Sexual selection in genetic algorithms
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1 Introduction
Genetic algorithms are optimization algorithms that try to mimic the process of natural selection. Accordingly, these machine learning algorithms used in the field of artificial intelligence are based on the biological theory of evolution. However, biological evolution comprises more than just natural selection. In particular, mate choice, or sexual selection, is a potent force that can counteract as well as enhance natural selection. Much of biological diversity and complexity is nowadays ascribed to this force.

The genetic algorithm approach faces two main problems. One is that an algorithm converges to a local extreme rather than to a global optimum. The other is that the genetic diversity of the population is lost, which also will result in being stuck in a local extreme. In this project, I hope to overcome these limitations by incorporating sexual selection in such an algorithm. To this end, I will construct genetic algorithms with 2 genders corresponding to two different ecological and sexual strategies. I will investigate systematically whether and under what circumstances these “two-sex” genetic algorithms perform better than the standard “unisexual” ones.

The idea underlying this project was proposed by Franjo Weissing who extended some recent results of Agrawal and Siller [1,13] to genetic algorithms. For me this seemed a very interesting idea which I would like to study in depth.

2 Theoretical framework
Genetic algorithms, introduced by Holland [9] are optimization algorithms inspired by Darwin’s theory of natural selection [5,6]. Problems are solved by mimicking an evolutionary process involving selection, mutation, and recombination (crossovers). These genetic algorithms utilize a population of individuals. Because fitter individuals, as rated by a fitness function, are more likely to reproduce and hence to transmit their problem solving strategy to the next generation, the algorithms tend to converge to a (local) fitness maximum. Genetic algorithms are able to solve a huge amount of problems but usually need a higher computation time than more specialized algorithms.

Genetic algorithms are usually relatively easy to implement. Because genetic algorithms search more solutions in parallel (a whole population of solutions), a genetic algorithm is less likely to get stuck in a local extreme than other methods. However, being stuck in a local extreme is still a big problem for genetic algorithms, often caused by a loss of genetic diversity.

In most genetic algorithms the members of a population are not distinguished according to sex, while sex differences are widespread and almost universal in biological populations. Still, the evolution and maintenance of sexual reproduction is not well understood. Consider two populations where one population reproduces sexually and one reproduce asexually. All else being equal, there is a twofold fitness advantage for the asexual population. So any asexual population would soon outnumber a sexual population which would become extinct.
According to some recent theoretical results [1,13], this two-fold cost of sex might be offset by evolutionary advantages of a sexual-population, provided that natural selection is enhanced by sexual selection in such a population. On the basis of such theories a genetic algorithm with 2 genders and sexual selection could outperform a regular genetic algorithm.

The following aspects are of relevance for this prediction. Following Agrawal and Siller [1, 13], mate choice is a powerful agent to remove deleterious mutations from a population. Miller and Todd [10] argue that natural selection lets evolution converge to a few locally optimal solutions where sexual selection often results in an unpredictable, divergent pattern of evolution. They remark that sexual selection may be viewed as being midway between natural selection by the inanimate environment and purposive artificial selection by humans.

At present, there are only a few studies on genetic algorithms that have incorporated sexual selection. Some of these studies seem to confirm that sexual selection can enhance the performance of a genetic algorithm [11], but there are others that could not find much improvement [7]. In this project I will test “gendered” genetic algorithms with different sexual selection strategies and compare them with regular genetic algorithms. It is one of my main goals to find out under what circumstances the inclusion of sexual selection improves the performance of genetic algorithms and when it is neutral or even detrimental to performance.

3 Research question
In this project I will propose several methods to include genders in genetic algorithms. The main research question is:
Are genetic algorithms with two sexes more efficient than genetic algorithms based on a unisexual or an asexual population? In which situations does sexual selection enhance the efficiency of a genetic algorithm?
Although the focus of this project is on genetic algorithms, I expect to get new insights into the relevance of sexual selection in biological evolution.

4 Methods
To find out which sort of genetic algorithm is more efficient I will implement several versions of a genetic algorithm in C++. One version corresponds to a “normal” genetic algorithm, while in others sexual selection will be incorporated. For testing the performance of the algorithms I will look at how fitness increases (a) with the number of generations, and (b) with computation time. The algorithms will be tested on different types of problems. At the moment I am thinking about using the well-known traveling salesman problem, a discrete statistical optimization problem and two other problems that still have to be determined.
5 Scientific relevance for AI
Genetic algorithms, being part of evolutionary computing, are a rapidly growing area of artificial intelligence. Building more efficient genetic algorithms by incorporating novel mechanisms like sexual selection would certainly be a major step forward, both from a fundamental and an applied point of view. Genetic algorithms are used to solve a wide variety of problems in scientific research and in commercial companies. A better performing genetic algorithm will be useful for both. More generally, it may be useful for the field of AI to use heuristics inspired by biological theory.

6 Planning
The figure below gives the global planning. The total project will take 24 weeks. It will start in December 2004, and it will be finished in June 2005.
Tasks:
A. Study literature
B. Implement some of the major algorithms described in the literature.
C. Design of the algorithms used in the experiment and choice of test problems.
D. Implementing the algorithms for the experiment.
E. Performing the experiment, adjusting parameters and evaluating the results.
F. Writing of the thesis.

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7 Resources and support
The department of Theoretical Biology of the University of Groningen will provide a working space and a computer. These are all the resources needed for this project.
Support at the Biological Centre will be given by Prof. Dr. Franjo Weissing and Dr. Sander van Doorn. Dr. Bart de Boer will be the internal adviser. Dr. Edwin de Jong from Utrecht University will give me some advice about genetic algorithms.
8 References


