

Substructural Neighborhoods for Local Search in the Bayesian Optimization Algorithm

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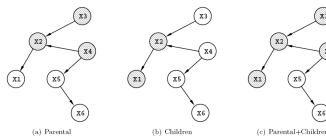
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1. Motivation

- Probabilistic models of EDAs allow better recombination of subsolutions
- Get we can more from these models? Yes!
- Model-based efficiency enhancement techniques:
 - Evaluation relaxation
 - Local search in substructural neighborhoods

3. Substructural Neighborhoods

- Neighborhoods that respect the dependencies between variables
- Exploits the underlying problem structure while not loosing generality of application
- Example: Neighborhoods for X_2



2. Bayesian Optimization Algorithm

- Use Bayesian networks to model good solutions and generate new ones:

$$p(X) = \prod_{i=1}^{\ell} p(X_i | \Pi_i)$$

- Model structure \rightarrow acyclic directed graph
 - Nodes represent variables
 - Edges represent conditional dependencies
- Model parameters \rightarrow conditional probabilities
 - Conditional Probability Tables based on the observed frequencies
 - Local structures: Decision Trees or Graphs
- Modeling fitness in BOA:

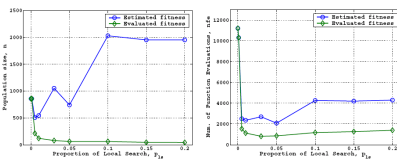
$$f_{est}(X_1, X_2, \dots, X_{\ell}) = \bar{f} + \sum_{i=1}^{\ell} (\bar{f}(X_i | \Pi_i) - \bar{f}(\Pi_i))$$

4. BOA with Substructural Hillclimbing

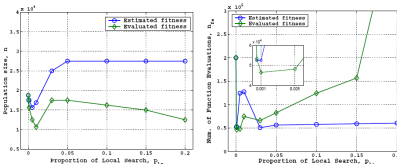
- After model sampling, each offspring undergoes local search with a certain probability p_{ls}
- Current model is used to define the neighborhoods
- Choice of best subsolutions is based on the surrogate fitness model
- Substructural Hillclimbing:
 1. Consider the first variable X_i according with the ancestral reverse ordering of variables in the Bayesian network.
 2. Choose the values (x_i, π_i) associated with the maximal substructural fitness $\bar{f}(X_i | \Pi_i)$.
 3. Set variables (X_i, Π_i) of the considered individual to values (x_i, π_i) if the overall fitness of the individual is improved by doing so, otherwise leave the individual unchanged.
 4. Repeat steps 2-3 for all remaining variables following the ancestral reverse order of variables.

5. Results

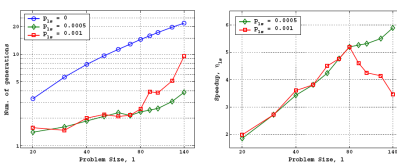
50-bit OneMax



10 x 5-bit Trap



Scalability
5-bit Trap



6. Conclusions

- Incorporation of substructural local search in BOA leads to significant speedups
- Use of surrogate fitness in local search provides effective learning of substructures with minimal cost on evals
- The importance of designing and hybridizing competent operators have been empirically demonstrated

