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Particle Swarm Optimization: A Survey

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Abstract
The particle swarm optimization (PSO) algorithm popularity has been increased in the last few years. PSO is relatively simple and reported good results in continuous optimization problems. This paper presents concepts of PSO along with mathematical model and advances in research work using PSO. Also comparison of PSO with other evolutionary algorithms such as Genetic algorithm is also presented.Applications of PSO in different domain are also presented.

Keyword:
Particle Swarm Optimization (PSO), Genetic Algorithm (GA), glb_best, per_best

1. INTRODUCTION TO SWARM INTELLIGENCE

Swarm is a large group of insects, moving around together. Swarm Intelligence(SI) is an approach used for problem solving by taking inspiration from the social behavior, dynamic movements with communications of insects and of other animals or birds.Swarm intelligence is the collective behaviour of decentralized, self-organized natural or artificial systems.SI systems represents a population of simple agents cooperatinglocally with one another and with their environment. The motivation often comes from nature, mainly biological systems. The agents follow very simple rules, and although there is no central control structure ordering how distinct agents should perform, local, and to a certain degree random, interactions between such agents lead to the arrival of "intelligent" global behaviour, unidentified to the individual agents. Examples of swarm intelligence in natural systems include ant colonies, bird flocking, animal herding, fish schooling etc.

PSO:

Particle Swarm Optimization (PSO) is inspired from the nature social behavior and dynamic movements with communications of insects, birds and fish. In the PSO algorithm, individuals searching for solutions to a given problem learn from their own past experience and from the experiences of others. Individuals evaluate themselves, compare to their neighbors and imitate only those neighbors who are superior to themselves.

Important steps of PSO algorithm:

a. Evaluation of fitness of each particle
b. Update individual best of each particle
c. Update global best
d. Update velocity and position of each particle

These steps are repeated until some stopping condition is met.

2. CONCEPTS AND ALGORITHM

- Uses a number of agents (particles) that constitute a swarm moving around in the search space looking for the best solution
- Each particle in search space adjusts its “flying” according to its own flying experience as well as the flying experience of other particles
- Collection of flying particles (swarm) - Changing solutions
- Search area is a collection of all Possible solutions
- Movement towards a promising area to get the global optimum
- Each particle keeps track:
  - its best solution, personal best, *per_best*
  - the best value of any particle, global best, *glb_best*
- Each particle adjusts its travelling speed dynamically corresponding to the flying experiences of itself and its colleagues

- A particle will move in a certain direction as a function of its current position x_i *(t)*, its velocity v_i *(t +1)*, the location of the particle's best success so far per_best$_i$, and theglb_best
- x_i *(t* + 1*)* = *f* (x_i *(t),* v_i *(t* + 1*),* per_best$_i$ *, glb_best*).
- Each particle modifies its position according to:
  - its current position
  - its current velocity
  - the distance between its current position and *per_best*
  - the distance between its current position and *glb_best*

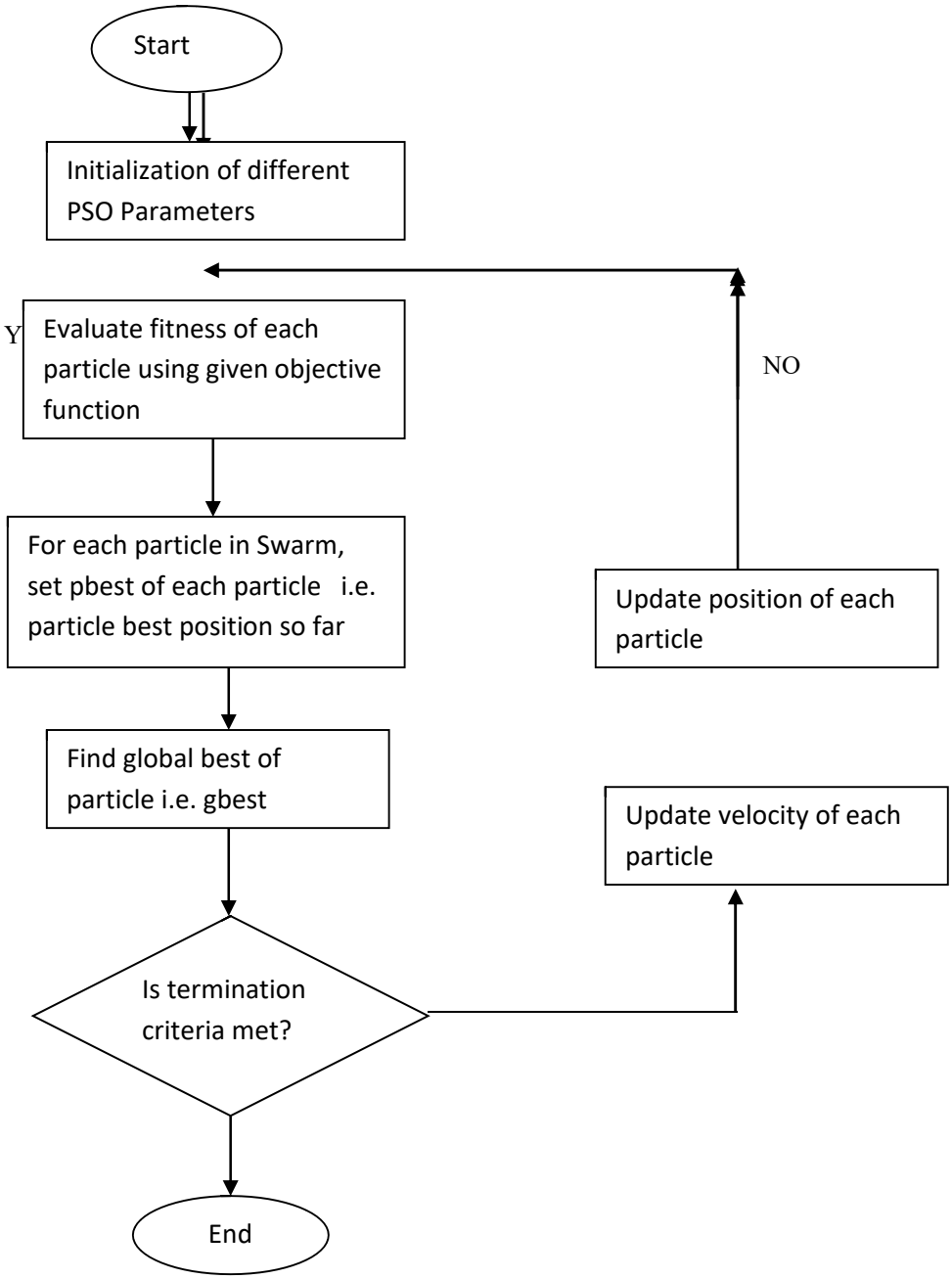

Figure2: Flowchart of PSO

Algorithm: Particle Swarm Optimization

1. Initialize Particle position x_i and velocity v_i for each particle in swarm, Define objective function f(x), Initialize per_best for each particle (Initially $pbest_i = x_{i \text{ for each particle}}$)

2. For i=1 to N (total number of particles in swarm)
- Evaluate objective function f(x)
  $f_i = f(x_i)$

- If $f_i > f(per\_best_i)$ then update per_best_i (personal best position)

  $per\_best_i = x_i$
  End

3. Find maximum $f(per\_best_i)$ value amongst all particles and set glb_best (global best position)

   $glb\_best = per\_best_i$ for which $f(per\_best_i)$ is maximum [for i=1 to N]

4. Fori=1 to N i.e. for each particle x_i in swarm, update velocity and particle position

   $velocity_i = velocity_i + constant_1 * random1 * (per\_best_i - x_i) + constant_2 * random2 * (glb\_best - x_i)$;

   $x_i = x_i + velocity_i$;
   [where $constant_1$ weight of local information and $constant_2$ weight of global information, random1 and random2are random variable]

   Endof for
5. If termination criteria satisfied (as per application) goto step 6 otherwise gotostep 2.

6. Stop.

3. MATHEMATICAL MODEL FOR PSO

A mathematical function f(x) –x2+5x+20 with constraints -10<=x<=10. Using 9 particles with initial position x1= -9.6, x2=-6, x3=-2.6, x4= -1.1, x5=0.6,x6=2.3, x7=2.8, x8=8.3, and x9=10. Our aim is to maximize f(x).
At t=0, objective function value is f1=-120.16, f2=-46,f3=0.24,f4=13.29,f5=22.64, f6=26.21, f7=26.16, f8=-7.39,f9=-30. If c1=c2=1
Then initial velocities for each particle will be zero.
At t=1, Personal best for each particle will be position pbest1= -9.6, pbest2=-6, pbest3=-2.6, pbest4= -1.1, pbest5=0.6, pbest6=2.3, pbest7=2.8, pbest8=8.3, and pbest9=10.
Global best will be position for which f(x) is maximum. Gbest=2.3.
Iteration will continue until we reach to maximum value of fitness function f(x).

4. RECENT RESEARCH WORK USING PSO

Forecasting task can be solved using PSO. In paper[1], the upcoming energy requirement of the state of Tamil Nadu in India, is forecasted using an artificial neural network (ANN) and it is optimized by particle swarm optimization (PSO) and by Genetic Algorithm (GA). Hybrid ANN model is used for forecasting. Results obtained using the hybrid models are compared with those of the ARIMA, hybrid ANN-GA, ANN-BP and linear models. Both PSO and GA have been developed in linear and quadratic forms and the hybrid ANN models have been applied to five-time series. Amongst the entire hybrid ANN models, ANN-PSO models are the best fit models in all the time series based on RMSE and MAPE.
In paper[2],prediction of number of deaths due to Covid 19 is presented. Using logistic function inferring of the number of deaths done. An estimation of the parameters of the proposed model is obtained using a Particle Swarm Optimization algorithm (PSO) that requires iteratively solving a quadratic programming problem. In addition to the total number of deaths and number of infected cases, the model enables the estimation of the infection fatality rate (IFR). Furthermore, using some mild assumptions, we derive estimates of the number of active cases.
Paper[3] presents a susceptible-exposed-infected-quarantinedrecovered-dead (SEIQRD) model to predict the spread of the disease in Italy in the near future. The prediction is based on formulating the SEIQRD model using one year

statistics of the disease. The parameters of the model are estimated using particle swarm optimization (PSO) algorithm.

In [4] study has been motivated by golf ball actionsthroughout the game to increase particle swarm optimization. Because, all actions from the first to the last move of the golf ball are the moves made by the player to win the game. Winning this game is also a result of successful execution of the chosen moves. Therefore, the actions of the golf ball are also an optimization, and this has a meaning in the scientific world. In this sense, the actions of the particles in the PSO algorithm have been related with the movements of the golf ball in the game. Thus, the velocities of the particles have transformed to parabolically descendent structure as they approach the goal. In this way, the result obtained is improved thousands of times with very small movements. For the application of the proposed new technique, the inverse kinematics design of the 7-joint robot arm has been done and the outcomes have been compared with the traditional PSO.

PSO algorithm can be used for medical disease detection. Diseases are grouped into ten categories. (i)Heart Disease(ii)Dental Disease(iii)Lymphatic Diseases(iv)Celiac Disease (CD)(v)Liver Disease(vi)Cancer Disease(vii)Brain Disease(viii)Hepatitis Disease(ix)Diabetes(x)Others [8].

5. COMPARISON OF PSO WITH OTHER EVOLUTIONARY ALGORITHMS

Genetic Algorithm is discrete whereas PSO is continuous in nature. Unlike GA, the variables in PSO can take any values based on their current position in the particle space and the corresponding velocity vector. Genetic algorithms do not handle complexity in an efficient way, because in such cases the number of elements undergoing mutation in very large which causes a considerable increase in the search space. So, in this case PSO is the best substitute as it requires lesser number of factors and lesser number of repetitions. GA usually converges towards a local optimum or even random points rather than the global optimum of the problem while as PSO tries to find the global optima.

Table 1 [6].

Qualitative comparison of Genetic Algorithm (GA) and PSO:

Sr. no.	Parameters for comparison	Genetic Algorithm	PSO
1	Ability to reach good solution without local search	Less	More
2	Progressof convergence using Homogeneous sub-grouping	True	True
3	Continuousness of search space	Less	More
4	Premature convergence	Medium	High
5	Average fitness cannot get inferior	False	False
6	Impact of best solution on population	Average	Best
7	Impact of population size on solution time	Exponential	Linear
8	Ranking of solution is required	True	False

6. APPLICATIONS

Different type of problems in the diverse areas of science can be solved using PSO. In medical diagnosis and health care problems PSO is providing promising solution. In economic science to optimize risk in investment portfolios PSO can be used. In engineering field PSO can be used to increase heat transfer of system and to predict heat transfer coefficient. Use of PSO in thermodynamics is also increasing rapidly. PSO has also been used for geometric optimization problems in order to find the best system configurations that best fit the design constraints. PSO is able to deal with a broad range of problems.

7. CONCLUSION

PSO has been extensively accepted to solve real-world nonlinear complex optimization problems in different domains. This study presented systematic view of PSO algorithm. Also recent research work in the area has been discussed. Applications in varies domain is also covered.

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