Hierarchical Breeding Control for Efficient Topology/Parameter Evolution

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1 The Approach

This paper adopts a hierarchical breeding control mechanism to obtain better search performance based on differential balancing of topology-altering operations and parameter-altering operations according to fitness level, in a fitness-structured multi-population model. The basic idea for this control mechanism arises from observing the human design process. Usually, preliminary or conceptual design involves more structural modification, and final or detailed design involves more parameter tuning – i.e., there is greater concentration on design topology in the early stage and more on parameter tuning in the later stage. Therefore, the key concept is to provide different breeding probabilities for topology-altering and parameter-altering operations according to fitness level of the subpopulation (Figure 1).

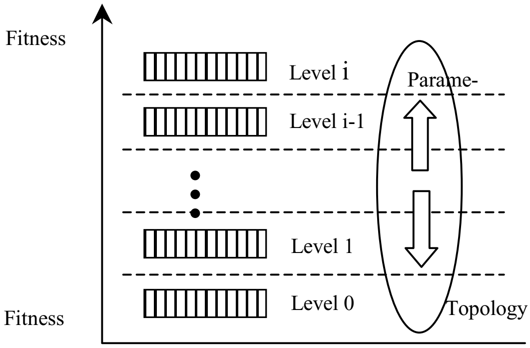

Fig. 1. Hierarchical breeding control structure. Subpopulations are organized in a hierarchy with ascending fitness levels.

In other words, topology-altering operations are given higher probability than parameter-altering operations at low fitness levels, and vice-versa at higher levels. To implement, switched modular primitives, which separate GP functions into a three-level hierarchy – operations affecting topology, intermediate topology, and parameters

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– are combined with topology/parameter control in Hierarchical Fair Competition GP (HFC-GP), which can strongly reduce premature convergence and enable scalability with smaller populations.

2 Results of the Approach

As a proof of concept for this approach, the eigenvalue assignment problem, which is to synthesize bond graph models with minimum distance errors from pre-specified target sets of eigenvalues, was used. The fitness function calculates the sum of distance errors between each target eigenvalue and the solution's corresponding eigenvalue, divides by the order, and performs hyperbolic scaling.

The results of 6- and 10-eigenvalue runs are provided in Figure 2, showing average distance error for each set across 10 experiments. Figure 2, left, illustrates the comparison between the basic approach (without topology/parameter control) and the hierarchical topology/parameter breeding control on typical complex conjugate and real 6-eigenvalue target sets. For all four cases, the average error in the hierarchical topology/parameter breeding control approach is smaller than that of the basic approach. The right side of Figure 2 represents the results on two 10-eigenvalue sets, and shows that the new approach outperforms the basic approach on these problems.

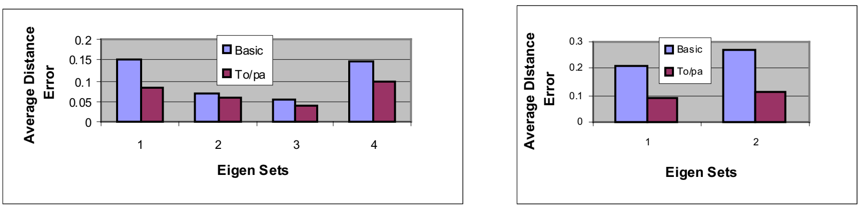

Fig. 2. Results for 6-eigenvalue sets (left, four cases) and 10-eigenvalue sets (right, two cases)

Results showed better performance for all tested eigenvalue sets when the new topology/parameter control method was used. This tends to support the conjecture that a carefully tailored representation and sophisticated topology/parameter control method will improve the efficiency of GP search. This, in turn, offers promise that much more complex multi-domain systems with more complex performance specifications can be designed efficiently.

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