CAT SWARM OPTIMIZATION: THEORY AND APPLICATION TO DIRECT AND INVERSE MODELING

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OUTLINE

- Cats' behavior
- Cat Swarm Optimization
- Direct Modeling
- Inverse Modeling
- Simulation Results
- Conclusion

CATS' BEHAVIOR

- Chu and Tsai (2007)
- Rest indolently most of the time when they are awake.
- Move speedily when they are tracing some targets.
- Curious about all kinds of moving things.

CAT SWARM OPTIMIZATION

- Solution Set -- Cats:
  - M-dimensional Position.
  - Velocities for each dimension.
  - A fitness value.
  - Seeking/Tracing flag.

Cat Swarm Optimization

- Sub-models:

  - Seeking Mode:
    - To model the situation where the cat is resting, looking around and seeking the next position to move to.

  - Tracing Mode:
    - To model the situation where the cat is tracing some targets.

CAT SWARM OPTIMIZATION

1. Initialize the position matrix for N-cats (NxM) where M is the number of variables to be optimized and values are in the range (0,1)
2. Initialize the velocity matrix (NxM) with values in the range (0,1)
3. Evaluate the fitness value of each of the N cats.
4. Cat with best fitness acts as the gbest
5. Define a Mixture ratio (MR) between 0 and 1 (say 0.2)
   - It means that
     - 80% (i.e 0.8 N) randomly selected will be in seeking mode
     - Rest 20% (i.e 0.2 N) will be in tracing mode

4. ## Seeking Mode Operation

- Copy (SMP) number of cats out of a single cat. [SMP : Seeking Memory Pool]
  - SMP : It is the number of copies of a cat to be produced in seeking mode.
- Out of these cats, randomly choose a cat and go to one (if CDC = 1) of its random dimension (variable). [CDC : Counts of Dimensions to Change]
  - CDC : Out of M dimensions of a cat, CDC dimensions are randomly changed. In the present case CDC=1.
- Change the magnitude of that dimension by (SRD) percentage : Mutation. [SRD : Seeking Range of selected Dimension]
  - SRD : It is the maximum difference between the new and old values in the dimension selected for mutation
- Repeat it for all the copied cats.
- Evaluate the fitness value of each position modified cats.
- The best fitted cat is retained and the remaining are discarded.
- Repeat it for all seeking mode cats.
- In this way, again 0.8N new cats are created out of seeking operations.

5. Tracing Mode Operation

- The remaining 0.2N are under tracing mode.
- They follow PSO steps without using personal best (Pbest) values.
- Evaluate the fitness value of each of 0.2N cats
- Find the global best position (gbest) of these cats.
- Using initial positions and gbest value, update the velocity of each cat [Update velocity matrix]

$$v_{k,d} = v_{k,d} + r_1 \times c_1 \times \left(x_{gbest,d} - x_{k,d}\right)$$

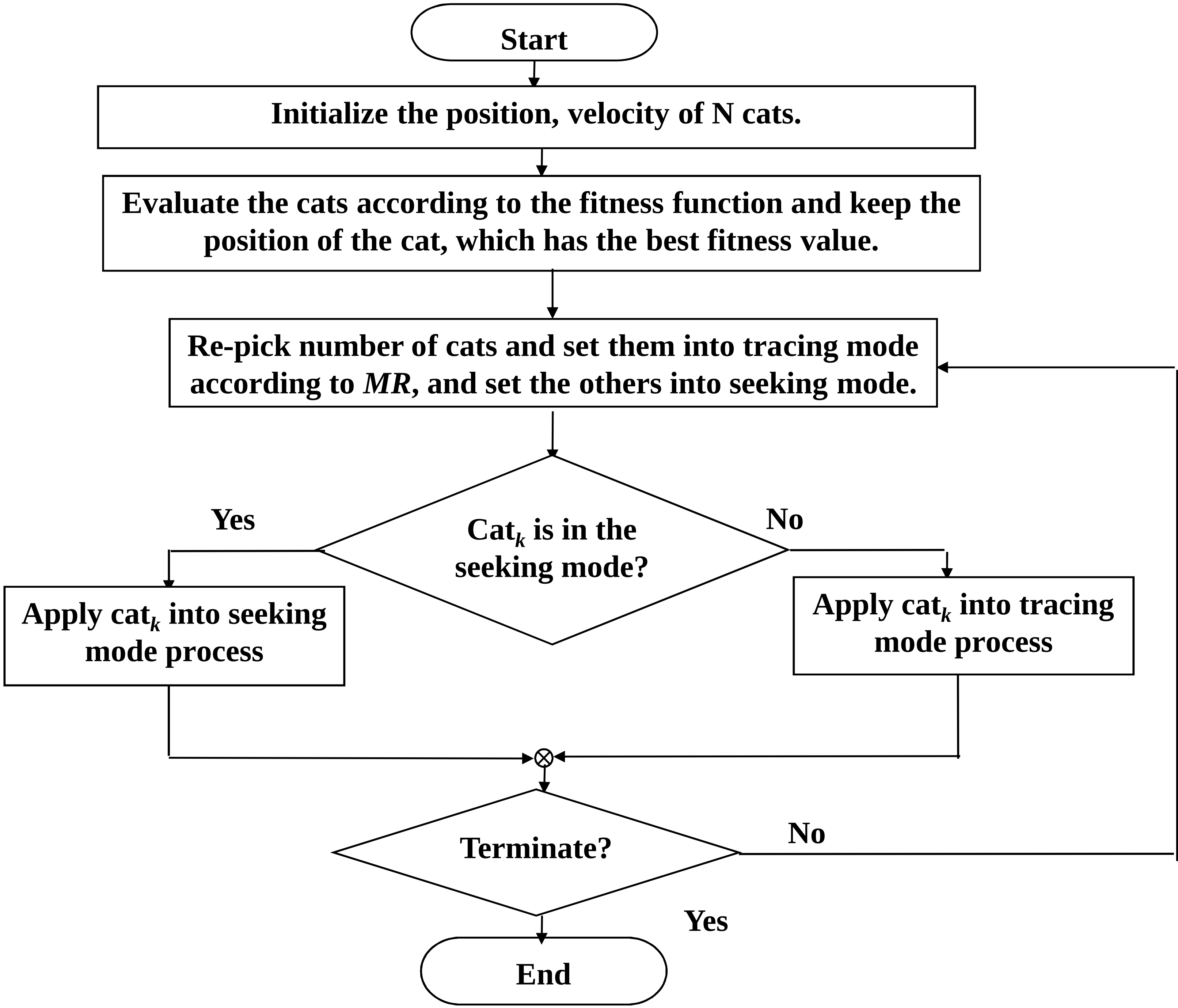
  - r_1 A random variable belongs to [0,1].
  - c_1 A constant, which is set to *2* in the experiments.

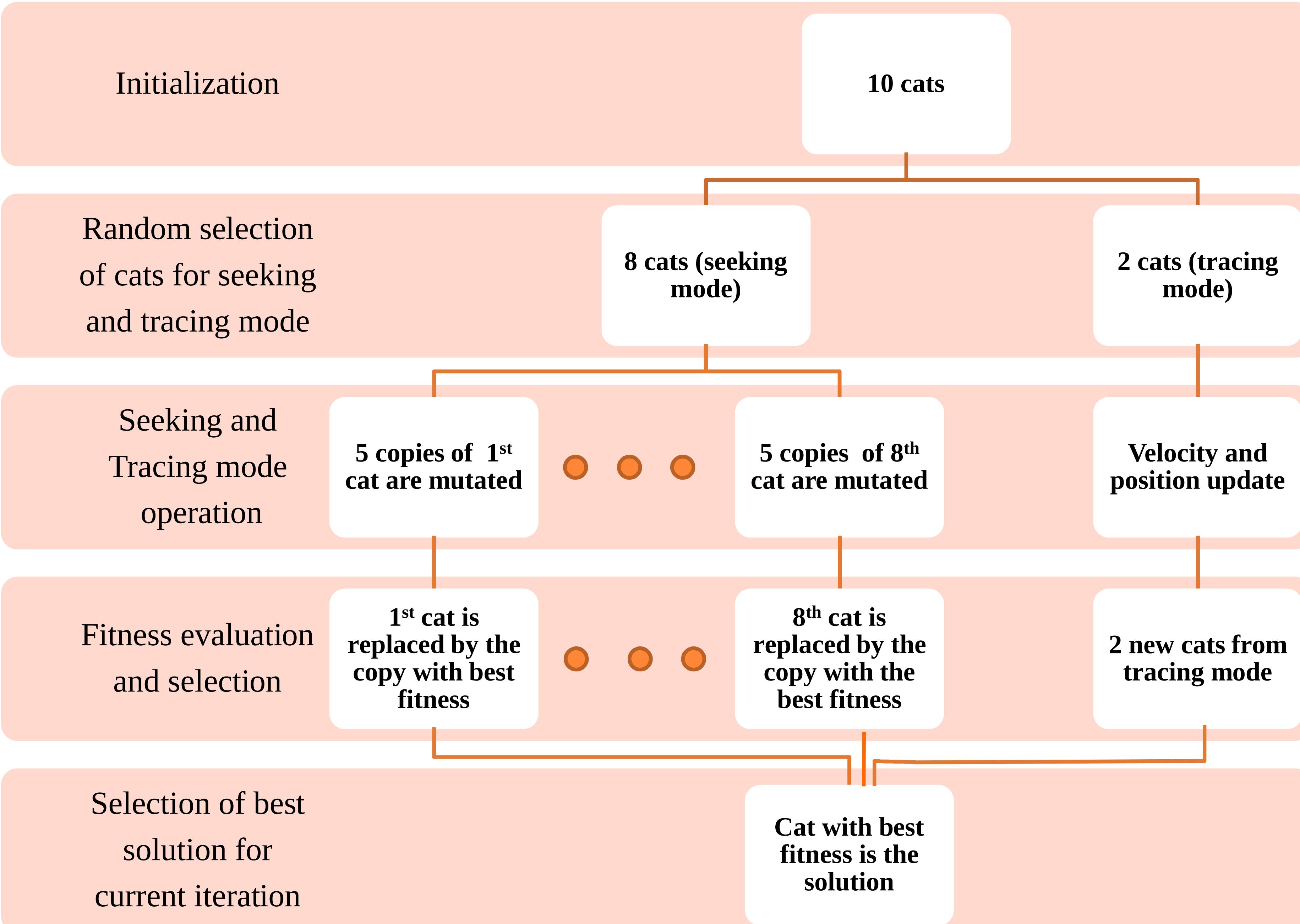
- Update the position of each particle using the modified velocity value.

$$x_{k,d} = x_{k,d} + v_{k,d}$$

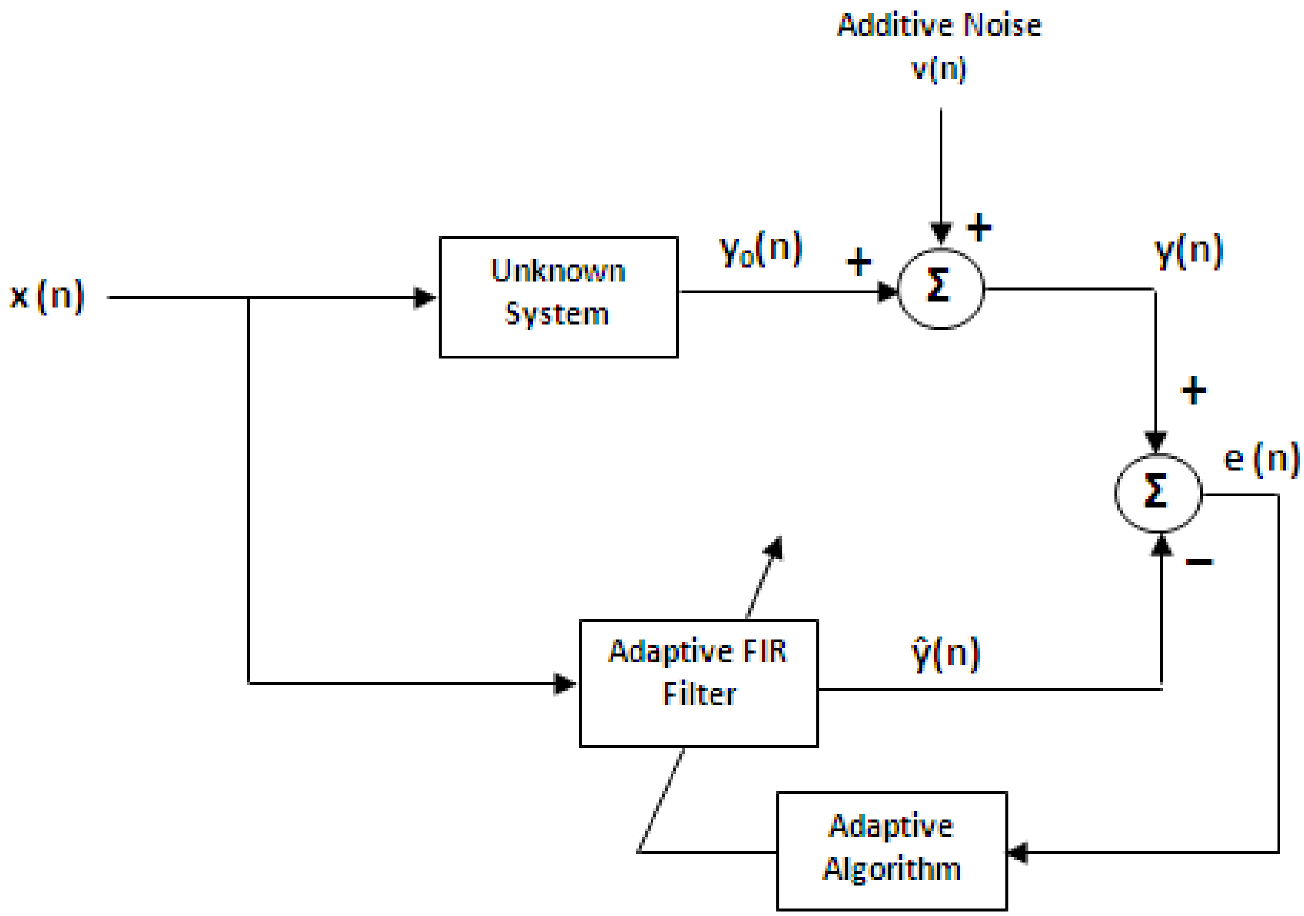
6. Create the new population by combining (0.8N + 0.2N) cats obtained from seeking and tracing mode respectively.
7. Evaluate the fitness value of each of the new N cats.
8. Update the gbest
9. Check the termination condition, if satisfied, terminate the program. Otherwise repeat steps 4 to 8.

FLOWCHART

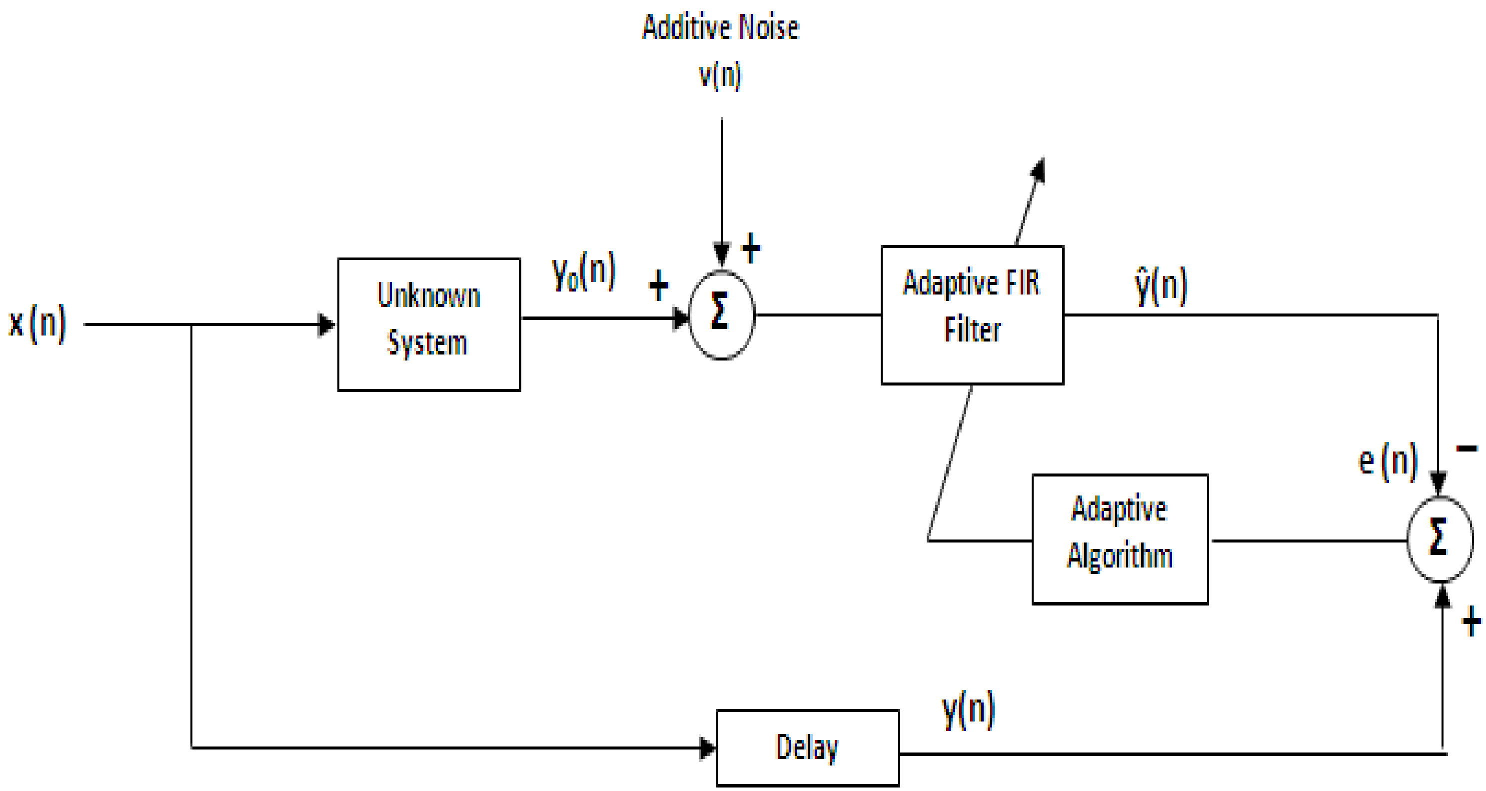

Start
Initialize the position, velocity of N cats.
Evaluate the cats according to the fitness function and keep the position of the cat, which has the best fitness value.
Re-pick number of cats and set them into tracing mode according to MR, and set the others into seeking mode.
Cat$_k$ is in the seeking mode?
Yes
No
Apply cat$_k$ into seeking mode process
Apply cat$_k$ into tracing mode process
Terminate?
No
Yes
End


Initialization
10 cats
Random selection of cats for seeking and tracing mode
8 cats (seeking mode)
2 cats (tracing mode)
Seeking and Tracing mode operation
5 copies of 1st cat are mutated
5 copies of 8th cat are mutated
Velocity and position update
Fitness evaluation and selection
1st cat is replaced by the copy with best fitness
8th cat is replaced by the copy with the best fitness
2 new cats from tracing mode
Selection of best solution for current iteration
Cat with best fitness is the solution

Direct Modeling



INVERSE MODELING



SIMULATION STUDY

- Transfer function of the benchmark plant

$$H(z) = 0.26 + 0.93\, z^{-1} + 0.26\, z^{-2}$$

- 4 different cases for simulation study:
    a) Direct modeling of the plant
    b) Inverse modeling of the plant
    c) Direct modeling of the plant with nonlinearity
    d) Inverse modeling of the plant with nonlinearity

- Nonlinearity = hyperbolic tangent function{tanh(x)}

PARAMETER SETTINGS

Parameter settings for CSO

Parameter	Value or Range
SMP	5
SRD	20%
CDC	80%
MR	2%
c_1	2.0
r_1	[0, 1]

Parameter settings for PSO

Parameter	Value or Range
Initial Weight	0.9
Final Weight	0.4
c_1	2.0
c_2	2.0
r_1	[0, 1]
r_2	[0, 1]

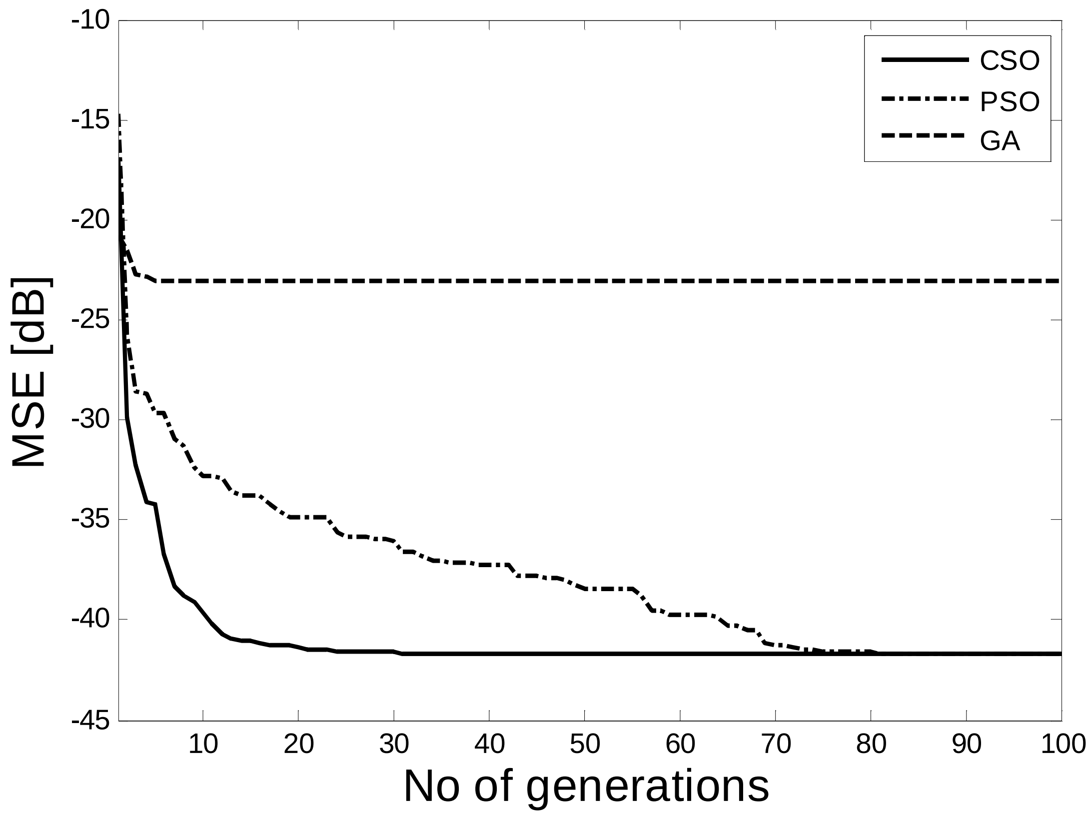
Parameter Settings

Parameter settings for GA

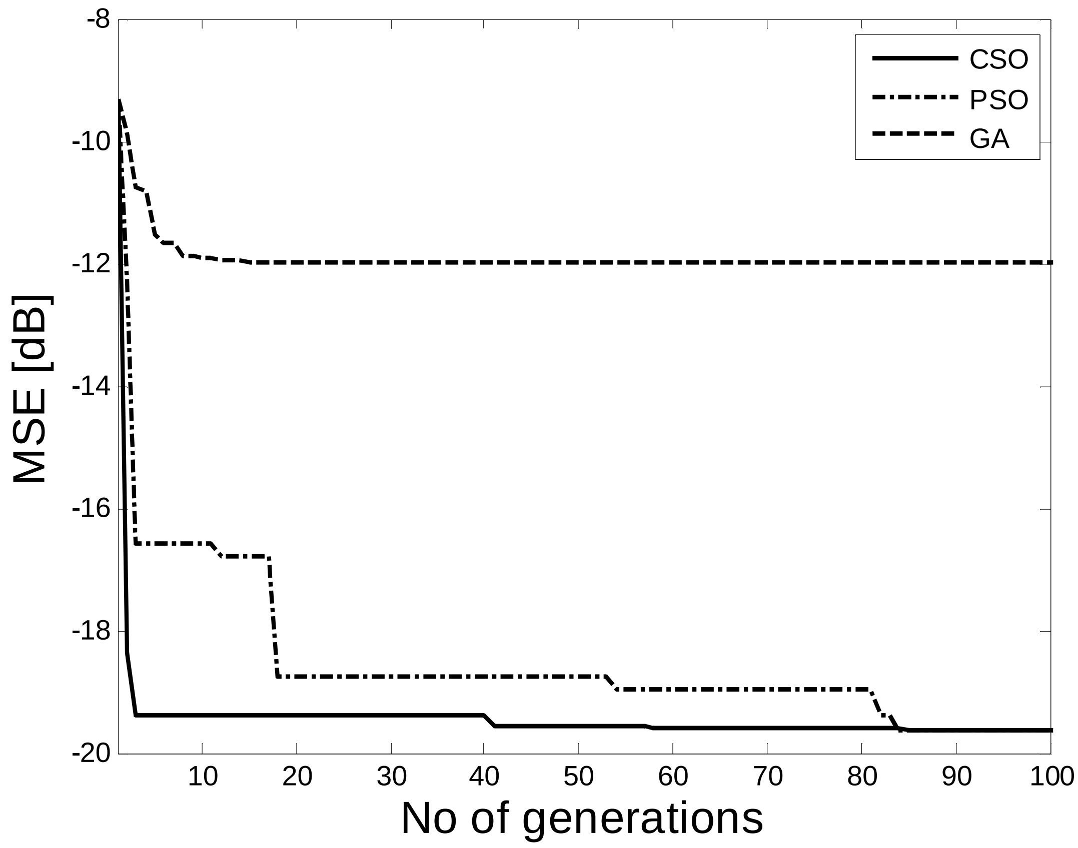
Parameter	Value or Range
Pc	0.8
Pm	0.1
No of bits	10

- **Iteration:** ***100***
- **Population Size:** ***50***
- **Rounds for Average:** ***50***

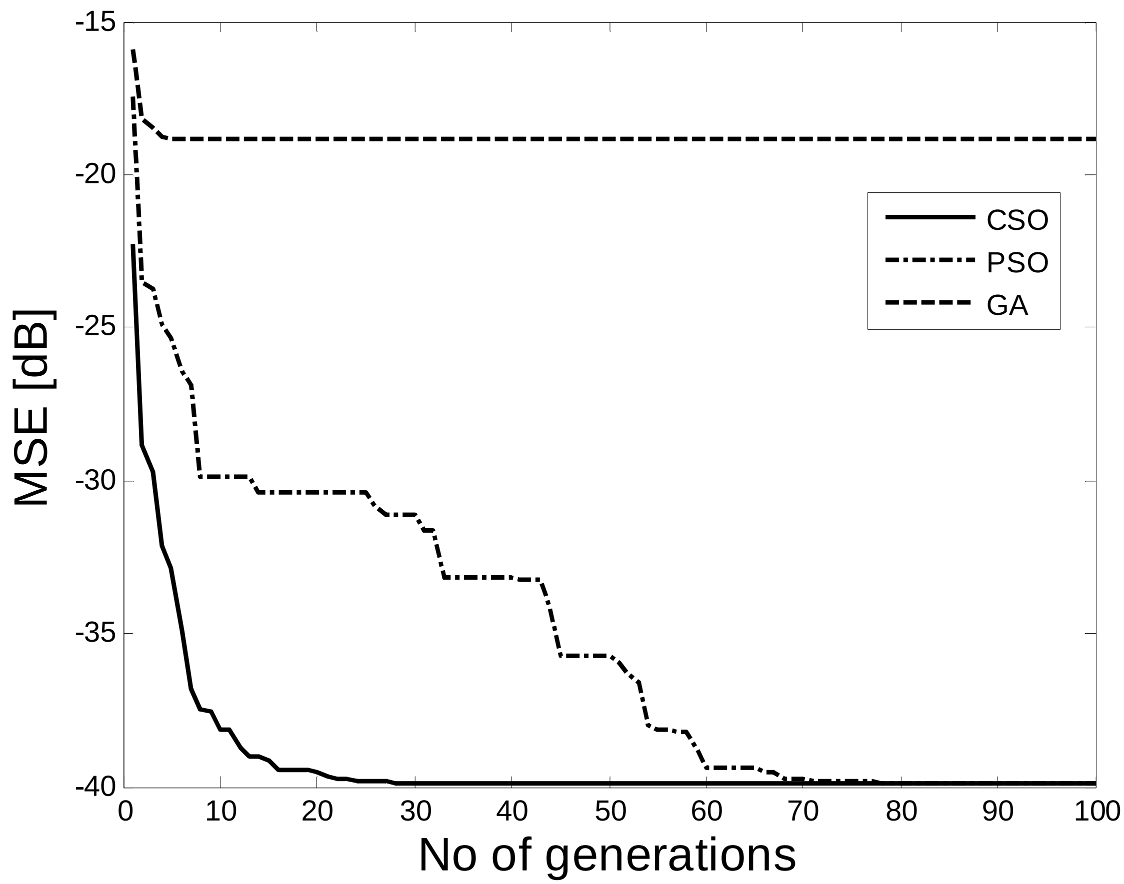
Convergence Characteristic for Direct Modeling



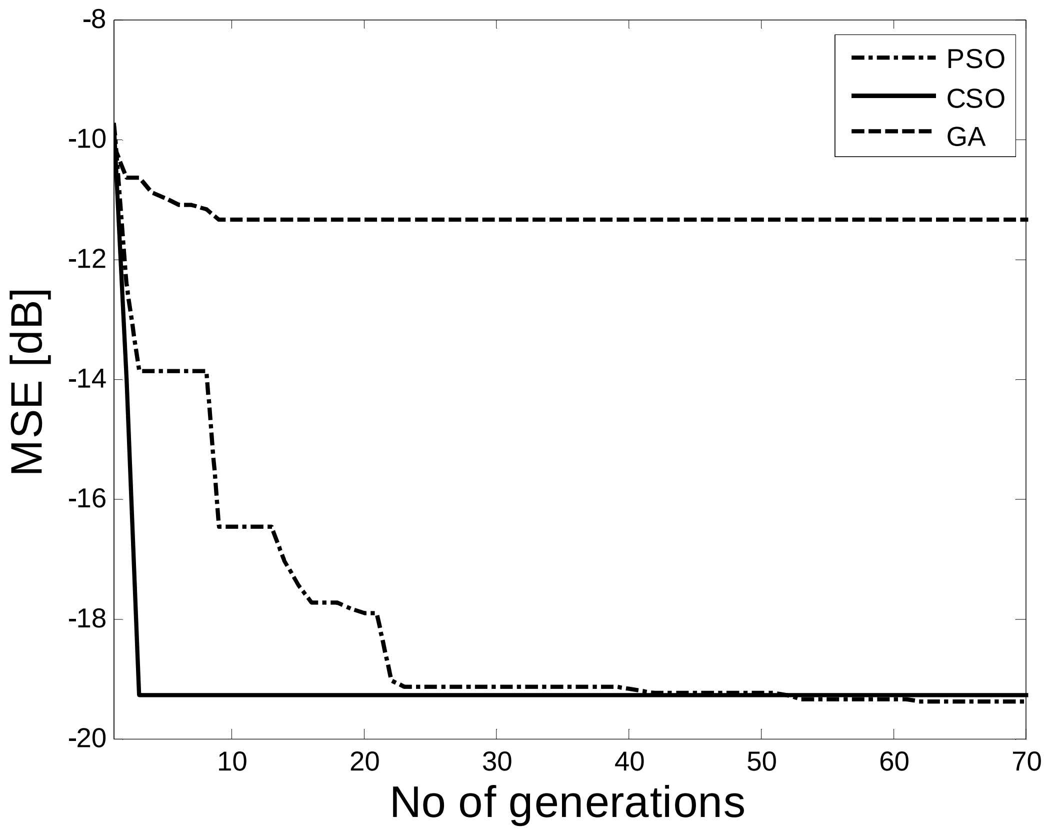
Convergence Characteristic for Inverse Modeling



CONVERGENCE CHARACTERISTIC FOR DIRECT MODELING WITH NONLINEARITY



Convergence Characteristic for Inverse Modeling with Nonlinearity



IIR SYSTEM IDENTIFICATION

2nd Order IIR System: $$H_s(z) = \frac{0.05 - 0.4z^{-1}}{1 - 1.1314z^{-1} + 0.25z^{-1}}$$

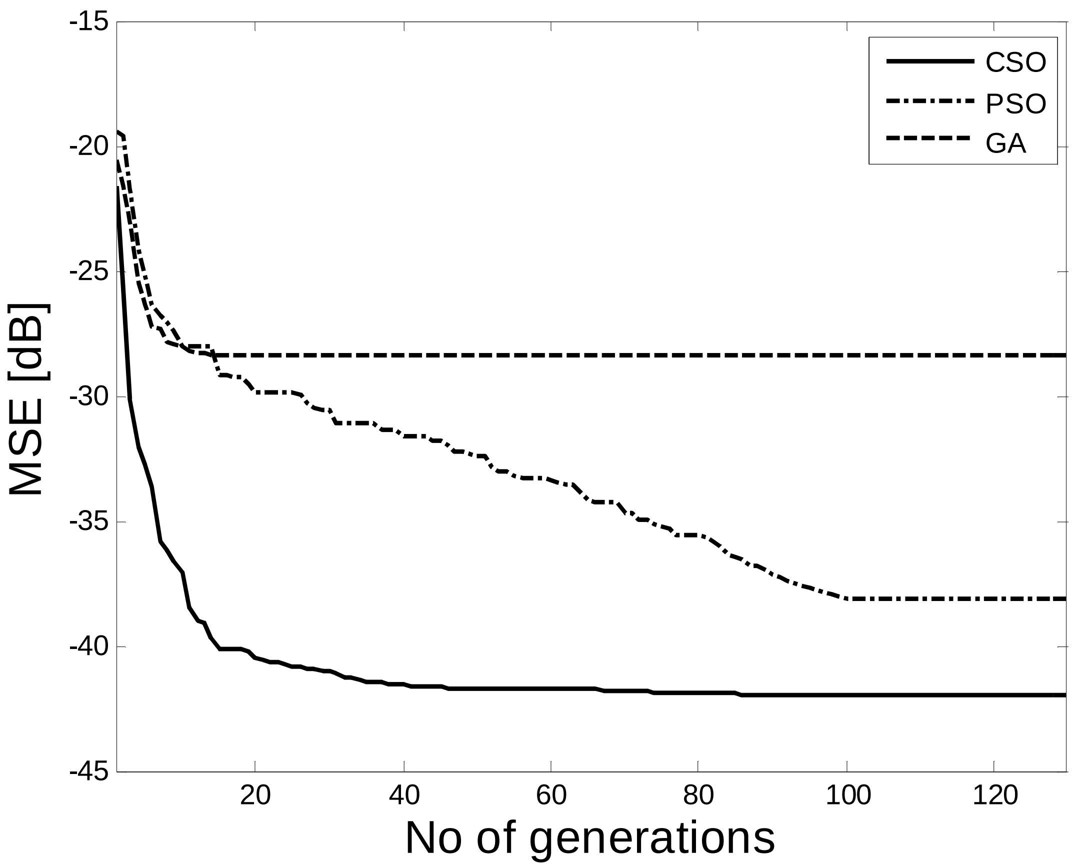
1. Equal Order Modeling

$$H_s(z) = \frac{a_0 + a_1 z^{-1}}{1 - b_1 z^{-1} - b_2 z^{-1}}$$

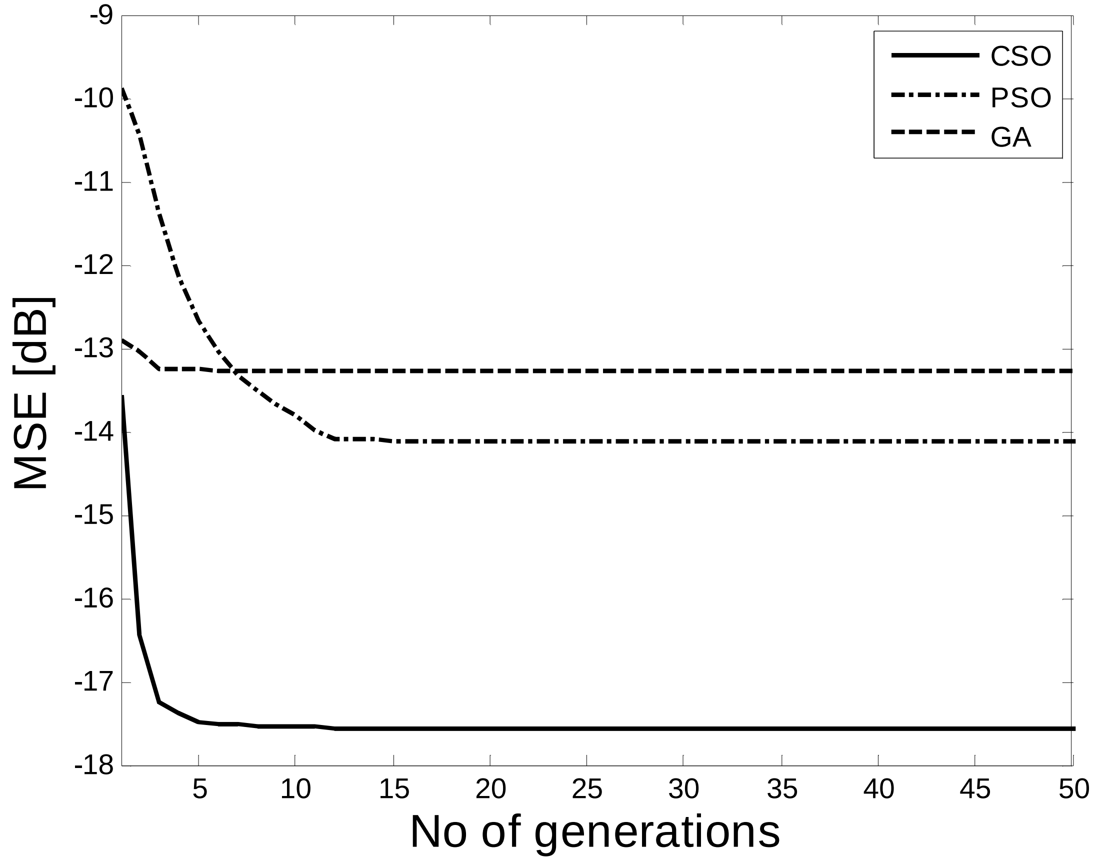
2. Reduced Order Modeling

$$H_s(z) = \frac{a_0}{1 - b_1 z^{-1}}$$

Convergence Characteristic for Equal Order Modeling of IIR System



CONVERGENCE CHARACTERISTIC FOR REDUCED ORDER MODELING OF IIR SYSTEM



Conclusion

- A new algorithm, Cat Swarm Optimization, is presented by modeling the behaviors of cat for solving the optimization problems.

- The experimental results indicate that CSO is a better candidate for finding the global best solutions in comparison to GA and PSO.

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Thank you for your attention

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