



# GENETIC ALGORITHMS

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## *Ask the Professor*

Genetic algorithms are well defined mathematical procedures that terminate into hopefully useful solutions to optimization problems. They are originally motivated by evolutionary biology that has brought forth significant incremental improvements in senses such as vision, hearing, smell, taste, tactile, not to mention planning, problem solving, learning and a host of associated higher order reasoning capabilities. These algorithms, attempt to emulate, albeit at differing levels, the evolutionary processes with recent fast and structured corresponding computational elements.

In order to recast the evolution stages into corresponding mathematical constructs, some common terminology proves useful. In the beginning, one needs to represent the many members of an abstract population related to the specific optimization problem to be solved by a particular genetic algorithm. Of course it is desirable to employ a suitable encoding scheme for each member representation in the selected population This could be done in terms of strings of digits, integers, or real numbers. Next, a way to evaluate the

fitness or the rank order of population members is required. This can be in the form of an appropriate continuous fitness function, or alternatively in the form of an ordering or indexing relation. This step is typically followed by some means of best selection, to retain only members of relatively high fitness to be passed on to the next generation, this is sometimes called elitism.

Continuing to imitate evolutionary biology, two essential transformations are introduced in order to replace the poor members of the population by better members. The first consists of the mating of randomly chosen pairs of parents, as in a roulette wheel, to produce novel pairs of off-springs by simply exchanging gene sets beyond a crossover point. This produces siblings in the next generation reflecting inheritance of significant traits from the parents and consequently ancestors in the previous generations. This important transformation is termed crossover and could encompass several variations in the type and location of crossover genes to be exchanged. It is designed to increase the likelihood of monotonically increasing the fitness in overall system performance, form or function. Also, the mutation transformation is similarly developed by changing one or few genes, with a small probability, in a set of randomly chosen members of the population so as to explore novel traits and thus widen the search regions that may help enhance fitness, or speed up the genetic algorithm computations toward convergence to optimal solutions.

After a certain number of successive generations the population will hopefully contain superior members (solutions) and termination of the algorithm is imminent whenever diminishing improvement in fitness is observed.

Genetic algorithms have been applied to solve many mathematical, scientific, and engineering optimization problems. They have been proven successful, even when multiple local optimal solutions are involved. This would be hard to solve by traditional optimization methods. The performance is usually judged by tracking the fitness function from one

generation to another and by examining best, average, worst fitness values.

One example of the application is in the area of autonomous robotics, where one or more robots are making decisions and planning to cover a given map but without running into obstacles in their way. The fitness function in this case is closeness to target and includes a penalty for proximity to any obstacle. The individual members of population are the decisions made. The robots generate initial decisions that are continuously improved by the genetic algorithm. Other constraints such as limited energy supply for the robots can also be incorporated in the genetic algorithm search for best decisions.

To sum up, genetic algorithms and their recent variants that add more features such as viability (survival) and fertility (reproduction), are powerful global random search computational tools with a variety of potential applications especially to intelligent and autonomous systems. They further exhibit an implicit parallelism that should enhance their statistical sampling functionality, accuracy, and consistency over feasible yet large problem search space.