ABSTRACT
This work has the purpose to present a new hybrid metaheuristic developed based on three fundamentals pillars extremely well known: Genetic Algorithms, Game Theory and Fuzzy Systems. This new approach tries to mimic a little bit more closer how a population of individuals evolves along time, like human social evolution emphasizing the social interaction between individuals and the non-binary behavior of human decision making against the classical cooperate-defect behavior present in the Prisoner’s Dilemma. In this way it is also presented the SIGA Algorithm [9], the approach of an individual more complex with a genotype composed of two chromosomes, one for the solution of the problem and the other representing its strategy, a binary or fuzzy. Finally some results are presented to an instance of the Traveling Salesman Problem.

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

General Terms
Algorithms, Theory.

Keywords

1. INTRODUCTION
In the last eight years some works were developed in the way to apply concepts of Evolutionary Game Theory and Game Theory to Genetic Algorithms through the application of Hawk-Dove Game, Prisoner’s Dilemma and its variations [1], [3], [5], [9], [10], and other games.

These approaches were established based on the observation of how Nature works like an ant colony, a bee swarm or even the human society. Besides that the classical Holland’s GA, the Goldberg’s SGA [4] and all their directly descendent don’t implement truly the concept of phenotype, they just say that the phenotype is the value of fitness, but its definition is wider. So, all these aspects were the inspiration to develop the Social Interaction Genetic Algorithm (SIGA), presented first in 2006 [9] not in 2009 [1] as it was affirmed in GECCO 2009 conference.

To provide a wider approach to the concept of phenotype, a simple question got its response. So, first the question: 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. Here it is important to remember the three basic aspects of evolution established by Darwin: first, diversity in a population of the same species; second, fighting for survival; third, natural selection.

In this way, the basic structure of GA contemplates all of them, but the second is just implicit not explicit as in the SIGA approach. On the other hand, the other aspects has some problems, the diversity of the population along the evolution process tending to decrease even a population with all individuals equals at the end of the execution process; and the selection process doesn’t as natural as in the nature, because in the GA only the best individual get the chance to reproduce and it’s not like that in nature.

So the GA was modified, in order to enable an individual to change its fitness and consequently increase its chances to survive and generate offspring. And 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, composed basically by three steps: (1) select randomly two individual; (2) get the behavior of each individual based on their strategies; (3) alter the individuals’ fitness value according to the payment table of the game. The strategy is also determined through a chromosome as the solution chromosome.

It is important to observe that the algorithm permits the use any kind of game depending only of the structure of the payment table, as the games mentioned. 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.

2. A BRIEF VIEW OF F-SIGA APPROACH
All the aspects of SIGA are respected and the only difference is that the binary cooperate-defect behavior of individuals in Prisoner’s Dilemma game gains a more generic approach [2]. So the strategy of an individual can be in the range from 0 to 1, i.e. from cooperate to defect.

To turn this in reality it was applied the concepts developed by [2] and it was defined a set of 729 mixed-strategies distributed through TFT, Pavlov, Random, the best 20 Borges Strategies and the worst 492 Borges Strategies. Each individual is composed by three fuzzy systems which has a specific factor of entrance based
of the past payoff payment to determine the final action, a point between cooperate or defect.

The factors are: (1) the Relation between the accumulated wealth of the player and his opponent's; (2) Last iterations between the parties; (3) Relation between the overall trends regarding the acquisition of wealth, expressed by the player's average gain per iteration divided by the global payoff mean of the whole group.

In figure 1 it is possible to see the payoff function with the new approach based on fuzzy concepts.

Figure 1. The payoff function

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^{23} possible different routes. Some results was obtained as shown in table 1.

Table 1. Results of best eleven simulations

<table>
<thead>
<tr>
<th>#</th>
<th>Selection Method</th>
<th>(Km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Hawk-Dove Roulette (HDR)</td>
<td>20,093</td>
</tr>
<tr>
<td>02</td>
<td>Hawk-Dove Tournament (HDT)</td>
<td>21,089</td>
</tr>
<tr>
<td>03</td>
<td>Tournament</td>
<td>21,286</td>
</tr>
<tr>
<td>04</td>
<td>Hawk-Dove Tournament (HDT)</td>
<td>21,474</td>
</tr>
<tr>
<td>05</td>
<td>Iterated Prisoner’s Dilemma Tournament (IPDT)</td>
<td>21,691</td>
</tr>
<tr>
<td>06</td>
<td>Prisoner’s Dilemma Roulette (PDR)</td>
<td>22,568</td>
</tr>
<tr>
<td>07</td>
<td>Weak Prisoner’s Dilemma Tournament (WPDT)</td>
<td>22,688</td>
</tr>
<tr>
<td>08</td>
<td>Prisoner’s Dilemma Tournament (PDT)</td>
<td>22,826</td>
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<tr>
<td>09</td>
<td>Without Prisoner’s Dilemma Roulette (WiPDR)</td>
<td>23,115</td>
</tr>
<tr>
<td>10</td>
<td>Prisoner’s Dilemma Roulette (PDR)</td>
<td>23,284</td>
</tr>
<tr>
<td>11</td>
<td>Fuzzy Social Interaction GA (F-SIGA)</td>
<td>23,553</td>
</tr>
</tbody>
</table>

4. FINAL REMARKS

The results of simulation with all these approaches indicates that the advent of Social Interaction in Genetic Algorithm enables a more realistic evolution process, i.e. more similar to nature. There are some good results comparing them to a Classical GA in simulation number 3, but it is interesting to notice that F-SIGA presents the worse performance for the instance from TSP used. Besides that there are too many parameters to define and instantiate before an execution starts, so in practice this approach, a priori, it is not a good choice if the objective is to solve the problem faster, but it has a great appeal in simulating complex systems in the way to analyze how it works along the time.

The next step is to execute more and more tests with another kind of problems, like Real Valued Parameter Function Problems, Knapsack Problem and Real-World Problems, in the way to testify the approach and classify it to a specific class of problem.

5. REFERENCES