Breeding for Success – Genetic Algorithms for Optimisation

Nature is very good at coming up with the best solution to a problem – using evolution. We can use methods based on the same principles to solve optimisation problems, such as finding the maximum of a complicated function of several variables. These techniques are called genetic algorithms.

A genetic algorithm is based on a population, with each member of the population holding a complete set of parameters for the function being searched (in a simple optimisation, the estimate of the position of the maximum) in the form of a gene. Then the population is allowed to evolve as follows:

Breed, allowing crossover. Two individuals are chosen as paremts, and a new individual is generated with genes which involve sections cut from both its parents' genetic material. This allows a jump to be made to a radically new solution without having to take a large number of small steps.

Mutation. This allows random changes to be made to the genes.

Evaluate fitness: evaluate the function being searched (the objective function) for each individual in this new population of parents and offspring

Select: pick the probability for each individual to survive according to its fitness. Note that this is done probabilistically rather than by simply selecting the few best individuals: a weak individual might still carry useful genetic material. Cull the population on this basis back to the original number of individuals.

Repeat

You should set up Python code to perform these operations for a simple two-dimensional optimisation. As an objective function, use

$$F(x,y) = (a + \cos(b\,(x^2+y^2))/(1+c(x^2+y^2)))^{-1}$$

Take the regions $-\pi$ to π for x and y, and code the (x,y) position in the genes, by describing each direction into binary code, using 5 binary digits for each direction.

Define Python functions to perform mutation and crossover, to evaluate fitness (i.e. the value of F(x,y)), and to cull the population. For display purposes, set up routines which will show the positions of the members of the population on the surface representing the fitness, Also set up a routine to display the population genetics graphically, as a black-and-white grid.

There are many parameters to experiment with in this model. Also, having ‘bred’ an optimised population, we can apply it to a new problem and see whether it can succeed in evolving a new good solution or whether it has become over-specialised.

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David Bowler, 2019