

Survey of Recombination- Operator Modeling

Kumara Sastry

Illinois Genetic Algorithms Laboratory (IlligAL)

Department of General Engineering

117 Transportation Bldg., UIUC

<http://www-illigal.ge.uiuc.edu>

Ksastry@uiuc.edu

Background

- ❖ Design decomposition
 - ◆ Goldberg, Deb, & Clark (1992)
 - ◆ BB mixing is critical to GA success
- ❖ Mixing issue usually overlooked
 - ◆ Success with fixed recombination operators
- ❖ Fixed recombination operators fail
 - ◆ Thierens & Goldberg (1993)
 - ◆ Problem specific crossovers

Why Study Mixing?

- ❖ Facetwise models assume *tight linkage*
 - ◆ *A priori* knowledge of building blocks (BBs)
- ❖ We don't have tight linkage
 - ◆ Incorporate BB mixing into GA dynamics
 - ◆ First analyze fixed crossover operators
- ❖ Modeling mixing
 - ◆ More effective GA designs
- ❖ Need to know what studies exist

Overview

- ❖ Mixing Problem
- ❖ Classification of Models
 - ◆ Crossover as a mixer
 - ◆ Crossover as a BB disruptor
 - ◆ Crossover as an innovator
- ❖ Summary & Conclusions

The Mixing Problem

- ❖ Goldberg, Thierens, & Deb, 1993
- ❖ How well fixed crossover operators solve
 - ◆ GA-easy problems
 - ◆ GA-hard problems
- ❖ An expanded view
 - ◆ Studies on modeling recombination operator

Models of Recombination

- ❖ Role of crossover operator
- ❖ Crossover as a mixer
 - ◆ Motivations from population genetics
- ❖ Crossover as a schema disruptor
 - ◆ Motivations from Schema theorem
- ❖ Crossover as an innovator
- ❖ All in one models

Crossover As A Mixer

- ❖ Motivation from quantitative genetics
 - ◆ Robbin's equilibrium (1918)
 - ◆ Geiringer's theorem (1944),
- ❖ Models predict
 - ◆ Linkage disequilibrium (Christiansen, 1989)
 - ◆ Rate of convergence to equilibrium (Rabani, Rabinovich, & Sinclair, 1998)
 - ◆ Marginal recombination distributions (Booker, 1993)

Relaxation Time

- ❖ Rate of convergence to equilibrium
 - ◆ Rabani, Rabinovich, & Sinclair, 1998
 - ◆ Prugel-Bennett, 2001
- ❖ Uniform crossover: $2\log_2 \ell$
- ❖ One-point crossover: $\ell \ln \ell$
- ❖ Two-point crossover: $0.5\ell \ln \ell$

Crossover As A Disrupter

- ❖ Motivations from schema theorem
- ❖ Syswerda (1989)
 - ◆ Schema survival rate
- ❖ De Jong and co-workers
 - ◆ De Jong (1975), Spears & De Jong (1991)
 - ◆ Multi-point crossover analysis
- ❖ Does not incorporate mixing

Crossover As An Innovator

❖ Goldberg, Thierens & Deb, 1993

- ◆ Allele-wise mixing (GA-easy problem)
- ◆ Mixing time:

$$t_x = (np_c p^\ell)^{-1}$$

- ◆ Control map: s vs. p_c
 - ★ Selection time, drift time, cross-competition
- ◆ Large sweet-spot for GA easy problems
- ◆ Fixed crossover operators are good!

Crossover As An Innovator II

- ❖ Thierens & Deb, 1993; Thierens, 1995
 - ◆ What about GA-hard problems: BB mixing
 - ◆ Two BBs, extend to m BBs.
 - ◆ Mixing time:

$$t_x = c \frac{2^{\mu k} 2^m}{np_c m^{5/2}}, \quad n \ln n > c \frac{2^{\mu k} 2^m}{np_c m^{5/2}} \ln s$$

- ◆ Population size grows exponentially!
- ◆ Sweet-spot shrinks exponentially!

All In One Models

- ❖ Exact difference equations
- ❖ Markov-chain models
- ❖ Statistical mechanics models
- ❖ Coarse grain analysis
- ❖ Mixing info hidden in complex formulation
 - ◆ Not very useful to design GAs

Summary & Conclusions

- ❖ Mixer models:
 - ◆ Uniform crossover is best
- ❖ Disrupter models:
 - ◆ n-point crossover is best
- ❖ Innovation models:
 - ◆ Fixed crossover operators are not enough
- ❖ All in one models:
 - ◆ Accurate, does not help in GA design