

Applications of Gravitational Search Algorithm (GSA)

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ABSTRACT

Natural phenomenon and swarms habits are the first-rate and comfortable discipline of study among the many researchers. A colossal quantity of algorithms have been developed on the account of common phenomenon and swarms conduct. These algorithms have been applied on the quite a lot of computational problems for the sake of options and offered huge final result than typical methods however there is no such algorithm if you want to even be utilized for the whole computational problems. In 2009, a company new algorithm used to be developed on the behalf of notion of gravity and was once as soon as named gravitational search algorithm (GSA) for regular optimization disorders. In short span of time, GSA algorithms attain reputation amongst researchers and has been utilized to massive number of disorders corresponding to clustering, classification, and parameter identification and so on. This paper grants the compendious survey on the GSA algorithm and its functions as well as enlightens the applicability of GSA in information clustering & Fuzzy systems.

1. INTRODUCTION

Nature has more often than not been a regular supply of advice for researchers and scientists. A tremendous quantity of algorithms had been developed based on the average process of evolution, authorized directions, swarms habits and so forth. Nature influenced algorithms are the modern-day state of art algorithms & works good with optimization problems as good as one of a kind issues than the classical approaches in view that classical methods are rigid in nature. It has been proved through many researchers that nature influenced algorithms are convenient to solve intricate computational problems corresponding to optimize purpose points [1, 2], pattern consciousness [3, 4], manipulate aspects [5, 6], photo processing [7, 8], filter modeling [9, 10], clustering [3], classification [11] and so forth. In final one and half of of decade a few nature influenced algorithms had been developed similar to Particle swarm optimization (PSO), Genetic Algorithm (GA), Simulated Annealing (SA), Ant colony optimization (ACO), artificial Bee colony (ABC) optimization, colossal Bang big Crunch (BB-BC) and lots of others. These algorithms exhibit better results than classical Algorithms.

GSA is a heuristic optimization algorithm which has been gaining curiosity among the many scientific local simply nowadays. GSA is a nature motivated algorithm which is based on the Newton's law of gravity and the regulation of movement [1]. The algorithm is intended to toughen the performance inside the exploration and exploitation capabilities of a populace headquartered algorithm, based on gravity concepts. . GSA is usually recommended to exclude the space between masses in its system, whereas mass and distance are every crucial components of the law of gravity. Regardless of the criticism, the algorithm remains to be being explored and accepted with the help of the scientific regional.

The gravitational search algorithm is the trendy nature influenced algorithm proposed with the support of E. Rashedi [3] to clear up the optimization issues headquartered on the regulation of gravity. Many

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researchers has utilized the gravitational search algorithm on gigantic numbers of disorders considering the fact that it requires easiest two parameters and having talents to seek out close global most appropriate resolution and supplies better final result as evaluate to other nature inspired algorithms.. The objective of this paper is to furnish whole survey for the researchers which might be doing study in the subject of optimizing problems (gravitational search algorithm), swarm intelligence and nature prompted algorithms. The essential rationale of this paper is to discover the range of algorithms that are derived from the customary GSA to remedy the optimization issues as just right as to discover the application of gravitational search algorithm in quite a lot of domains similar to pattern recognition, power process, information mining, classification & clustering and how many algorithms are proposed by way of utilizing gravitational search algorithm plus extraordinary nature stimulated strategies corresponding to GA, PSO, SA and plenty of others. (Hybrid GSA)

2. A BRIEF REVIEW OF GSA

GSA used to be introduced through Rashedi et al. In 2009 and is intended to solve optimization problems. The populace-established heuristic algorithm is founded on the law of gravity and mass interactions. The algorithm is constituted of collection of searcher retailers that have interaction with each other via the gravity drive [1]. The marketers are regarded as objects and their performance is measured with the aid of their plenty. The gravity force motives a global action the place all objects transfer towards other objects with heavier plenty. The sluggish motion of heavier masses ensures the exploitation step of the algorithm and corresponds to excellent options. The masses are honestly obeying the regulation of gravity as proven in Equation (1) and the legislation of movement in Equation (2).

$$F = G (M1M2 / R2) \quad (1)$$

$$a = F/M \quad (2)$$

Based on Equation (1), F represents the magnitude of the gravitational drive, G is gravitational steady, M1 and M2 are the mass of the first and 2d objects and R is the gap between the 2 objects. Equation (1) suggests that within the Newton regulation of gravity, the gravitational drive between two objects is instantly proportional to the product of their lots and inversely proportional to the rectangular of the gap between the objects. Even as for Equation (2), Newton 2d regulation indicates that after a drive, F, is utilized to an object, its acceleration, a, is determined by the drive and its mass, M.

In GSA, the agent has 4 parameters which can be function, inertial mass, lively gravitational mass, and passive gravitational mass [1]. The function of the mass represents the answer of the situation, the place the gravitational and inertial masses are determined making use of fitness perform. The algorithm is navigated by adjusting the gravitational and inertia masses, whereas each and every mass offers a solution. Lots are attracted by means of the heaviest mass. As a consequence, the heaviest mass grants an ultimate solution within the search area. The steps of GSA are as follows:

Step 1: Retailers' initialization:

$$X_i = (x_i^1, \dots, x_i^d, \dots, x_i^n), \text{ for } i = 1, 2, \dots, N$$

The positions of the N quantity of dealers are initialized randomly.

x_i^d represents the positions of the ith agent within the dth dimension, while n is the gap dimension.

Step 2: Health evolution and excellent health computation:

For minimization or maximization problems, the health evolution is performed with the aid of evaluating the great and worst fitness for all sellers at each generation.

Minimization problems:

$$\begin{aligned} best(t) &= \min_j fit_j(t) \\ j &\in \{1, \dots, N\} \\ worst(t) &= \max_j fit_j(t) \\ j &\in \{1, \dots, N\} \end{aligned}$$

Maximization problems:

$$\begin{aligned} best(t) &= \max_j fit_j(t) \\ j &\in \{1, \dots, N\} \\ worst(t) &= \min_j fit_j(t) \\ j &\in \{1, \dots, N\} \end{aligned}$$

$fit_j(t)$ represents the fitness value of the j^{th} agent at iteration t , $best(t)$ and $worst(t)$ represents the best and worst fitness at iteration t .

Step 3: Gravitational constant (G) computation:

Gravitational constant G is computed at iteration t [4].

$$G(t) = G_0 e^{(-\alpha t/T)}$$

G_0 and α are initialized at the beginning and will be reduced with time to control the search accuracy. T is the total number of iterations.

Step 4: Masses of the agents' calculation:

Gravitational and inertia masses for each agent are calculated at iteration t .

$$M_{ai} = M_{pi} = M_{ii} = M_p, \quad i = 1, 2, \dots, N.$$

$$m_i(t) = \frac{fit_i(t) - worst(t)}{best(t) - worst(t)} \quad (10)$$

$$M_i(t) = \frac{1}{\sum_{j=1}^N m_j(t)} \quad (11)$$

M_{ai} and M_{pi} are the active and passive gravitational masses respectively, while M_{ii} is the inertia mass of the i^{th} agent.

Step 5: Accelerations of agents' calculation:

Acceleration of the i^{th} agents at iteration t is computed.

$$a_i^d(t) = F_i^d(t) / M_{ii}(t)$$

$F_i^d(t)$ is the total force acting on i^{th} agent calculated as:

$$\begin{aligned} &\sum_j rand_j \\ a_i^d(t) &= F_{ij}^d(t) \\ &\in \neq Kbest, ji \end{aligned}$$

$Kbest$ is the set of first K agents with the best fitness value and biggest mass. $Kbest$ will decrease linearly with time and at the end there will be only one agent applying force to the others.

$F_{ij}^d(t)$ is computed as the following equation:

$$F_{ij}^d(t) = G(t) \cdot (M_{pi}(t) \times M_{aj}(t) / R_{ij}(t) + \varepsilon) \cdot (x_j^d(t) - x_i^d(t))$$

$F_{ij}^d(t)$ is the force acting on agent i from agent j at d^{th} dimension and t^{th} iteration. $R_{ij}(t)$ is the Euclidian distance between two agents i and j at iteration t . $G(t)$ is the computed gravitational constant at the same iteration while ε is a small constant.

Step 6: Velocity and positions of agents:

Velocity and the position of the agents at next iteration ($t+1$) are computed based on the following equations:

$$v_i^d(t+1) = \text{rand}_i \cdot x \cdot v_i^d(t) + a_i^d(t)$$

$$x_i^d(t+1) = x_i^d(t) + v_i^d(t+1)$$

Step 7: Repeat steps 2 to 6

Steps 2 to 6 are repeated until the iterations reach their maximum limit. The best fitness value at the final iteration is computed as the global fitness while the position of the corresponding agent at specified dimensions is computed as the global solution of that particular problem. Fig. 1 shows the flowchart of GSA

FLOWCHART OF GSA

3. APPLICATION OF GSA ON DATA CLUSTERING

Data clustering, the process of grouping equivalent objects in a collection of observations is likely one of the attractive and fundamental tasks in knowledge mining that's utilized in many areas and functions reminiscent of text clustering and knowledge retrieval, data compaction, fraud detection, biology, pc vision, knowledge summarization, advertising and consumer analysis, and many others. The recognized k-method algorithm, which greatly utilized to the clustering difficulty, has the drawbacks of relying on the preliminary state of centroids and may just converge to the nearby optima alternatively than global optima. An information clustering algorithm centered on the gravitational search algorithm (GSA) is proposed in this research. On this algorithm, some candidate options for clustering main issue are created randomly and then have interaction with one one more via Newtons gravity regulation to search the crisis house. The efficiency of the presented algorithm is compared with three other recognized clustering algorithms, including k-means, genetic algorithm (GA), and particle swarm optimization algorithm (PSO) on four actual and standard datasets. Experimental results affirm that the GSA is a powerful and conceivable procedure for information clustering.

4. APPLICATION OF GSA ON FUZZY SYSTEM

In standard GSA the swarm measurement used to be regarded a regular price (50 for their experiments), and the robust quantity of objects was set to the swarm size and used to be diminished to at least one lineally. Additionally the gravitational coefficient was once decreased by means of an exponential function as equation (2) Linearly, exponentially, or other schedules for mathematically modeling the hunt procedure of a swarm intelligence algorithm is also valuable for tackling some benchmark features (as it used to be shown in [10]); but for fixing difficult engineering issues, this planning isn't sensible, most commonly. Seeing that in intricate optimization problems, like information mining, the search process of GSA is non-linear and really difficult and it's difficult if now not unimaginable, to model mathematically the quest procedure. As a consequence adjusting the GSA parameters with the aid of predefined mathematical models reduces the performance of GSA and it is going to lead to untimely convergence, local capturing, bad exploitation, bad exploration, etc.

Then again, some working out of the GSA search process has been collected, and linguistic description of its search system is available. This understanding and linguistic description make a fuzzy procedure a

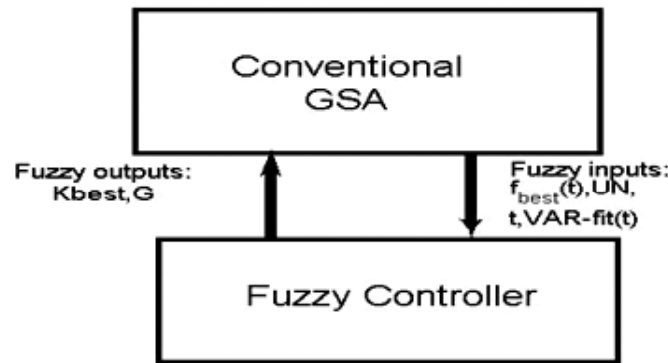


Figure 1: Block diagram of GSA

excellent candidate for controlling dynamically the GSA parameters. Correctly, fuzzy programs are the nice instruments for controlling elaborate procedure in engineering issues ([6], [7], and [8]). It will have to be acknowledged that the inspiration of controlling the hunt system of the bio inspired algorithms by fuzzy informed techniques, had been effectually applied

The fuzzy controller is built with three inputs and two outputs. The inputs are as follows:

- (1) $f_{best}(t)$: The maximum health value among the all objects in new release t .
- (2) UN : The quantity of iterations, which f_{best} is unchanged.
- (3) $VAR\ fit(t)$: The variance of the received fitnesses in generation t . UN is introduced as an input of fuzzy controller to know when the article method converged (or captured) to a nearby premiere and $VAR\ fit(t)$ is introduced as a metric of objects variety. Definitely giant values of $VAR\ fit(t)$ exhibit significant objects variety and vice versa.

Two outputs are:

- (1) $Kbest$: The number of strong plenty (objects).
- (2) G : The gravitational coefficient.

The next eight fuzzy rules will also be extracted from the linguistic descriptions in previous subsection, to manage intelligently the search approach of GSA:

1. IF UN is high, and $f_{best}(t)$ is low, THEN $Kbest$ is high and G is excessive.
2. IF $VAR\ fit(t)$ is medium, and UN is low, and $f_{best}(t)$ is medium, THEN $Kbest$ is low and G is medium.
3. IF $f_{best}(t)$ is medium, and UN is medium, THEN $Kbest$ is medium and G is medium.
4. IF UN is high and $f_{best}(t)$ is high, THEN $Kbest$ is low and G is low.
5. IF $f_{best}(t)$ is low and $VAR\ fit(t)$ is low, THEN $Kbest$ is high and G is excessive.
6. IF $f_{best}(t)$ is medium and $VAR\ match(t)$ is excessive, THEN $Kbest$ is excessive and G is medium.
7. IF $f_{best}(t)$ is high and $VAR\ match(t)$ is medium, THEN $Kbest$ is low and G is medium.
- (eight) IF $f_{best}(t)$ is excessive and $VAR\ fit(t)$ is high, THEN $Kbest$ is low and G is excessive.

Each and every of those principles has a precise duty to improve the effectiveness and powerfulness of GSA. For illustration recall the rule 5:

This rule is considered to restrict premature convergence or regional taking pictures. Suppose all of the lots had been located in an small discipline ($VAR\ fit(t)$ is low) and ineffective of resolution area ($f_{best}(t)$ is

low). Surely, the fuzzy controller should steer the plenty into higher and strong hypervolumes of the answer space. This is completed via the end result of this rule, the place the Kbest and G supply excessive values. The fuzzy controller has been designed with the above fuzzy rules and its normalized inputs and outputs membership capabilities are proven in determine 1 and determine 2, respectively. It have to be stated that one of a kind varieties of inputs, membership function shapes, membership operate locations and fuzzy rules is also offered and even these parameters can be optimized by another optimization algorithm

5. CONCLUSION AND FUTURE SCOPE

On this paper, the evolutions and applications of GSA have been presented. Headquartered on the assessment, the core work on GSA has been specializing in the algorithm and the appliance points. Despite the fact that GSA is still a latest algorithm, the development of the GSA related researches has been promising. At the time of writing, there are more than a few variants of GSA which had been developed and the algorithm has been applied in fixing quite a lot of issues corresponding to in neural community training, image processing, classification, clustering, multi-purpose optimization, networking, filter modeling, controller design and so forth. Headquartered on the evaluation, it is determined that GSA was once widely utilized in solving engineering issues notably in energy techniques issues and controller design.

The more than a few GSA variations had been proposed to overcome the weaknesses of GSA. Centered on the literature, the usual GSA has some weaknesses corresponding to using complicated operators and lengthy computational time. GSA also suffers from gradual browsing speed within the last iterations yet another hindrance is the difficulty for the suitable determination of gravitational steady parameter, G. The parameter controls the quest accuracy and does now not guarantee a world solution at all time.

Regardless of the weaknesses, GSA has been generally adapted due its ease of implementation and the potential to clear up totally nonlinear optimization problems of tricky engineering techniques .It has been reported that GSA might perform successfully in terms of CPU time and might produce result more continuously with larger precision]. GSA has been verified to outperform different optimization algorithms equivalent to PSO and ACO in terms of converging speed and neighborhood minima avoidance and could generate better pleasant answer within shorter computational time and stable convergence traits in comparison with PSO and GA

However, changes to the common GSA are nonetheless wanted to be done with a view to constantly fortify the algorithm efficiency. Despite the fact that quite a few Researches were executed on GSA, the algorithm nonetheless have various advantages for improvements. There are still extra enhancements could be accomplished to the constitution of GSA and there are a lot of feasible hybrid procedures might be explored. Future study should mix GSA with different optimization algorithms equivalent to ACO, synthetic Fish school Algorithm (AFSA), synthetic Immune process (AIS) and Differential Evolution (DE). Considering improving the algorithm is constantly an open difficulty, future research is predicted to provide new procedures with better efficiency

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