# Fitness First and Fatherless Crossover

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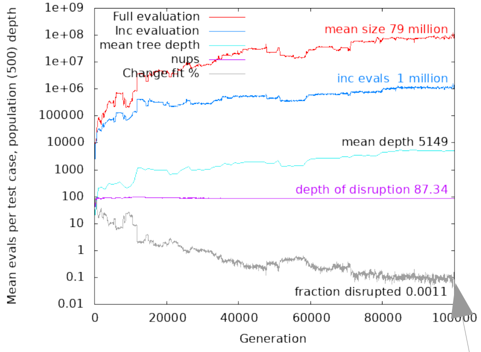
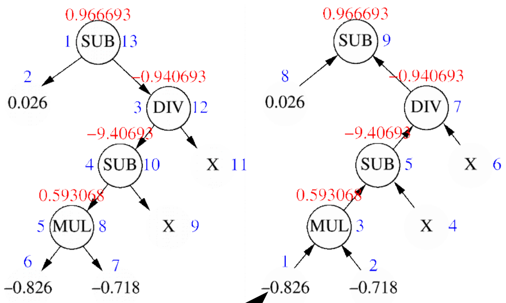
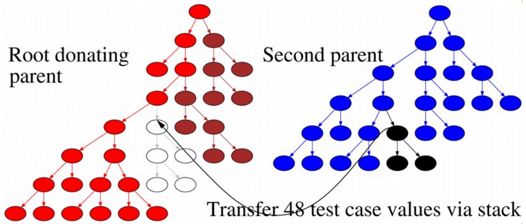



**Convergence** sextic polynomial. Grey % child's !=parent's fitness. After gen 800 most children have identical fitness to mum, and on average (purple dotted line) incremental evaluation evaluates subtrees of depth 87.34. Saving up to 100 fold in evaluations of GP operations (blue v. top red). Note log scale.

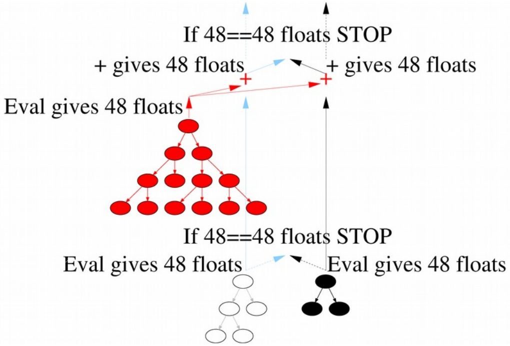



Left: Conventional top-down recursive evaluation of (SUB 0.026 (DIV(SUB (MUL -0.826 -0.718) X) X)). X=10. Blue integers indicate evaluation order, red floats are node return values. Right: **Bottom Up Evaluation**: starting with leaf -0.826 and working to root node. Both return exactly the same answer.



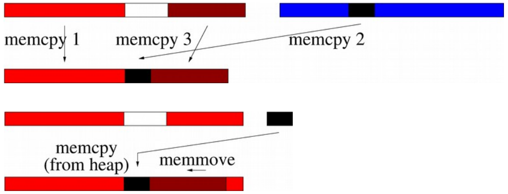

**Fitness first**

Fitness is evaluated using only parents, i.e., before the child is created by crossover. Subtree to be inserted (black) is evaluated on all test cases and values transferred to evaluation of mum at the location of the subtree to be removed (white). Use EuroGP [3] incremental evaluation, so differences between original code (white subtree) and new are propagated up mum until either all differences are zero or we reach the root node.




Evaluate the subtree to be removed from the mum (white) and the subtree to be inserted (black). Proceeds up the mum's tree until either the evaluation in the mum and unborn child are the same or reach the root node. The red subtree is in the mum but it is identical to the code in its child and so need be evaluated only once. Note the code from the parents is evaluated without creating the child.

New code in red. Disrupted nodes in colour, size indicates number test cases where parent and child evaluation are different, colour average difference. Grey nodes ignored. **Up to 99.9% crossover are not visible externally**




**Fatherless Crossover**

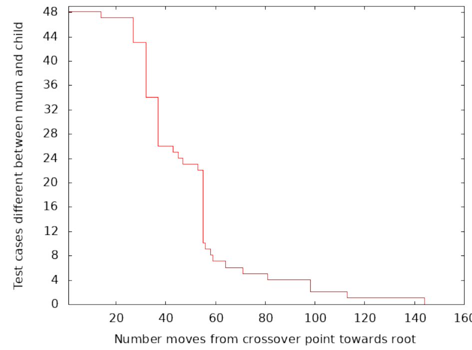
If mum's last child, reuse her buffer. Dad subtree overwrites mum's buffer. Shuffle rest of buffer (brown) up or down (needed in 71% of children). Only subtree part of dad used.

| | |
|---|---|
| Terminal set: | X, 250 constants between -0.995 and 0.997 |
| Function set: | MUL ADD DIV SUB |
| Fitness cases: | 48 fixed input -0.97789 to 0.979541 (randomly selected from -1.0 to +1.0). Target $y = xx(x-1)(x-1)(x+1)(x+1)$ |
| Selection: | Tournament size 7 with fitness $= \frac{1}{48}\sum_{i=1}^{48} \lvert GP(x_i) - y_i \rvert$ |
| Population: | 500. Panmictic, non-elitist, generational. |
| Parameters: | Initial population ramped half and half [1] depth between 2 and 6. 100% unbiased subtree crossover. At least 1000 generations |

DIV is protected division `(y!=0)? x/y : 1.0f`

**250x SPEEDUP**
*Equivalent* of **692 billion GP operations per second** on 16core 3.8Ghz i7 desktop with AVX-512

C++ code
http://www.cs.ucl.ac.uk/staff/W.Langdon/ftp/gp-code/GPinc.tar.gz




Incremental evaluation of first member of generation 1000.

Number of test cases where evaluation in the root donating parent (mum) and its offspring are identical never falls.

**INFORMATION THEORY OF GP CONVERGENCE**

All functions loose information. Without side effects, lost information cannot be restored. Disruption passes up tree but once lost on a test case cannot be restored. In deep trees impact does not reach root. Hence child behaves identically to its mother and therefore has the same fitness. Deep trees give GP a smooth landscape. Relatively insensitive, order log n, to number of test cases.

1. GECCO 2021, doi:10.1145/3449726.3459437
2. GPTP 2021, Fitness First
3. EuroGP 2021, Incremental Evaluation in GP, doi:10.1007/978-3-030-72812-0_15
4. Dissipative Polynomials, GECCO LAHS 2021 workshop doi:10.1145/3449726.3463147

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