same as raw fitness.
Wrapper:	Standard productions to generate a Java Class with a main() method which prints the fitness values in the standard output
Parameters:	Population Size (M) = 500, Maximum Generations (G) = 10, Prob. Mutation (Pm) = 0.01, Prob. Crossover (Pc) = 0.9, Prob. Duplication (Pd) = 0.01, Prob. Pruning (Pp) = 0.01, Codon Size = 8, Selection Mechanism: Steady State GA with Generation Gap (G) = 0.9 Initial Population: Min Codons = 20, Max Codons = 30

BNF Grammar

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<expr> ::= <expr> <op> <expr> | ( <expr> <op> <expr> ) | <pre-op> ( <var> ) | <pre-op> (
<var> ) | <var> | <var> | <var> | <var>
<op> ::= + | - | / | *
<pre-op> ::= Math.sin
<var> ::= x | 1.0

```

Trigonometric Identity Results – Run 1

Family	Generations	Phenotype	Raw Fitness
1	10	(Math.sin (x) / (Math.sin (x) + x))	0.09000251206375098
2	10	Math.sin (1.0) - 1.0 / (1.0 + Math.sin (x) + Math.sin (1.0))	0.07755368226363055
3	10	Math.sin (1.0) - Math.sin (1.0) - (Math.sin (x) * Math.sin (x))	0.10374436597507322
4	10	(Math.sin (1.0) * Math.sin (1.0))	0.08231529558020259
5	10	(1.0 / Math.sin (1.0) - 1.0)	0.07734710250291478
6	10	(Math.sin (x) / (Math.sin (x) - Math.sin (1.0) - x / 1.0))	0.07073258030042903
7	10	((Math.sin (x) / x) / 1.0 - Math.sin (x)))	0.0848465700743908
8	10	(Math.sin (x) + Math.sin (1.0))	0.0837724318417429
9	10	1.0 - Math.sin (x) * Math.sin (x)	0.10550637435248064
10	10	(Math.sin (x) / x - Math.sin (x))	0.07500117542106016
Best	10	1.0 - Math.sin (x) * Math.sin (x)	0.10550637435248064

Trigonometric Identity Results – Run 2

Family	Generations	Phenotype	Raw Fitness
1	10	1.0 - Math.sin (x) - Math.sin (1.0)	0.0720839523134854
2	10	(x - x / Math.sin (1.0))	0.07448560434800366
3	10	Math.sin (1.0) - 1.0	0.08668535077194481
4	10	(1.0 - Math.sin (1.0))	0.06658680593402581
5	10	(1.0 - (Math.sin (1.0) + x - x * Math.sin (1.0)))	0.09461972442933347
6	10	(1.0 - Math.sin (x) * Math.sin (x))	0.09383267580622552
7	10	(Math.sin (1.0) - 1.0)	0.07322919548594099
8	10	1.0 - 1.0	0.07586175231215292
9	10	(1.0 - Math.sin (x) * Math.sin (x))	0.09253707352056613
10	10	1.0 - Math.sin (x) - Math.sin (1.0) + ((1.0 - Math.sin (x)) * Math.sin (x))	0.12135094167226684
Best	10	1.0 - Math.sin (x) - Math.sin (1.0) + ((1.0 - Math.sin (x)) * Math.sin (x))	0.12135094167226684

Trigonometric Identity Results – Run 3

Family	Generations	Phenotype	Raw Fitness
1	10	Math.sin (1.0) * Math.sin (1.0)	0.0835563765368876
2	10	(1.0 / Math.sin (1.0) - Math.sin (1.0))	0.09402434473649977
3	10	(Math.sin (1.0) * (1.0 - Math.sin (x)) / 1.0 * Math.sin (x))	0.08651153876987756
4	10	((1.0 - 1.0) - Math.sin (x))	0.08398036495641421
5	10	Math.sin (1.0) - 1.0	0.07106531816851365
6	10	x / (x + (x + Math.sin (1.0)) * x)	0.07891241190038918
7	10	x / x - 1.0 - (Math.sin (x) * 1.0) / x	0.08816410500078439

8	10	$(1.0 - \sin(x) * \sin(x) - \sin(1.0))$	0.1249894880441519
9	10	$(1.0 - \sin(x)) / (\sin(1.0) + x)$	0.0819802180709715
10	10	$(1.0 * \sin(1.0) * (\sin(1.0) - \sin(x) * \sin(x)))$	0.12506935146407785
Best	10	$(1.0 * \sin(1.0) * (\sin(1.0) - \sin(x) * \sin(x)))$	0.12506935146407785

Trigonometric Identity Results – Run 4

Family	Generations	Phenotype	Raw Fitness
1	10	$(\sin(1.0) - 1.0) * (\sin(x) + x)$	0.0918956827456898
2	10	$((1.0 + \sin(x)) - \sin(1.0))$	0.07657150871866118
3	10	$(\sin(x) / ((\sin(1.0) + \sin(x) + (1.0 * x) / \sin(1.0))) / x - x + (x + 1.0 / (1.0 + \sin(1.0) * x)))$	0.07756194367685701
4	10	$\sin(x) * \sin(1.0)$	0.07660930873844064
5	10	$\sin(1.0) / (1.0 * x + \sin(1.0))$	0.07006871264743325
6	10	$((\sin(1.0) * \sin(1.0) - \sin(1.0) * \sin(1.0)) - \sin(1.0) * \sin(1.0))$	0.07249588027949519
7	10	$(\sin(x) + 1.0 + (\sin(x) * \sin(x)) / 1.0 * \sin(x))$	0.0950417437261839
8	10	$(\sin(1.0) / (1.0 + x))$	0.08926815112295206
9	10	$(\sin(x) - (\sin(x) * 1.0 / \sin(1.0))) / \sin(1.0)$	0.07933056393950356
10	10	$((\sin(1.0) - \sin(x)) / x)$	0.1097557977853763
Best	10	$((\sin(1.0) - \sin(x)) / x)$	0.1097557977853763

Trigonometric Identity Results – Run 5

Family	Generations	Phenotype	Raw Fitness
1	10	$\sin(x) * ((1.0 / x) - 1.0)$	0.09215432002434072
2	10	$(1.0 / (x + (x + 1.0 / 1.0)))$	0.07458731710737168
3	10	$(\sin(x) / (1.0 + (x + x)) - (\sin(x) * \sin(x)) * (x / x)) - \sin(x) / (1.0 + (x + x))$	0.10708499434919262
4	10	$(\sin(1.0) * (\sin(x) + \sin(1.0)) * 1.0)$	0.08865364165531152
5	10	$(1.0 - \sin(1.0)) - \sin(x)$	0.0684048826006973
6	10	$(\sin(1.0) - \sin(x) * (\sin(x) / 1.0))$	0.09671571501367052
7	10	$(1.0 / (1.0 + x))$	0.08020574833344016
8	10	$(\sin(x) / (1.0 + x))$	0.07762691493112493
9	10	$(1.0 / (x * 1.0 + 1.0))$	0.068614911433823
10	10	$(\sin(1.0) * (\sin(x) / x)) - \sin(x)$	0.06743039387979417
Best	10	$(\sin(x) / (1.0 + (x + x)) - (\sin(x) * \sin(x)) * (x / x)) - \sin(x) / (1.0 + (x + x))$	0.10708499434919262

Trigonometric Identity Results – Run 6

Family	Generations	Phenotype	Raw Fitness
1	10	$(\text{Math.sin}(1.0) - 1.0) / (x - 1.0 - 1.0 + \text{Math.sin}(x))$	0.0869739150505286
2	10	$(\text{Math.sin}(1.0) * (1.0 - \text{Math.sin}(x)) * \text{Math.sin}(x))$	0.12528686880760348
3	10	$(1.0 - \text{Math.sin}(1.0)) / x$	0.0661168990754472
4	10	$(x / (1.0 + x))$	0.0808060906443953
5	10	$\text{Math.sin}(x) / 1.0 / ((x + (1.0 / 1.0)) + 1.0 - x)$	0.09241440143151275
6	10	$(\text{Math.sin}(1.0) - ((\text{Math.sin}(x)) * \text{Math.sin}(x)) * 1.0)$	0.12011762906638895
7	10	$(\text{Math.sin}(1.0) - (\text{Math.sin}(x)) * \text{Math.sin}(x))$	0.1277764679271336
8	10	$1.0 - 1.0 / \text{Math.sin}(1.0)$	0.083650241677013
9	10	$\text{Math.sin}(1.0) + 1.0 / (\text{Math.sin}(x) - 1.0 - \text{Math.sin}(1.0))$	0.08992125451307434
10	10	$\text{Math.sin}(1.0) - 1.0 + (\text{Math.sin}(1.0) - 1.0) * 1.0$	0.07622234792948983
Best	10	$(\text{Math.sin}(1.0) - (\text{Math.sin}(x)) * \text{Math.sin}(x))$	0.1277764679271336

Trigonometric Identity Results – Run 7

Family	Generations	Phenotype	Raw Fitness
1	10	$(\text{Math.sin}(x) / (\text{Math.sin}(1.0)) * x / ((x - x) - \text{Math.sin}(x) - 1.0))$	0.09543608346708082
2	10	$\text{Math.sin}(1.0) * 1.0 - \text{Math.sin}(x) * \text{Math.sin}(x)$	0.1473099256479427
3	10	$x / x - \text{Math.sin}(1.0)$	0.09363988290252005
4	10	$\text{Math.sin}(x) / (1.0 + (1.0 + \text{Math.sin}(x)) + 1.0)$	0.07824652061479635
5	10	$\text{Math.sin}(x) * \text{Math.sin}(x) * (1.0 * \text{Math.sin}(1.0) * \text{Math.sin}(x))$	0.08212564585229935
6	10	$(\text{Math.sin}(1.0) - \text{Math.sin}(x)) * \text{Math.sin}(x)$	0.1203353957081619
7	10	$1.0 - \text{Math.sin}(x) * \text{Math.sin}(x)$	0.10914536603138528
8	10	$(\text{Math.sin}(1.0) * \text{Math.sin}(x))$	0.09675384127368794
9	10	$(\text{Math.sin}(1.0) / (\text{Math.sin}(1.0) + \text{Math.sin}(1.0)))$	0.08560538368066742
10	10	$\text{Math.sin}(1.0) * \text{Math.sin}(1.0) - 1.0$	0.07658761458673137
Best	10	$(\text{Math.sin}(1.0) - \text{Math.sin}(x)) * \text{Math.sin}(x)$	0.1203353957081619

Trigonometric Identity Results – Run 8

Family	Generations	Phenotype	Raw Fitness
1	10	$((\text{Math.sin}(x) / x + \text{Math.sin}(1.0)) * (1.0 / (1.0 / 1.0))) * x * \text{Math.sin}(1.0) - (\text{Math.sin}(x) / x + \text{Math.sin}(1.0)) * (1.0 / (1.0 / 1.0)) * x)$	0.10899412168111935
2	10	$1.0 * ((\text{Math.sin}(1.0)) * x) - \text{Math.sin}(1.0) * x - \text{Math.sin}(1.0) * \text{Math.sin}(1.0)$	0.08584009097064181
3	10	$\text{Math.sin}(x) / (x + x)$	0.07717790231135176
4	10	$(1.0 / (\text{Math.sin}(x) * \text{Math.sin}(x) + x / x))$	0.07779851966413572
5	10	$\text{Math.sin}(1.0) - (1.0 + \text{Math.sin}(x)) * \text{Math.sin}(x)$	0.08832599961736236
6	10	$(1.0 - (1.0 / x) + \text{Math.sin}(x))$	0.0877324430971941

7	10	$(\sin(1.0) + \sin(x)) * 1.0 * (\sin(1.0) - (\sin(x) + x) + x)$	0.14370661640665258
8	10	$(1.0 / ((1.0 / x - (1.0 * (x + 1.0)))) - \sin(1.0))$	0.080195355849598
9	10	$\sin(1.0) / ((1.0 + x) + x)$	0.07915543972581013
10	10	$(1.0 / (1.0 + \sin(x) + \sin(x)))$	0.09606002050186772
Best	10	$(\sin(1.0) + \sin(x)) * 1.0 * (\sin(1.0) - (\sin(x) + x) + x)$	0.14370661640665258

Trigonometric Identity Results – Run 9

Family	Generations	Phenotype	Raw Fitness
1	10	$1.0 - 1.0 * \sin(x) * \sin(x) / \sin(1.0)$	0.09683163839130474
2	10	$x / ((1.0 * \sin(1.0)) - \sin(x) - x - x) * 1.0$	0.07160577379623542
3	10	$\sin(1.0) / (1.0 + x * \sin(x) * x)$	0.07736585963664275
4	10	$1.0 - 1.0$	0.07170619283841727
5	10	$(\sin(x) / 1.0 / x - (\sin(x) * \sin(x)))$	0.08646385687788048
6	10	$(\sin(x) / (x + x))$	0.07336751921013054
7	10	$1.0 - 1.0$	0.06787012094069998
8	10	$\sin(1.0) - 1.0$	0.07794633736477102
9	10	$(\sin(1.0) - 1.0)$	0.08512719210930664
10	10	$(1.0 / (x - (1.0 + x + 1.0)) / \sin(x) + 1.0)$	0.11506339927800766
Best	10	$(1.0 / (x - (1.0 + x + 1.0)) / \sin(x) + 1.0)$	0.11506339927800766

Trigonometric Identity Results – Run 10

Family	Generations	Phenotype	Raw Fitness
1	10	$(\sin(1.0) - \sin(x) * \sin(x))$	0.1011105649472567
2	10	$((x / \sin(1.0) + x * \sin(x)) / (x + x))$	0.12177364128278752
3	10	$(1.0 - ((x * \sin(x) / x) * \sin(x))) * 1.0$	0.09716013055046885
4	10	$\sin(1.0) - \sin(x) * \sin(x)$	0.1323813045746452
5	10	$(1.0 - (\sin(x) * \sin(x)))$	0.09838964685838854
6	10	$((\sin(x) / x - x / x / x) / 1.0)$	0.07874854481321891
7	10	$\sin(1.0) - ((\sin(x) / 1.0) * (\sin(x) * 1.0))$	0.10252224281413669
8	10	$(1.0 - (\sin(x) * \sin(x)))$	0.16383044695653917
9	10	$(((1.0 - (\sin(1.0) * 1.0) + 1.0) / 1.0) / (\sin(x) / (1.0 - ((1.0 - (\sin(1.0) * 1.0) + 1.0) / 1.0))))$	0.07854957667165284
10	10	$(1.0 - \sin(x) * \sin(x))$	0.08544668838137098
Best	10	$(1.0 - (\sin(x) * \sin(x)))$	0.16383044695653917

Trigonometric Identity Results – Average

Run	Generations	Best Phenotype	Raw Fitness
1	10	$1.0 - \text{Math.sin}(x) * \text{Math.sin}(x)$	0.10550637435248064
2	10	$1.0 - \text{Math.sin}(x) - \text{Math.sin}(1.0) + ((1.0 - \text{Math.sin}(x)) * \text{Math.sin}(x))$	0.12135094167226684
3	10	$(1.0 * \text{Math.sin}(1.0) * (\text{Math.sin}(1.0) - \text{Math.sin}(x) * \text{Math.sin}(x)))$	0.12506935146407785
4	10	$((\text{Math.sin}(1.0) - \text{Math.sin}(x)) / x)$	0.1097557977853763
5	10	$(\text{Math.sin}(x) / (1.0 + (x + x))) - ((\text{Math.sin}(x) * \text{Math.sin}(x)) * (x / x)) - \text{Math.sin}(x) / (1.0 + (x + x)))$	0.10708499434919262
6	10	$(\text{Math.sin}(1.0) - (\text{Math.sin}(x) * \text{Math.sin}(x)))$	0.1277764679271336
7	10	$(\text{Math.sin}(1.0) - \text{Math.sin}(x) * \text{Math.sin}(x))$	0.1203353957081619
8	10	$(\text{Math.sin}(1.0) + \text{Math.sin}(x)) * 1.0 * (\text{Math.sin}(1.0) - (\text{Math.sin}(x) + x) + x)$	0.14370661640665258
9	10	$(1.0 / (x - (1.0 + x + 1.0)) / \text{Math.sin}(x) + 1.0)$	0.11506339927800766
10	10	$(1.0 - (\text{Math.sin}(x) * \text{Math.sin}(x)))$	0.16383044695653917
Avg	10		0.123947979

Experiment 3 – Using Families (x10) with Max Generations 100 and Population 50 (12/06/2006)

Trigonometric Identity Tableau for GE (O'Neill-style)

Objective:	Find a new mathematical expression, in symbolic form that equals a given mathematical expression, for all values of its independent variables. Examined Function: $\text{Math.cos}(2 * x)$ Desired Trigonometric Identity: $1 - 2\text{Sin}^2x$.
Terminal Operands:	x, the constant 1.0
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Raw Fitness:	The sum, of the absolute values of errors taken over the fitness cases (x_i, y_i) . With the above Raw Fitness the best individuals have lower values. For this reason a kind of Adjusted Fitness will be used and assigned to each individual. Adjusted Fitness of an individual i is typically defined as following: $Fa(i) = 1 / (1 + Fs(i))$ where Fs the Standardised Fitness of i. In this case the Adjusted Fitness of an individual i is calculated as following: $Fa(i) = 1 / (1 + Fr(i))$ where Fr the Raw Fitness of i. The fitness value varies from 0 to 1 and Invalid individuals will have Raw Fitness Value 0.
Standardised Fitness:	Same as raw fitness.
Wrapper:	Standard productions to generate a Java Class with a main() method which prints the fitness values in the standard output
Parameters:	Population Size (M) = 50, Maximum Generations (G) = 100, Prob. Mutation (Pm) = 0.01, Prob. Crossover (Pc) = 0.9,

Prob. Duplication (Pd) = 0.01, Prob. Pruning (Pp) = 0.01, Codon Size = 8, Selection Mechanism: Steady State GA with Generation Gap (G) = 0.9 Initial Population: Min Codons = 20, Max Codons = 30

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<expr> ::= <expr> <op> <expr> | ( <expr> <op> <expr> ) | <pre-op> ( <var> ) | <pre-op> (
<var> ) | <var> | <var> | <var> | <var>
<op> ::= + | - | / | *
<pre-op> ::= Math.sin
<var> ::= x | 1.0

```

Trigonometric Identity Results – Run 1

Family	Generations	Phenotype	Raw Fitness
1	100	1.0 - Math.sin (1.0)	0.07070064283312498
2	100	Math.sin (1.0) - 1.0	0.07376591594026576
3	100	Math.sin (x) * (Math.sin (x) * (Math.sin (x) * (x - x - Math.sin (x))))	0.11944249578328904
4	100	x / (1.0 + (x / (Math.sin (1.0) * Math.sin (1.0) - Math.sin (x))) / (Math.sin (1.0) + Math.sin (x)))	0.13155971587504808
5	100	((Math.sin (1.0) - 1.0) / Math.sin (x))	0.10330934559253158
6	100	(1.0 - x) / (x + Math.sin (1.0))	0.08913691839854865
7	100	x - x	0.07162320293363318
8	100	(1.0 / 1.0 - (1.0 * (Math.sin (x) + 1.0 * Math.sin (x))) * Math.sin (x))	0.9999999999999999
9	100	(Math.sin (1.0) - 1.0)	0.07738739913243887
10	100	Math.sin (1.0) - 1.0 + Math.sin (1.0) - 1.0	0.06286129706902618
Best	100	(1.0 / 1.0 - (1.0 * (Math.sin (x) + 1.0 * Math.sin (x))) * Math.sin (x))	0.9999999999999999

Trigonometric Identity Results – Run 2

Family	Generations	Phenotype	Raw Fitness
1	100	Math.sin (1.0) - Math.sin (x) / Math.sin (1.0) * Math.sin (x)	0.12167650910564516
2	100	(Math.sin (1.0) + (Math.sin (x) - (1.0 / x)))	0.08868862961083811
3	100	1.0 - (Math.sin (x) * Math.sin (x)) - Math.sin (x) * Math.sin (x)	0.9999999999999984
4	100	(Math.sin (1.0) - (Math.sin (x) * Math.sin (x)))	0.11652352384505825
5	100	(Math.sin (1.0) - 1.0)	0.07872275116976325
6	100	(Math.sin (1.0) - (Math.sin (x) * Math.sin (x)))	0.10933567968759514
7	100	((1.0 - Math.sin (1.0)) - Math.sin (x) * Math.sin (x))	0.1305048865431383
8	100	(x - x)	0.09219074450737319
9	100	x / (x + 1.0) * Math.sin (1.0)	0.07700357850995337
10	100	(Math.sin (x) / x * (Math.sin (1.0) - Math.sin (x)))	0.12037252457577786
Best	100	1.0 - (Math.sin (x) * Math.sin (x)) - Math.sin (x) * Math.sin (x)	0.9999999999999984

Trigonometric Identity Results – Run 3

Family	Generations	Phenotype	Raw Fitness
1	100	$(1.0 / ((\text{Math.sin}(1.0) + x) + \text{Math.sin}(x) + \text{Math.sin}(x)))$	0.08875250960085522
2	100	$\text{Math.sin}(x) / (x + (x * x))$	0.09383147849013217
3	100	$(\text{Math.sin}(x) / (\text{Math.sin}(1.0) + x - x / (1.0 - \text{Math.sin}(x) / x)))$	0.09821757808823832
4	100	$1.0 - (\text{Math.sin}(x) * (\text{Math.sin}(x) + \text{Math.sin}(x)))$	0.9999999999999993
5	100	$(1.0 - \text{Math.sin}(1.0)) * \text{Math.sin}(1.0)$	0.09281672210044721
6	100	$x - x$	0.06970969693358668
7	100	$(1.0 / ((\text{Math.sin}(x) + 1.0) + (x * \text{Math.sin}(x)) * \text{Math.sin}(x) / 1.0)) * \text{Math.sin}(1.0)$	0.10811526689740257
8	100	$x / ((1.0 * x) + \text{Math.sin}(1.0) + 1.0)$	0.07600529007961393
9	100	$(\text{Math.sin}(1.0) - x) / (x + x / \text{Math.sin}(x) + 1.0 * x - (\text{Math.sin}(x) + \text{Math.sin}(x)))$	0.11633755917904702
10	100	$(1.0 - 1.0)$	0.07645606245243967
Best	100	$1.0 - (\text{Math.sin}(x) * (\text{Math.sin}(x) + \text{Math.sin}(x)))$	0.9999999999999993

Trigonometric Identity Results – Run 4

Family	Generations	Phenotype	Raw Fitness
1	100	$1.0 / (1.0 + x + \text{Math.sin}(x))$	0.0809363996271637
2	100	$1.0 - \text{Math.sin}(x) * ((1.0 / (\text{Math.sin}(1.0) + \text{Math.sin}(1.0))) + (x + (\text{Math.sin}(x) - x))) * 1.0$	0.13341012631913943
3	100	$\text{Math.sin}(x) * (\text{Math.sin}(x) * (x / ((\text{Math.sin}(x) * 1.0 + \text{Math.sin}(x) - 1.0) - x - 1.0)))$	0.11780266421569881
4	100	$\text{Math.sin}(1.0) - \text{Math.sin}(x) / (\text{Math.sin}(1.0) / \text{Math.sin}(x))$	0.11603501666063361
5	100	$(1.0 - \text{Math.sin}(1.0)) * \text{Math.sin}(1.0) / x$	0.10566543226350275
6	100	$(1.0 / (1.0 + x) - x) + x$	0.07723151063922917
7	100	$(\text{Math.sin}(x) - ((\text{Math.sin}(1.0) * \text{Math.sin}(1.0)) / 1.0) + 1.0)$	0.08581791399150628
8	100	$1.0 / (((x * x) - 1.0 * x) * \text{Math.sin}(x) + (x + 1.0) + x + 1.0)$	0.09591968639997636
9	100	$(1.0 - \text{Math.sin}(1.0)) / x$	0.08360126739389317
10	100	$(\text{Math.sin}(1.0) - 1.0)$	0.07537694582385207
Best	100	$1.0 - \text{Math.sin}(x) * ((1.0 / (\text{Math.sin}(1.0) + \text{Math.sin}(1.0))) + (x + (\text{Math.sin}(x) - x))) * 1.0$	0.13341012631913943

Trigonometric Identity Results – Run 5

Family	Generations	Phenotype	Raw Fitness
1	100	$(\text{Math.sin}(1.0) - 1.0 / (\text{Math.sin}(1.0) + \text{Math.sin}(x) + \text{Math.sin}(1.0)))$	0.08724757922746566
2	100	$1.0 / (\text{Math.sin}(1.0) + (x + \text{Math.sin}(x)))$	0.07799413868319417
3	100	$x - x$	0.10671722047034857

4	100	$(\sin(1.0) - 1.0) + ((1.0 / (\sin(x) + \sin(x) / 1.0) + (1.0 - 1.0))) / (x + 1.0)$	0.09439954227876073
5	100	$(\sin(x) - \sin(x))$	0.09120528943401596
6	100	$(\sin(1.0) * \sin(x))$	0.07605653738058626
7	100	$((x - 1.0 - \sin(x)) * \sin(1.0) / (x + x))$	0.09748076532706343
8	100	$((x * (\sin(x) / \sin(1.0))) / (x - 1.0 / x + 1.0)) / 1.0$	0.07166699780187161
9	100	$(\sin(x) * (\sin(x) - (\sin(x) + \sin(x) * \sin(1.0))))$	0.11881573113039419
10	100	$(\sin(1.0) - (\sin(x) * \sin(x)) / \sin(1.0))$	0.1588666986346559
Best	100	$(\sin(1.0) - (\sin(x) * \sin(x)) / \sin(1.0))$	0.1588666986346559

Trigonometric Identity Results – Run 6

Family	Generations	Phenotype	Raw Fitness
1	100	$\sin(1.0) / x - 1.0$	0.08837499837258608
2	100	$\sin(1.0) - 1.0$	0.07086688882765113
3	100	$\sin(1.0) / (x + x + x)$	0.09956727689640968
4	100	$(1.0 / (1.0 + (\sin(x) * (x / \sin(1.0)))) * \sin(x) * ((\sin(1.0) * 1.0 - (\sin(1.0) * 1.0) + 1.0) + \sin(1.0)))$	0.08774346526147474
5	100	$\sin(1.0) - (\sin(x) * \sin(x))$	0.10335162016658579
6	100	$\sin(1.0) - (\sin(x) * \sin(x))$	0.11544186524485663
7	100	$1.0 - \sin(1.0)$	0.0702259829879223
8	100	$1.0 / (x - \sin(x) / (x * (\sin(x) - \sin(1.0))))$	0.08195600443283856
9	100	$1.0 - 1.0$	0.07843805098990052
10	100	$(1.0 - 1.0 * 1.0 * 1.0 / \sin(1.0))$	0.08403887616532676
Best	100	$\sin(1.0) - (\sin(x) * \sin(x))$	0.11544186524485663

Trigonometric Identity Results – Run 7

Family	Generations	Phenotype	Raw Fitness
1	100	$\sin(x) / (1.0 / ((x - \sin(x)) - x))$	0.10732116319233845
2	100	$\sin(1.0) / (1.0 / (1.0 + \sin(x)) + \sin(x))$	0.11223820298840435
3	100	$(1.0 - \sin(x) * \sin(x) - (\sin(x) * \sin(x) - 1.0) - 1.0)$	0.9999999999999984
4	100	$(\sin(1.0) - (\sin(x) * \sin(x)))$	0.12770249097714328
5	100	$\sin(1.0) - (\sin(x) / \sin(1.0)) * \sin(x)$	0.13664956963137603
6	100	$((1.0 - \sin(1.0)) * \sin(1.0))$	0.09048243490843716
7	100	$(\sin(x) / (\sin(1.0) - x - x))$	0.06970579682366211
8	100	$((1.0 / \sin(1.0)) - 1.0)$	0.07713513161765231

9	100	$\text{Math.sin}(1.0) - \text{Math.sin}(x) * \text{Math.sin}(x)$	0.13583117037305845
10	100	$(\text{Math.sin}(x) / 1.0 * (\text{Math.sin}(1.0) * 1.0 / x - \text{Math.sin}(x)))$	0.09517407572417542
Best	100	$(1.0 - \text{Math.sin}(x) * \text{Math.sin}(x) - (\text{Math.sin}(x) * \text{Math.sin}(x) - 1.0) - 1.0)$	0.9999999999999984

Trigonometric Identity Results – Run 8

Family	Generations	Phenotype	Raw Fitness
1	100	$(1.0 * 1.0 / 1.0 / (1.0 + (\text{Math.sin}(x) + x)))$	0.08915585955431492
2	100	$(\text{Math.sin}(1.0) / (1.0 - x / (\text{Math.sin}(x) / x) / 1.0 * (1.0 * (\text{Math.sin}(x) / 1.0 * \text{Math.sin}(x)))) * 1.0)$	0.1253032992581488
3	100	$\text{Math.sin}(1.0) + \text{Math.sin}(x)$	0.08974530106513381
4	100	$1.0 - \text{Math.sin}(1.0)$	0.08177231859200301
5	100	$\text{Math.sin}(1.0) / (x / \text{Math.sin}(x) / (x - x - ((\text{Math.sin}(x) + 1.0 * \text{Math.sin}(x))) - 1.0))$	0.0869199900962641
6	100	$(\text{Math.sin}(x) / (x + x * \text{Math.sin}(x)) - \text{Math.sin}(x))$	0.10529697701816994
7	100	$(1.0 - 1.0)$	0.06926610113067765
8	100	$\text{Math.sin}(1.0) - 1.0$	0.0853702684012347
9	100	$(\text{Math.sin}(1.0) - 1.0 * 1.0 / \text{Math.sin}(1.0))$	0.0998053850787462
10	100	$\text{Math.sin}(1.0) - (\text{Math.sin}(x) * (\text{Math.sin}(x) * 1.0))$	0.10320416923434143
Best	100	$(\text{Math.sin}(1.0) / (1.0 - x / (\text{Math.sin}(x) / x) / 1.0 * (1.0 * (\text{Math.sin}(x) / 1.0 * \text{Math.sin}(x)))) * 1.0)$	0.1253032992581488

Trigonometric Identity Results – Run 9

Family	Generations	Phenotype	Raw Fitness
1	100	$(\text{Math.sin}(x) / (\text{Math.sin}(x) + 1.0 + (\text{Math.sin}(x) + \text{Math.sin}(x) + x - 1.0)))$	0.08581923700373555
2	100	$\text{Math.sin}(x) / (\text{Math.sin}(x) - x / \text{Math.sin}(x) * ((\text{Math.sin}(1.0) + \text{Math.sin}(1.0)) * \text{Math.sin}(1.0) + \text{Math.sin}(x)))$	0.08460700835595926
3	100	$(1.0 * (\text{Math.sin}(1.0) * \text{Math.sin}(1.0) - (\text{Math.sin}(x) * \text{Math.sin}(x))) / \text{Math.sin}(1.0))$	0.16504135279573065
4	100	$1.0 / (1.0 / (\text{Math.sin}(x) + \text{Math.sin}(1.0)) + \text{Math.sin}(x))$	0.0796321636663166
5	100	$(x - x) - \text{Math.sin}(1.0)$	0.06772297865841369
6	100	$1.0 + (((\text{Math.sin}(x) / ((\text{Math.sin}(x) - \text{Math.sin}(1.0) * 1.0) - 1.0)) * \text{Math.sin}(x)) * x)$	0.26455964556094685
7	100	$\text{Math.sin}(1.0) - \text{Math.sin}(x) * \text{Math.sin}(x)$	0.11362640713393156
8	100	$1.0 - (\text{Math.sin}(1.0) + \text{Math.sin}(x) * \text{Math.sin}(x) * 1.0)$	0.12965373150590453
9	100	$(\text{Math.sin}(1.0) + \text{Math.sin}(x)) - \text{Math.sin}(x) - (\text{Math.sin}(x) * \text{Math.sin}(1.0)) * (\text{Math.sin}(x) + \text{Math.sin}(x) / \text{Math.sin}(1.0))$	0.4288863764466971

10	100	$(1.0 - \sin(x) * \sin(x) * (1.0 + x/x))$	0.9999999999999991
Best	100	$(1.0 - \sin(x) * \sin(x) * (1.0 + x/x))$	0.9999999999999991

Trigonometric Identity Results – Run 10

Family	Generations	Phenotype	Raw Fitness
1	100	$((\sin(1.0) - 1.0) / \sin(x)) * 1.0 * 1.0 / (1.0 + x))$	0.07968467493822297
2	100	$(1.0 / ((x / \sin(x)) / (\sin(1.0) - x))) / \sin(x))$	0.09632383308783685
3	100	1.0 - 1.0	0.07610829626212628
4	100	$\sin(x) / (1.0 / (\sin(x) - \sin(x) * x) * x)$	0.102882502183332
5	100	$(\sin(1.0) - (1.0 - (\sin(1.0) - \sin(1.0)) / x) * \sin(1.0))$	0.08224566443447515
6	100	1.0 - $\sin(1.0) * \sin(1.0)$	0.07750334819586141
7	100	$((\sin(1.0) / (1.0 / x + ((\sin(x) * \sin(x) - x) - \sin(x) * x))) / \sin(1.0))$	0.08008454701119146
8	100	$(\sin(1.0) - \sin(x) * \sin(x))$	0.13864923328779527
9	100	1.0 - 1.0	0.07763786182754354
10	100	$((\sin(1.0) * 1.0 - (\sin(1.0) * \sin(x))) - 1.0) * \sin(x)$	0.11445173478439577
Best	100	$(\sin(1.0) - \sin(x) * \sin(x))$	0.13864923328779527

Trigonometric Identity Results – Average and Best Individual of each Run

Run	Generations	Best Phenotype	Raw Fitness
1	100	$(1.0 / 1.0 - (1.0 * (\sin(x) + 1.0 * \sin(x))) * \sin(x))$	0.9999999999999999
2	100	$1.0 - (\sin(x) * \sin(x)) - \sin(x) * \sin(x)$	0.9999999999999984
3	100	$1.0 - (\sin(x) * (\sin(x) + \sin(x)))$	0.9999999999999993
4	100	$1.0 - \sin(x) * ((1.0 / (\sin(1.0) + \sin(1.0))) + (x + (\sin(x) - x)) * 1.0)$	0.13341012631913943
5	100	$(\sin(1.0) - (\sin(x) * \sin(x)) / \sin(1.0))$	0.1588666986346559
6	100	$\sin(1.0) - (\sin(x) * \sin(x))$	0.11544186524485663
7	100	$(1.0 - \sin(x) * \sin(x) - (\sin(x) * \sin(x) - 1.0) - 1.0)$	0.9999999999999984
8	100	$(\sin(1.0) / (1.0 - x / (\sin(x) / x) / 1.0 * (1.0 * (\sin(x) / 1.0 * \sin(x)))) * 1.0)$	0.1253032992581488
9	100	$(1.0 - \sin(x) * \sin(x) * (1.0 + x/x))$	0.9999999999999991
10	100	$(\sin(1.0) - \sin(x) * \sin(x))$	0.13864923328779527
Avg	100		0,567167122274459

Results Summary

- **Average Raw Fitness of Experiment 1 (MaxGen 100, Population 500):**
0.686220222777789
- **Average Raw Fitness of Experiment 2 (MaxGen 10 x 10 Families of Population 500):**
0.123947979
- **Average Raw Fitness of Experiment 3 (MaxGen 100 x 10 Families of Population 50):**
0.567167122274459