A brief overview of population-based optimization techniques and their applications post 2011

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***Abstract*-Naturally occurring phenomenon serves as an unbiased guide for solving various optimization problems. This paper compiles some of the population-based, stochastic optimization algorithms including the recently developed social impact theory based optimizer, SITO. The current state of research, including the natural phenomena followed by each and some of their applications to solve various optimization problems is illustrated. The applications after the year 2011 are covered. The efficiency and robustness of various algorithms explored herein, includes particle swarm optimization (PSO), harmony search (HS) and social impact theory based optimizer (SITO).**

***Keywords*-Optimization, Particle Swarm optimization, Harmony Search, Social Impact Theory Based Optimizer.**

I. INTRODUCTION

Optimization is an intelligent search problem in order to determine the best-suitable or optimal solution under a given set of constraints. Population based techniques are now been used extensively to solve various complex optimization problems due to their ability to explore the entire search space in order to find an effective solution. These algorithms use a set of population or agents that interact with each other to proceed towards a global optimal result iteratively.

Particle swarm optimization [1], mimics the behavior of swarms which scatter across the search space to find the best path to reach the destination. Harmony search involves finding an optimal solution by relating the problem with the improvising process of composing a piece of music, in order to produce a perfectly pleasing state of harmony [2]. The harmony in music can thus be used for solving optimization problems to obtain near optimal solution [3]. The more recently developed, social impact theory based optimization [4] is based on social behavior of humans and their impact on each other to reach to a single optimum opinion. The fundamental steps and working of each algorithm along with some of their applications after year 2011 are reviewed first and then the three techniques are compared. Due to limited number of applications of SITO available, to the best of authors knowledge the applications of SITO after year 2010 have been covered.

The paper is organized as Section 1 provides a brief introduction, Section 2 defines the complete process of Particle Swarm Optimization algorithm, Harmony search algorithm is discussed in Section 3, Section 4 demonstrates the working of Social Impact Theory based Optimizer, the four techniques are compared in Section 5 and Section 6 concludes the paper.

II. PARTICLE SWARM OPTIMIZATION (PSO)

- Particle swarm optimization, motivated by the social behavior exhibited by organisms such as birds (also based on evolutionary computing) was put forward by James Kennedy and R.C. Eberhart in 1995 [1]. The individual particles in the swarm represent the potential solutions and spread across the search space. The particles occupy a particular position and move with certain velocity and change their positions according to their previous best position and neighborhood best position to proceed towards the fitter position. Individual and global best fitnesses and positions are updated by comparing the newly evaluated fitnesses against the previous individual and global best fitnesses, and replacing the best fitnesses and positions as necessary [5]-[7].The particle swarm optimization uses two principles
- gbest (globalbest), the best fitness of entire population as a whole as each particle is affected by every other best performance particle.

- lbest (localbest), the best fitness of an individual and its k-nearest neighbors in the population.

The position of a particle is updated as:

$$X_i + 1 = X_i + V_i + 1 \quad (1)$$

where X_i = Particle position and V_i = Particle velocity

The velocity is calculated as:

$$V_i + 1 = V_i + C1R1(P_i - X_i) + C2R2(P_g - X_i) \quad (2)$$

where P_i=Best particle position, P_g=Best global position, C_i=Social parameters and R_i=Random number between 0 and 1. The velocity and the position update of the particles are mainly the determinants of the optimization problems and are updated until certain stopping condition is met such as number of iterations or the required optimum solution is obtained etc.

A. *Applications*

Year 2012

- On fast and accurate block-based motion estimation algorithms using particle swarm optimization
  A more accurate block matching algorithm has been proposed in [8]. In order to provide accurate motion estimation in particular context of video motion estimation with very low computational cost modifications in PSO is done.

- Optimum design of unbraced steel frames to LRFD–AISC using particle swarm optimization
  Optimum W sections are selected from 272 W-sections list for beams and columns of unbraced frame using PSO. In the design of algorithm various constraints are imposed as defined in [9].

- Application of Particle Swarm Optimization for Solving Optimal Generation Plant Location Problem
  The optimal generation location is determined in [10] to save overall fuel cost as well as the total emission and system losses. Initially the generator is placed in all the possible locations of the test system. The location giving the best results is then considered to be the optimum for installing the new generator.

- Predictive Driving Guidance of Full Electric Vehicles Using Particle Swarm Optimization
  PSO is used to optimally distribute energy between various electric vehicles (EV) taking into account battery autonomy, driving comfort indexes and travel time as objectives [11].

- Solving Routing Problem using Particle Swarm Optimization
  The entire network is partitioned into smaller networks and evaluated to find a single best solution with the objective of minimizing the cost of the path [12].

- An Efficient Resource Allocation Scheme Using Particle Swarm Optimization
  The behavior of PSO is emulated to enhance the performance of the system by optimal allocation of resources. The position of the particle is defined by a pair of points and forms a feasible solution if certain condition illustrated in [13] is satisfied.

- Cosmological parameter estimation using Particle Swarm Optimization (PSO)
  [14] considers identifying an optimal set of parameters that best fits the observational data. Six dimensional cosmological models are considered to determine the parameters from WMAP seven year data.

- Control System Design Using Particle Swarm Optimization (PSO)
  PSO is used for selecting efficient and robust weighting matrices for control system [15]. The technique is applied with the objective to design an optimal controller used for controlling induction motors, vehicular drive-shaft control, etc.

- Target Classification in Wireless Sensor Network Using Particle Swarm Optimization (PSO)
  After successful detection of target by the sensors, the targets are classified by extracting the discriminating features. The randomly selected features represent the particle position and the best fit particle with minimum distance is considered as the global best solution [16].

Year 2013

- Calibration of Three-Axis Magnetometer Using Stretching Particle Swarm Optimization Algorithm
  Stretching PSO (SPSO) is used for solving calibration problem and derives a model for sensor errors [17]. The developed algorithm searches for calibration parameters, providing a stable convergence.

- Radial Basis Function Network Training Using a Nonsymmetric Partition of the Input Space and Particle Swarm Optimization
  An integrated framework using both fuzzy model (FM) and PSO is used to determine the parameters of radial basis function (RBF) networks [18]. The combined

approach resulted in models with higher accuracy and reduced computational times.

- A novel multi-swarm algorithm for optimization in dynamic environments based on particle swarm optimization
  A novel algorithm based on the concept of PSO was developed in [19] For finding peaks and tracking them after a particular time period improved multi-swarm approach has been incorporated. A novel awakening–sleeping mechanism is also utilized for optimization in dynamic environment.

- A hybrid intelligent algorithm by combining particle swarm optimization with chaos searching technique for solving nonlinear bilevel programming problems
  Hybrid of PSO and Chaos Searching Technique (CST) is used for solving problems with two levels [20]. The CST is embedded in PSO to improve the worse particles. The front list particles are updated using PSO and the end list particles using CST.

III. HARMONY SEARCH (HS)

Harmony search (HS) is a powerful metaheuristic algorithm developed by Zong Woo Geem et al. in 2001 [3]. The HS algorithm is based on developing a perfect state of harmony by refining the improvisation process to generate the best pleasing music by various musicians. The musicians remember the best played previous notes and add new notes so as to generate more beautiful sounds and the same can be related to the optimization problems seeking the best fit solution [21].

When a musician is improvising, he or she has three possible choices: (1) play any famous piece of music (a series of pitches in harmony) exactly from his or her memory; (2) play something similar to a known piece (thus adjusting the pitch slightly); or (3) compose new or random notes. Zong Woo Geem et al. formalized these three options into quantitative optimization process in 2001, and the three corresponding components include: harmony memory, pitch adjustment and randomization [22].

The harmony memory is used to store the best new harmonies. A parameter, raccept is assigned to the memory to use it effectively which range between 0 and 1. To obtain correct solutions the value used is approximately between 0.7-0.95.

The next component, pitch adjustment is determined by brange and rpa, the pitch bandwidth and pitch adjustment rate respectively. Practically the pitch is adjusted linearly as

$$pnew = pold + brange * \omega \qquad (3)$$

where *pnew* = pitch after adjustment, *pold* = existing solution (pitch) in harmony memory and ω = random number varying between 1 and -1. The last component, randomization is included to incorporate diversity in solution space to further divert towards global optimality. The probability of randomization is

$$P_r = 1 - raccept \qquad (4)$$

$$P_p = raccept * rpa \qquad (5)$$

where P_r is the randomization probability and P_p is the pitches adjusting probability. Below Table 1 connects HS algorithm and optimization process.

TABLE I

RELATION OF HARMONY SEARCH ALGORITHM AND OPTIMIZATION

HARMONIC SEARCH	OPTIMIATION PROCESS
Aesthetics	Objective
Instruments	Decision variable
Notes	Value of variable
Pitch range	Solution set
Harmony	Best value range or solution
Experience	Memory
Practice	Iterations

A. *Applications*

Year2012

- A coevolutionary differential evolution with harmony search for reliability–redundancy optimization
  HS along with differential evolution is used to solve reliability-redundancy problem. The problem is divided into two parts continuous and integer part [23]. The integer part is evolved by means of HS.

- Broadcast scheduling in packet radio networks using Harmony Search algorithm
  Broadcast scheduling problem in packet radio networks is solved using HS. Optimal TDMA frame length with very low computational time is found [24].

- Feature Selection With Harmony Search
  Good- quality subsets with compact size are being identified in [25]. Using HS for feature selection resulted in fast convergence, simplicity and efficiency in finding minimal subsets.

- An Elite Decision Making Harmony Search Algorithm for Optimization Problem
  Some probability rule is used in [26] to generate new solutions from global best and second best solutions.

The fitter solution replaces the less fit one and is repeated until a solution near to optimum is obtained.

- Network partitioning using harmony search and equivalencing for distributed computing
  Efficient partitioning of distributed applications requires minimizing the number of tie lines between clusters while maintaining a balance between them. The proposed algorithm tries to achieve the above said objectives in [27].

- Global best harmony search with a new pitch adjustment designed for Nurse Rostering
  HS is applied for optimal assignment of a set of nurses with different skills and contracts to different types of shifts, over a predefined period. To tackle Nurse Rostering problem two main improvements have been made to HS [28].

- Edge preserving image enhancement via Harmony Search Algorithm
  The various iterations using harmony search algorithms tries to boost the relative number of edges in the image, enhance the overall intensity of edges and improve the entropy measure in the image. The fitness measure proposed by Munteanu and Rosa [29] is used to measure the fitness of the solution set.

- Harmony search to solve the container storage problem with different container types
  The main objective is to optimize the container arrangement so as to minimize the container load/unload operations. Different size and types of containers considered are defined in [30]

- Image Compression Using Harmony Search Algorithm
  The variance for each red, green and blue component of an image is determined using equation in [31]. It is assumed that the least variance values would lead to a compressed image without much visual information loss.

- Application of the Harmony Search optimization algorithm for the solution of the multiple dam system scheduling
  This paper [32] aims to maximize the daily benefits gained from a reservoir system. The quantity of water unit flowing out of each reservoir is considered as decision variable.

Year2012

- Hybridization of Harmony Search and Ant Colony Optimization for optimal locating of structural dampers
  A hybrid technique using Hs and two concepts borrowed from Ant Colony Optimization is used to find optimal locations for dampers within a structural system [33].

- One-way urban traffic reconfiguration using a multi-objective harmony search approach
  Optimal alternative directions to improve traffic mobility after major road problem is provided in [34] using multi-objective HS. The focus is on reconfiguration of one-way roads in a city so as to optimize transportation networks.

- HSA based solution to the UC problem
  HS is tested on both large and small scale unit commitment (UC) problems and it is concluded that the applied method is powerful enough to solve both the problems. The scheduling of the units satisfied the constraints without any violation [35].

- A harmony search algorithm for nurse rostering problems
  Optimal workload to the available staff nurses at healthcare organizations meeting the operational requirements and a range of preferences has been allocated [36].

- Power Loss Minimization in Distribution System Using Network Reconfiguration in the Presence of Distributed Generation
  Identifying optimal locations for installation of distributed generation (DG) units with an objective of minimizing real power loss and improving voltage profile in distribution system has been presented [37].

- Optimal power flow solution using improved harmony search method
  Five standard IEEE test systems are employed to test the proposed algorithms designed using improved HS to solve optimal power flow (OPF) problem [38].

IV. SOCIAL IMPACT THEORY BASED OPTIMIZER (SITO)

Social Impact Theory based Optimizer (SITO) is a binary population-based meta-heuristic algorithm that mimics human behavior, feelings and thoughts for optimization process. It is based on social psychology of humans and investigates the impact of a group of people on an individual in the society. The first version of this novel optimizer was developed in 2006 and is based on Dynamic theory of social impact by Latane' [39]. According to Latane', social impact is defined as any influence on individual feelings, thoughts, behavior that is exerted by the real, implied or imagined presence of others. This impact may result in change in the attitude of the individual. The individual may be persuaded by the society or the society may support the individual. Thus, the individual will change the attitude if the persuasive impact dominates the supportive one. The likelihood that the individual will be affected by the society depends on three factors:

- Strength
  Strength is defined as the ability of a person to influence other individuals. The strength is determined by the fitness value of an individual. Better the fitness, stronger the individual.
- Immediacy
  Immediacy defines the spatial distance between influencing individuals. Closer the individuals more will be the influence.
- Number
  The number defines how many individuals influence a person in the group. More the number, increased will be the impact.

After a desired number of iterations, the population starts converging to a common attitude or fitness. The individuals represent the candidate solution c_i. Each solution holds multiple attitudes along different dimensions represented by binary vector $\{0, 1\}^D$. Fitness value, f_i and a strength parameter, s_i is associated with each individual. The fitness is computed using some cost function, $f_i = f(c_i)$. Further, three variants of SITO are discussed.

A. Original SITO (Osito)

In Osito, the cost-strength mapping is given by

$$s_i = \frac{f_{max} - f_i}{f_{max} - f_{min}} \tag{6}$$

where f_{max} is the maximum value of cost function and f_{min} is the minimum value of cost function

The impact is calculated as persuasive or supportive. The persuasive impact is given by:

$$I_i^P = \frac{1}{\sqrt{|P_i|}} \sum_{j \in P_i} \frac{q_j}{{\delta_{ji}}^2} \tag{7}$$

and the supportive impact is given by:

$$I_i^S = \frac{1}{\sqrt{|S_i|}} \sum_{j \in S_i} \frac{q_j}{{\delta_{ji}}^2} \tag{8}$$

where P_i denotes number of persuaders in the neighborhood of an individual, S_i denotes number of supporters in the neighborhood of an individual and δ_{ji} denotes Euclidean distance between two individuals. Impact is inversely proportional to square of Euclidean distance between two individuals so closer the individual more would be its impact. If there are no supporters or persuaders of an individual than impact will be zero.

B. Simplified SITO (Ssito)

The strength can also be computed by analyzing the impact of one individual on other and can be associated with a pair of individuals [40]. The mapping done in simplified SITO (Ssito) algorithm is as:

$$s_{ij} = max(f_j - f_i, 0) \tag{9}$$

where f_i and f_j are the cost values of individual i and j respectively. In Ssito, there are two different update rules:

SUM rule: In this strength of supporters and persuaders is summed up.
Net Impact is given by:

$$I_i = \sum_{j \in P_i} q_{ji} - \sum_{j \in S_i} q_{ji} \tag{10}$$

P_i denotes number of persuaders in the neighborhood of an individual and S_i denotes number of supporters in the neighborhood of an individual.

MEAN rule: Mean of the supporters or persuaders is computed.
Net Impact is given by:

$$I_i = \frac{1}{|N_p|} \sum_{j \in P_i} q_{ji} - \frac{1}{|N_s|} \sum_{j \in S_i} q_{ji} \tag{11}$$

N_p denote number of persuaders and N_s denote number of supporters.

C. Galam SITO (Gsito)

This variant is based on Galam model [41], in which individuals interact in groups of random sizes. Further, the strength is computed using equation (8) of Osito and impact is calculated using Ssito equations (10), (11).

D. Applications

There are very few applications of SITO available till date to the best of author's knowledge due to its recent development. So, the applications of SITO starting form year 2011 are included. But with the growing pace the use of this human opinion based algorithm may help to obtain more satisfactory results as compared to genetic and other binary particle swarm algorithms.

Year2011

- Simplified Social Impact Theory Based Optimizer in Feature Subset Selection
  The SITO algorithm is used for dimensionality reduction to remove noisy and irrelevant dimensions. The method is applied on four data sets from UCI machine learning repository and the results are compared with binary particle swarm optimization algorithm [42]. The SITO algorithm is found to be more powerful than the later algorithm.

- A novel approach using dynamic social impact theory for optimization of impedance-tongue (iTongue)
  The Social Impact Theory based optimizer has been used for classification of samples collected from single batch production of Kangra orthodox black tea [43].

Year2012

- Enhancing electronic nose performance: A novel feature selection approach using dynamic social impact theory and moving window time slicing for classification of Kangra orthodox black tea (Camellia sinensis (L.) O. Kuntze)
  In [44], SITO is used in conjunction with principal component analysis (PCA) and support vector machines (SVMs) classifier for classification of samples collected from the single batch production of Kangra orthodox black tea.

- Linear Bayes Classification for Mortality Prediction
  The features for simple byes Classifier used for ICU patients mortality prediction are selected using SSITO variant of SITO in [45]

- Binary Social Impact Theory based Optimization and Its Applications in Pattern Recognition
  In [46] recent applications of SITO algorithms for pattern recognition in electronic nose, electronic tongue, new born EEG and ICU patient mortality prediction are discussed.

V. Comparison

Table 2. compares the three techniques discussed in this paper.

TABLE II

COMPARISON OF THE THREE TECHNIQUES

Parameters	PSO	HS	SITO
Year	1995	2001	2006
Structural Components	Organisms (birds, flocks, fishes)	Music	Individuals (humans)
Decision variables	Position and Velocity	Notes	Attitudes
Dynamics	Evolution	Improvisation	Social impact
Inspiration	Best path	Pleasing harmony	Variation in human behavior

VI. Conclusion

Connecting natural phenomena with computing have gifted researchers with more efficient and improved capabilities to solve different optimization problems. With the increase in use and effectiveness of nature-inspired optimization algorithms, many techniques mimicking natural processes have been developed. The study presented in this paper, tends to discuss some of the algorithms starting from the earlier developed Evolutionary Algorithms, then mid-age Particle swarm optimization and harmony search and the recently developed Social optimization algorithm, Social Impact Theory Based Optimizer. Astonishing results employing the natural techniques have been obtained. The main properties of algorithms that lead to the alarming results are (1) each uses a population of local solutions i.e., every solution in the search space is selected for further processing, (2) the relative effectiveness of each solution is measured to select the local best solutions (3) accelerate towards the global best solution using the local best solutions.

Further, different optimization problems solved employing these techniques have been demonstrated. Due to wide diversity of applications available and to demonstrate the current state of research, the authors have covered the areas of application starting from year 2012 i.e. post 2011 of the two techniques. Due to limited use of SITO till now, all the application known to the best of the authors knowledge have been illustrated. It has been observed that the results obtained using SITO outperformed against PSO and genetic algorithms. Finally, the techniques are compared using different parameters. Once again, a technique using natural phenomena, human thinking process is developed which have not yet been widely explored but can be employed to obtain more satisfactory results.

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