A new metaheuristic based on the self-defense techniques of the plants in nature

Camilo Caraveo, Fevrier Valdez, Oscar Castillo, Patricia Melin
Division of Graduate Studies Tijuana Institute of Technology Tijuana, México
camilo.caraveo@Gmail.com, fevrier@tectijuana.mx, ocastillo@tectijuana.mx, pmelin@tectijuana.mx

***Abstract*- In this work a new metaheuristic of optimization bio-inspired on the plants self-defense techniques applied to optimization problems is presented. Plants are living beings that are part of a habitat, and in some recent works the authors claim that plants are able to react to different external stimuli. In nature, plants are exposed to a variety of predatory animals such as bacteria, fungi, insect predators in this case (herbivores), and the plants are required to develop different coping techniques to protect themselves from attacks by predators. The development for this approach we consider as a main idea the predator prey model of Lotka and Volterra, where two populations interact with each other and the objective is to maintain the balance between these two. The performance of this algorithm is tested on optimization problems of mathematical functions.**

Keywords; self-defense, mechanism, predator prey model, plants, clone, graft.

I. INTRODUCTION

In the literature multiple algorithms of search and of optimization bio-inspired by natural processes have been recently tested and developed. This with the purpose of solving different optimization problems, and in the area of computer and engineering different metaheuristic have been proposed such as bio-inspired algorithms, like the bee colony, ant colony, gravitational search and other [8, 9, 12, 14], with all methods trying to achieved, the solution of a multiple problem with smaller error value. In these papers we present a new optimization meta-heuristic based on the self-defense mechanisms of plants. This with the purpose of competing with existing methods of optimization. The plants are immobile beings that are exposed to variety of pathogens in the environment where they live. However, some insects have managed to be immune to chemical attacks by plants. This proposed algorithm takes as reference the Lotka and Volterra predator-prey model, which was proposed in1926, the model is formed by two differential equations of first order nonlinear, Which are used to model the growth of a pair of populations that interact with each other (prey and predator) [6, 7], and the goal is to maintain a balance between the two populations.

II. THE COPING STRATEGIES OF THE PLANTS

To survive, plants had to develop self-defense techniques. Plants are living beings that react to different external stimuli [4]. In [3, 14] the authors mention the techniques of self-defense of plants in the nature, they use those techniques in order to attract the natural enemy of the predator attacker, it can also be a call for other types of animals, such as insect pollinators, bees, birds, and other insects, in order to reproduce and let before dying offspring also cause internal problems to the aggressor animal [10, 11] and sometimes the dead. In Fig. 1 a general illustration is shown to represent the process of the plants [3,4, 7,15].

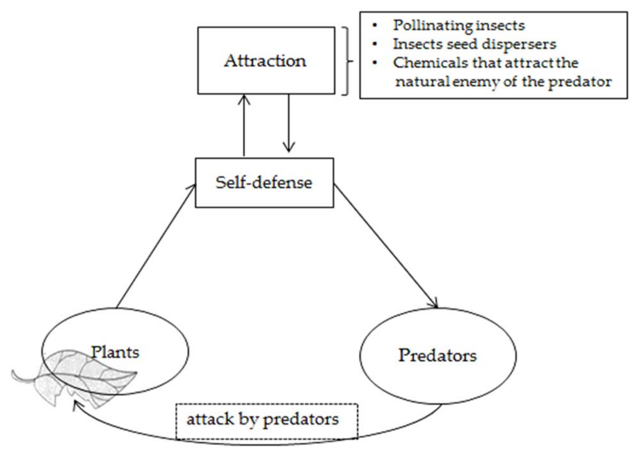

Fig. 1 Self-defense scheme plant

Plants are organisms (immobile) and cannot escape, but each plant cell has active defense mechanisms (are activated when the plant comes into contact with the pathogen). This is an important difference from the immune system of vertebrates, because in vertebrates there are specialized cells that travel quickly to the site of the infection, where the invading organism eliminates or limit their distribution. In plants, the defense mechanism located in each cell minimizes the infection. Then, the disease may be defined as the result of a successful infection. However, a condition of this type does not kill the plant. It could be interpreted that, by natural selection, pathogens have survived with less toxicity (not kill their host when they need to reproduce) [1, 2, 5, 6, 11].

III. PREDATOR-PREY MODEL

The Lotka-Volterra equations are a bio-mathematical model that aims to answer the previous questions by predicting the dynamics of prey and predator populations under a number of assumptions:

The ecosystem is isolated: no migration, no other species present, and no pests.

The prey population grows exponentially in the absence of predators: reproduction is proportional to the number of individuals. Prey only die when they are killed by the predator.

The predator population decreases exponentially in the absence of prey.

The population of predators affects prey, and decreases in proportion to the number of prey and predators (that is to say in proportion to the number of possible encounters between prey and predator).

The population size of prey or predator affects also in proportion to the number of encounters, but with different proportionality constant (it depends on how satisfy their hunger predators to find prey).

In summary the predator prey model represents the growth of two populations that interact with each other and the goal is to maintain a balance between the two. The predator prey model consists of the following pair of equations. Eq (1), (2) [15]:

$$\frac{dx}{dt} = \alpha x - \beta xy \quad (1)$$

$$\frac{dy}{dt} = -\delta xy + \lambda y \quad (2)$$

Where:

$\boldsymbol{x}$:Represents the preys population

y: Representsthe predators population

$\frac{dx}{dt}$ Represents the growth of the population of prey at time t

$\frac{dy}{dt}$ Represents the growth of the population of predator at time t

α: It represents the birth rate of prey.

β: It represents the death rate of the predators.

δ: represents the susceptibility of prey.

λ: represents the ability of predation.

IV. PROPOSED ALGORITHM USING LÉVY FLIGHTS

We propose an approach that takes as reference the Lotka and Volterra predator-prey model, this system of linear equations is used to model the growth of two populations. In Fig. 2 a general illustration of our proposal that is based on the traditional predator prey model is presented and shows, the evolutionary process of the plants and the different methods of biological reproduction considered in this work [3,4].

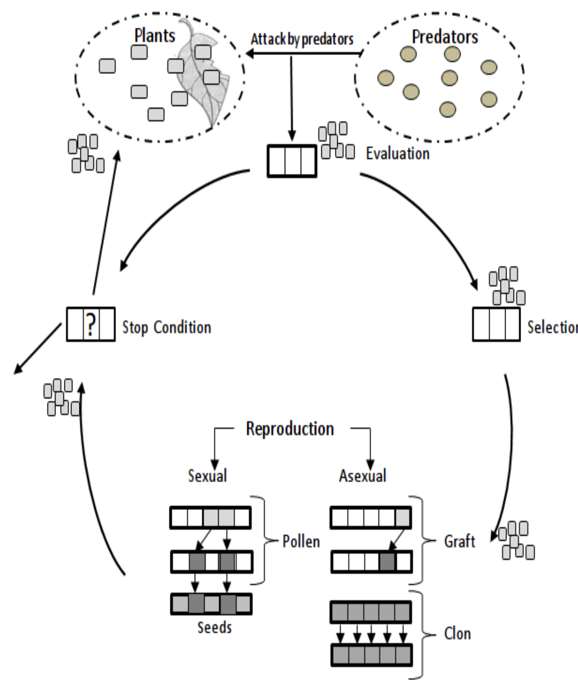

Fig. 2 Illustration of our proposed algorithm

In nature, the plants have distinct methods of biological reproduction, and in paper we use the most common: **cloning**, and **graft**. **Cloning**: the offspring are identical to the parent plant, in this case we use as the basis of the plant that survived along the iterations, and this plant is used to inherit their characteristics for future generations. **Graft**: in our proposal used as a basis for a plant with better fitness, to inherit the characteristics to the new generations of plants [3].

The equations 1 and equation 2 are used to model the confrontation of prey against predators, in this case plants and insects, the interactions between both species are used to generate the new generations of plants [3,4]. In Fig. 3 we describe the steps of the proposed optimization algorithm [2,3].

The initial sizes of both populations (prey, predators) are defined by the user, and the parameters (α, β, δ, λ) are also defined by the user. The authors of the original predator prey model (Lotka and Volterra) they recommended the following parameter values for the variables of α= 0.4, β = 0.37, δ = 0.3, λ = 0.05. In each iteration of the algorithm the populations of prey and predator interact with each other, and the different operators shown in Fig. 3 Flowchart are applied. In this work, we only present results of experiments using as methods of reproduction: the cloning and graft.The population is re-evaluated and if the stopping criterion is not satisfied, we return to the iterative cycle of the algorithm [3,4].

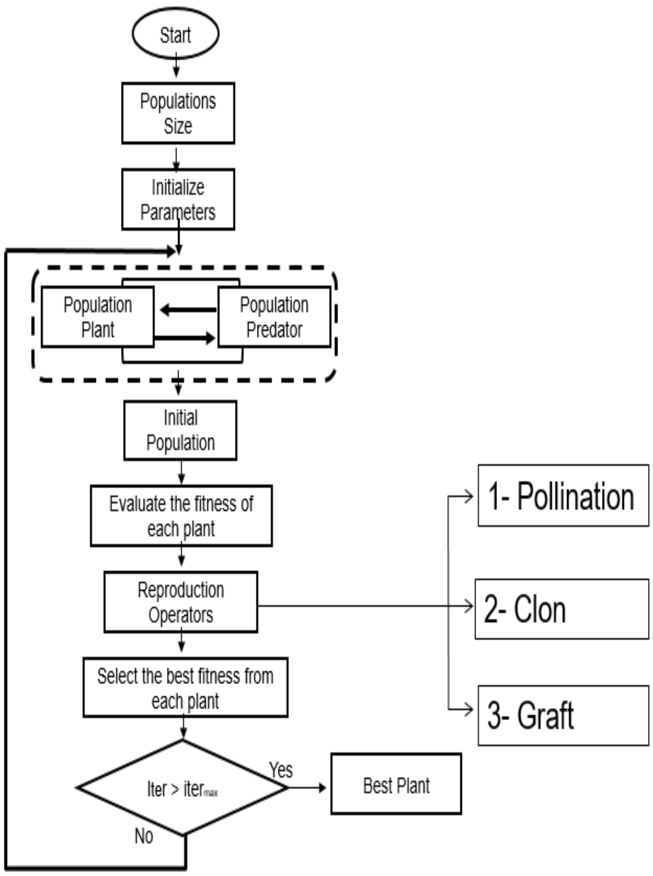

Fig. 3 The Flowchart of the proposed approach

In [2, 3, 4] the authors presented previous work with some variations in the method of reproduction, and now in this paper the main contribution is the adaptation of new methods of reproduction and improvements to the proposed algorithm, and in this work the algorithm shows more stable performance in the presented complex problems.

V. SIMULATION RESULTS

The performance of the proposed algorithm is tested on mathematical functions, 30 experiments were performed with 10 benchmark functions with 30 and 50 variables. The mathematical definition of the set of functions used in this work is described below.

Ackley Function

The function is normally evaluated on $x_i \in$ [-32.768, 32.768].

$$f(x) = -a \cdot \exp\left(-b\sqrt{\frac{1}{d}\sum_{i=1}^{d} x_i^2}\right) - \exp + \ldots \qquad (3)$$
$$\ldots\left(\frac{1}{d}\sum_{i=1}^{d}\cos(cx_i)\right) + a + \exp(1)$$

Rosenbrock Function

The function is evaluated on $x_i \in$ [-5, 10], for all i = 1… d,

$$f(x) = \sum_{i=1}^{n-1}[100(x_{i+1} - x_i^2)^2 + (1 - x_i)^2] \qquad (4)$$

Powell Function

The function is evaluated on $x_i \in$ [-4, 5], for all i = 1…d.

$$f(\mathrm{x}) = \sum_{i=1}^{d/4}[(x_{4i-3} + 10x_{4i-2})^2 + 5(x_{4i-1} - x_{4i})^2 + \ldots \qquad (5)$$
$$\ldots(x_{4i-2} - 2x_{4i-1})^4 + 10(x_{4i-3} - x_{4i})^2]$$

Griewank Function

The function is normally evaluated on $x_i \in$ [-600, 600]

$$f(\mathrm{x}) = \sum_{i=1}^{d}\frac{x_i^2}{4000} - \prod_{i=1}^{d}\cos\left(\frac{x_i}{\sqrt{i}}\right) + 1 \qquad (6)$$

Levy Function

The function is evaluated on the hypercube $x_i \in$ [-10, 10]

$$f(x) = \sin^2(\pi\omega_1) + \sum_{i=1}^{d-1}(\omega_1 - 1)^2[1 + 10\sin^2 + \ldots \qquad (7)$$
$$\ldots(\pi\omega_{i+1})] + (\omega_d - 1)^2[1 + \sin^2(2\pi\omega_d)],$$

Where, $\omega_i = 1 + \frac{x_i - 1}{4}$ for all *i=1….d*

Dixon-price Function

The function is normally evaluated on $x_i \in$ [-10, 10].

$$f(x) = (x_1 - 1)^2 + \sum_{i=2}^{d} i(2\pi_i^2 - x_{i-1})^2 \qquad (8)$$

Zakharov Function

The function is normally evaluated on $x_i \in$ [-5, 10]

$$f(x) = \sum_{i=1}^{d} x_i^2 + (\sum_{i=1}^{d} 0.5ix_i)^2 + (\sum_{i=1}^{d} 0.5ix_i)^4 \qquad (9)$$

Rastrigin Function

The function is evaluated on $x_i \in$ [-5.12, 5.12].

$$f(x) = 10n + \sum_{i=1}^{n} [x_i^2 - 10\cos(2\pi x_i)] \quad (10)$$

Schwefel Function

The function is normally evaluated on $x_i \in [-500, 500]$.

$$f(\mathrm{x}) = 418.9829\,\mathrm{d} - \sum_{i=1}^{d} x_i \sin(\sqrt{|x_i|}) \quad (11)$$

Sphere Function

The function is normally evaluated on $x_i \in [-5.12, 5.12]$.

$$f(x) = \sum_{i=1}^{n} x_i^2 \quad (12)$$

Table I shows the results obtained from the experiments for the mathematical functions considered in this work. In the table we can find the number of variables, the average value of the experiments, the standard deviation, and the best value obtained. The configuration parameters of the algorithm were manually set, based on previous knowledge of the algorithm, the size of the population was used in the following ranges, plants [300 to 350], and herbivore [200 to 250].

TABLE I. RESULTS OBTAINED WITH CLONE REPRODUCTION METHOD

Function	Experimental results with 30 and 50variables			
	Values			
	Dim	***Best Value***	***σ***	***Average***
Ackley	30	8.88178E-16	1.55E-01	0.237640591
	50	8.88E-16	0.211417	1.34E-01
Griewank	30	0.00E+00	0.045857	0.01185416
	50	0.00E+00	0.084452	0.03659968
Rastrigin	30	0.00E+00	0.19938774	0.31478144
	50	0.00E+00	0.24186211	0.15264679
Schwefel	30	.84177E-05	0.0045796	0.025464
	50	2.88168E-02	0.034892	0.096761
Sphere	30	2.1631E-43	0.14623194	0.0661934
	50	2.196E-162	0.29016375	0.17650009
Powell	30	2.8549E-54	0.05286436	0.5286436
	50	4.4633E-97	0.0826458	0.8645721
Rosenbrock	30	1.918721	8.618153	19.58296
	50	13.67637767	13.8101436	44.69458908
Levy	30	0.18902455	0.84331208	0.76403202
	50	1.6787E-05	0.29736436	0.31374808
Dixon	30	8.3645E-06	0.01246358	0.68943257
	50	5.7935E-05	0.2654893	0.0246824
Zakharov	30	3.2564E-03	0.8653254	0.2568467
	50	6.9317E-01	1.26482314	0.1536487

TABLE II RESULTS OBTAINED WITH THE GRAFT REPRODUCTION METHOD

Function	Experimental results with 30 and 50 variables			
	Values			
	Dim	***Best Value***	***σ***	***Average***
Ackley	30	3.17E-90	7.669544	1.39E-01
	50	3.34E-16	54.39928	8.96E-01
Griewank	30	0	0.19867627	0.073713
	50	0	0.16631567	0.0520497
Rastrigin	30	0	0.22900912	0.15502662
	50	0	0.21154451	0.11063972
Schwefel	30	0.012887627	0.365874	0.86254783
	50	0.0580497	0.987452	0.53652148
Sphere	30	4.6946E-277	1.47316931	0.52437853
	50	2.29513E-67	0.28737522	0.13637064
Powell	30	1.11523E-93	0.24304224	0.12067599
	50	3.31167E-67	1.42821085	0.53065226
Rosenbrock	30	1.918721	8.618153	19.58296
	50	13.67638	13.81014	44.69459
Levy	30	0.13535614	1.10044347	0.95391818
	50	0.30798781	1.50254037	1.75416046
Dixon	30	0.70610769	0.43293851	2.82608469
	50	0.6985765	0.7516658	1.975011
Zakharov	30	3.15227E-16	0.00297996	0.00076831
	50	1.76931E-14	0.24840202	0.10617961

Tables I and II show the results of the tests performed with each of the mathematical functions.The values have shown that performance of the proposed approach is efficient and stable, and we consider that it can be improved using any intelligent method to find the parameters that are optimal for the system variables of *α, β, δ, λ*, but in this work they were manually established based on the observed behavior.

Statistical comparison

To conclude, in this work is necessary to perform a statistical comparison between the proposed method vs Flower Pollination Algorithm (FPA) [12, 13] for the considered problems. The statistical test used for these problems is the Wilcoxon test, whose parameters are shown in Table III. With the parameters of Table II, we use the statistical Wilcoxon test for the problems shown in this work, with the parameters shown in the Table III. With a rejection region For the values lower than level of Significance. So the statistical test results are that: with a probability of error of **0.027708,** we can conclude that the average of the proposed method is higher than the average of FPA algorithm.

TABLE III. DATA FOR THE STATISTICAL WILCOXON TEST.

Parameters	***Values***
Level of significance	**0.05%**
Ha	$\mu_1 < \mu_2$
H0	$\mu_1 \geq \mu_2$
W. Value	**-2.201398**

Analyzing the values of the statistical comparison we can find that our proposal needs some improvements and it would also be interesting to adapt some intelligent method that finds the optimal parameters for the variables and consider other biological processes in plants.

VI. CONCLUSIONS

Plants are living organisms that have not been explored in both their properties and their physiological processes. In this work we adapt some of their processes of biological reproduction to propose a new optimization algorithm to solve complex problems. Our first goal [2,3] was adapting the predator prey model and convert it to an iterative algorithm, our second goal was to integrate an intelligent method for adjusting parameters and achieve greater stability and performance, and the results are acceptable for recent algorithms. In this work simulation results are shown only with the graft and cloning methods of reproduction, but the ultimate goal is to integrate the three methods and achieve with this even further improvements to the proposed approach.

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