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Galaxy Gravity Optimization(GGO) An Algorithm for Optimization, Inspired by Comets Life Cycle

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Abstract— **The aim of this paper is to propose an optimization algorithm which is inspired by the comet's life. Like other evolutionary algorithms, this proposed algorithm commences with an initial population. The individuals of the population are comets which are composed of two parts: a nucleus and small celestial bodies. These comets after exit of Kuiper belt due to the gravitational disorder which has been triggered by solar system planets, and entering to the solar system, start the main competition for more survival in the solar system. Along this competition the weakened comets collapse and convert to rubbles along the solar orbit which comets where orbiting and other comets depending on their gravitational power relatively absorb these rubbles (small celestial bodies). The comet which has been able to lose least of its mass and gain the most, along its orbits and based on gravitational mutation (having better orbits); has been able to spend more time in solar system so it converges with a higher fitness function in a global maximum. The results of the proposed algorithm which have been experimented on some benchmark functions, represent that this algorithm is capable of dealing with a variety of optimization problems.**

Keywords- Optimization Algorithm, Evolutionary Algorithm, Gravitational Mutation, Fitness Function, Comet, Comet's Orbit, Global Maximum

I. INTRODUCTION

In this paper a new evolutionary algorithm for optimization will be discussed, which has been inspired by the life period of comets. In general terms, optimization means to increase the quality level of something [1], in which there is a function such f(x) which should be acquired which quantity of X becomes optimized (maximum or minimum). There is a variety of approaches on optimization problems which have been inspired by nature. Genetic Algorithm (GA)-(j. holland, k. dejong, 1960) [2] is a perfect example of it which advances optimization problems ahead to evolution, using operators inspired by natural genetic variations and natural selection. Another example for this, is the Simulated Annealing (SA) algorithm (Scott Kirkpatrick 1983) [3].

This technique simulates the annealing process in which a substance is heated above its melting temperature, and then gradually cools down to produce the crystalline lattice, which minimizes its energy probability distribution [1]. On the other hand, Ant Colony Optimization (ACO) is inspired by the foraging behaviour of real ants [3]. Also the inspiration source of Particle Swarm Optimization (PSO) which was formulated by Edward and Kennedy in 1995 was the social behaviour of animals, such as bird flocking or fish schooling [1]. Of other famous available algorithms, Evolutionary Programming (E_P) [6] by D. Fogel, 1966 and Evolutionary Strategy (E_S) [7] by I. Rechenberg, 1989 and Imperialist Competitive Algorithm (ICA) [8] by Esmaiil Atashpaz-e Gargari, 2007 could be mentioned. These available algorithms are widely used to solve different optimization problems. Uses such as: industrial planning, allocation of resources, planning, decision making, statistical pattern recognition and machine learning. Furthermore, optimization techniques are widely used in the fields of chemistry, business, industry, engineering and computer sciences.

In this paper, all the individuals are divided to two main sorts: comet and smaller celestial bodies .Gravitational variations are the main element of this algorithm which could cause comets converge in global maxima. This paper states how the gravitational variations of planets and the sun may cause a comet to survive longer.

In section II, historical events on this area is being discussed. In section III, the proposed algorithm will be discussed in details. Eventually in section IV, the proposed algorithm will be tested with benchmark functions such: Ackley, Rosenbrock, Eggholder, Rastrigins and conclusion occupies section V.

II. HISTORY

A. A history of gravitational force and mass of the comets

Gravity is a phenomenon in which objects mass causes objects gravitate towards each other. The effect of gravity in objects emerges to make the concept of weight.

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The unit of is calculated in meters per second-square. Gravitational force was discovered by Isaac Newton in 1687 [9]. This force has been existing since the first days of universe birth, and is one of the elements to make solar system come into being. So it has a long history. A rock along its way, by its gravity which is triggered by its mass, absorbs other rubbles (small celestial bodies) near it, and by this way its mass increases. The unit of mass is Kilogram. Gravitational force is everywhere, both on the earth with stable force (1 or 10) and in the galaxy with different quantities depending on the state of celestial bodies including: planets, asteroids, meteors, stars, moons and comets. For instance, two objects with different masses which are located in definite distances from each other, each one is influenced by the other one but the gravitational force of the object with greater mass is more. For instance, the earth and its moon could be mentioned, in which earth's mass in greater than moon's, so the moon which is always escaping or moving, orbits in a definite orbit around the earth, and that is due to the dominant gravitational force of earth on the moon. Tide is a phenomenon representing the influence of moon's gravity on earth, in which when moon is on the sea, sea level rises temporarily. Or of other instances, the movements of satellites around the earth, by earth gravity could be mentioned. Also the occurrence of the solar system is owing to titanic tremendous gravitational force of the sun which gets all the celestial bodies around it under its effect. So escaping planets are captured in a definite orbit depending on the quantity of their mass. Every object has an amount of gravitational force. For instance, two pens also have this force and will effect each other, but their force is not that tangible. One of the major reasons for falling meteorite on earth is the great mass of earth, and when the orbit of asteroid and earth approach each other, this event happens. Such occurrence could happen for comets as well, to which history is witnessing [10] [11]. To calculate the gravitational force of something, the mass of it should be considered and to calculate the mass, materials which the object has made of, should be considered. So there is a direct relation between gravity, mass and material. When we weigh an object, in fact we have calculate the gravitational force which has influenced that. Every object has a mass, which till is stationary, doesn’t have weight and as gets moving (by any force) the object gains weight. The unit of mass is kilogram and for weight it is Newton. Objects weigh differently on different planets. The criterion to calculating earth's mass is 1 or 10 and other celestial bodies masses are measured and compared based on this criterion. For instance, Table I illustrates a human weighing 80 Kgs whose weight variations are compared depending on being on different solar system planets, earth's moon and the sun.

B. *Comets*

Between 1449-1450, astronomers made the first efforts to record the path of comets in the night sky. In 1705, Edmond Halley recognised that the comets which were observed in 1531, 1607 and 1682, in fact had been a single comet and foretold it would be observed in 1758. From then on, that comet acquired the name Halley. In 1994, the first observation of comet-impact to a planet occurred. Scientist were amazed by watching the impact of Shoemaker Levy 9 to the Jupiter's atmosphere. In 2004, the Stardust spacecraft collected some dust sample of comet Wild 2. In 2005, Deep Impact spacecraft impacted the comet Tempel1 in order to illustrate its nucleus. Comet is a cosmic snowball which is created of frozen gases, stone and dust, and is in general, nearly the size of a small city. Structure of comet comprises three main parts: nucleus, coma and tail. The central part occupies nucleus which consists of dust, gas and ice. As comet approaches the sun, it outgases, its ice evaporates and makes a big cloud surrounding all the comet which is called coma. Tail is also made of dust and evaporating ice. In the Fig 1, fundamental constituent parts of a comet are illustrated. The sources of comets are Oort cloud and Kuiper belt. Comets come to solar system from every side. Their source must be an enormous place near solar system (Oort cloud), but some of them come from nearer distances, from Kuiper belt. Comets are periodic and non-periodic, in which non-periodic comets are not limited to the sun gravitational force, and have parabolic orbit. Periodic comets consist of long-period comets (more than 200 years) and short-period comets (20 to 200 years). Comets are different from other solar system celestial bodies in terms of material. For instance, planetoids are made of metal and stone but comets are made of ice, dust and stone. In 1943, Kenneth Essex Edgeworth claimed, there were a source for comets and other greater objects, beyond the planets. In 1950, Jan Oort, a Dutch astronaut, claimed that comets came from a very distant place, far from solar system, and named this cosmic region:

Oort cloud, in which there were many celestial objects. Oort cloud occupies a volume equal to 5000-100000 astronomical unit, and is located in a zone of space which the effect of solar gravitational force is less than other near starts to it. Oort cloud probably is including 100 billion to 2 trillion icy celestial objects in the sun orbit, which is called Oort cloud belt [10] [11].

TABLE I. THE WEIGHT COMPARISON ON THE MOON, SUN AND OTHER PLANETS BASED ON THEIR GRAVITY, WITH THE FIXED MASS QUANTITY OF 8 KGS

Weigh-Kg	**Gravity Power**	**Mass-Kg**	**State**
80	1 or 10	8	earth
13.6	1.7 or 0.17	8	moon
2240	280 or 28	8	sun
29.6	3.7 or 0.37	8	Mercury
72	9 or 0.9	8	Venus
30.4	3.8 or 0.38	8	Mars
203.2	25.4 or 2.54	8	Jupiter
100	1.25 or 12.5	8	Saturn
87.2	1.09 or 10.9	8	Uranus
91.2	1.14 or 11.4	8	Neptune
5.6	0.07 or 00.7	8	Pluto

C. *Kuiper belt*

In 1951, Gerard Kuiper made a hypothesis in which he claimed, there were a disk-like belt in the region of Pluto, which was including icy objects, beyond Neptune and including a community of comets. From then on, it was named Kuiper belt. Sometimes these icy objects are pushed to an orbit around the sun by the gravity and become short-period comets. Short-period comets are mostly originated from Kuiper belt and the long-period ones of Oort cloud. However, there are some exceptions for this rule. For instance, comet Halley has got a short-periodic alternation, nonetheless it has originated of Oort cloud. There are two major family of short-period comets: first one is Jupiter family, with a period less than 20 years, and the second one is Halley family, with a period between 20-200 years. Dynamic differences of these two groups are due to the effect of other objects on them. In Fig 2 the state of Kuiper belt is illustrated. The objects in the Oort cloud get disturbed by events beyond the sun, but Kuiper belt's comets could not get disturbed directly by any other force than sun's gravitational force. If the sun passes near another star (or a big molecular cloud), comets will orbit around an elliptical orbit to the side of solar system, but Neptune which is near Kuiper belt, plays an important role in stability of objects of Kuiper belt or vice versa in pushing them out of their orbits [12]. Table II illustrates a data on some famous comets.

For more information about other related space and galaxy-based evolutionary algorithms and their usages in different fields, like space gravity optimization and galaxy-based search algorithm, it can be referred to [28] [29] [30] [31].

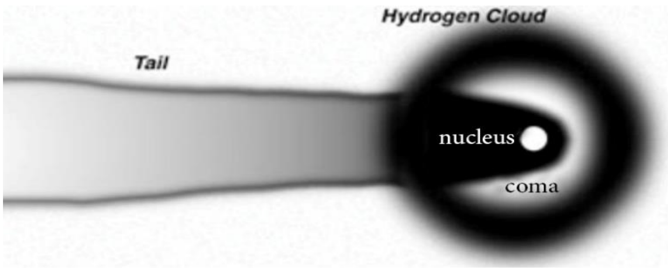

Figure 1. Parts of comet[22]

TABLE II. SOME FAMOUS COMETS[24]

Comet Name	Alternation Period	Discovery Year
Halley	76.3	1066
Great Comet of 1811	3000	1811
Fnke's Comet	3.3	1819
Great Comet of 1864	2.800.000	1864

D. Orbit

Although comets are different than planets and stars, but such planets, they have an orbit around the sun, orbits in elliptical, hyperbola or parabolic shapes. Elliptical and parabolic orbits make comets very distant of the sun in their orbital climax. In the 17th century, with the achievements of Johannes Kepler, Isaac Newton and Halley, it became obvious that the eccentric behaviour and movements of comets were adhering to the planet movement rules. Halley succeeded to recognise the alternative period and orbit of a bright comet which was later named after him. Then it became clear that this comet had been observed years before Christ's birth, roughly every 76 years. In the Fig 3 the orbit of Halley's comet is illustrated. Most of the comet orbits are in the shape of a very stretched ellipse.

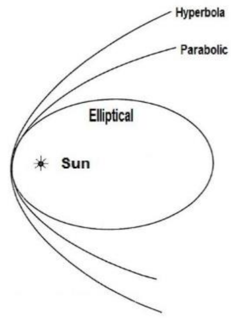

Figure 2. Different possible orbits for comets

Other ones have parabolic or hyperbola orbits which are counted as non-periodic comets. Sometimes comet's orbit changes due to the gravitational power of big planets such Jupiter or the intensive gravitational power causes that to fragment such comet Shoemaker-Levy 9 [11].

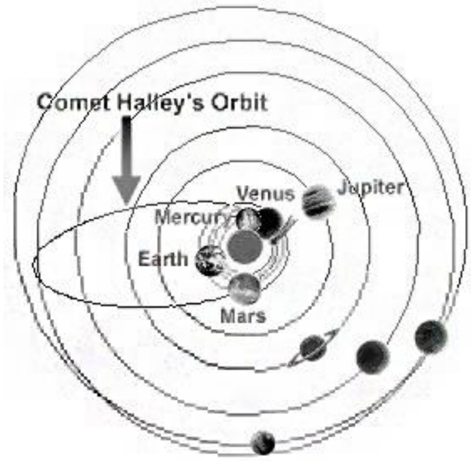

Figure 3. Orbit of Halley's comet[23]

III. THE PROPOSED ALGORITHM

Fig 1 illustrates the flowchart of proposed algorithm. This algorithm commences with an initial population (comet and smaller celestial bodies). Some of the best comets are chosen as the new generation. Some of these small celestial bodies, along the course of comets and depending on the extent of comet's gravitational force, and those small celestial bodies, will be distributed among comets. The power of a comet is measured with fitness or cost function. The comet's power is calculated based on the distance it has travelled in different orbits along generations, till collapse. In this paper, celestial bodies smaller than comets (tiny relative to the comet), are used for increasing and decreasing the comet's mass, using mass increasing and decreasing operator. In implementation stage, comet along with time elapsing and repeatedly passing its path of the solar perigee will collapse and fragment to smaller celestial bodies as orbiting its last one. Each comet which does not travel in a proper orbit, will gradually lose its mass and collapse ultimately. The comet which is in a proper orbit and acquires highest mass, prolongs its orbit and can survive longer time in the solar system, and its fitness function will converge with a better position. Our operators are: gravitational operator (increase and decrease mass) and gravitational mutation operator. Gravitational operator applies to the comet along its way, and causes smaller celestial bodies collect. Meanwhile it is also used at the moments of comet's entrance from Kuiper belt to the solar system. The second operator, which is called gravitational mutation operator, occurs due to the nearness of comet's orbit to one of the powerful planetary orbits and triggers the comet's orbit path. This transformation in orbit can be from circular shape to elliptical or vice versa, and also can affect the length and position of the orbit which will in turn affect a striking influence on the life time of the comet in the solar system.

A. Generating the initial population (comets)

The aim of optimization is to finding the optimized value per variables values. We have an array of variables values for optimization. In genetic algorithm this array is named chromosome but in this study is comet. For optimization in a 6-dimensional array, every comet is presented with the 1*6 array. It means we have 6 dimensions per comet which has these values respectively: present comet's mass,present length of the comet orbit, total lenght of the comet's orbits, celestial body's mass of mth per comet nth, the number of small celestial bodies per comet nth and the total of comet's mass. Following formula represents that:

Comet X=[MainCometMass, MainOrbit, SumOrbit, AsteroidMass, nAsteroids, TotalMass]

Every comet has a distance from each small celestial body in that orbit (variable in each generation). On the other hand, four major planets (Saturn, Jupiter, Neptune, Uranus) and the sun have a distance from comets (variable in each generation). For instance, if we have n comets, it will be presented as following in which D_{comx} is the distance of comet from nth celestial bodies.

$D_{comx}=[d_{ast1},d_{ast2},\ldots\ldots,d_{astn}]$ $\quad D_{jup}=[j_{r1},j_{r2},\ldots\ldots,j_{rn}]$

$D_{sat}=[sa_{r1},sa_{r2},\ldots\ldots,sa_{rn}]$ $\quad D_{ura}=[u_{r1},u_{r2},\ldots\ldots,u_{rn}]$

$D_{nep}=[n_{r1},n_{r2},\ldots\ldots,n_{rn}]$ $\quad D_{sun}=[su_{r1},su_{r2},\ldots\ldots,su_{rn}]$

D_{comx} is the vector of distance between the comet and its smaller celestial body.

(D_{jup}, D_{sat}, D_{ura}, D_{nep}, D_{sun}) are respectively: Jupiter, Saturn, Uranus, Neptune and the sun distances of each comet. Values of each variable are presented in real values. The fitness function of comet is the total of variable values of comet's orbit in each generation till the end of algorithm which in principle is the total distance travelled by the comet. So in (1) we have: (Fitness Function (FF))

$$FF(\text{Comet}) = \sum_{\text{n=1}}^{\text{number of perigees}} \text{Sum (Main Orbit's)} + Total\ Mass \tag{1}$$

In order to implement the optimization algorithm, first the initial population should be generated. We have comets as equal to N_{com} and smaller celestial bodies as N_{ast}. Therefore, there are two entities: comet and smaller celestial bodies. To start, and along the orbit path, we distribute smaller celestial bodies between comets, depending on their gravitational force and the distance between them .First, accidental fitness function will be generated for each comet (orbit and mass) which will be used in choosing parent stage. Comet and its smaller celestial bodies are represented as:

Comet x=round{Comet x,Asteroids of comet x}

There is a vector of orbits equal to chosen comets which as it approaches the end, distribution of the smaller celestial bodies gets higher, and orbit prolongs as well, and becomes more elliptical and vice versa: Orbit's=$[o_1,o_2,o_3,\ldots\ldots\ldots\ldots o_n]$

B. Parent selection

First of all, based on fitness function (mass value and orbit length), the bests will be chosen, in which c_{max} is the cost of the strongest comet and c_i and c_j costs of present comet.

$$\text{Rock Pr x} = \text{Normal} = C_{max} - C_i \,/ \sum_j C_{max} - C_j \tag{2}$$

Also for better selection we apply a formula to each fitness function for selection pressure:

$$\text{Rock Pr x} = \text{Sp} = (C_{max} - C_i)^{\wedge\alpha} \,/ (\sum_j C_{max} - C_j)^{\alpha} \;, \alpha = 2 \tag{3}$$

After specifying fitness function by operators, it is the turn to selecting by roulette wheel [13].

In Fig 4, General view of roulette wheel is illustrated.

C. Movement, from Kuiper belt to solar system

As mentioned previously, gravitational disorders, triggered by massive planets such: Jupiter, Neptune, Uranus and Saturn cause these celestial objects to enter our solar system from Kuiper belt and Oort cloud. These comets which are composed of gas, ice and tiny celestial objects, based on their movement and after making their entrance into solar system, caused by vigorous gravitational force of the sun, make an oval orbit around the sun. More precisely, Kuiper belt celestial objects are located between the Neptune, Pluto and Eris orbit which includes short-period comets. Oort cloud is located far away of solar system and also surrounding it in all orientations and is including many comets as well.

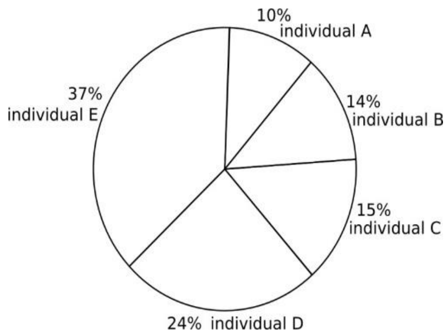

Figure 4. General view of roulette wheel[25]

Entering solar system is based on the mass and velocity, which make weight. It means that the best make comets, and other tiny celestial bodies which are afloat along the comet's orbit, distribute among them. That is apparent which due to the relation between mass and velocity, whatever these two variables get higher in amount, due to higher velocity, orbit prolongs as well. The number of small tiny celestial objects is also more in longer orbits, and comets will attract a number of them depending on weight and distance of the small celestial bodies. Fig 6 depicts how and how much of these tiny celestial bodies are being distributed among comets in any orbit depending on the comet of that orbit. Application of gravitational operator is in two places. In gathering small celestial objects as well as causing to make gravitational disorder. Of course when this operator causes comet's orbit change, it becomes gravitational mutation operator. First, mass or weight should be normalized between 0 to 1, and main planets between 0.9-1. Formula 2 explains Newton's gravity law.

$$\mathrm{Gravity}(o1, o2) = \mathrm{G} * ((\mathrm{m}(o1)) * (\mathrm{m}(o2))/r^2 \mid \mathrm{G}=6.67*10^{(-11)} \quad (4)$$

Which o1 and o2 are (comet, planet) or (comet, celestial objects) and G is global gravitational constant. Also r^2 is distance between two object. As there is no gravity in the space, in above formula, mass should become weight.

Weight=mass*speed

So we have above formula in below form:

$$\mathrm{Gravity}(o1, o2) = \mathrm{G} * (\mathrm{w1} * \mathrm{w2})/r^2 \qquad \mathrm{G}=6.67*10^{(-11)}$$

Which w1 and w2 are weights of o1 and o2. (5)

This event occurs to all comets, smaller celestial bodies and one of the four main planets. After, those which bear more mass and velocity or in other word bear higher gravity will be chosen and enter solar system. Others as smaller celestial bodies will distribute along the orbits which are the same number of comets. Moreover, this event occurs for each comet and their small celestial bodies to increase the mass, along the orbit path. Fig 7 presents this subject. After comet entrance, an orbit should be chosen for it which is as following. Considering gravitational force of any comet, a proper orbit will be chosen for each.

Orbit (r_1, r_2) $\quad$ $r_1 = r_2$ => circle $\quad$ $r_1 <> r_2$ => ellipse

In above formula r_1 and r_2 are two radiuses of the oval orbit. The length of the orbit will also be specified initially based on the mass and random velocity (if is explained). Now it is time to collect the small celestial bodies which this time will be done by the gravitational formula, on comets and small celestial bodies. In every orbit, we have once, collection of small celestial bodies along the present orbit, and once the loss of mass due to passing from solar perigee in the orbit.

- Mass add mutation:

Possibility and rate of mutation are respectively 3.0 and 1.0. This happens when mass rate has not exceeded the threshold.

Mutation Probability=0.3 Mutation Rate=0.1;

$$\mathrm{MassAdd}(\mathrm{com}(x)) = (\mathrm{com.TotalMass}) + \left(\left(\frac{1}{20} * (\mathrm{com.TotalMass})\right) + \left(\frac{1}{10} * (\mathrm{MainOrbit})\right)\right) \quad (6)$$

Which increase the mass (1/20) and the orbit length (1/10) of present comet; and then it will be added with present mass and orbit length value. Obviously, the longer orbit is, the higher mass rate will go.

- Mass loss mutation

Each comet has two points in its orbit: solar perigee and solar climax. Solar perigee is the point in which comet has the least distance to the sun and loses most of its mass, and due to extreme nearness to the sun, its velocity rises up (Fig 5 represents this). The less differences between two orbits is, the less mass loss occurs. This event happens when the mass rate has not exceeded threshold. Here we will find the longest orbit and raise its value 10 times and divide the result in its present orbit. Then this value will be reduced from present comet mass.

$$MassLose(com(x)) = (com.TotalMass) - \left(\frac{Orbitmax * 10}{com}.mainOrbit\right) \quad (7)$$

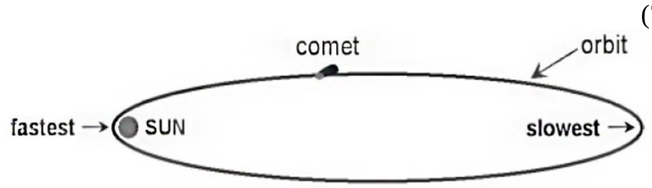

Figure 5. The solar perigee and climax, and the velocity of comet in these points[26]

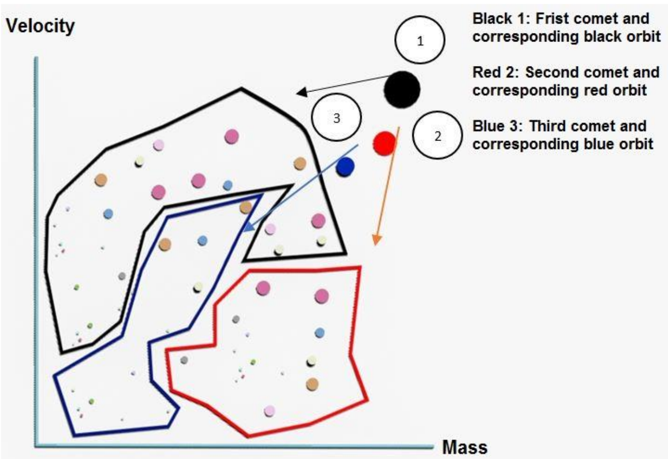

Figure 6. Distribution of small celestial bodies among comets, depending on comet's orbit

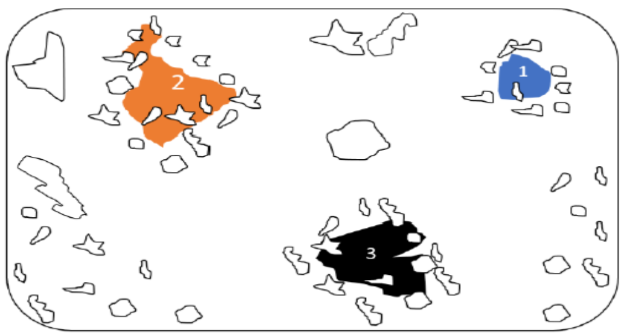

Figure 7. Movement of rubbles towards comet based on gravitational force

D. Gravitational mutation

Change in comet's orbit: in many cases this change occurs due to nearness of comet to one of the giant planets, thus some gain longer period and some shorter. Other comets orbits convert from oval to either parabolic or hyperbolic. Thus, it was such that in 1886, The Broxel comet orbit's period cycle changed from twenty-nine to a bit more than seventy years and by passing Jupiter by a distance of 88000 Km of it. Some planets which have the potential to changing orbit are: Jupiter, Saturn, Uranus and Neptune. Initially, the gravity formula will be applied for each comet and four main planets. The changes are totally random and affect the shape, position and length of the orbit, resulting its sudden change in lifetime and in that generation. In Table III, mass and velocity of the sun and main planets is shown. Also in Fig 8, the different states of orbital transformations are presented.
Mutation probability=0.5 Mutation rate=0.2

$$R1 = \frac{r1}{1}, \frac{r1}{2}, \frac{r1}{3}, \dots, \frac{r1}{n}$$
$$R2 = \frac{r2}{1}, \frac{r2}{2}, \frac{r2}{3}, \dots, \frac{r2}{m} \quad (8)$$

Jupiter= 1; Saturn=0.7; Uranus=0.4; Neptune=0.3

First, a value between 0 and 1 should be assigned for influential planets, depending on their masses. Afterwards, in mutational gravitation action, a planet, accidentally and considering the value of mutational probability will be chosen, and depending on its mass will affect orbit. Based on (2), this effect is implemented on both comet and planet.

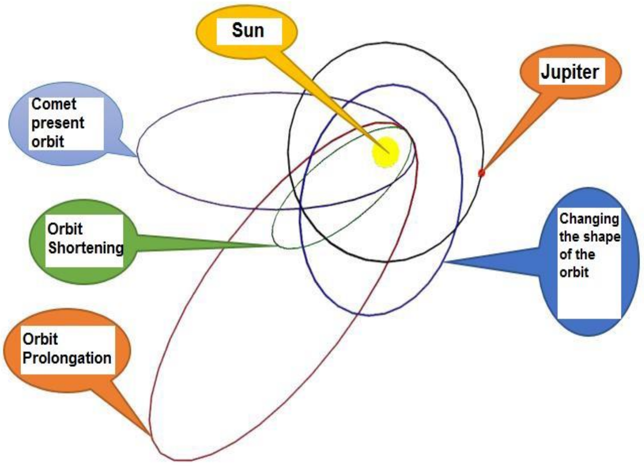

Figure 8. Different states of comet orbital changes

TABLE III. MASS AND VELOCITY OF MAIN PLANETS AND SUN

Name	Velocity	Mass
Earth	40320 km/h	1
Sun	0	332000
Jupiter	216000 km/h	318
Saturn	129600 km/h	95
Uranus	75600 km/h	15
Neptune	68400 km/h	17

E. Calculation of the total fitness function

The total fitness function is calculated based on the total length of comet's orbits till collapse and is calculated as following:
We calculate the length of the orbit which is needed for total fitness function, using oval environment formula.

$$\mathrm{Orbitlenth} = \mathrm{Eliipse\ Perimeter} = (2 * \pi) * \mathrm{sqrt}(\frac{r^1 + r^2}{2})$$
$$\mathrm{Fitness} = (\mathrm{orbit\ lenth}) + (\mathrm{orbit\ lenth} + 1) + (\mathrm{orbitlenth} + 2) + (\mathrm{orbit\ lenth} + n)\ \ \mathrm{until\ comet\ collapse} \quad (9)$$

Or, the fitness function which was hinted in (1) can be used. Obviously, the comet which has been able to survive a longer time in solar system, has gained a higher fitness function. It is possible to use fitness or cost function for evaluating evolutionary algorithm. For this algorithm, both of them has been used, which is illustrated in section IV. Fitness function means that, respected value of algorithm should be increased during different iterations and cost function means, this value should be decreased. Most of the algorithms used cost function but there are algorithms which uses fitness function. In both perspective, the respected algorithms value should go toward best result.

F. Eliminating the comet

Now it is the time to find out if the comet's mass has reached to zero. If so, the value of its fitness function will be stored and itself will be eliminated and its debris will be distributed along its orbit. In other words, its rubbles will be released to join other comets if they ever change their orbit or entering to a new generation as small celestial bodies or rubbles.

G. Generation production

Now, time to enter a new generation. First, a new generation will be generated and then best of them will be chosen based on the mass and velocity, and from the present generation the best will be chosen based on orbital length as well. Eventually, some of the best will be chosen for next generation, based on best of the present generation and next generation [14].

M = (μ + λ): which λ is best of next generation and μ is best of present. In the survivor-selection stage, following formula specifies the minimum iteration that algorithm repeated to reach to a relative proper answer.

$$\mathrm{Takeover\ time} = \tau = \ln \lambda / \ln(\lambda / \mu) \quad (10)$$

In which, λ represents the number of new comets, to shift to the next generation (choosing the best) and μ represents the initial population. Moreover, in this stage, fitness proportionate selection algorithm can be used to specify the value of fitness function between 0 and 1.

$$\mathrm{Ci} = \mathrm{Pfps(i)} = \mathrm{fi} / (\mathrm{j} = 1\ \mathrm{to}\ \mu * \mathrm{fj}) \quad (11)$$

The best of new generation will be chosen by roulette wheel algorithm. Now the condition of the end has been surveyed and in which case it is not satisfied, the new generation will repeat all the stages again (for more detailed data on implementing by Matlab software, refer to [15].

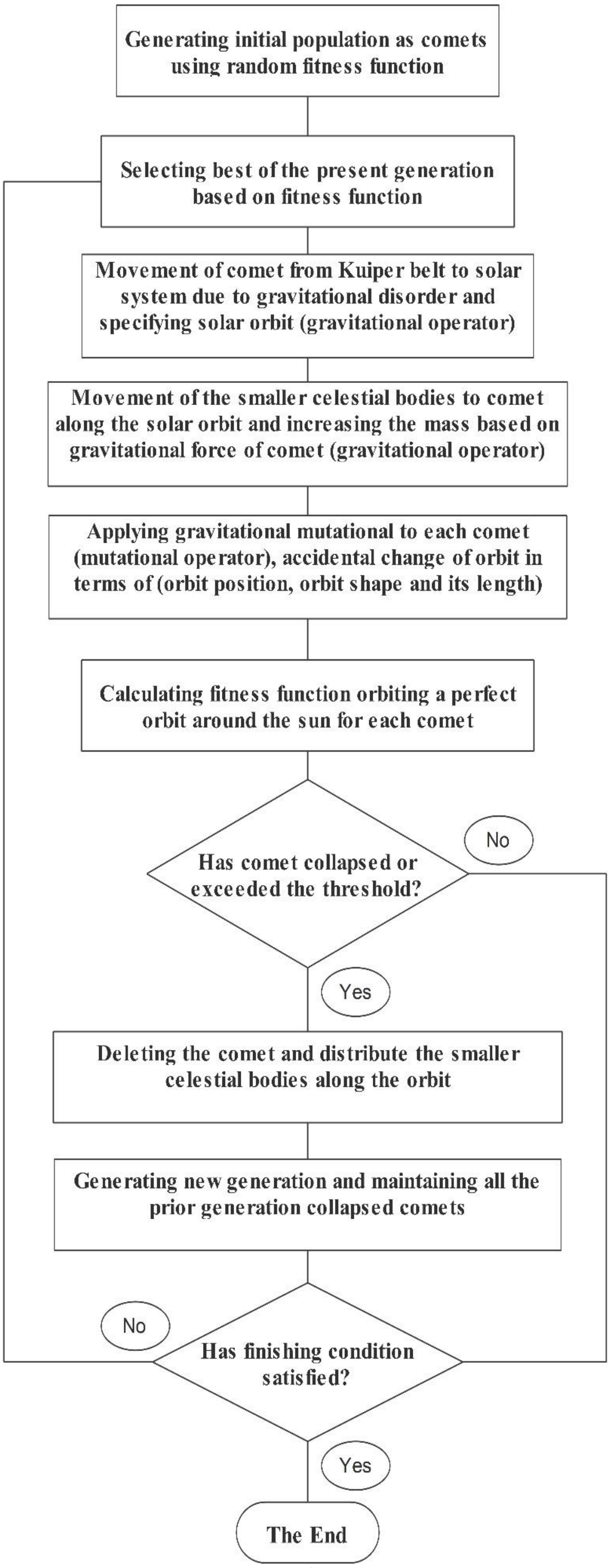

Fig. 1. Flowchart of proposed method

IV. EXPERIMENTAL AND VALIDATING RESULTS

$$f(x,y) = -20\exp\left(-0.5\sqrt{-0.2(x^2+y^2)}\ \right) - \exp\left(0.5(\cos(2\pi y))\right)$$
$$+e+20$$
$$f(0,0)=0$$
$$-5 \le x,y \le 5 \tag{12}$$

$$f(x) = An + \sum_{i=1}^{n}[x_i^2 - A\cos(2\pi x_i)] \ \text{Where}: A = 10$$
$$f(0,0)=0$$
$$-5.12 \le x,y \le 5.12 \tag{13}$$

$$f(x) = \sum_{i=1}^{n-1}[100(x_{i+1}-x_i^2)^2 + (x_i-1)^2]$$
$$\min = \begin{cases} n=2 \ \rightarrow f(1,1)=0, \\ n=3 \ \rightarrow f(1,1,1)=0, \\ n>3 \ \rightarrow \ f(1,000,1\_(n)\text{times})=0 \end{cases}$$
$$-\infty \le x_i \le +\infty \ \text{ and } \ 1 \le i \le n \tag{14}$$

$$f(x,y) = -(y+47)\sin\left(\sqrt{|\frac{x}{2}+(y+47|}\right) - x\sin\left(\sqrt{|x-(y+47)|}\right)$$
$$f(512,404,2319) = -959.6407$$
$$-512 \le x,y \le 512 \tag{15}$$

Galaxy Gravity Optimization

Brgin
1. Generate initial population as:
Comet X=[MainCometMass, MainOrbit, SumOrbit, AsteroidMass, nAsteroids, TotalMass]
While (No. of iterations < Max iterations)
2. Parent Selection with selection pressure(SP) as:

$$\boldsymbol{Parents\ with\ SP} = (\boldsymbol{C_{max}} - \boldsymbol{C_i})^{\wedge\alpha} / (\sum_j \boldsymbol{C_{max}} - \boldsymbol{C_j})^{\alpha}\ , \boldsymbol{\alpha} = \mathbf{2}$$

3. Moving toward solar system based on gravitational disorder calculated with gravity formula for two objects (o1 and o2):
Gravity(o1,o2)=G(w1*w2)/r^2 , G=6.67*10^ (-11)*
4.1. Mass add mutation based on:

$$\boldsymbol{MassAdd}(\boldsymbol{com}(\boldsymbol{x})) = (\boldsymbol{com.TotalMass}) + ((\frac{\mathbf{1}}{\mathbf{20}} * (\boldsymbol{com.TotalMass})) + (\frac{\mathbf{1}}{\mathbf{10}} * (\boldsymbol{MainOrbit}))$$

4.2. Mass lose mutation based on:

$$\boldsymbol{MassLose}(\boldsymbol{com}(\boldsymbol{x})) = (\boldsymbol{com.TotalMass}) - (\frac{\boldsymbol{Orbitmax} * \mathbf{10}}{\boldsymbol{com}}.\boldsymbol{mainOrbit})$$

5. Changing comets orbit's radiuses(R1 and R2):

$$\boldsymbol{R1} = \frac{\boldsymbol{r1}}{\mathbf{1}}, \frac{\boldsymbol{r1}}{\mathbf{2}}, \frac{\boldsymbol{r1}}{\mathbf{3}}, \dots, \frac{\boldsymbol{r1}}{\boldsymbol{n}}$$
$$\boldsymbol{R2} = \frac{\boldsymbol{r2}}{\mathbf{1}}, \frac{\boldsymbol{r2}}{\mathbf{2}}, \frac{\boldsymbol{r2}}{\mathbf{3}}, \dots, \frac{\boldsymbol{r2}}{\boldsymbol{m}}$$

6. Calculating fitness function value based on comet orbit's length :

$$\boldsymbol{Fitness} = (\boldsymbol{orbit\ lenth}) + (\boldsymbol{orbit\ lenth} + \mathbf{1}) + (\boldsymbol{orbitlenth} + \mathbf{2}) + (\boldsymbol{orbit\ lenth} + \boldsymbol{n})\ \ \boldsymbol{until\ comet\ collapse}$$

7. If comet collapsed or exceeded the threshold go to 8, else go to 10
8. Eliminating the comet and distribute it along the last orbit
9. Generating new generation(M) based on selecting bests from
- present(μ) and next(λ) generations based on :
- M = (μ + λ)
- End if
10. If finishing condition satisfied go to The End, else go to 2
- End if
End while
-The End

Pseudo code of the Galaxy Gravity Optimization algorithm (GGO)

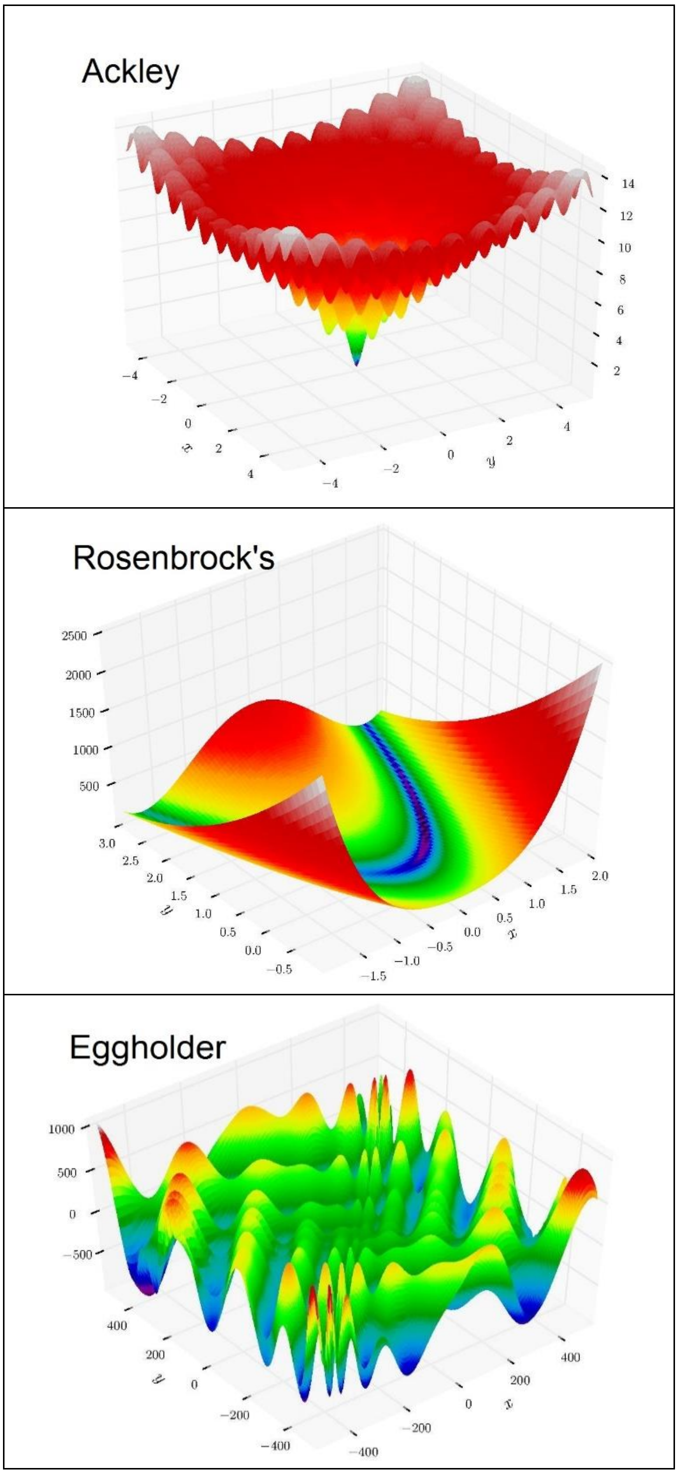

Figure 9. three-dimensional display of 12, 13, 15 functions, with different domains[27]

In order to validate an evolutionary algorithm and testing its optimization abilities, we use some functions to test proposed algorithm by some of them. Experimental functions here are respectively: Eggholder, Rosenbrock, Rastrigin and Ackley, which respectively have been displayed in (12), (13), (14) and F15. Three-dimensional display of three of them with different domains has been presented in Fig 9. Final results of implementing algorithm on the values of Table IV are presented in Fig 10.

TABLE IV. VALIDATION VALUES FOR NEW GGO ALGORITHM

Mutation rate	0.1
Mutation probability	0.3
Variable bounds	[-10:10]
Variable number	6
Number of comet	20
Initial population	50
Perigee number	300

Results of Fig 10 indicates that after 300 solar perigees, algorithm has become maximized in an appropriate point. As displayed before in the second section of Fig 10, initially, comet 1 had the best situation from orbit and mass point of view, and then this has respectively reached to: comet 19, 10, 4 and finally comet 10 and has remained stable till end. In section 3 of this Fig, the best fitness value for comet 10 is observable which is 8.95. The aim of optimization or maximization is to acquire a proper result, and in this algorithm, fitness has been chosen instead of cost which is able to be changes easily as well. In addition, this algorithm will work for optimization problems (test functions), as presented in the following.

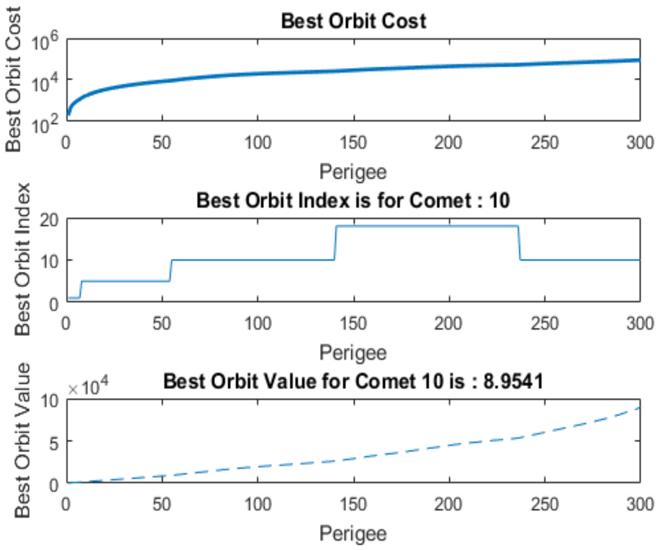

Figure 10. Result of proposed algorithm with Table IV values

In Fig 11, 12 and 13, value of cost function against number of iteration, and finally the best value of it, respectively for GA, PSO and SA, are observable. Also Fig 14 represent cost function value against number of perigee for (12), (13), (14), (15), that implemented by proposed algorithm. Results indicate that this algorithm is able to converge with optimization points and work well in optimization operation. Moreover, this algorithm is capable of involving in other problems such as clustering, which can take place in future works. Table V indicates the best and worst cost values, relative to test functions, for GA, PSO, SA and GGO. The implementation of proposed algorithm and other three has been applied on the benchmark test functions, based on values from Table IV and Table V.

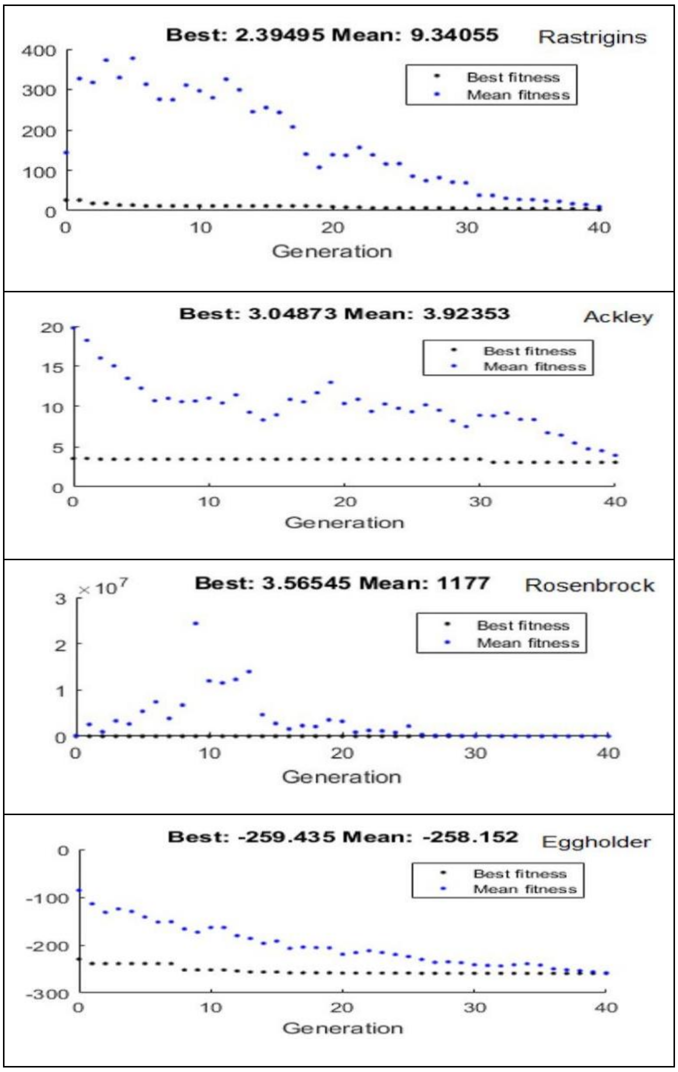

Figure 11. value of cost function and the average against the number of generation for (12), (13), (14), (15) by genetic algorithm

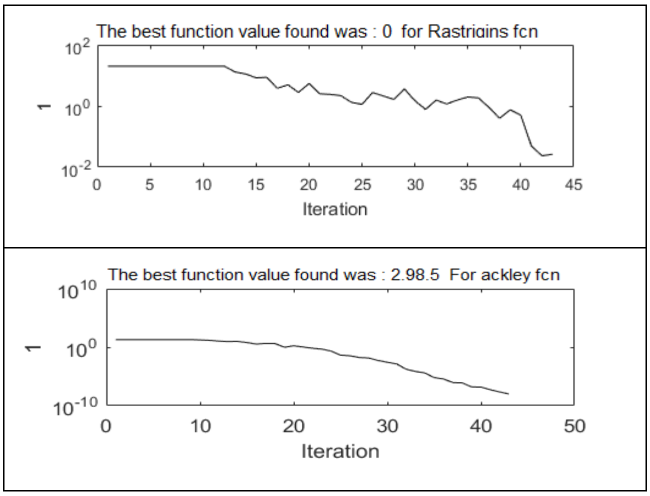

Figure 12. the value of cost function against the number of iteration for (12), (13) by particle swarm optimization

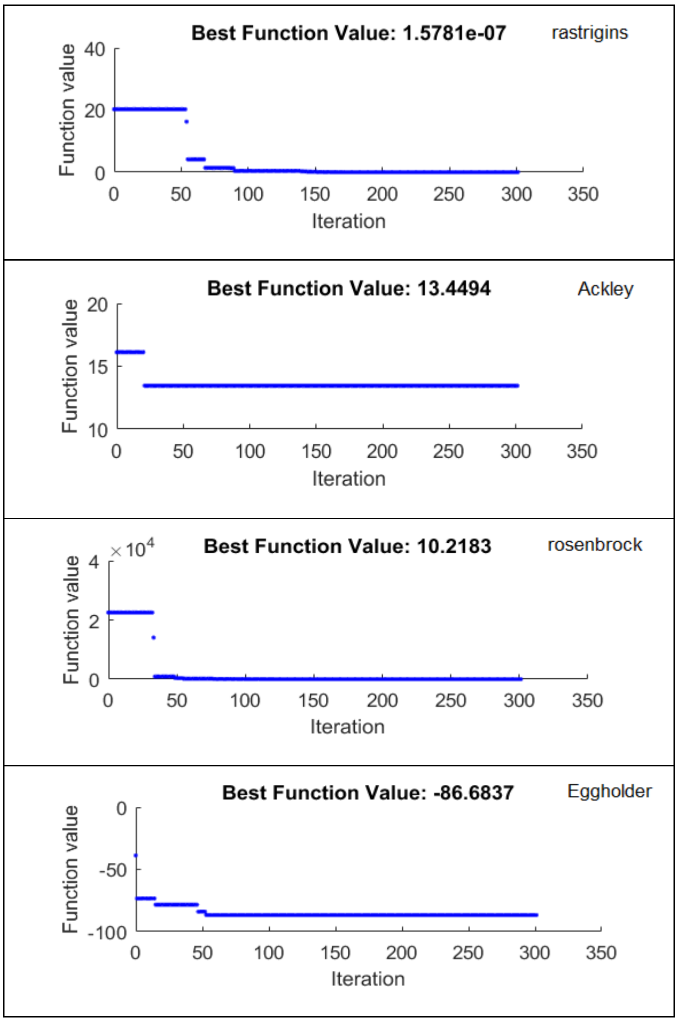

Figure 13. the value of cost function against the number of iteration for (12), 13, 14, 15 by simulated annealing

TABLE V. BEST AND WORST ACQUIRED VALUES BY DIFFERENT ALGORITHMS AND THE PROPOSED ALGORITHM RELATIVE TO BENCHMARK TEST FUNCTIONS

Iteration	**Var**	**Algorithm**	**Function**	**Worst cost**	**Best cost**
40	3	GA	Eggholder	-	-258.15
40	3	GA	Rosenbrok	3.56	-
45	2	PSO	Rastriains	-	·
45	2	PSO	Ackley	2.98	-
350	4	SA	Eggholder	-	-86.68
350	4	SA	Ackley	13.44	-
1000	6	GGO	Eggholder	-	-87.06
200	6	GGO	Rosenbrok	6.40	-

V. CONCLUSION

This paper modeled an evolutionary algorithm based on comets life. Every entity is called comet. Population comprises two sections: comet and smaller celestial bodies. Total cost function is calculated based on comet's lifetime in solar system which is equal to total length of comet's all orbits. The proposed algorithm has been tested by the benchmark test functions' for optimization and the results are indicating that algorithm has been able to converge in good optimized points. Moreover, the acquired results have been compared by using standard algorithms such as genetic algorithm, particle swarm optimization and simulated annealing , indicated proper results. Thus the comparison of this algorithm with other standard ones such ant colony algorithms, E_S, E_P and ICA and also testing it with more test functions will occupy future works.

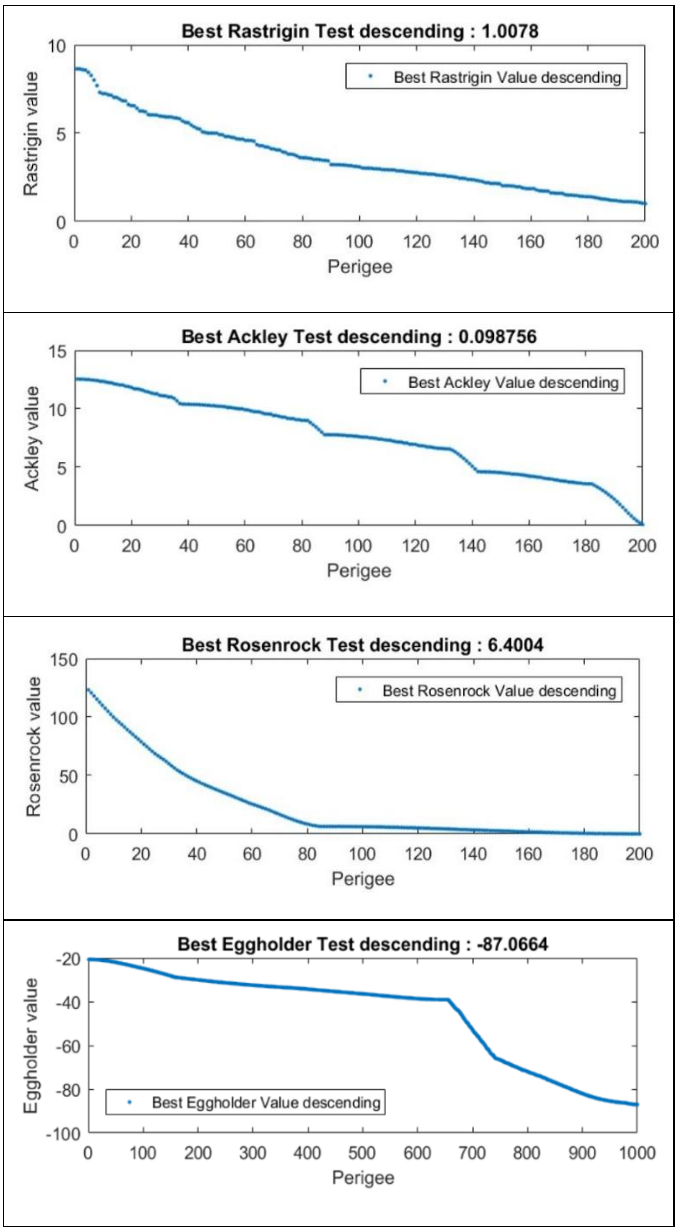

Figure 14. the values of comets cost function against the number of solar perigees for (12), (13), (14) and (15) by proposed algorithm(GGO)

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