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Levy Differential Evolutionary Particle Swarm Optimization (LEVY DEEPSO)

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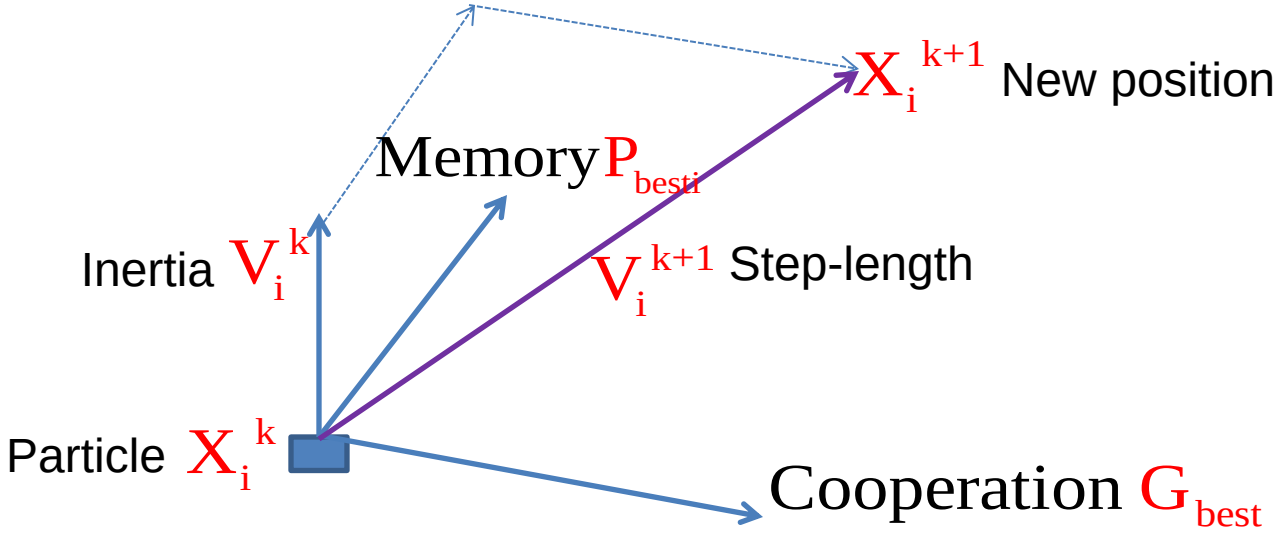
Particle Swarm Optimization[1]

- Particles: Possible solutions in the feasible space
- Velocity (Step-length) of a particle i:

$$V_i^{k+1} = w_I . V_i^k + R_1 . w_M . (P_{besti} - X_i^k) + R_2 . w_C . (G_{best} - X_i^k)$$



Particle Swarm Optimization

- Velocity of a particle is influenced by:

(1) Inertia

Follow in the same direction

(2) Personal memory

Follow particle's personal best obtained so far

(3) Cooperation

Follow the global best particle

Particle Swarm Optimization

- New position of a particle I:

$$X_i^{k+1} = X_i^k + V_i^{k+1}$$

Differential Evolutionary PSO (DEEPSO)[2]

- Velocity updating rule:

$$V_i^{k+1} = w_I^* . V_i^k + w_M^* . (X_{r1} - X_i^k) + w_C^* . P . (G_{best}^* - X_i^k)$$

(1) Inertia

Follow the same direction

(2) Perception

Follow the randomly sampled particle chosen from the matrix of individual past bests

(3) Cooperation

Follow the mutated global best particle

DEEPSO

- Each weight and global best particle are subject to mutation as follows

$$W^{*} = W(1+\tau.N[0,1])$$

- P= communication probability
- Allow communication $\Leftrightarrow$ rand()<P

Research challenge

- Optimization involves….
- Global Exploration: To explore unknown and large-scale search space
- Local Exploitation

Levy flight (Step)[3]

- Levy flight: It is a random walk whose step length is drawn from the Levy distribution.
- Levy distribution is defined as follows:
-

$$L(s,\gamma,\mu)=\begin{cases}\sqrt{\frac{\gamma}{2\Pi}}.\exp\left[-\frac{\gamma}{2(s-\mu)}\right].\frac{1}{(s-\mu)^{3/2}}, & 0<\mu<s<\infty \\ 0 & \text{otherwise}\end{cases}$$

where,

$\mu>0$ is a minimum step

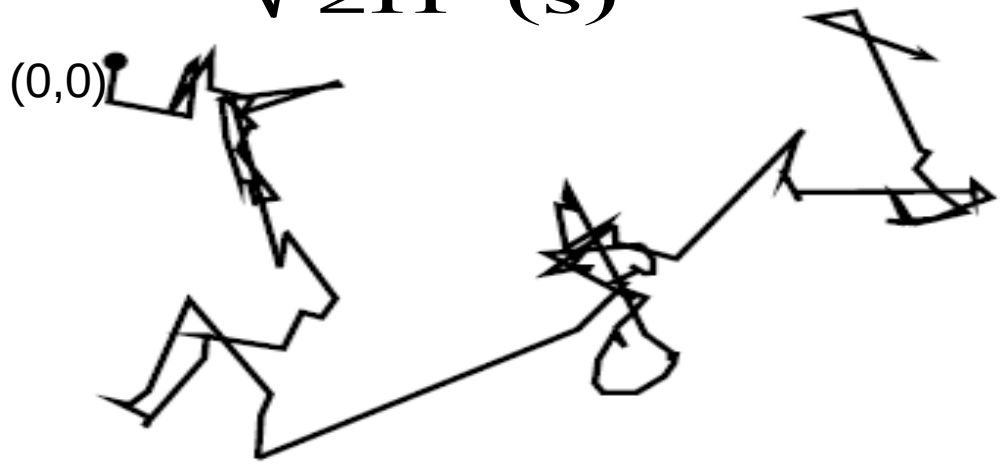
γ is a scale parameter

Levy flight (Step) cont..

- Generalized Levy distribution:

$$\text{as } s \to \infty,$$

$$L(s,\gamma,\mu) \approx \sqrt{\frac{\gamma}{2\Pi}} \cdot \frac{1}{(s)^{3/2}}$$



- Levy flights in 50 consecutive steps starting at origin(0,0)[3]

Levy Step cont....

- Many animals (e.g. Silky sharks and swordfish) and insects make use of Levy flights to search the food. [4]
- Light can be related to levy flight[5]

Mathematical formulations of Levy step [3]

$$\text{Step length} = \frac{u}{|v|^{1/\beta}}$$

where,

$\beta = 3/2$;

u and v are drawn from normal distributions as follows

$$u \sim N(0, \sigma_u^2)$$

where,

$$\sigma_u = \left\{ \frac{\Gamma(1+\beta) * \sin(\Pi * \beta/2)}{\Gamma[(1+\beta)/2] * \beta * 2^{(\beta-1)/2}} \right\}^{1/\beta}$$

$$v \sim N(0, \sigma_v^2)$$

where

$$\sigma_v = 1$$

$$Levystep=\alpha*step\ length*(X_i^k - G_{best})$$

where,

α=Levy_constant

α=(mean(Xmax-Xmin))/100;

Levy Differential Evolutionary Particle Swarm Optimization (LEVY DEEPSO)

- **Proposed Velocity updating rule:**

$$V_i^{k+1} = w_I^* . V_i^k + w_M^* . (X_{r1} - X_i^k) + w_C^* . P . (G_{best}^* - X_i^k)$$

$$+ \alpha . \frac{u}{|v|^{1/\beta}} . (X_i^k - G_{best})$$

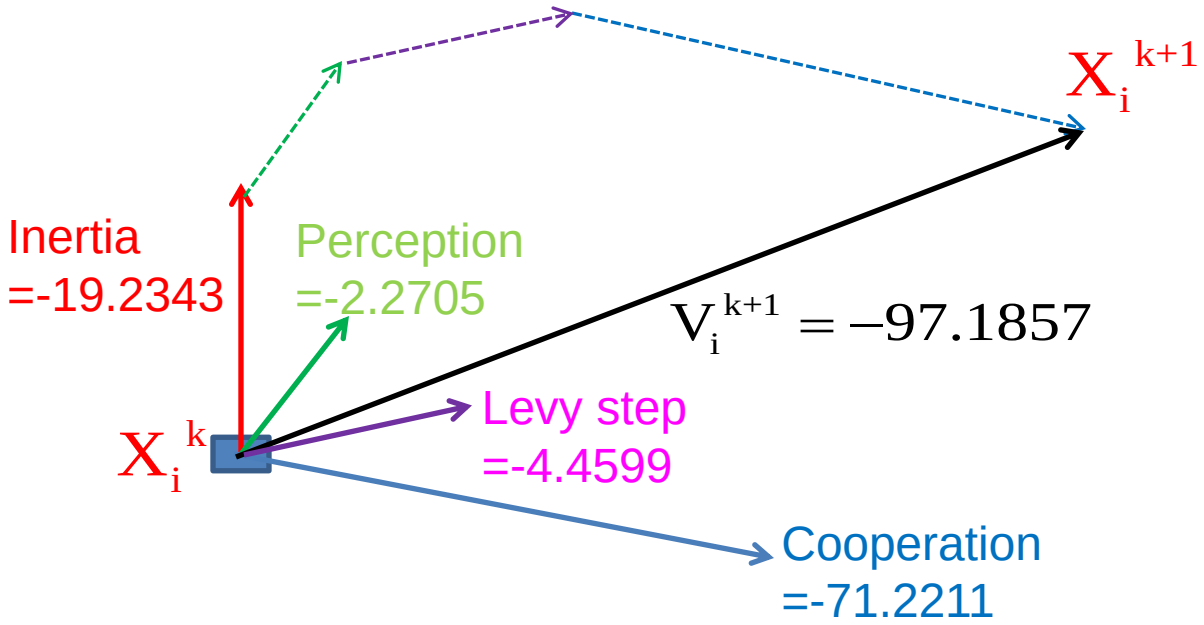
(1) Inertia

(2) Perception

(3) Cooperation

(4) Levy step

Velocity components of WT-2 active output power (Case-1)



Levy DEEPSO parameters

Parameters	Symbol	Numerical value
Populations size	N	100
Levy Exponent	β	1.5 (Levy distribution)
		1 (Cauchy distribution)
		2 (Normal distribution)
Levy Coefficient	σ_u	0.6966
Mutation Rate	τ	0.5
Communication Probability	P	0.5

OPF Constraints

- Equality constraints: Power balance equations
- Inequality constraints:
- Max. active power output of slack generator
- Nodal voltages and load angles for load buses
- Generator reactive power capability
- Allowable branch power flows

Constraint Handling Method

- Select the maximum of the average sum of deviations at iteration T [6]

$$\max\left(\frac{1}{T\text{-}1}\sum_{t=1}^{T-1}\sum\left|\Delta P_{t-1}\right|,\frac{1}{T\text{-}1}\sum_{t=1}^{T-1}\sum\left|\Delta V_{t-1}\right|,\frac{1}{T\text{-}1}\sum_{t=1}^{T-1}\sum\left|\Delta Q_{t-1}\right|,\frac{1}{T\text{-}1}\sum_{t=1}^{T-1}\sum\left|\Delta S_{t-1}\right|\right)$$

Simulation Results: Test bed 1

- MATLAB 2014a, Intel core i7-2600 CPU with 8.00 GB RAM
- Cases:1 & 4:- IEEE 57-bus system with 3 wind generators.

Stats.	Case:1	Case:4
fbest	72683.2050000	72899.2898699
o@fbest	72683.2030000	72899.2878940
g@fbest	0.0020000	0.0019759
fworst	72711.0200000	72946.6329200
fmean	72693.4419032	72910.9009446
fmedian	72691.7280000	72908.5313215
fstd	7.8654229	11.0157609

Simulation Results cont....

- Cases:2 & 5:- IEEE 57-bus system with 2 wind generators and 01 solar generator.

Stats.	Case:2	Case:5
fbest	72046.6066509	71689.7826879
o@fbest	72046.6001290	71689.7807285
g@fbest	0.0065219	0.0019594
fworst	72087.6270438	71731.3254569
fmean	72064.9103084	71700.9445623
fmedian	72066.6457403	71696.0686322
fstd	10.7606750	10.55165807

Simulation Results cont....

- Cases:3 & 6:- IEEE 57-bus system with 01 wind generator and 02 solar and small-hydro generators.

Stats.	Case:3	Case:6
fbest	60285.5868115	61278.5378234
o@fbest	60285.5842623	61278.5359725
g@fbest	0.0025492	0.0018509
fworst	60333.8249495	61326.3446038
fmean	60299.3470939	61292.5909826
fmedian	60297.0594339	61289.4746795
fstd	12.106446	10.7437215

References

[1] J. Kennedy and R. Eberhart, “Particle Swarm Optimization”, *proceedings of IEEE International Conference on Neural Networks (ICNN’95)*, vol. IV, Perth, Australia, 1995, PP. 1942-1948.

[2] V. Miranda and R. Alves, “Differential Evolutionary Particle Swarm Optimization(DEEPSO): A successful hybrid”, *proceedings of 2013 BRICS Congress on Computational Intelligence & 11th Brazilian congress on Computational Intelligence,* Ipojuca, Brazil, Sept. 2013, pp. 368-374.

[3] X S Yang, “Random Walks and Levy Flights”, in *Nature Inspired Meta-heuristic algorithms,* vol. 2, U.K., Luniver Press, 2010, pp. 11-19.

[4] Brown C. Liebovitch and L.S. Glendon, “Levy flights in Dobe Ju/’hoansi foraging patterns”, *Human Ecol.,* vol. 35, pp. 129-138, 2007.

[5] Barthelemy P., Bertolotti J., and Wiersma D. S., “A Levy flight for light”, *Nature,* vol. 453, pp. 495-498, 2008.

[6] V. Miranda and Leonel Carvalho (2014), “DEEPSO Evolutionary Swarms in the OPF challenge”, [online] Available http://sites.ieee.org/psace-mho/panels-and-competitions-2014-opf-problems/, pp. 16.