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Genetic algorithm: review and applications

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ABSTRACT

Genetic algorithm is a stochastic searching algorithm. It searches a solution space for an optimal solution to a problem. The main characteristic of the genetic algorithm in comparison to other optimization methods is how the searching is done. A "population" of the possible solutions to the problem is chosen and the algorithm evolves over multiple generations to find better and better solutions. In this paper a review of the work done by the researchers in the field of genetic algorithm is done to explore the advantages and applicability of this optimization technique.

I INTRODUCTION

A genetic algorithm is a search technsique used in computing to find exact or approximate solutions to optimization and search problems [1]. This technique was introduced by John Holland in the early 1970s. [2] Genetic algorithms (GAs) are receiving increasing application in a variety of search and optimization problems. These efforts have been greatly aided by the existence of theory that explains what GAs are processing and how they are processing it, the theory largely rests on Holland's exposition of schemata.

It is an adaptive heuristic search method using techniques inspired by evolutionary biology such as inheritance, mutation, selection and crossover.

It follows the idea of survival of the fittest - Better and better solutions evolve from previous generations until a near optimal solution is obtained. GA uses the main three operations, the selection, crossover and mutation to produce new generations from the old ones. GA has been widely used to solve optimization problems in many applications such as traveling salesman problem, airport traffic control, information retrieval (IR), reactive power optimization, job shop scheduling, and hydraulics systems such as water pipeline systems. In water pipeline systems we need to achieve some goals optimally such as minimum cost of construction, minimum length of pipes and diameters, and the place of protection devices. GA shows high performance over the other optimization techniques, moreover, it is easy to implement and use. Also, it searches a limited number of solutions [3].

A. Encoding

The decision variables of a problem are normally encoded into a finite length string this could be a binary string or a list of integers.For example: 0 1 1 0 1 1 0 1 0 or 2 3 4 1 1 4 5.

B.**Selection**

Genetic Algorithms are optimization algorithms that maximize or minimize a given function. Selection operator deserves a special position in genetic algorithm since it is the one which mainly determines the evolutionary search spaces. It is used to improve the chances of the survival of the fittest individuals. There are many traditional selection mechanisms used and many user specified selection mechanisms specific to the problem definition [4].

The selection operator mainly works at the level of chromosomes. The goodness of each individual depends on its fitness. Fitness value may be determined by an objective function or by a subjective judgment specific to the problem. As the generations pass, the members of the population should get fitter and fitter (i.e. closer and closer to the solution). Selection is one of the important operations in the GA process. Different selection mechanisms work well under differentsituations. Appropriate method has to be chosen for thespecific problem to increase the optimality of the solution. For example, the proportional roulette has been used in many problems [5] and it outperformed the other strategies in the salesman problem, achieving best solution quality with low computing times [6].The selection mechanisms are shown in Fig. 1.

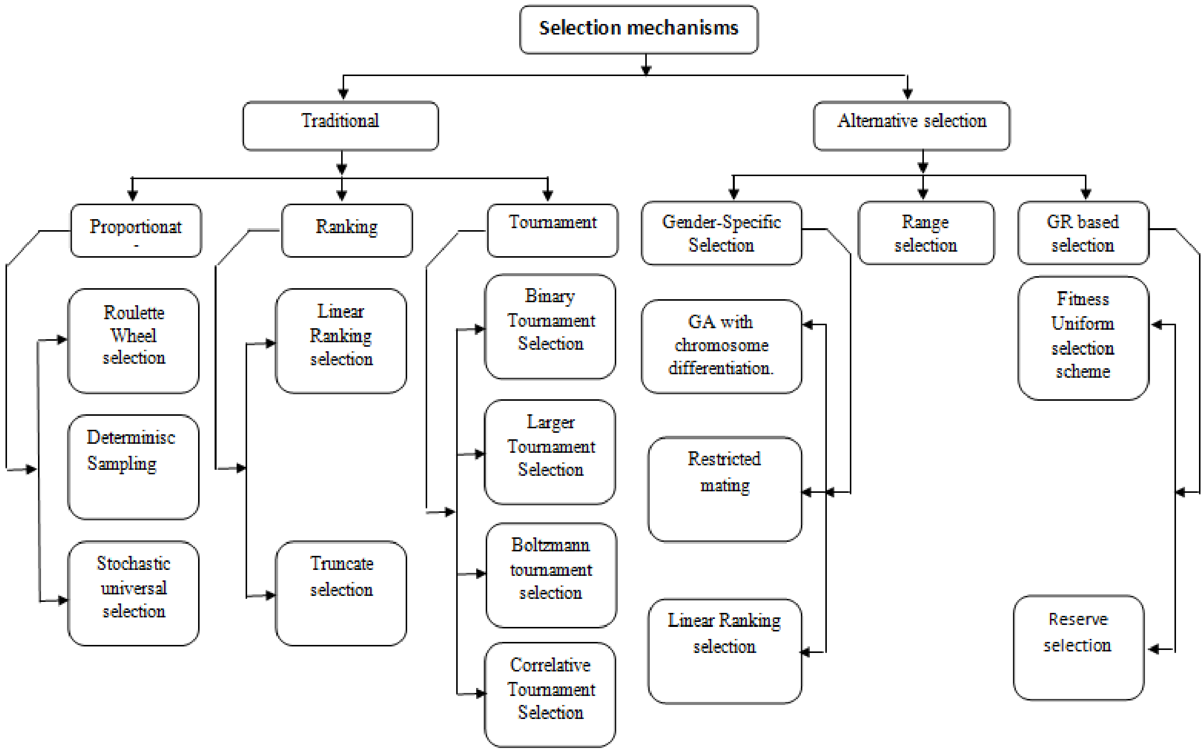

Fig. 1 Selection mechanisms

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II GENETIC ALGORITHM MYTHOLOGY

2.1 Initialization

Initially many individual solutions are randomly generated to form an initial population. The population size depends on the nature of the problem, but typically contains several hundreds or thousands of possible solutions. Traditionally, the population is generated randomly, covering the entire range of possible solutions (the search space). Occasionally, the solutions may be "seeded" in areas where optimal solutions are likely to be found.

2.2 Selection

During each successive generation, a proportion of the existing population is selected to breed a new generation. Individual solutions are selected through a fitness-based process, where fitter solutions (as measured by a fitness function) are typically more likely to be selected. Certain selection methods rate the fitness of each solution and preferentially select the best solutions. Other methods rate only a random sample of the population, as this process may be very time-consuming.

Most functions are stochastic and designed so that a small proportion of less fit solutions are selected. This helps keep the diversity of the population large, preventing premature convergence on poor solutions. Popular and well-studied selection methods include roulette wheel selection and tournament selection.

2.3 Reproduction

The next step is to generate a second generation population of solutions from those selected through genetic operators: crossover (also called recombination), and/or mutation.

For each new solution to be produced, a pair of "parent" solutions is selected for breeding from the pool selected previously. By producing a "child" solution using the above methods of crossover and mutation, a new solution is created which typically shares many of the characteristics of its "parents". New parents are selected for each new child, and the process continues until a new population of solutions of appropriate size is generated. Although reproduction methods that are based on the use of two parents are more "biology inspired", some research [5] suggests more than two "parents" are better to be used to reproduce a good quality chromosome.

These processes ultimately result in the next generation population of chromosomes that is different from the initial generation. Generally the average fitness will have increased by this procedure for the population, since only the best or genetic algorithm from the first generation are selected for breeding, along with a small proportion of less fit solutions, for reasons already mentioned above.

2.4 Termination

This generational process is repeated until a termination condition has been reached. Common terminating conditions are:

• A solution is found that satisfies minimum criteria;

• Fixed number of generations reached;

• Allocated budget (computation time/money) reached;

• The highest ranking solution's fitness is reaching or has reached a plateau such that successive iterations no longer produce better results;

• Manual inspection;

• Combinations of the above.

Simple Genetic algorithm pseudocodes:

1. Choose the initial population of individuals.
2. Evaluate the fitness of each individual in that population.
3. Repeat on this generation until termination: (time limit, sufficient fitness achieved, etc.)
   a. Select the best-fit individuals for reproduction.
   b. Breed new individuals through crossover and mutation operations to give birth to offspring.
   c. Evaluate the individual fitness of new individuals.
   d. Replace least-fit population with new individuals.

III APPLICATIONS OF GENETIC ALGORITHM

3.1. Automotive Design

Using Genetic Algorithms [GAs] to both design composite materials and aerodynamic shapes for race cars and regular means of transportation (including aviation) can return combinations of best materials and best engineering to provide faster, lighter, more fuel efficient and safer vehicles for all the things we use vehicles for. Rather than spending years in laboratories working with polymers, wind tunnels and balsa wood shapes, the processes can be done much quicker and more efficiently by computer modeling using GA searches to return a range of options human designers can then put together however they please.

3.2. Engineering Design

Getting the most out of a range of materials to optimize the structural and operational design of buildings, factories, machines, etc. is a rapidly expanding application of GAs. These are being created for such uses as optimizing the design of heat exchangers, robot gripping arms, satellite booms, building trusses, flywheels, turbines, and just about any other computer-assisted engineering design application. There is work to combine GAs optimizing particular aspects of engineering problems to work together, and some of these can not only solve design problems, but also project them forward to analyze weaknesses and possible point failures in the future so these can be avoided.

3.3. Robotics

Robotics involves human designers and engineers trying out all sorts of things in order to create useful machines that can do work for humans. Each robot's design is dependent on the job or jobs it is intended to do, so there are many different designs out there. GAs can be programmed to search for a range of optimal designs and components for each specific use, or to return results for entirely new types of robots that can perform multiple tasks and have more general application.

3.4. Evolvable hardware

Evolvable hardware applications are electronic circuits created by GA computer models that use stochastic (statistically random) operators to evolve new configurations from old ones. As the algorithm does its thing in the running model, eventually a circuit configuration will come along that does what the designer wants. It could use a built-in GA library and simulator to re-design itself after something like radiation exposure that messes up its normal configuration, or encounters a novel situation in which it needs a function it doesn't already have. Such GAs would enable self-adaptation and self-repair.

3.5. Optimized Telecommunications Routing

GAs are being developed that will allow for dynamic and anticipatory routing of circuits for telecommunications networks. These could take notice of the system's instability and anticipate the re-routing needs. Using more than one GA circuit-search at a time, soon your interpersonal communications problems may really be all in your head rather than in your telecommunications system. Other GAs are being developed to optimize placement and routing of cell towers for best coverage and ease of switching

3.6. Biomimetic Invention

Biomimicry or biomimetics is the development of technologies inspired by designs in nature. Since GAs are inspired by the mechanisms of biological evolution, it makes sense that they could be used in the process of invention as well. GAs rely primarily on something called implicit parallelism (like to like), using mutation and selection in secondary roles toward a design solution. GA programmers are working on applications that not only analyze the natural designs themselves for a return on how they work, but can also combine natural designs to create something entirely new.

3.7. Trip, Traffic and Shipment Routing

New applications of a GA known as the "Traveling Salesman Problem" or TSP can be used to plan the most efficient routes and scheduling for travel planners, traffic routers and even shipping companies.

3.8. Computer Gaming

GAs have been programmed to incorporate the most successful strategies from previous games – the programs 'learn' – and usually incorporate data derived from game theory in their design. Game theory is useful in most all GA applications for seeking solutions to whatever problems they are applied to.

3.9. Encryption and Code Breaking

On the security front, GAs can be used both to create encryption for sensitive data as well as to break those codes. Encrypting data, protecting copyrights and breaking competitors' codes have been important in the computer field.

3.10. Computer-Aided Molecular Design

The de novo design of new chemical molecules is a burgeoning field of applied chemistry in both industry and medicine. GAs are used to aid in the understanding of protein folding, analyzing the effects of substitutions on those protein functions, and to predict the binding affinities of various designed proteins developed by the pharmaceutical industry for treatment of particular diseases. The same sort of GA optimization and analysis is used for designing industrial chemicals for particular uses, and in both cases GAs can also be useful for predicting possible adverse consequences. This application has and will continue to have great impact on the costs associated with development of new chemicals and drugs.

3.11. Gene Expression Profiling

The development of microarray technology for taking 'snapshots' of the genes being expressed in a cell or group of cells has been a boon to medical research. GAs have been and are being developed to make analysis of gene expression profiles much quicker and easier. This helps to classify what genes play a part in various diseases, and further can help to identify genetic causes for the development of diseases. Being able to do this work quickly and efficiently will allow researchers to focus on individual patients' unique genetic and gene expression profiles, enabling the hoped-for "personalized medicine" we've been hearing about for several years.

IV CONCLUSION AND FUTURE SCOPE

Genetic algorithm is a probabilistic solving optimization problem which is modeled on a genetic evaluations process in biology and is focused as an effective algorithm to find a global optimum solution for many types of problem. This algorithm is extremely applicable in different artificial intelligence approaches as well as different basics approaches like object oriented, robotics and other in future we shall concentrate on the development of hybrid approaches using genetic algorithm an object oriented technology.

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