On Decentralizing Selection Algorithms

2023/09/27

Introduction

- Natural parallelism of Evolutionnary Algorithms (EA)
- Coarsely and finely grained parallel architectures
  - Coarsely: small number of large structures
  - Finely: large number of small structures
- In this paper, solutions to adapt EAs to effectively exploit finely grains architectures

Selection algorithm

- Selection algorithm: stage of a genetic/evolutionary algorithm, choice of parents of a new generation

- Involves 2 elements:
  - Selection pool
  - Selection probability distribution over this pool

Centralized control

- Centralized control: a « master control process » assigns tasks to « slave processes »
- requires **overhead communication**
- Overhead communication generates a lot of costs

- **A goal is to reduce communication overhead by decentralizing selection**

Decentralized selection with global pools

- For most centralized EAs, global pool (entire population)
- Most traditionnal selection algorithms (fitness proportinal, rank proportional) require global calculations that involve high communication overhead

- Tournament selection: k individuals are picked randomly (uniform probability), and the individual w/ best fitting value is chosen to be the parent
  - → no need to calculate some global data

- Binary tournament selection (k = 2): good contender for decentralizing selection
  - Equivalent to standard linear ranking scheme
  - Easily implemented by assigning each member of the population to a separate processor

Experiments

- Application of De Jong’s functions F3, F4, Peak problems and Hamiltonian circuit

- Settings:
  - Pc=0.6
  - Pm=0.001
  - n=100
  - Number of runs: 100
  - No elitism

Results

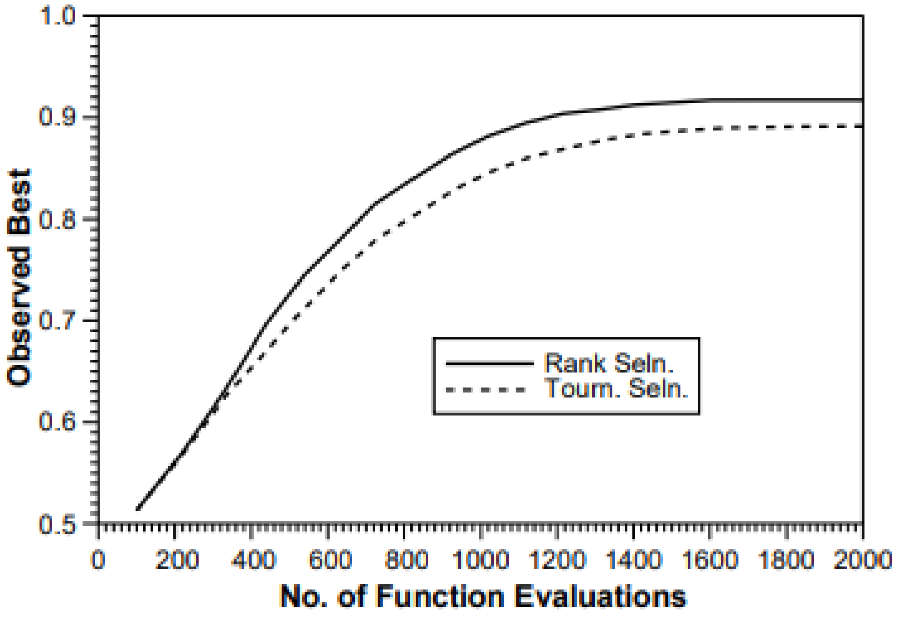


Figure 1: Best-so-far Performance Curves for function HC10 using linear rank and binary tournament selection schemes and population size 100.

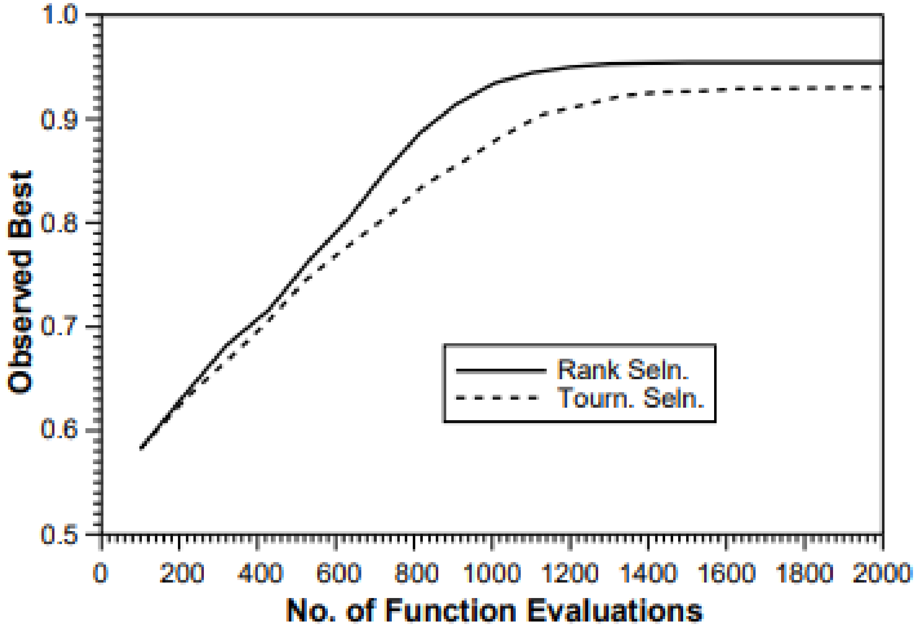


Figure 2: Best-so-far Performance Curves for function Peak6 using linear rank and binary tournament selection schemes and population size 100.

Observations:

- Binary tournament selection has a worse performance than linear ranking, when they are supposed to be equivalent
- Costs remain still high (though lower than before)

- **Why does binary tournament have worst performance than linear ranking ?**

- Further analysis
- Experiment:
  - Computation of number of offspring produced by each individual
  - Statistics on the actual number of offpring for each individuals.
  - Process repeated 100 times with different random number seeds

Results

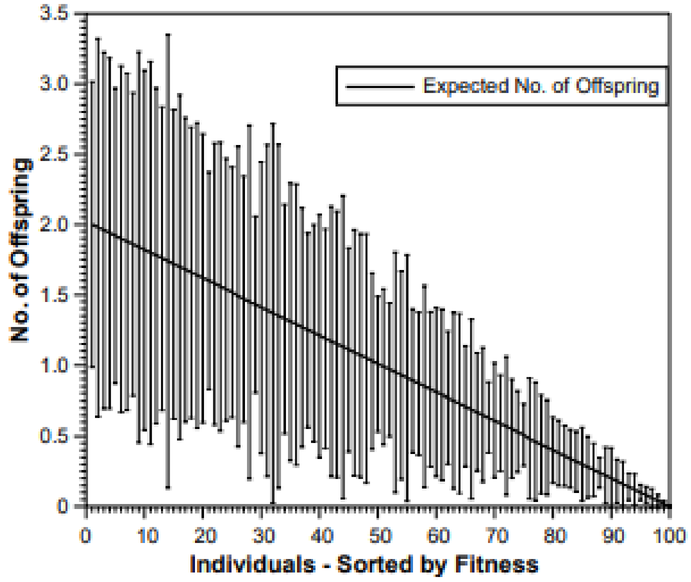


Figure 3: Variance in the expected number of offspring using binary tournament selection, population size 100 for function HC10.

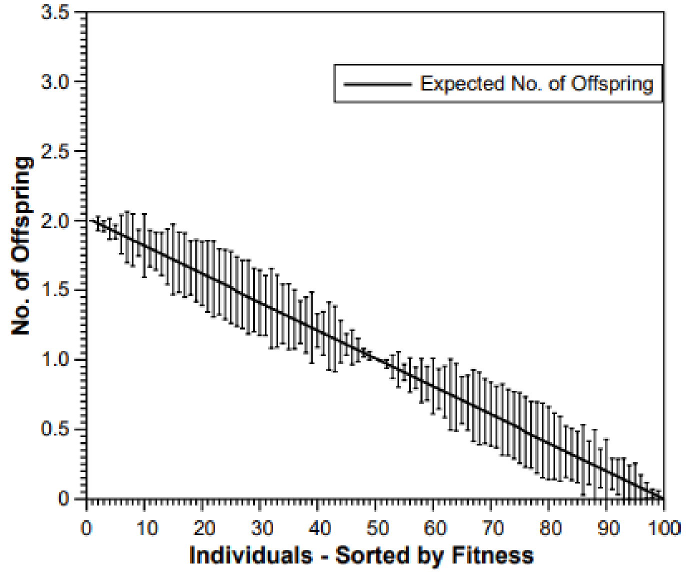


Figure 4: Variance in the expected number of offspring using linear rank selection, population size 100 for function HC10.

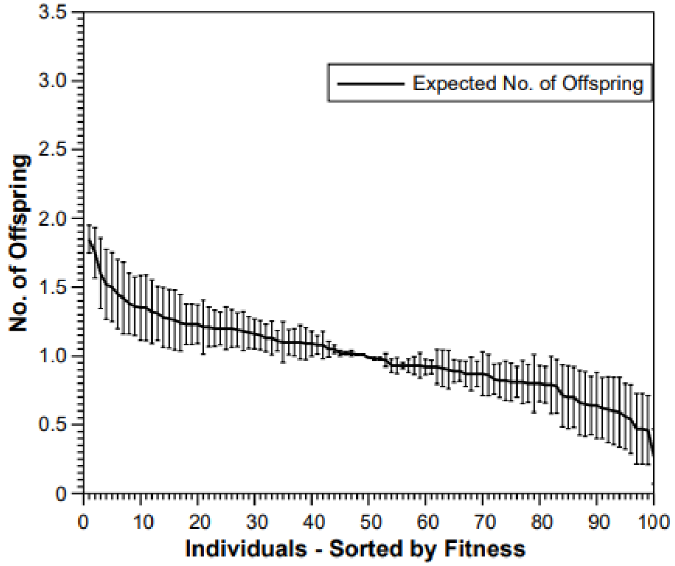


Figure 5: Variance in the expected number of offspring using proportional selection, population size 100 for function HC10.

Observations

- Binary tournament has much higher variance
  - Linear ranking is usually implemented as an « expected value » model which minimises the variance due to sampling.
- Increased selection variance increases genetic drift in finite populations → can decrease search performance
- Increase population size to reduce variance and increase performance

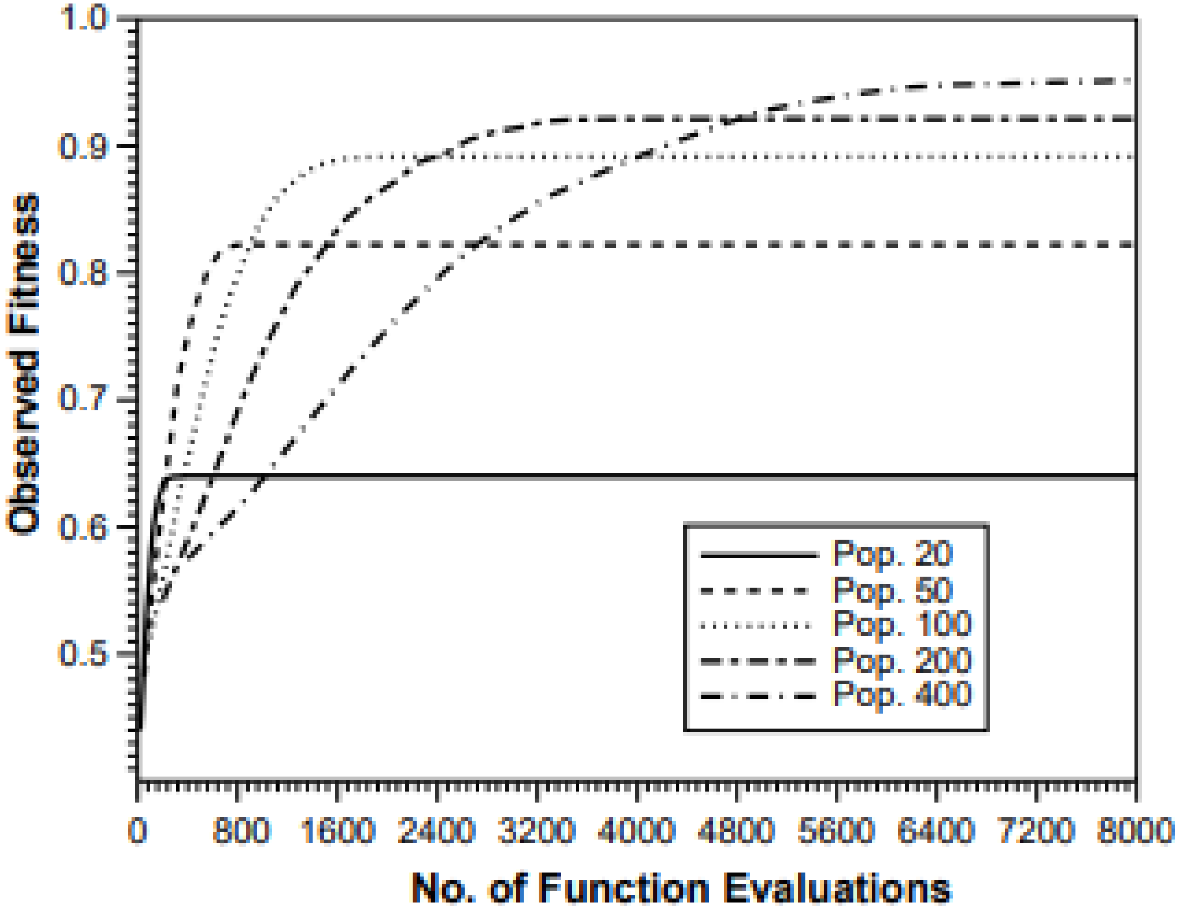


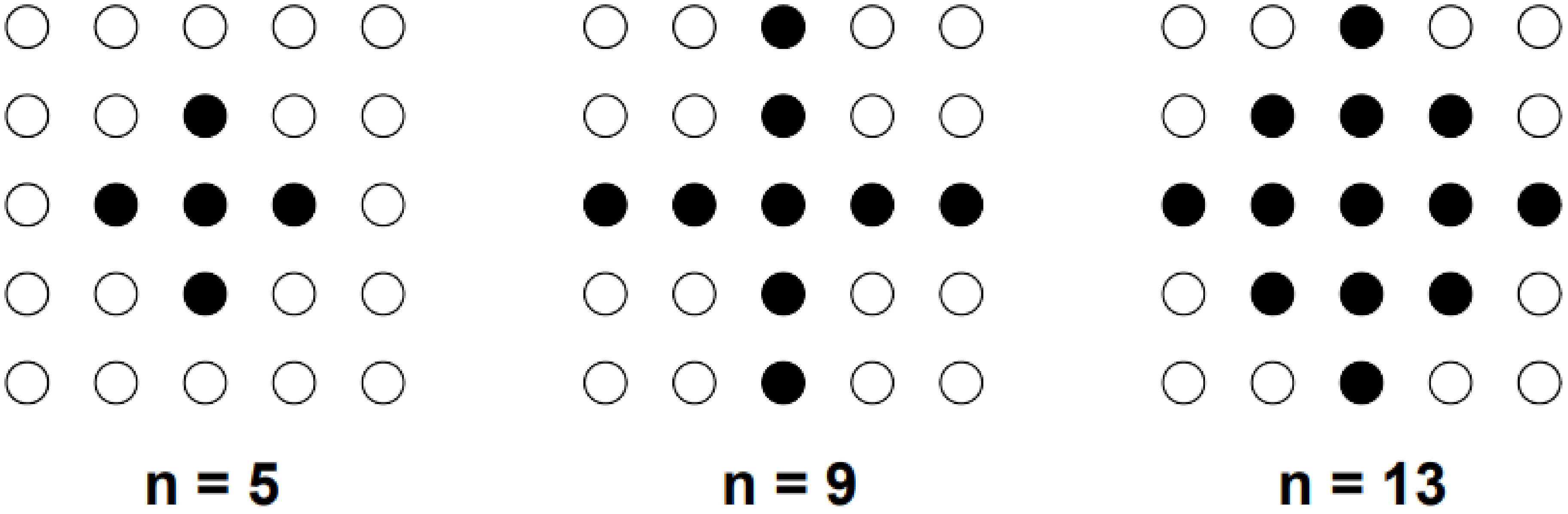
Figure 6: Best-so-far Performance Curves using binary tournament selection with different population sizes for function HC10.

- Bigger population sizes increase performance, but they also increase overhead communications and therefore costs

Decentralized selection with local pools

- Local pools: define a distance metric/topology
- Most popular topologies: two-dimensional square toroidal grid.
- Modified EA is run in parallel on each gris point
- Neighborhoods should be small to avoid high communication overhead

- Sizes of neighbourhood studied



Results

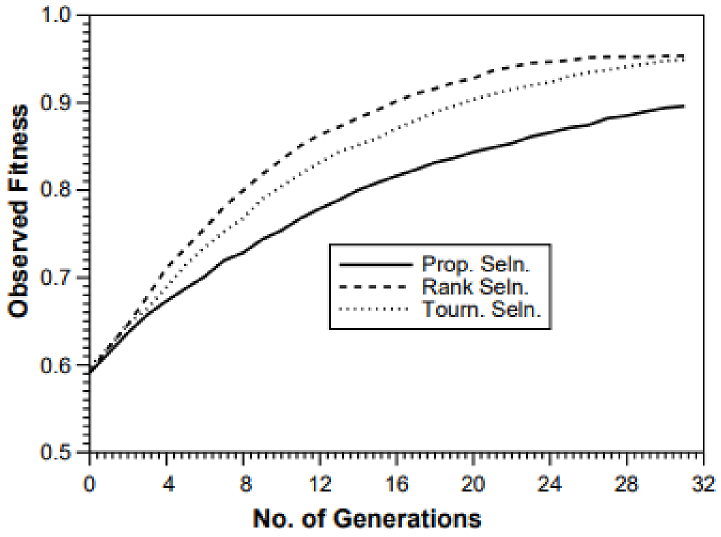


Figure 8: Best-so-far Performance Curves for the three selection schemes using a 32 × 32 toroidal grid and a neighborhood size of 5 for function HC10.

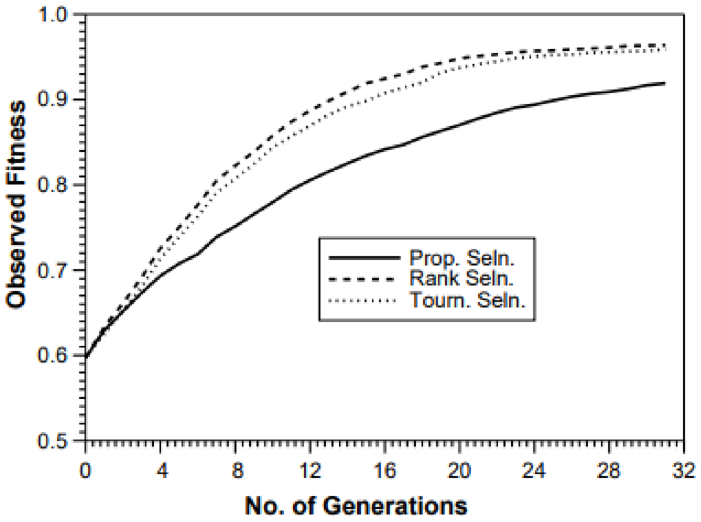


Figure 9: Best-so-far Performance Curves for the three selection schemes using a 32 × 32 toroidal grid and a neighborhood size of 9 for function HC10.

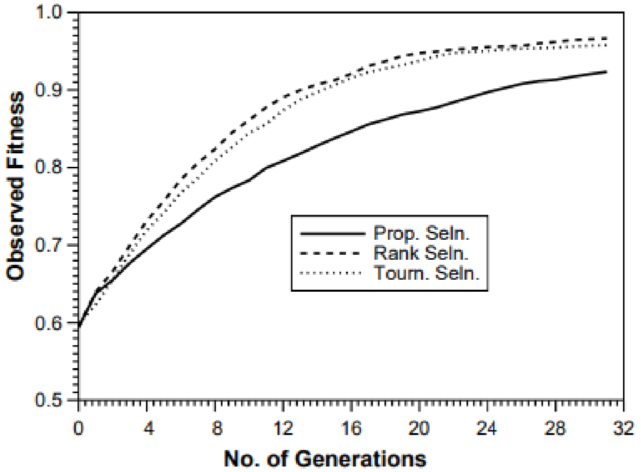


Figure 10: Best-so-far Performance Curves for the three selection schemes using a 32 × 32 toroidal grid and a neighborhood size of 13 for function HC10.

Observations

- For all neighborhoods, performance of proportional selection is lower
- As the pool size increases, binary tournament becomes equivalent to ranking selection

- Further analysis: same experiment as earlier
- Process repeated 100 times w/ different random number seeds

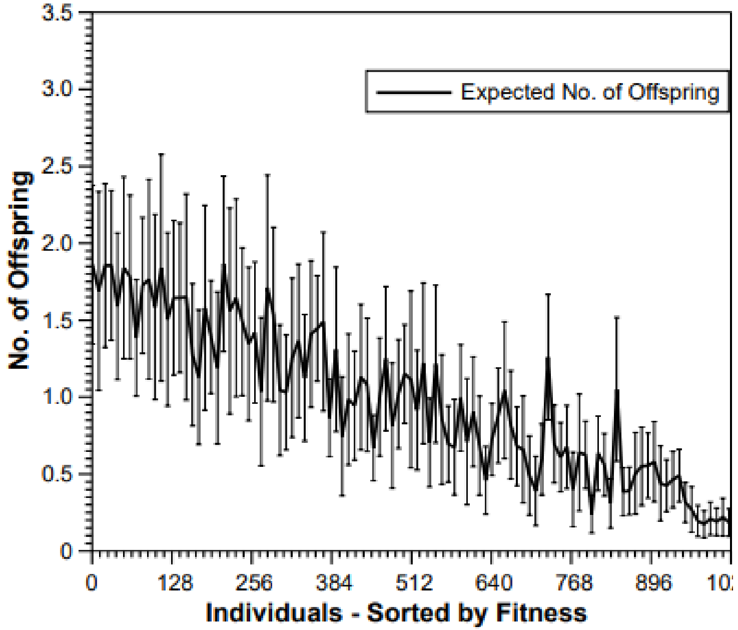


Figure 11: Variance in the expected number of off spring using binary tournament local selection, a 32 › 32 toroidal grid and a neighborhood size of 5 for func tion HC10.

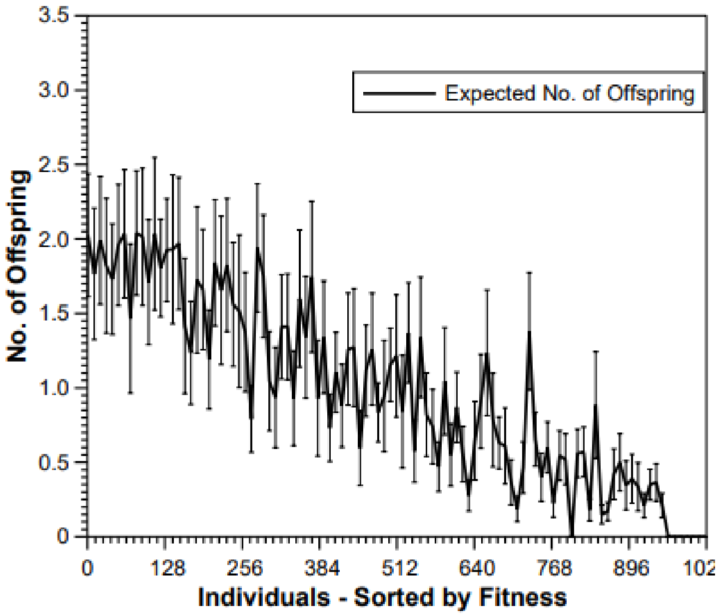


Figure 12: Variance in the expected number of off- spring using linear rank local selection, a 32 × 3: toroidal grid and a neighborhood size of 5 for func- tion HC10.

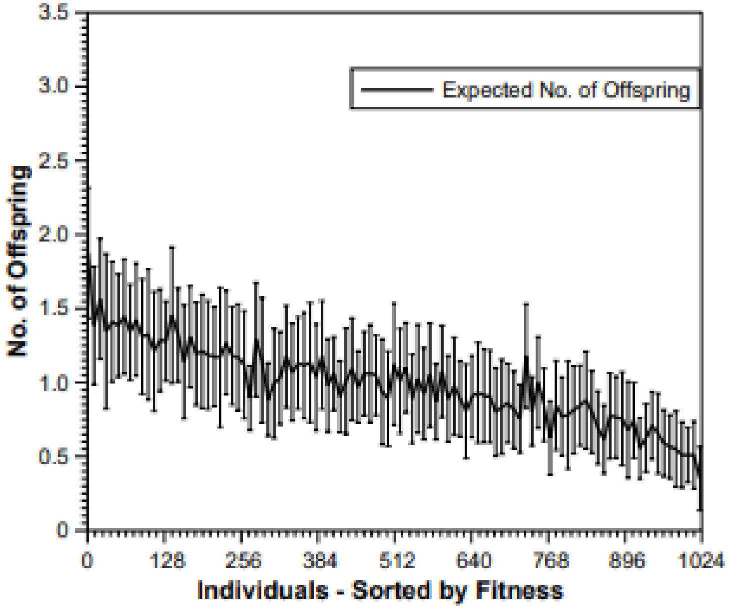


Figure 13: Variance in the expected number of off- spring using proportional local selection, a 32 × 32 toroidal grid and a neighborhood size of 5 for func- tion HC10.

Observations

- For local ranking & binary tournament, different expected number of offspring for members with similar fitness
- Local proportional : more uniform but weaker selection pressure

- Performance improvements depending on the size of neighborhood, but especially from 5 to 9, but from 9 to 13 suite negligible
    - → the highest neighborhood size is not necessarily better.

Improve search performance without increasing overhead

- Combining local tournament selection on small neighborhoods w/ elitist policy: replace the individual assigned to a grid point by an offspring only if it has higher fitness

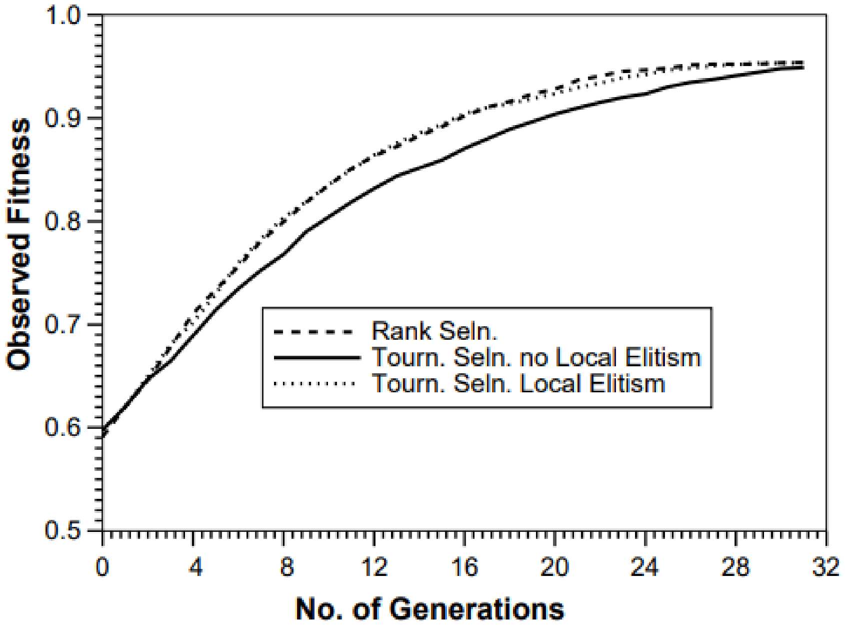


Figure 14: Best-so-far Performance Curves for linear rank and binary tournament (with and without local elitism) local selection schemes using a 32×32 toroidal grid, neighborhood size of 5, for function HC10

Conclusion

- Results obtained show the importance of variance analysis, which must be reduced (increasing poplation size)
- Among the local selection schemes studied, binary tournament selection seems to be most appropriate redarding searcj perspective & communication overhead