Presented by Aghiles Gasselin

Niching in Genetic Algorithms

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History of the work

- Niching in GAs: Maintains diversity
- Resource Sharing: Promotes cooperation & competition
- Need for Niching: Prevents convergence to single solution

Resource sharing basic algorithm

1. For each of the finite resources r;, divide it up among all qualified individuals contending for it, in proportion to their various merits (that is, the relative strengths of their claims). Thus two equally deserving individuals should be allocated equal amounts of the resource. If the resource is discrete, and cannot be evenly divided, then for each indivisible unit of the resource, randomly choose among equally deserving individuals. This random choice results in an expected uniform distribution of resources among equally deserving candidates.
2. For each individual, add all rewards/credits earned in the first step, and use this amount (perhaps scaled) as the fitness for GA selection. 3
3. After a new generation is produced, replenish/renew the resources and start over at the first step above. Continue to loop until some stopping criterion is met.

Applications and Instances of Resource Sharing:

- Learning Classifier Systems (LCS): Classifiers compete for rewards

- Example Sharing: Maintains diverse set of rules

Visualization of notion of competition and niche overlap in the case of resource sharing

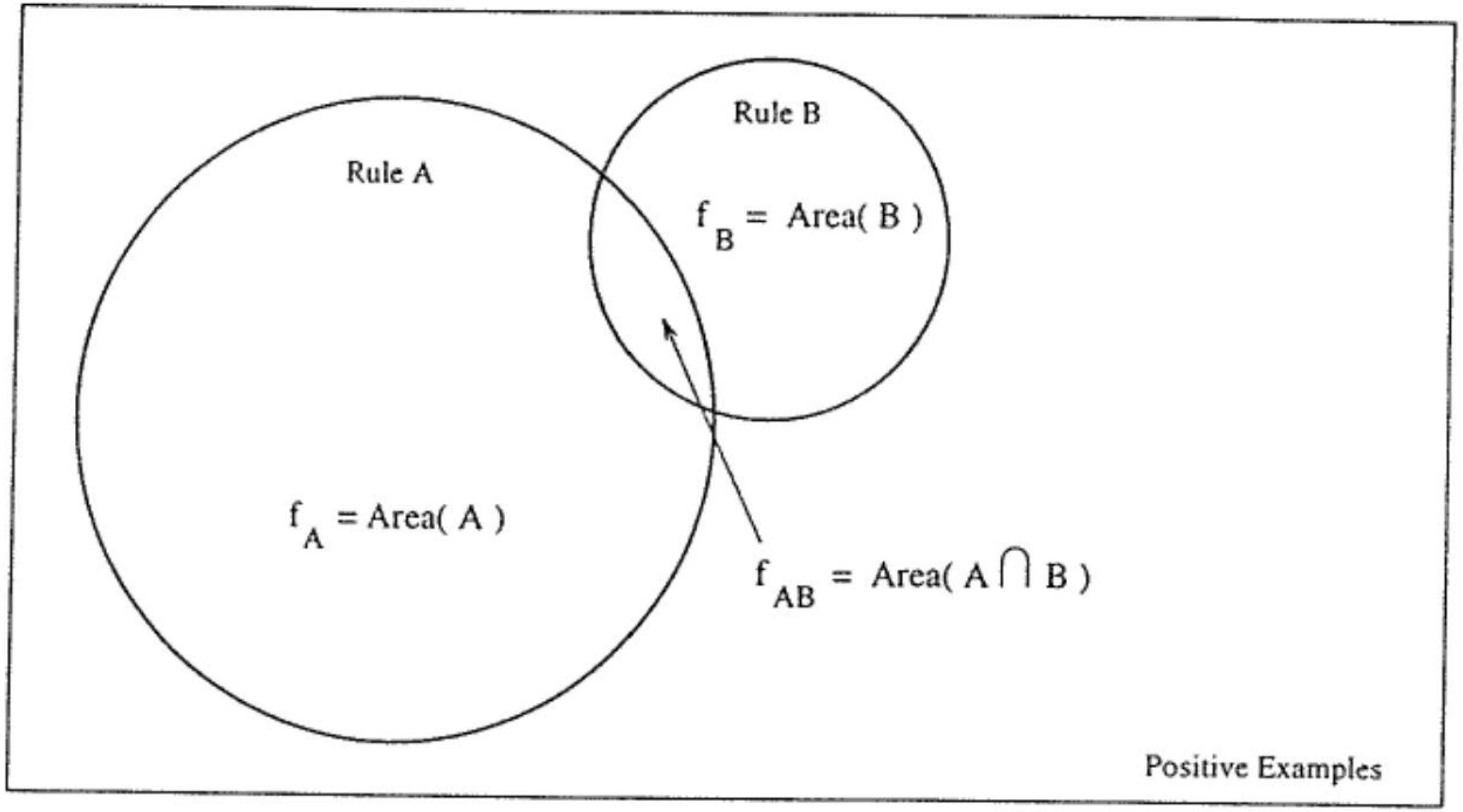

Figure 1: In the case of the learning classifier system (LCS), *implicit niching* is induced by rules competing to classify examples. We can use area in the space of examples to indicate a rule's coverage, which is also its *objective* (i.e., unshared) fitness.

Calculating the shared fitness with different set of rules

fAB : amount of resources in the overlapping coverage of riles A and B
nA, nB : number of copies of rules A and B in population of size N (so nA +nB = N)
fA, fB : objective fitnesses for rules A and B

$$f_{sh,A} = \frac{f_A - f_{AB}}{n_A} + \frac{f_{AB}}{n_A + n_B}.$$

$$f_{sh,B} = \frac{f_B - f_{AB}}{n_B} + \frac{f_{AB}}{n_A + n_B}.$$

Motivation

- Predictive map for GA behavior
- Analyze transition between cooperation and competition

Review of Key Niching Results:

- Niching Equilibrium: Equal shared fitnesses
- Expected Niche Maintenance Times: Duration of niche maintenance

N : population size
r0 : ratio of overlap
r’f : ratio of fitness

$$P_{A,eq} = \frac{1 - r_o}{1 - 2r_o + r'_f}.$$

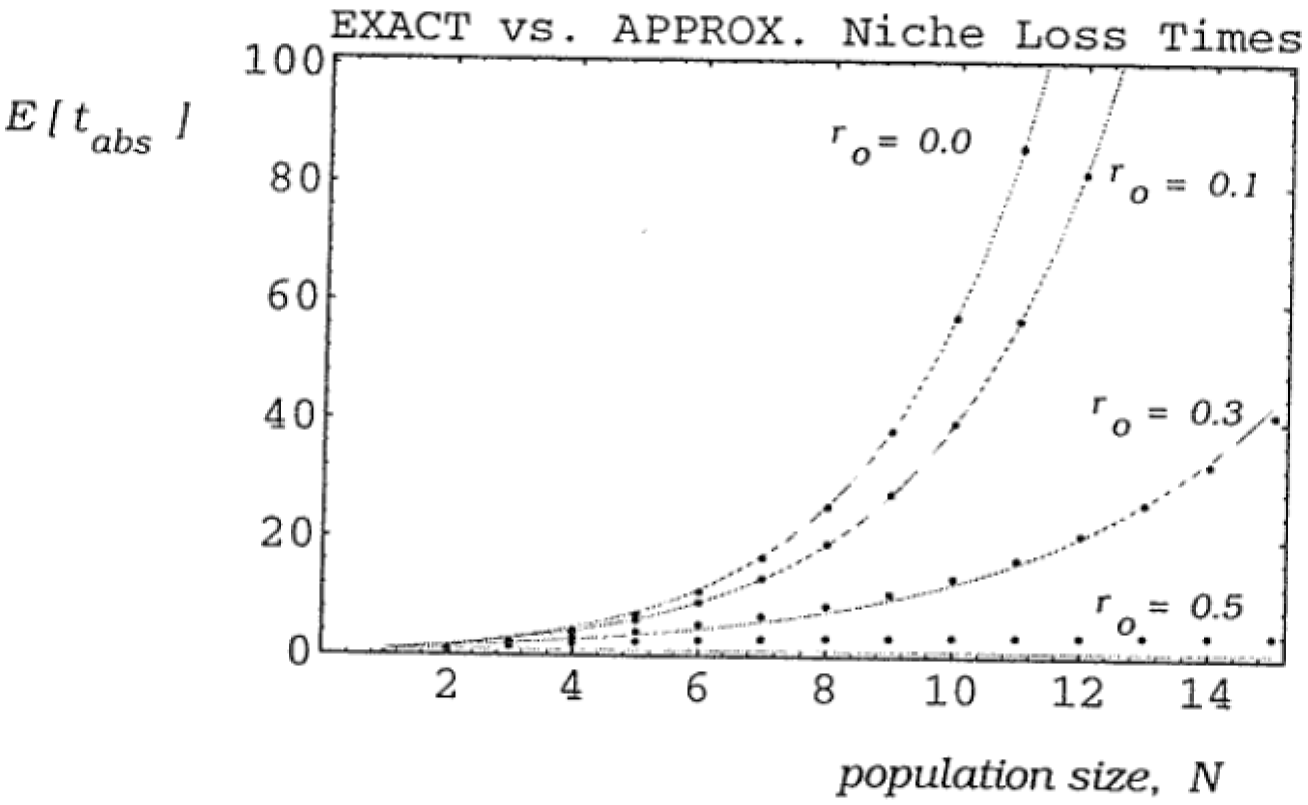

Figure 2: A comparison of *exact* expected niche loss times to the approximated times, as a function of population size. The exact results (from the Markov models) are shown as solid dots. The approximations, from the closed-form expression, are shown as dashed lines. The plots indicate general agreement for small niche overlap r_o. For all plots shown $r'_f = \frac{1}{2}$.

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Niching Equilibrium in Genetic Algorithms

Niching Equilibrium

- Context: Maintenance of diverse solutions in GAs
- Equations & Assumptions: Probability of selecting individual A
- Steady State: Linear recurrence relation on proportion

Convergence Times

- Objective: Calculate time to reach niching equilibrium
- Expression: Convergence time grows logarithmically with population size

$$t_{conv} = \frac{-\ln(P_{A,eq}N - 1)}{\ln \beta}.$$

N : population size
tCONV : time to convergence
PA,EQ : proportion of the current population, at equilibrium
BETA : function of r’f and r0

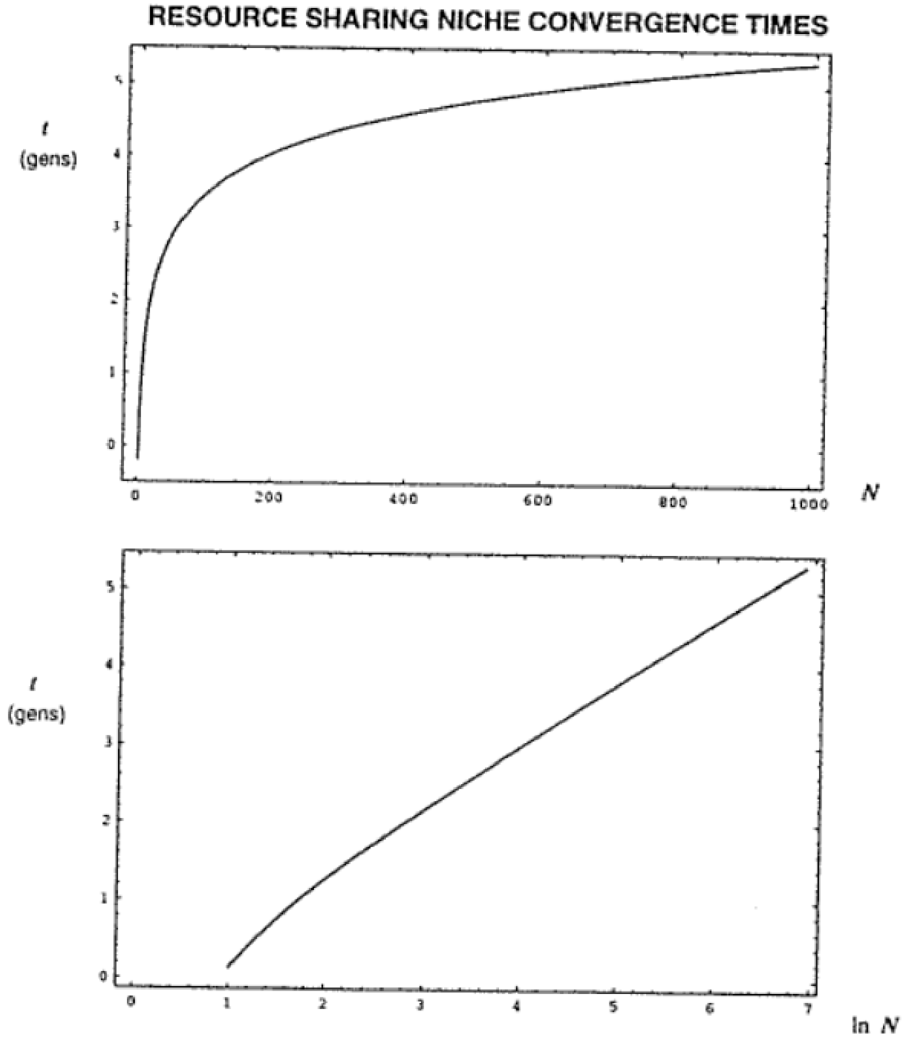

Figure 3: Expected niche convergence time grows logarithmically in population size N.

Cooperation vs. Competition

- Dilemma: Boundary between cooperating and competing species
- Boundary Definition: Comparing niche maintenance and convergence times

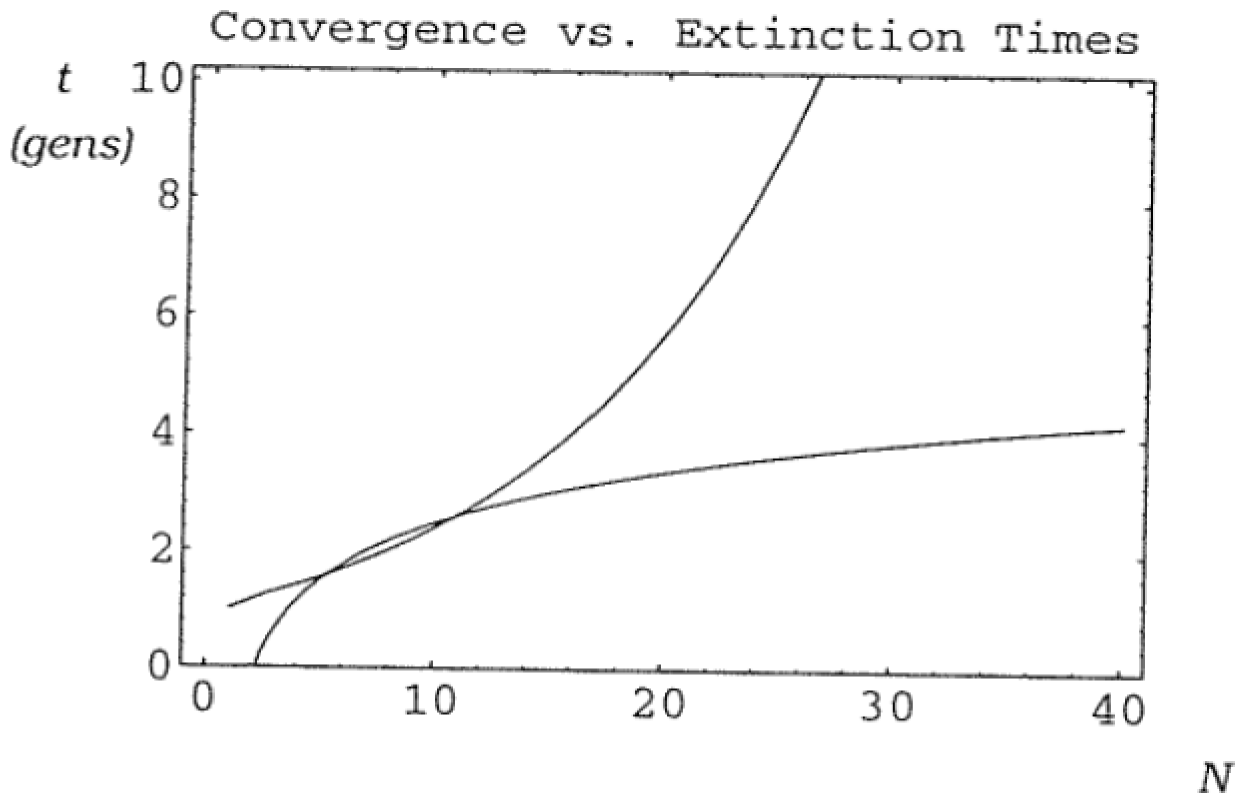

Figure 4: Expected niche extinction times (upper curve) versus expected niche convergence times (lower curve). Here fitness ratio $r_f = 2$ with very high overlap $r_o = 0.45$ (near maximum).

Control Map

- Concept: Predict cooperation or competition
- Equations: Numerical solutions for different values of constant C
- Visualization: Boundaries between cooperation and competition

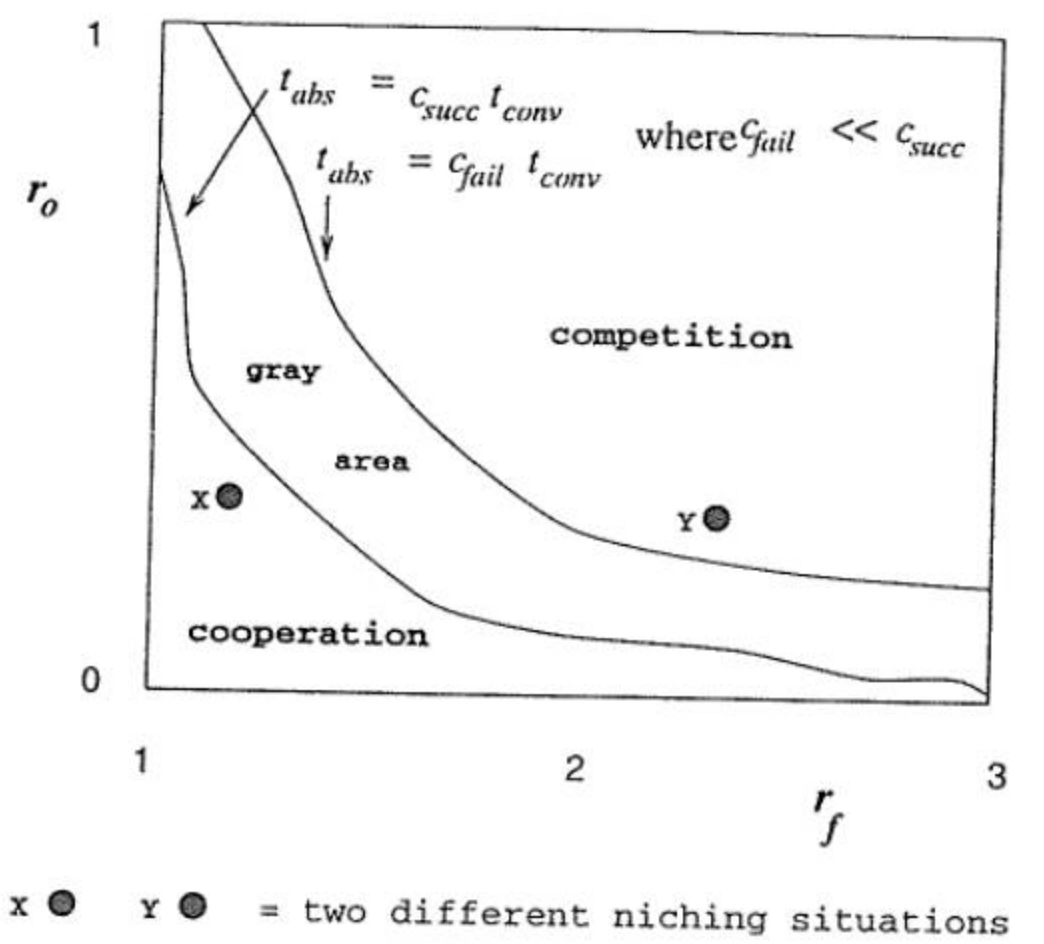

Figure 5: Speculative *cooperative-competitive* boundary for resource sharing given population size N, found by setting $c\, t_{conv} = t_{abs}$.

Example & Empirical Results

- Markov Chain Model: Simulate niching performance
- Niche Performance: Probability of both niches represented after 200 generations
- Results: Theoretical boundaries vs empirical results

$$c\, t_{conv} = t_{abs},$$

$$c\,\frac{-\ln(P_{A,eq}N-1)}{\ln\beta} = \frac{(1-2r_o+r'_f)^N}{(1-r_o)^N+(r'_f-r_o)^N},$$

$$c\,\frac{-\ln(\frac{1-r_o}{1-2r_o+r'_f}N-1)}{\ln(\frac{r_o}{r'_f-r_o+1})} = \frac{(1-2r_o+r'_f)^N}{(1-r_o)^N+(r'_f-r_o)^N}.$$

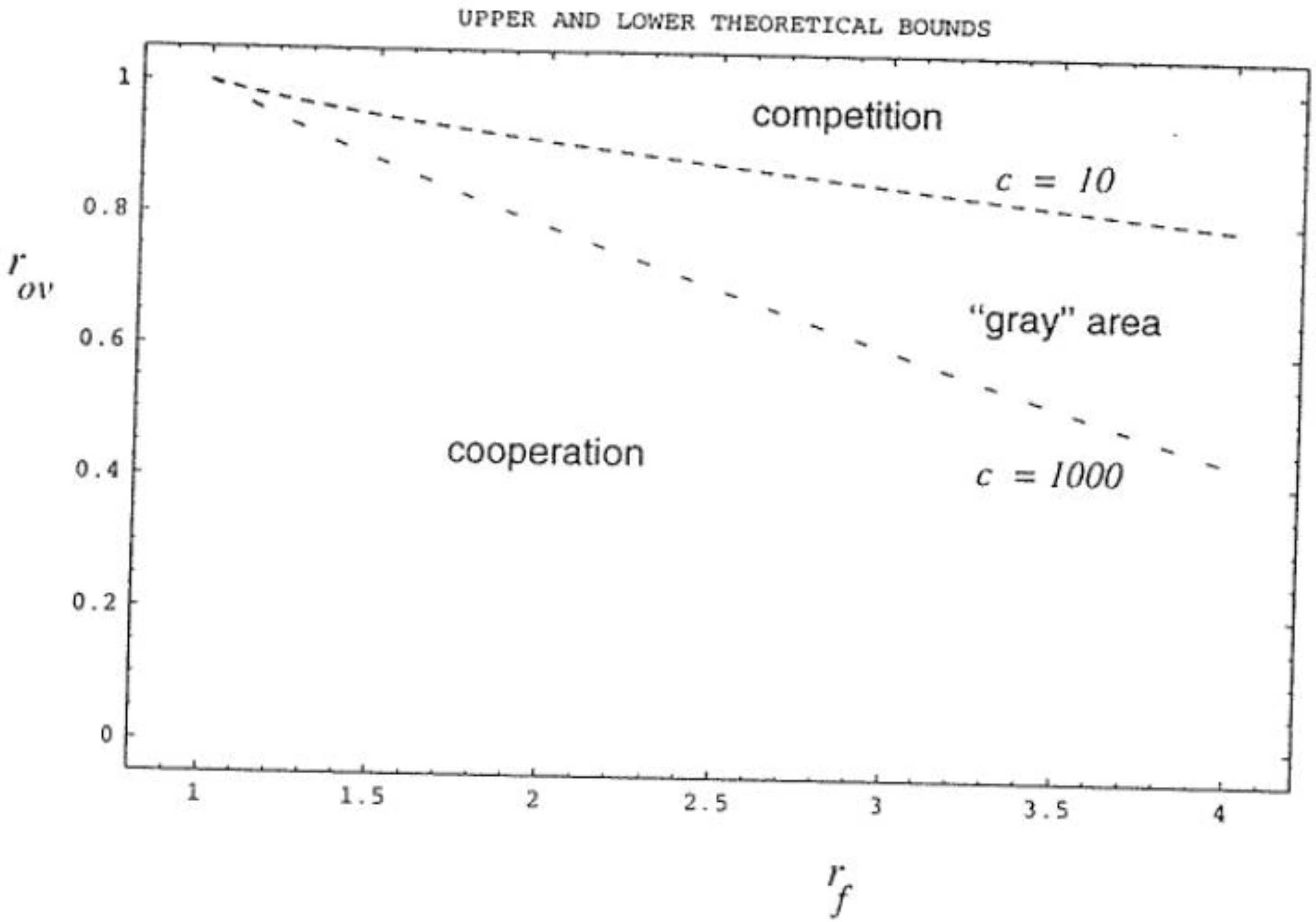

Figure 6: Theoretical *cooperative-competitive* boundary for resource sharing given population size $N = 50$, and by arbitrarily choosing $c = 10$ for the niching failure boundary (the lower bound on competition) and $c = 1000$ for the niching success boundary (upper bound on cooperation).

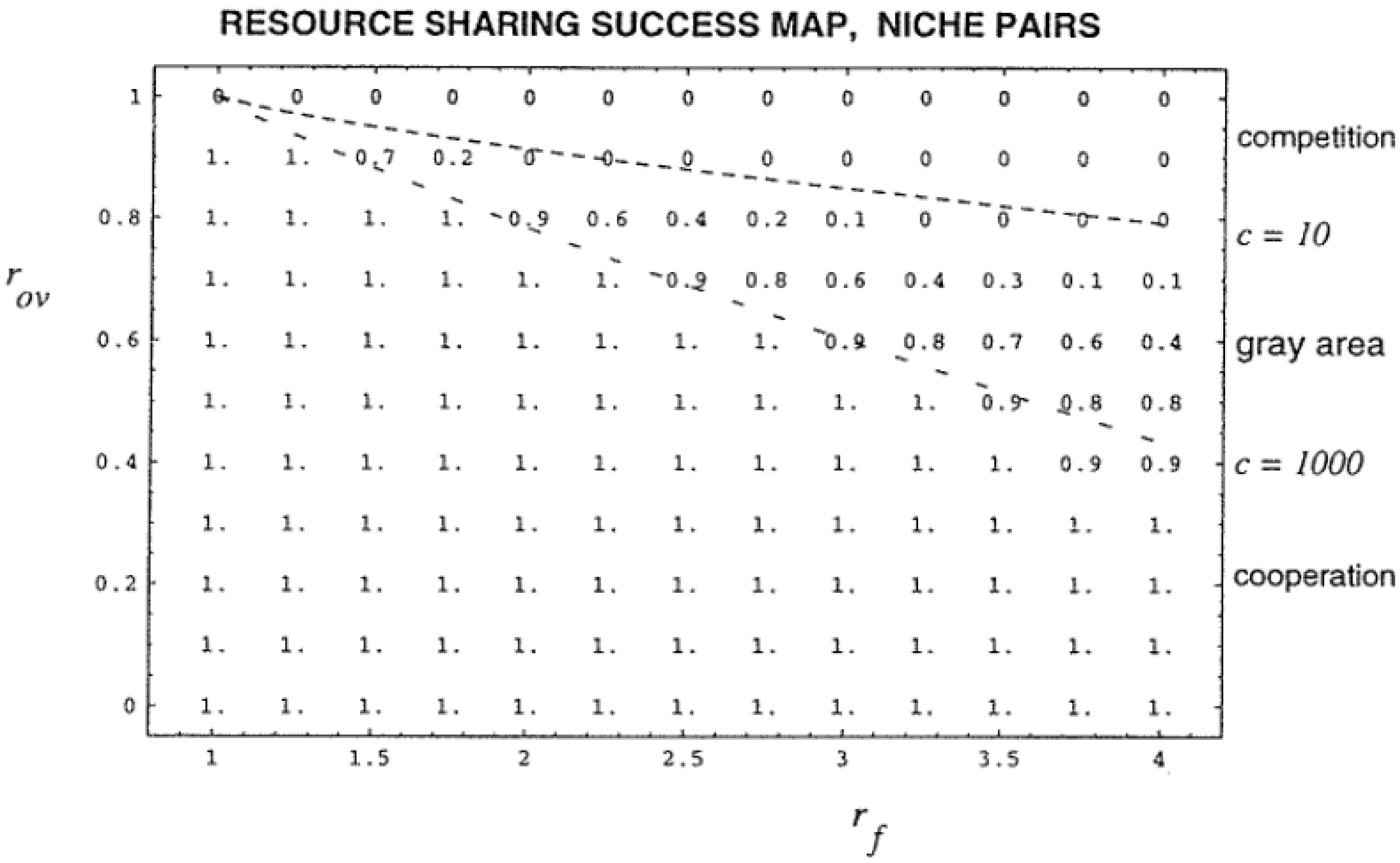

Figure 7: Analytical results superimposed on empirical results: the numbers plotted are the expected survival rate for the niche *pairs* (i.e., both niches survive), after $t = 200$ generations. These niching success probabilities are obtained to infinite precision via the Markov chain, but are here shown rounded to the nearest tenth.

Discussion

- Limitations: Choice of constant C
- Implications: Applications of control map in adjusting GA parameters

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Niching Boundaries in Genetic Algorithms

Niching Boundaries

- Concept: Success or failure determined by niche convergence and loss times
- Modeling: Boundary plotted for fitness difference (rs) and overlap (ro)
- Observations: Linear boundary for resource sharing

Comparison with Previous Bounds

- Old vs. New Bounds: New bounds tightly encapsulate niching gray area
- Improvements: More accurate prediction of niching success or failure

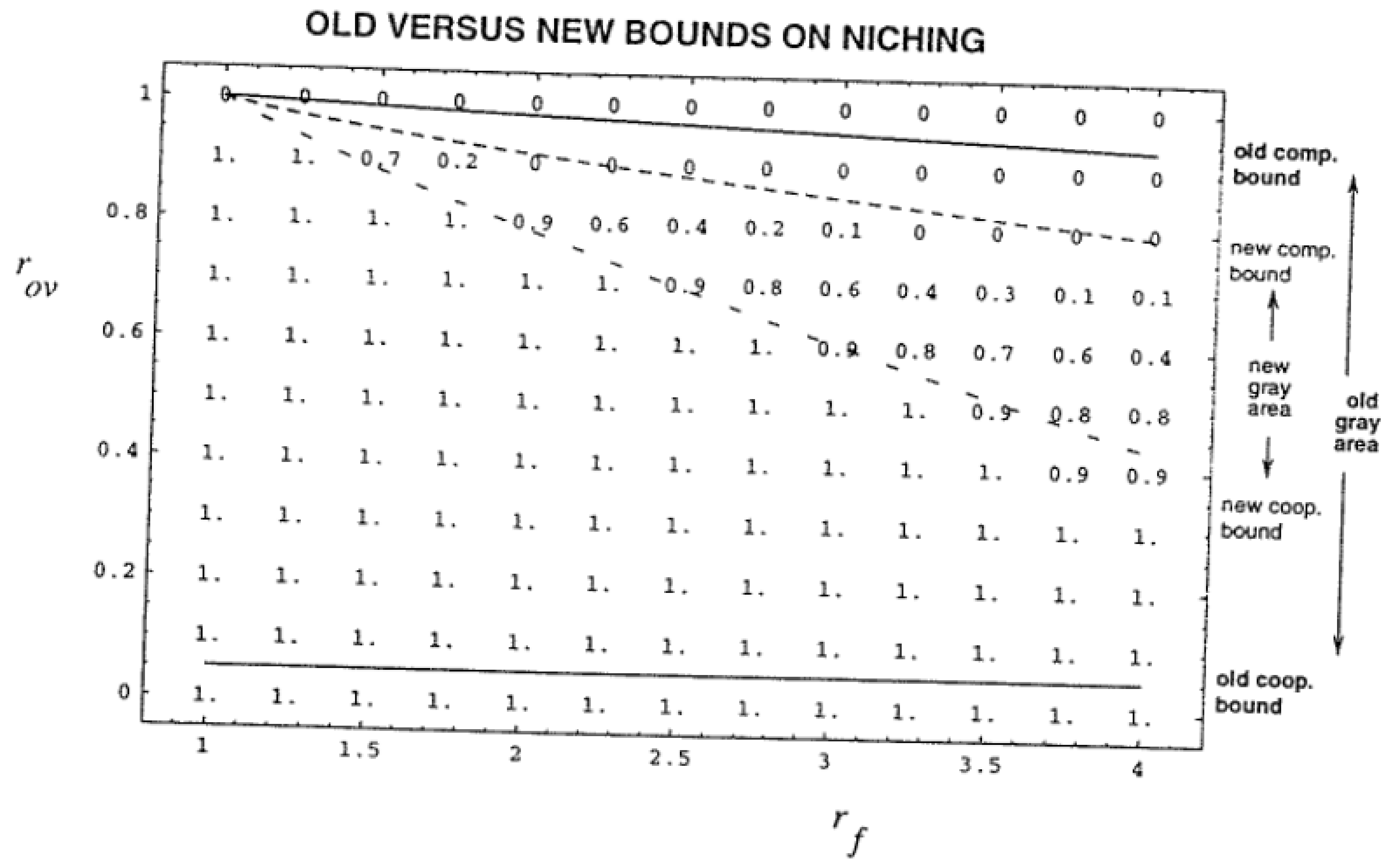

Figure 8: A comparison of our previous theoretical predictions (solid lines) of pair-wise niching success and failure versus our new bounds (dashed lines), both superimposed on the actual results.

Complete Scenarios for Two-Niche

- Extension: Analysis includes inverse fitness ratio
- Observations: New bounds outperform old, accuracy decreases at extreme fitness differences

Limitations and Control

- Control Parameters: Niche radius (σs), sharing function exponent (αs), population size N
- Practical Control Map: Set parameters for survival of niche pairs

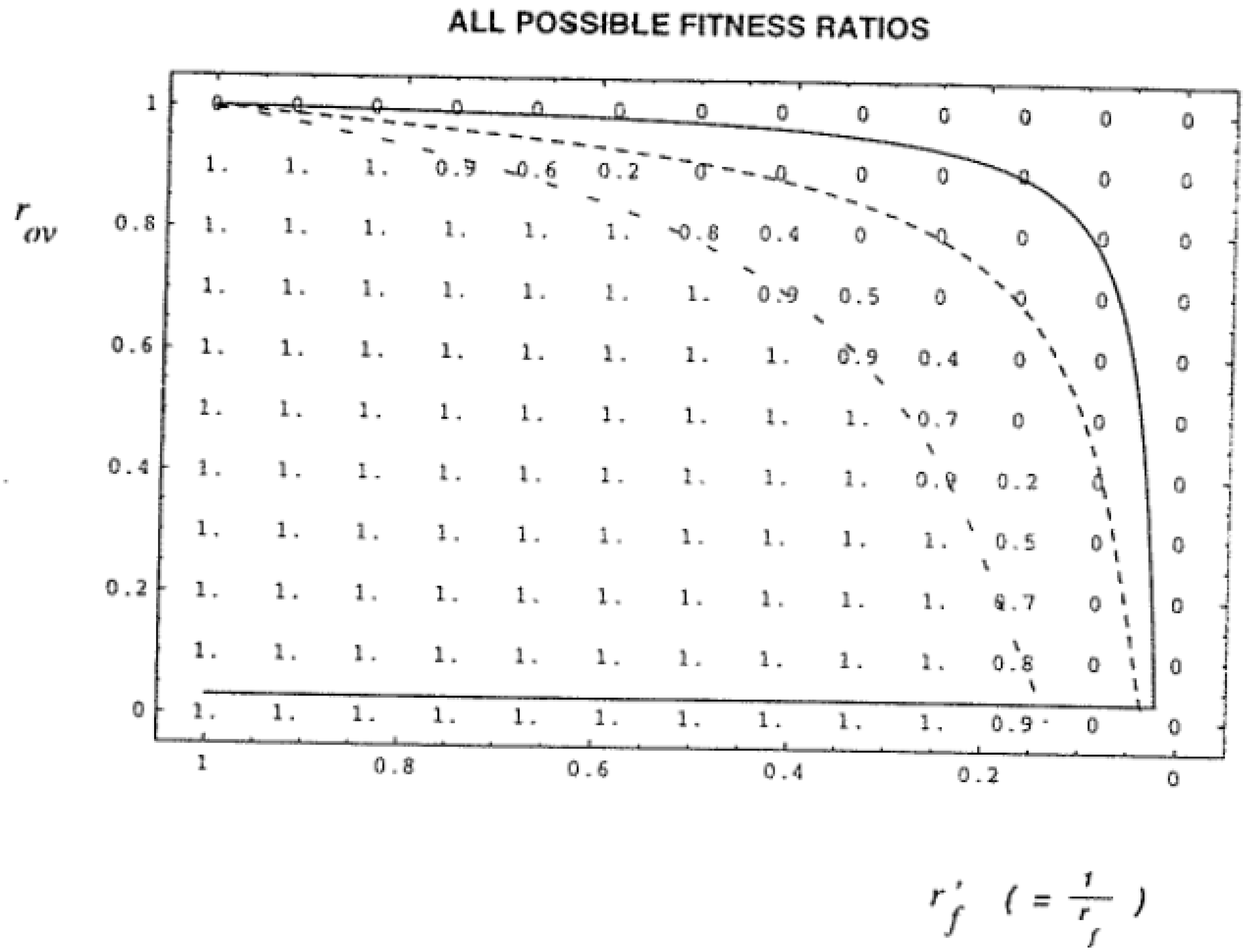

Figure 9: By varying the inverse fitness ratio r'_f, we can extend our comparison in Figure 8 to include all possible fitness ratios ($1 \leq r_f < \infty$).

Other Limitations

- Scope: Predictive map limited to resource sharing, single pair of niches
- Future Research: Extend map to multiple pairs and sharing types

Summary and Future Work

- Increasing fitness difference rs and increasing overlap r, slow niche convergence time while also speeding up niche loss
- Proposed boundary as a navigational tool
- Such a navigational tool is the first step in being able to tune our niched GAs to promote exactly the kinds of cooperation and competition we deem appropriate for the problem at hand.