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Problem Solving Using Nature's Way-Genetic Algorithm

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ABSTRACT
Nature is extremely superior in designing systems of high complexity. The nature is responsible for design process called evolution. Two fields are closely related which are evolutionary biology and evolutionary computation. Evolutionary biology is the field that from observations in nature builds models of evolution while evolutionary computation is a field that tries to simulate evolutionary biology. One of the important evolutionary algorithms is Genetic Algorithm. Our paper discuss about the relationship between genetics and evolution. This Paper focuses on the relationship between genetics and evolution. We have taken up one step closer towards the two fold goal of understanding the design principles of nature and the ability to use these principles in the design of artificial systems.

KEYWORDS
Genetic Algorithm, Evolution, Darwin's Theory, Evolutionary computation

INTRODUCTION

Scientific discussion of evolution date back than 200 years Darwin suggested that slight variation among individuals significantly affects the gradual evolution of the population. He called this differential reproductive process of varying individuals - natural selection. Darwin recognized that the reproductive rates of organisms are so high that they would result in enormous population increases if all the offspring survived. [5]But the Darwinian theory cannot explain the origin of complex structures, for example an eye, an immune system and missing links of species that the paleontologists have not found. Mendel (1822-1884) accurately observed patterns of inheritance and proposed a mechanism to account for some of the patterns. Genes determine individual traits. Various kinds of offspring appear in proportion that can be predicted from Mendel's laws. We often use the term Mendelian genetics to refer to the most basic patterns of inheritance in sexually reproducing organisms with more then one chromosome. Mendel gave his classic paper experiments in plant hybrids for Natural Science Society in 1865. Mendel observed that the spherical seed trait was dominant, being expressed over the dented seed trait, which he called recessive In diploid organisms, chromosomes come in pairs One of each chromosome pair derives from each parent; it does not matter whether, for example, the dominate allele was contributed by mother or father. In the biological world, sexual species work by copying the instructions. The genes are the instruction that is copied; the phenotype is the result and is not copied. So we create a population of individuals, each represented by a chromosomes (a collection of genes) specific to a problem we are trying to solve. Genes are implemented by a series of computer bits .The value of each gene is initially assigned randomly. The population is then evaluated to determine how well each individual does the required task. The best member of the population thus becomes the parents for the next generation. The genes of the offspring are created by selecting [6] two Parents at random. This mimics the crossover or recombination of sexual reproduction in nature and is repeated until a second generation is created. Random changes to individual bits are done by mimicking the biological mutation. The resultant population is then evaluated as before and the process is repeated as many times as desired until the required performance is achieved. Genetic Algorithm mimics the above reproduction, crossover and mutation in the form of Genetic Algorithm operators. This technique covers all possible options and converges on a solution that is beyond the ability of best programmers. Genetic Algorithm are adaptive search methods that simulate natural processes such as selection, mutation etc. Initially Genetic Algorithm was most applicable to numerical parameter optimizations due to an easy mapping from the problem to representation space. Now day's Genetic Algorithm has varied applications.

RELATIONSHIP BETWEEN GENETICS AND EVOLUTION

In biology [6] there is a difference between the genotype and the phenotype of an organism. The genotype is the genetic encoding of the organism, in particular the DNA molecules that resides in each and every cell in the body of an organism .These DNA molecules contain genes. More specifically these genes are converted into proteins which is the basic building block of our bodies. The phenotype is the appearance of an organism and its functionality and behavior. Thus ultimately genotype determines the phenotype of the organisms. In biological terms when two organisms of the same species mate, create offspring. Genetically copies of the DNA molecules of both parents mixed up and the children receive part from the father and part from the mother. In other words the genotype of the offspring is the mix of genotypes of its parents and it is called crossover in terms Genetic Algorithm. In other times when we copy this genetic information, some errors may occur and we call them mutation in the terminology of Genetic Algorithm. Mutations generally happen very rare, but they introduce some new variations in the genetic information. As a result of these crossover and mutation the offspring will have

some new variations. Thus some new traits in the organism come from the father and some new traits come from mother. In the real world scenario, not all individuals who are born will survive .Generally if we see the case for rabbit not all its offspring are able to survive, they are eaten by predators i.e they have to compete with other rabbits for their survival. Consequently a small portion of each generation of rabbit will actually create offspring and pass on their genetic information to the next generation. In particular those rabbits with good traits will be able to survive and individuals with bad traits will not be able to survive. These concepts reminds of theory of Natural selection called "Survival of the fittest". We can thus conclude that traits which are dominant will move to the offspring while the recessive traits will not move to the offspring and hence they would diminish from further generations. Over time, the population as a whole will slowly change or evolve due to genetic variation and adapt to cope better with the environmental challenges through natural selection. In a nutshell, it is how evolution and natural selection happen in the real world. This way, over subsequent generations, the population will become more and more successful at solving the problem.

GENETIC ALGORITHM: AN OVERVIEW

A Genetic Algorithm operates as a simulation in which individual agents, organized in a population, compete for a survival and try to achieve a better adaptation [5]. The agents are called chromosomes. The chromosomes structure is made of genes. Traditionally Genetic Algorithm operates on strings of bits. Genetic Algorithm uses two techniques a) selective pressure and b) adaptive inheritance. Selection is a stochastic process with survival process of an agent. The adaptation is measured by evaluating the phenotype in the problem environment. The selection creates a pressure which promotes survival of better individuals and crossover helps to have a better offspring's, mutation is then applied to improve extra variability. The initial population is generated randomly then the iterations continue until some resources are exhausted. Finally the population dynamics is observed and the simulation is stopped if the convergence to the solution is achieved. To apply Genetic Algorithm to any problem first a suitable encoding needs to be chosen then an appropriate fitness function needs to be constructed. This function will translate a genotype to its respective solution. Finally a better solution will have a higher fitness value. The algorithm thus works as follows[6]:---Produce an initial generation of genomes using a random number generator.

1. Determine the fitness of all of the genomes.
2. Determine which genomes are allowed to reproduce.
3. Crossover the genome pairs in the allowable population.
4. Pick the 2 fittest genomes of the 2 parents and 2 children resulting from the crossover and add them to the next generation.
5. Produce random mutations through the next generation population.
6. Calculate the next generation's fitness, if achieved move to step 8 else back to step 2
7. Finish

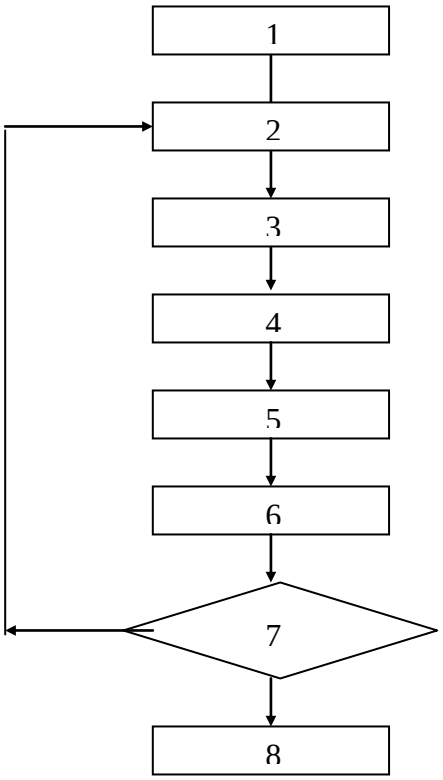

Fig1 Flowchart for Genetic Algorithm

Thus as the name suggest Genetic Algorithm mimic the process of biological evolution in developing a solution. For example[4] in the traveling salesman problem , the solution would start by generating a set of possible tours and then calculating each tour's length. The shorter is the length, the higher the fitness of solution.

ADVANTAGES AND DISADVANTAGES OF GENETIC ALGORITHM

Genetic Algorithm has proved in various areas, still there is a debate on the actual net effect and improvement of the parameters like the amount being crossed over, its occurrences and percentage of mutation. Defining fitness factors and determining the optimal values is another area of investigation. Genetic Algorithm also has its pros and cons which are given below [6]:

ADVANTAGES

Genetic algorithms excel in their ability to manipulate many parameters simultaneously. Genetic Algorithms are very good at solving such problems, in particular, their use of parallelism enables them to produce multiple equally good solutions to the same problem, possibly with one candidate solution optimizing one parameter and another candidate optimizing a different one, and a human overseer can then select one of these

candidates to use[7]. Finally, one of the qualities of genetic algorithms which might at first appear to be a liability turns out to be one of their strengths, namely Genetic Algorithms know nothing about the problems they are deployed to solve. Instead of using previously known domain-specific information to guide each step and making changes with a specific eye towards improvement, as human designers do, they are "blind watchmakers". They make random changes to their candidate solutions and then use the fitness function to determine whether those changes produce an improvement. Genetic Algorithm uses payoffs (objective function), not derivatives or other auxiliary information.

DISADVANTAGES

Operating on dynamic data sets is difficult, as genomes begin to converge early on[8] towards solutions which may no longer be valid for later data. For specific optimization problems, simpler optimization algorithms may find better solution than Genetic Algorithm. Genetic Algorithm can not effectively solve problems in which only fitness measure is right or wrong , as there is no way to converge on the solution as there is no hill to climb. In such cases a random search may find a solution as quickly as GA.

Representing the selection operators/fitness function is not as easy as it seems to. Modeling fitness still appears to be an art with a high degree of trial and error.

APPLICATIONS OF GENETIC ALGORITHM

Genetic Algorithm has been applied to various kinds of problems successfully. Genetic Algorithm can be applied to the domains about which there is insufficient knowledge of the size or the complexity is too high. Genetic Algorithm is most successful in numerical parameter optimization. The reason is that numerical solutions can be easily represented as linear chromosomes both crossover and mutation act on linear sequences of alleles. . Below is the list of [9] some applications where Genetic Algorithm has already proved:

- Aircraft wing design
- Scheduling problems
- Routing problems
- VLSI Technology ,Chip Design
- Telecommunication Networks
- Robotics
- Stock market prediction

And, of course there are many more applications. It is impossible to list all the existing Genetic Algorithm applications here.

CONCLUSION

Genetic Algorithm can be called as another class of heuristic search algorithms that can be applied to problems for which there are no efficient algorithms available. However it turned out that they performed practically well than other search algorithms. We hope that the results of this paper has taken us one step closer towards the two fold goal of understanding the design principles of nature and the ability to use these principles in the design of artificial systems. Evolution is a problem-solving process whose power we are only beginning to understand and exploit; despite this, it is already at work all around us, shaping our technology and improving our lives, and in the future, these uses will only multiply.

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