Inherent Fault Tolerance in Evolved Sorting Networks

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Abstract. This poster paper summarizes our research on fault tolerance arising as a by-product of the evolutionary computation process. Past research has shown evidence of robustness emerging directly from the evolutionary process, but none has examined the large number of diverse networks we used. Despite a thorough study, the linkage between evolution and increased robustness is unclear.

Discussion

Previous research has suggested that evolutionary search techniques may produce some fault tolerance characteristics as a by-product of the process. Masner et al. [1, 2] found evidence of this while evolving sorting networks, as their evolved circuits were more tolerant of low-level logic faults than hand-designed networks. They also introduced a new metric, bitwise stability (*BS*), to measure the degree of robustness in sorting networks.

We evaluated the hypothesis that evolved sorting networks were more robust than those designed by hand, as measured by *BS*. We looked at sorting networks with larger numbers of inputs to see if the results reported by Masner et al. would still be apparent. We selected our subject circuits from three primary sources: hand-designed, evolved and "reduced" networks. The last category included circuits manipulated using Knuth's technique in which we created a sorter for a certain number of inputs by eliminating inputs and comparators from an existing network [3].

Masner et al. found that evolution produced more robust 6-bit sorting networks than hand-designed ones reported in the literature. We expanded our set of comparative networks, comprising 157 circuits sorting between 4 and 16 inputs. Our 16 bit networks were only used as the basis for other reduced circuits.

Table 1 shows the results for our entire set of circuits. We listed the 3 best networks for each width to give some sense of the inconsistency between design methods. As with the 4-bit sorters, evolution produced the best 5-, 7- and 10-bit circuits, but reduction was more effective for 6, 9, 12 and 13 inputs. Juillé's evolved 13-bit

* Foster was partially funded for this research by NIH NCRR 1P20 RR16448.

E. Cantú-Paz et al. (Eds.): GECCO 2003, LNCS 2723, pp. 456–457, 2003.

network (J13b_E) was inferior to the reduced circuits and Knuth's 12-bit sorter (Kn12b_H) was the only hand-designed network to make this list.

Table 1. Top 3 results for all sorting networks in Shepherd [4]. K represents the number of inputs to the network and BS indicates the bitwise stability, as defined in [1]. The last character of the index inidicates the design method: *E* for evolved, *H* for hand-designed, *R* for reduced

	Best circuit		**2nd best circuit**		**3rd best circuit**	
K	**Index**	**BS**	**Index**	**BS**	**Index**	**BS**
4	M4A_E	0.943359	M4Rc_E	0.942057	Kn4Rd_R	0.941840
5	M5A_E	0.954282	M5Rd_R	0.954028	M5Rc_R	0.953935
6	M6Ra_R	0.962836	Kn6Ra_R	0.962565	M6A_E	0.962544
7	M7_E	0.968276	M7Rc_R	0.968206	M7Ra_R	0.967892
9	M9R_R	0.976066	G9R_R	0.975509	Kn9Rb_R	0.975450
10	M10A_E	0.978257	H10R_R	0.978201	G10R_R	0.978189
12	H12R_R	0.981970	G12R_R	0.981932	Kn12b_H	0.981832
13	H13R_R	0.983494	G13R_R	0.983461	J13b_E	0.983305

Our data do not support our hypothesis that evolved sorting networks are more robust, in terms of bitwise stability, than those designed by hand. Masner's early work showed evolution's strength in generating robust networks, but support for the hypothesis evaporated as we added more circuits to our comparison set, to the point that there is no clear evidence that one design method inherently produces more robust sorting networks. Our data do not necessarily disconfirm our hypothesis, but leave it open for further examination. One area for future study is the linkage between faults and the evolutionary operators. Thompson [5] used a representation method in which faults and genetic mutation had the same effect, but these operators affected different levels of abstraction in our model.

References

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