Game Theory as a New Paradigm for Phenotype Characterization of Genetic Algorithms

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ABSTRACT
In this paper, it is presented a new way to characterize the phenotype in the context of Genetic Algorithms through the use of Game Theory as a theoretical foundation to define a new phase in the algorithm, named *Social Interaction*. It is executed before the reproduction phase and allows individuals to fight for their own survival improving their fitness according to the rules of a game. Thereby, a new algorithm is presented and some good results were produced for Traveling Salesman Problem an improvement in Genetic Algorithm execution.

Categories and Subject Descriptors
I.2.8 [**Computing Methodologies**]: Artificial Intelligence – *Heuristic Methods.*

General Terms
Algorithms, Performance.

Keywords
Genetic Algorithms, Game Theory, Social Interaction.

1. INTRODUCTION
Melanie Mitchell affirms in her book that in the context of Genetic Algorithm there is no notion of phenotype and the Classical Theory of Genetic Algorithms says that every individual has its fitness value fixed and immutable, but in nature it doesn't happen like this [4].

So, the question is: there is some way to permit individuals to alter their fitness value during the evolution process? The answer is: Yes, Game Theory could be used as theoretical foundation to characterize a new phenotype approach because it precisely formalizes situations of Interests Conflicts.

In this way, the basic structure of Genetic Algorithms is modified, in order to enable an individual to change its fitness and consequently increase its chances to survive and generate offspring. So, before the reproduction phase, the individuals will be exposed to an environment, i.e. a game, where they will be fighting for their existence for some time in a new phase called *Social Interaction*.

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Therefore, we have a new algorithm that better simulates the Nature's role than Classical Genetic Algorithms (CGA). Besides that, individuals have a "Real Phenotype Characterization" based on behavior as stipulated in Game Theory.

2. NEW GENETIC ALGORITHM
The proposed algorithm is presented on the figure below.

// Genetic Algorithm with Social Interaction
1. Begin
2. Generate Initial Population
3. Evaluate all individuals from initial population
4. Repeat
   // *Social Interaction Phase*
   4.1. Repeat
      4.1.1. Select randomly two individuals
      4.1.2. Get the behavior of each individual
      4.1.3. Alter the individuals' fitness value according to the payment table of the game
   Until *Stop Condition 2* is satisfied
   // *Reproduction Phase*
   4.2. Repeat
      4.2.1. Select two individuals according to the selection method established
      4.2.2. Crossover Operation
      4.2.3. Mutation Operation applied on the offspring
   Until *Stop Condition 3* is satisfied
   4.3. Exchange the current individuals from population for the newer individuals generated in reproduction phase
   Until *Stop Condition 1* is satisfied
5. The best individual of population is the solution of the problem
6. End

Figure 1. New Genetic Algorithm Structure

In the figure above, the selected area corresponds to the new phase called *Social Interaction* and it is just an interactive structure that is subdivided in three steps.

It is important to observe that the algorithm permits the use any kind of game like Hawk-Dove Game and Prisoner's Dilemma Game, for example. It also permits any kind of selection method like Roulette, Rank, Tournament and others. Therefore, this new structure enables a wide combination of games and selection methods that could work better for a specific category of problems or worse for another.

Based on that, some new selection methods were constructed and they produced some good solutions to a specific problem, which are shown in the next section.

3. SIMULATIONS AND RESULTS

The simulations were made based on the Traveling Salesman Problem (TSP) in the way to minimize the distance of all Brazilian States' capitals connected through highways. The number of defined vertex is 26 which mean 7.75 x 10^{24} possible different routes. Thus, the problem can be expressed as follow.

$$Min(Fitness) = \sum_{1}^{26} d_{ij} \ , \ i \neq j$$

A total of forty tests were executed including classical and new genetic algorithm approaches and the results of the best ten tests can be seen in the table below.

#	Selection Method	(Km)
01	Hawk-Dove Roulette (HDR)	20,093
02	Hawk-Dove Tournament (HDT)	21,089
03	Tournament	21,286
04	Hawk-Dove Tournament (HDT)	21,474
05	Iterated Prisoner's Dilemma Tournament (IPDT)	21,691
06	Prisoner's Dilemma Roulette (PDR)	22,568
07	Weak Prisoner's Dilemma Tournament (WPDT)	22,688
08	Prisoner's Dilemma Tournament (PDT)	22,826
09	Without Prisoner's Dilemma Roulette (WiPDR)	23,115
10	Prisoner's Dilemma Roulette (PDR)	23,284

Table 1. Results of best ten simulations

It is interesting to detach the evolution process of the most IPD selection methods like fifth test in the figure two below.

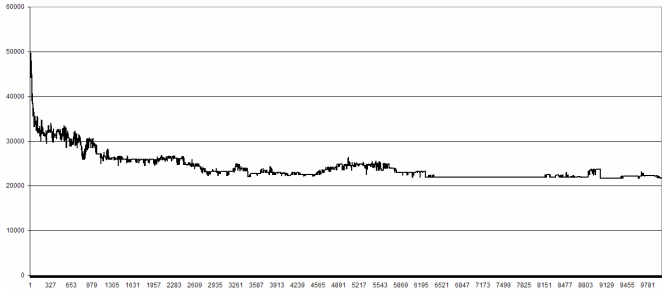

Figure 2. Evolution process of IPD Selection Methods

Initially a strong and fast evolution occurs but it has some variations between evolution and involution. Also, in that test the best individual appears only 37 times in all execution where a million were generated. In consequence, it can be affirmed that this kind of configuration with Social Interaction can control the diversity in population which is an important aspect of quality measure of the evolution process.

After observation of results, it is possible to state that: nine of the best ten results were obtained through the new approach presented in this paper.

4. FINAL REMARKS

It would be pretentious to affirm that these are the final conclusions about this new approach of phenotype characterization for Genetic Algorithms, but there are some indications that it works well in the problem test defined.

Also, sixteen new selection methods were created having in mind the aim to test the possibilities of selection methods and social interaction environment combination.

Once again, there are no conclusive in the sense to affirm that a specific method works better to a particular category of problems than another and some efforts are being made in direction to evolve theoretic concepts of Evolutionary Algorithms and this paper is one of them.

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6. REFERENCES

[1] Fogel, D. B. Evolutionary computation: toward a new philosophy of machine intelligence. 2. ed. IEEE Press, 2000.

[2] Goldberg, D. Genetic Algorithms in search, optimization and machine learning. Addison Wesley Longman, Inc., 1989.

[3] Luce, D. R.; Raiffa, H. Games and decision: introduction and critical survey. New York: Dover, 1957.

[4] Mitchell, M. An introduction to genetic algorithms. MIT Press, 1999.

[5] Poundstone, W. Prisoner's Dilemma: John Von Neumann, Game Theory, and the Puzzle of the Bomb. Anchor Books, 1992.

[6] Teixeira, O. N. Proposta de um novo algoritmo genético baseado na teoria dos jogos. Dissertação de Mestrado (Programa de Pós-graduação em Engenharia Elétrica – Computação Aplicada) - Universidade Federal do Pará, Belém, 2005.

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