Energy Wasting Optimization (EWO)

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Abstract: In recent decades, the heuristic or intelligent algorithms have been used in many fields of science and engineering. Some of these algorithms are according to nature and physics principles. Many optimization methods have been proposed, but in general, there is not an efficient method to solve correctly optimization problems. In this paper, a new optimization algorithm based on energy wasting on the electrical circuits and particles moves according to Ohm's law is introduced (Energy Wasting Optimization algorithm (EWO). In this algorithm, the set of particles with different potentials are moving on an electrical circuit to the lowest potential of particle (best answer) based on Ohm's law and the rate of energy wasting. This algorithm and PSO (particle swarm optimization) algorithm's performance are compared on some standard benchmark functions. In most cases, the efficiency and convergence speed in the optimal point is significantly improved.

Keywords: Optimization, Energy Wasting Optimization, swarm intelligence, Heuristic algorithms

1. Introduction

More scholars today tend to apply optimization methods of swarm intelligence to intricate engineering problems[1-3].Hence, random optimizations have been high on the agenda of investigation in recent years, which are normally categorized into two major classes of algorithms. Arising from the evolutionary theory, the first class is executed based upon random operators; for instance, genetic algorithm[3, 4]. Conversely, the second class includes the algorithms of swarm intelligence such as Ant colony Optimization (ACO) and Particle Swarm Optimization (PSO). They are deployed based on the collective behavior of the individuals in a society and their collaboration to reach an ultimate goal[5-9].

Inspired by biological processes or physical principles, a large number of heuristic algorithms have been presented in the recent decades. The most famous and useful methods include genetic algorithm, harmony search, particle swarm optimization, gravitational search, and so on[10, 11].

Genetic algorithm borrows its concept from Darwin's Theory of Evolution in which each generation gives precedence to the best species to reproduce. As a result, the species with improper characteristics gradually vanish and this, in turn, forms the evolution of a generation[12].

Harmony search is an algorithm relying on the imitation of the improvement process in music playing[13]. Swarm optimization algorithm stems from the social behavior of animal groups such as birds or fish during migration[5]. Gravitational search algorithm is inspired by the similarities between kinematic and classic motions of bodies inside the gravitational field[6].

Although numerous heuristic algorithms to date have been introduced by researchers in different fields of science and engineering, there has been no algorithmic method to solve all sorts of optimization problems. This paper is a research into a heuristic algorithm that will be explained in more detail in the next section.

In this paper, a new optimization algorithm called "energy wasting optimization algorithm" is based on the movements of particles (with different potentials) and the amount of energy loss in the search space on an electrical circuit towards the particle with the lowest potential according to Ohm's law is expressed.

2 EWO algorithm

Energy Wasting Optimization algorithm, which is abbreviated as EWO in this paper, is based upon particles' moving tendency in an electric circuit toward the particle with the lowest potential. In EWO, particles with different potentials are assumed search factors; just like particles in PSO or ants in ACO. Having generated a primary population randomly in the search space, each particle is identified with a random potential vector as stated below:

$$\vec{P_i} = (P_i^1 ,\dots\dots , P_i^d ,\dots\dots, P_i^n) \quad , \qquad for \quad i = 1,\dots\dots, N \ . \qquad (1)$$

Where P_i^d is the potential of particle i – the location of particle i – in dimension d. The aim is to find the location of the minimum of the objective function, $f(\vec{P})$, which has been determined in the search space.

2.1 The mechanism of particles' motion

In each repetition of the algorithm, the particle that has the best objective function is identified. Then a resistor is assumed within the distance between each particle and the particle that has the best objective function, as illustrated in the following figure:

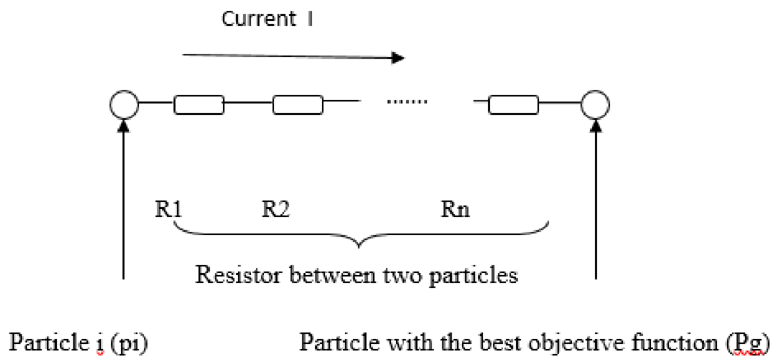


Fig. 1. The mechanism of particles' motion.

According to Ohm's law, the current i between two particles is calculated by the following equation:

$$I = V/R = (Pi – Pg) / (R1 + R2 + \dots\dots + Rn) \ . \qquad (2)$$

If the sum of particles' resistors is assumed to be 1, then there will be:

$$R1 + R2 + \dots\dots + Rn = 1 \ , \qquad (3)$$

$$I = Pi - Pg \ . \qquad (4)$$

On the other hand, voltage drop on R1 is gained through the following:

$$\text{Voltage drop on the resistor (R1)} = R1 \times (Pi - Pg). \quad (5)$$

Also, updating the potential of each particle is obtained by:
Potential in iteration (t+1) = potential in iteration (t) - the voltage drop on the resistor (R1)

$$Pi(t+1) = Pi(t) - R1 \times (Pi - Pg). \quad (6)$$

In which R1 is a random number between 0 and 1, so that EWO algorithm can acquire a random feature. Furthermore, W is considered to be a compromise between two concepts, namely exploitation and exploration. (Next sections will explain them in more detail.)

$$Pi(t+1) = W \times Pi(t) - C1 \times rand \times (Pi - Pg). \quad (7)$$

Where C1 value is usually set as 2.

2.2 The Pseudo-code of EWO algorithm

1. Generating a random primary population and initializing the parameters.
2. Evaluating the fitness of each particle, and then identifying the particle with the best
1. objective function.
2. Calculating the voltage drop of each resistor between each particle and the particle with
3. the best fitness function.
4. Updating the potential of each particle.
5. Go to step 2 until the stop criteria is attained.
6. End.

2.3 Exploitation and exploration in EWO algorithm

Exploitation and exploration are two key concepts in heuristic algorithms that allow them to scan the search space to find a solution with the highest efficiency while avoiding falling into the trap of local optimums.

Exploration concept enables the algorithm to search the entire search space through finding new locations; similar to mutation operator in genetic algorithm. By contrast, exploitation concept gives the algorithm the opportunity to search the optimum locations close by in order to find the best points; just like selection operator in genetic algorithm. Therefore, there should be a compromise between exploration and exploitation, so that an optimum solution can be achieved.

Generally, one of the appropriate methods to reach a compromise is by setting the exploration effect more than that of exploitation, mainly in the first iterations of the algorithm. After a period of time, exploration effect is reduced while exploitation effect is increased[6, 14].

To compromise between exploration and exploitation in EWO, just like PSO, the parameter W is set to be 0.9 at the beginning. Then it is gradually reduced to reach the value of 0.1 through the following equations:

$$W(t) = \alpha t + \beta \tag{8}$$

Or

$$W(t) = -0.8\,\frac{t}{T} + 0.9 \tag{9}$$

Thus, the search space is being entirely explored while W is large enough which means particles' motion is at its peak. However, exploitation prevails over exploration when W value decreases through time.

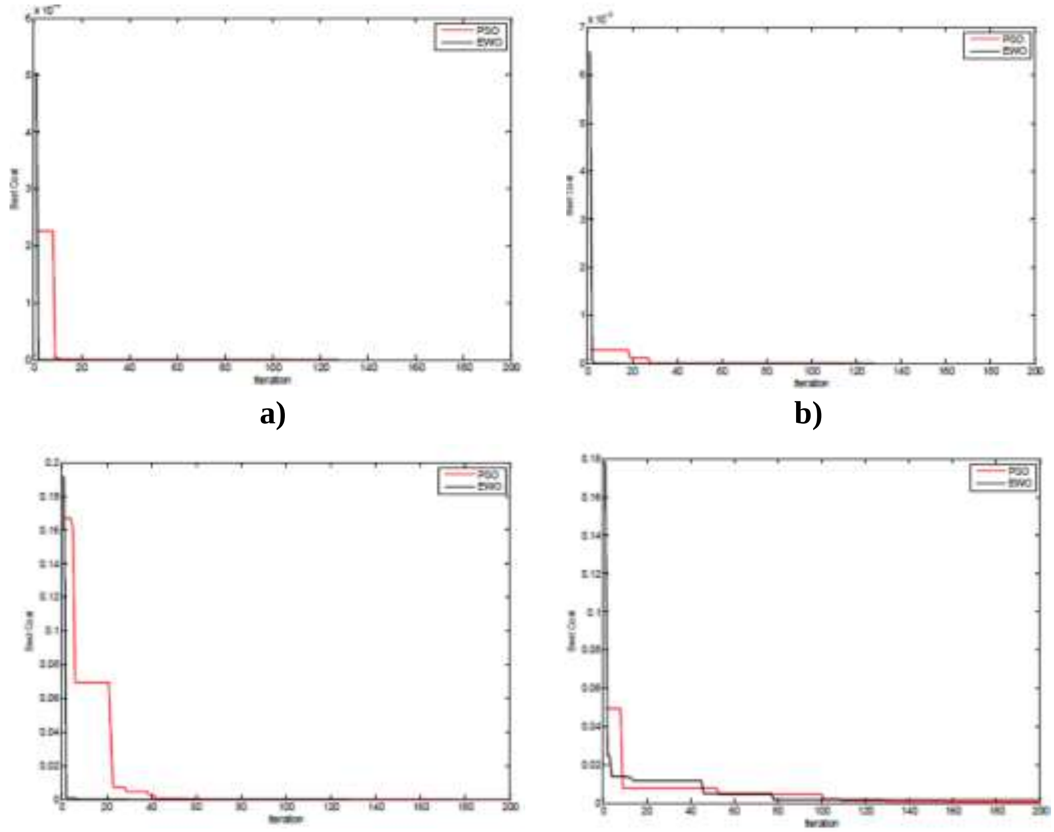
3 Results and discussion

In order to illustrate EWO, this algorithm has been applied to some standard benchmark functions. [10] Then, the acquired results have been compared with the results obtained by PSO, which is so similar to EWO. Table 1 shows the results of minimization of the algorithms executed 20 times on standard benchmark functions.

Table 1. The results of minimization of PSO and EWO algorithms executed 20 times on standard benchmark functions.

Function	The average of the best fitness	
	PSO	EWO
F1	1.43×10^{-43}	3.1573×10^{-175}
F2	2.8947×10^{-21}	2.9381×10^{-85}
F3	2.148×10^{-45}	1.9541×10^{-167}
F4	4.8997×10^{-24}	2.8965×10^{-84}
F6	0	0
F7	3.3661×10^{-4}	1.2052×10^{-4}
F9	0	0
F10	8.8818×10^{-16}	8.8818×10^{-16}
F11	0	0
F19	-1.8997	-1.8997
F20	-1.1698	-1.1698
F21	-10.1532	-10.1532
F22	-10.4028	-10.4028
F23	-10.5363	-10.5363

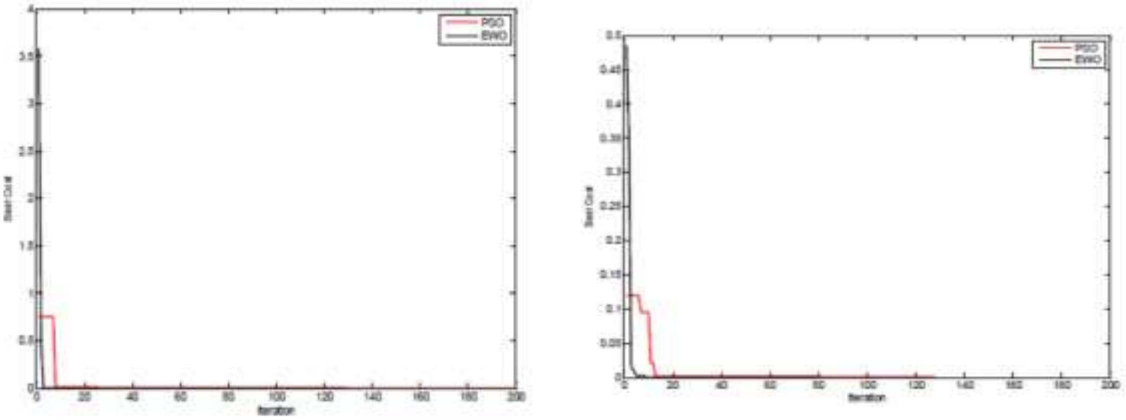
Figures 2 and 3 also show the performance results of the EWO and PSO algorithms on some benchmark functions.



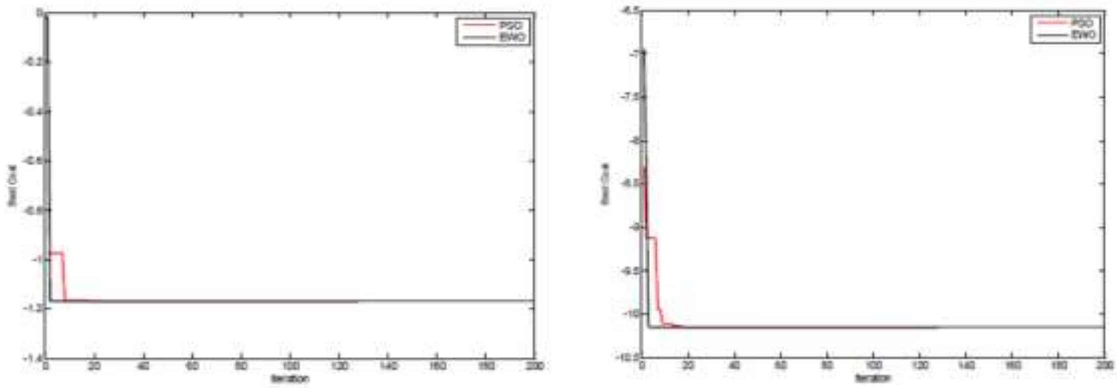
c) **d)**

Fig. 2. Performance of EWO and PSO algorithms on functions F1 (a), F3 (b), F4 (c), F7 (d)

In Figures 2- (a), (b) and (c), the proposed algorithm achieves the optimal response in a smaller number of iterations than the PSO and does not involve local responses in any way. In Figure 2- (d), the proposed algorithm, such as PSO, is involved in local responses, but still escapes these responses with fewer repetitions than PSO.



a) **b)**



c) **d)**

Fig. 3. Performance of EWO and PSO algorithms on functions F9 (a), F10 (b), F20 (c), F21(d)

Figures 2 and 3 show that:

1. In most cases, the EWO algorithm converges faster than the PSO.
2. The EWO is rarely involved in local responses and is faster than the PSO in the event of an EWO mutation involving local responses.
3. In many cases, EWO started with worse responses than PSO, but converged sooner and reached the optimal response.

To compare the complexity of EWO and PSO algorithms, the execution time of these two algorithms is shown in Table1.All programs were performed in MATLAB R2013A software, Windows 7 Ultimate environment with Intel (R) Core (TM) i3-3120M processor with 2.5GHz speed and 4GHz RAM. In both execution algorithms, the maximum iteration and the same initial population size were selected.

Table 1. Comparison of execution time of EWO and PSO algorithms (in seconds)

F9	F7	F6	F4	F3	F2	F1	function
0.34	0.49	0.28	0.37	0.41	0.39	0.36	EWO
0.506	0.86	0.47	0.52	0.62	0.54	0.52	PSO
F23	F22	F21	F20	F19	F11	F10	function
1.56	1.22	0.93	1.44	1.503	0.59	0.36	EWO
2.11	1.65	1.46	1.97	1.85	0.79	0.59	PSO

According to the above table, it can be concluded that the time complexity of the EWO algorithm is less and its execution speed is higher than PSO.

4 Conclusion

The increasing dimensions of scientific problems and the inefficiency of classical methods in solving them have attracted the desire of researchers to use new solutions. In this paper, a new algorithm called energy wasting optimization algorithm was introduced. In this algorithm, the basis of particle motion in search space is the motion of a particle from a point with more potential to a point with less potential based on energy loss on a simple electrical circuit, In this regard, Ohm's law is used to achieve the best potential (best place).

An important advantage of the EWO algorithm is that the search space with a very simple resistance electrical circuit is completely randomly searched (which reduces the volume of calculations) On the other hand, Ohm's law (to update the potential of each particle) has been used without any changes, which has increased the efficiency of this algorithm compared to PSO. In order to show the efficiency of the EWO algorithm, this algorithm is applied to a number of standard benchmark functions and the results are compared with the PSO algorithm, which shows the results of the high performance of the EWO algorithm.

Although EWO algorithm has shown that it is highly efficient in terms of convergence and computational volume, but it is still in its infancy, which can certainly achieve better performance with more research and experiments. Proof of convergence theory of this algorithm and also its use For engineering issues such as image processing, pattern recognition, etc. can also be important scientific topics for future research.

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