Intelligent Data Analytics

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Outline

- **Analysis of Data**
- **Steps of Data analysis**
- **Types of Decisions/ Operations/Actions**
- **Computational Intelligence**
- **AI/ Machine Learning Techniques in Communication Technologies (Decision Making and Quality of Service)**
- **Examples on Decision Making**

Analysis of Data

- Decision Making , Reasoning and arriving at a solution requires analysis of data
- Data analytics (two types)

  a) Statistical/Operation research/ Mathematical based methods

  b) Intelligent based on computational intelligence techniques (AI/ Machine Learning/ ANN/ Fuzzy Logic/ Evolutionary Computing)
- Big Data Analytics- both statistical and intelligent methods are used

Steps of Data analysis

- Pre-processing of data

  a) Generation of missing data

  b) Normalization of data

  c) Features Extraction- Three types

  i) Statistical (Mean, variance, cummulants)

  ii) Transform domain (DFT, wavelet, cosine and S-transforms)

  iii) Technical features (relates to the types of data)

  d) Features reduction

  i) Factors Analysis (FA)

  ii) Principal Component Analysis (PCA)

  iii) Linear Discriminant Analysis (LDA)

Types of Decisions/ Operations/Actions

- ❖ Filtering
- ❖ Clustering
- ❖ Forecasting/ Prediction
- ❖ Classification
- ❖ Parameters Estimation/ System Identification/ Pattern recognition/ Direct Modelling of systems
- ❖ Inverse Modelling / Deconvolution/ Channel Equalization/ Nonlinearity Compensation
- ❖ Optimization
  - a) Maximization or Minimization
  - b) Single Variable/ Multi-Variables
  - c) Single objective / Multi-objectives
  - d) With/Without constraints
- ❖ Detection
  - \- Extraction of signals from low SNR

Available Techniques for Different Operations

- ❖ Filtering- LMS, RLS, BP ……..
- ❖ Feature Reduction- PCA,LDA
- ❖ Clustering- K-Means, Hierarchical, Fuzzy C-Means……
- ❖ Forecasting/ Prediction- Regression, Logistic Regression, Non-Linear Regression, Nature Inspired Techniques, All ANNs
- ❖ Classification- All Regressions, Neuro Fuzzy Techniques, All ANNs, Naïve Bayes, Decision Tree, Random Forest, SVM….
- ❖ Parameters Estimation/ System Identification/ Pattern recognition/ Direct Modelling of systems- LMS,RLS,ANNs-BP,FLANN,Bio-Inspired Techniques……
- ❖ Inverse Modelling / Deconvolution/ Channel Equalization/ Nonlinearity Compensation- LMS,RLS,ANNs-BP,FLANN,Bio-Inspired Techniques…….
- ❖ Optimization – Nature Inspired Techniques
  - a) Maximization or Minimization
  - b) Single Variable/ Multi-Variables
  - c) With/Without constraints
- ❖ Detection – Bio-Inspired Techniques, ANNs
  - \- Extraction of signals from low SNR
- ❖ Distributed Learning- Incremental and Diffusion

Intelligent Systems

- ❖ Fixed Systems
- ❖ Adaptive Systems
- ❖ Intelligent/Smart/Cognitive Systems

Computational Intelligence

❖ **Artificial Neural Networks (ANNs)**

1) Perceptron
2) Multilayer Artificial Neural Networks
3) Functional Link Artificial Neural Network (FLANN)
4) Radial Basis Function Neural Network (RBFN)
5) Recurrent Neural Network (RNN)
6) Spiking Neural Network
7) Convolutional Neural Network (CNN) ……

❖ **These networks**- Two modes of operations

Mode-1 : Training (Usually 80% of the old data)

i) **Supervised Learning** -with some adaptive learning algorithms using past/ old/ known data e.g. Back Propagation Learning

ii) **Unsupervised Learning**- No past training data is required only learning algorithm is used e.g. Reinforcement Learning (Learning of bicycle)

Mode-2: Testing or Validation (Usually 20% of the old data)- To evaluate the performance of the trained model

❖ **Fuzzy Logic :** Proposed by Lotfi Zadeh in 1965

– It embodies human-like thinking into a control system

– Emulates human deductive thinking

1) **TS (Takagi-Sugeno)**: Proposed by Takagi, Sugeno and Kang in 1985

– Format of this rule is : If x is A and y is B THEN Z=f(x,y). Here, AB are fuzzy sets in antecedents and z= f(x,y) is a crisp function in the consequent

2) **Mamdani** : Proposed by Mamdani and S. Assilian

– It is a method to create a control system by synthesizing a set of linguistic rule obtained from experienced human operators.

– These output fuzzy sets are combined using aggregation methods

– The defuzzifier rule is used to obtain the desired crisp output

3) **Rough**

– Rough set proposed by Pawlak in 1982

– Fuzzy rough sets proposed by Dubois and Prade in 1990

❖ **Biological Inspired Technique/ Nature Inspired Techniques/ Evolutionary Computing**

1) Genetic Algorithm (GA)

2) Differential Evolution (DE)

3) Particle Swarm Optimization (PSO)

4) Cat Swarm Optimization (CSO)

5) Ant Colony Optimization (ACO)

6) Bacterial Foraging Optimization (BFO) and so on

❖ **These techniques -used for optimization (minimization and maximization)**

1) single and multivariable functions

2) With or without constraints

3) Single or Multi-objectives

AI/ Machine Learning Techniques (Decision Making and Quality of Service)

Few Examples:

- Spectrum Management
- Channel Estimation/ Equalization
- Classification of Wireless Signal
- Multi-objective Routing Optimization
- Resource Allocation
- Massive IoT Management
- Secured Link Assurance
- Autonomous Drive
- Drove Guidance
- Traffic Prediction
- Multiple Radio Access
- Handover Forecasting
- Demand Side Management

Examples on Decision Making

- Clustering (K-means/ Hierarchical)
- Classification (ANN-BP-Based/Naïve Bayes)
- Prediction (Regression/Logistic Regression/FLANN/RBFN)
- Optimization (Nature Inspired Techniques
  - Single Objective (GA/DE/PSO)
  - Multi-Objective (GA/DE/PSO)
- Feature Reduction (PCA/LDA)
- Unsupervised Learning (Reinforcement Learning)

Intelligent Computing

- Genetic Algorithm
- Particle Swarm Optimization
- Cat Swarm Optimization
- Differential Evolution
- Ant Colony Optimization

Genetic Algorithm

Genetic Algorithm

- Based on the mechanics of biological evolution
- Initially developed by John Holland, University of Michigan (1970's)
  - To understand processes in natural systems
  - To design artificial systems retaining the robustness and adaptation properties of natural system.
- It is a stochastic algorithm
- It does not use gradient information
- Provide efficient techniques for optimization and machine learning applications

Applications of GA

- Optimization–numerical and combinatorial optimization problems, e.g. travelling salesman, routing, graph colouring and partitioning
- Robotics–trajectory planning
- Machine learning–designing neural networks, classification and prediction, e.g. prediction of weather or protein structure
- Signal processing–filter design
- Design–semiconductor layout, aircraft design, communication networks
- Automatic programming–evolve computer programs for specific tasks, design cellular automata and sorting networks
- Economics–development of bidding strategies, emergence of economics markets
- Immune systems–model somatic mutations
- Ecology–model symbiosis, resource flow

PARTICLE SWARM OPTIMIZATION

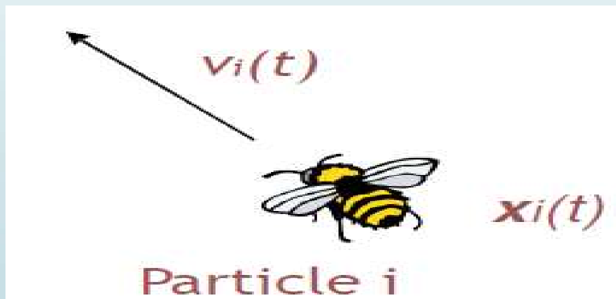
PARTICLE SWARM OPTIMISATION

- Eberhart and Kennedy (1995)
- Multi dimensional search

James Kennedy and Russell Eberhart. Particle swarm optimization. In Proceedings of the IEEE International Conference on Neural Networks, volume IV, pages 1942–1948, Piscataway, NJ, 1995

- Each candidate solution is called **PARTICLE**
- The population is set of vectors and is called **SWARM**
- The particles change their components and move (fly) in a space
- They can **evaluate** their actual position using the function to be optimized
- The function is called **FITNESS EVALUATION**

- Each particle is characterized by
  - Position vector….. $X_i(t)$
  - Velocity vector…... $V_i(t)$



- Each particle has
  - Individual knowledge ***pbest***
    - its own best-so-far position
  - Social knowledge ***gbest***

ur

- Velocity update:

$$V_i(t+1) = W \times V_i(t) + C_1 \times rand \times (pbest_i(t) - X_i(t)) + C_2 \times rand \times (gbest(t) - X_i(t))$$

- Position update:

$$X_i(t+1) = X_i(t) + V_i(t+1)$$

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

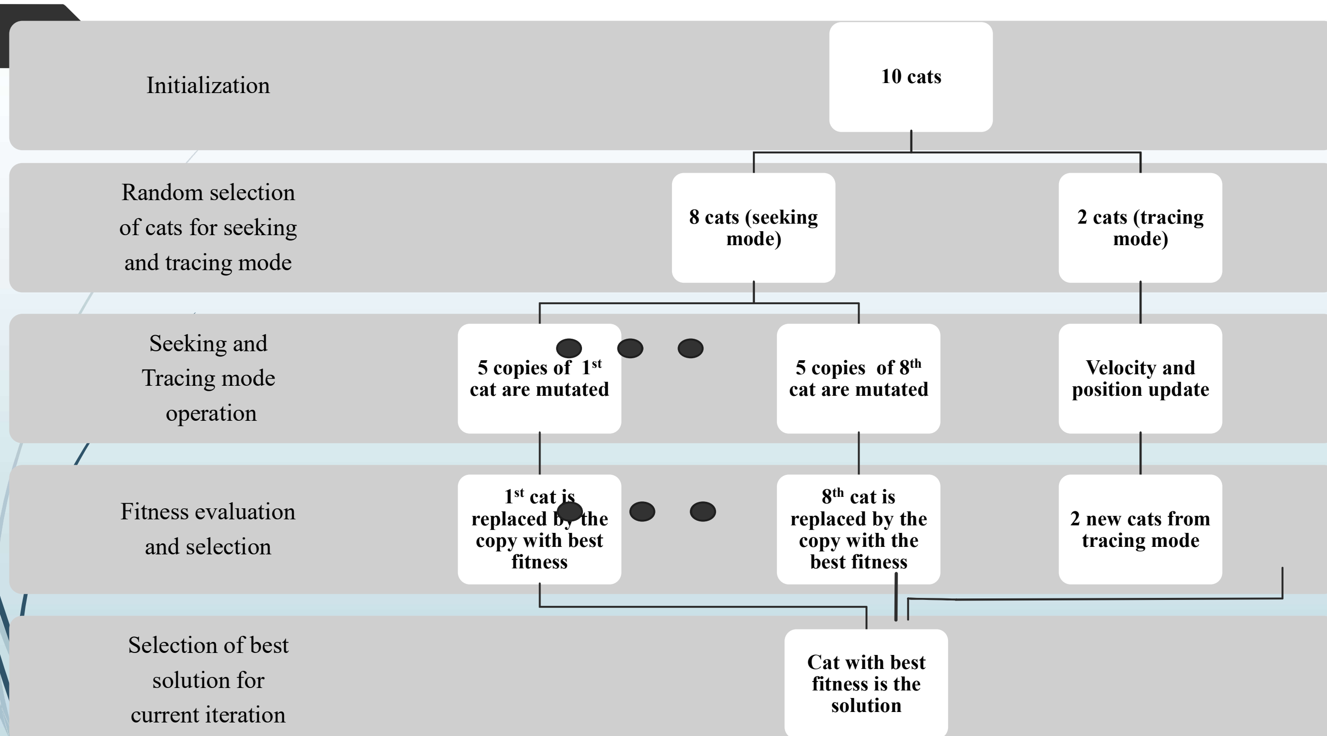
- ❑ Solution Set -- Cats:
  - ❑ M-dimensional Position.
  - ❑ Velocities for each dimension.
  - ❑ A fitness value.
  - ❑ Seeking/Tracing flag.

Cat Swarm Optimization

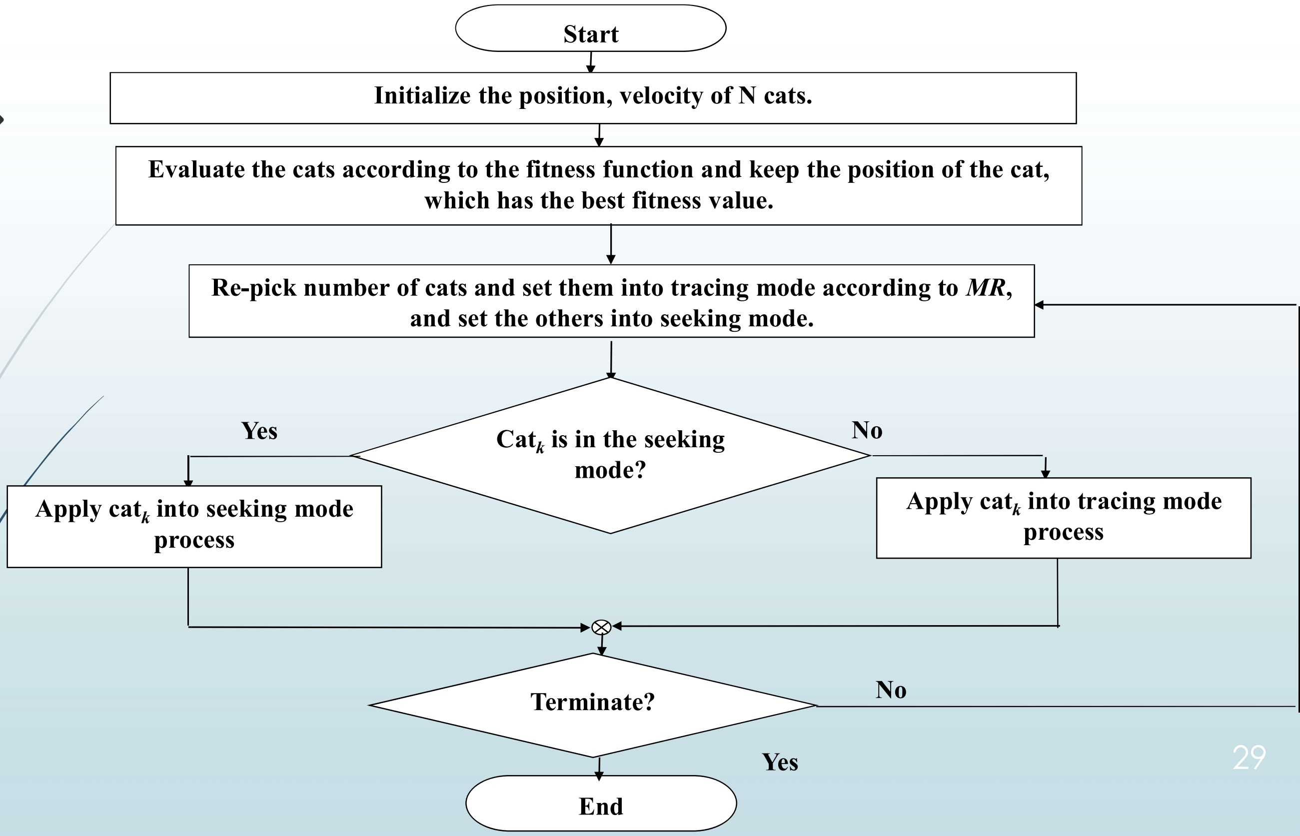
❑ Sub-models:

- ❑ - 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.



FLOWCHART



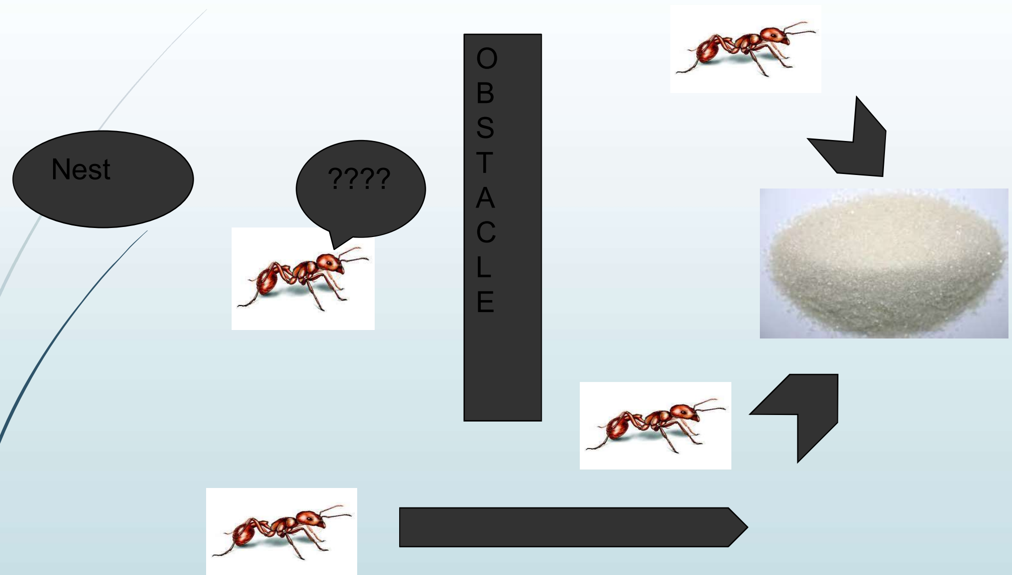
Ant Colony Optimization

Introduction

- ❑Insects that live in colonies - ants, bees, wasps, termites have long fascinated everyone from naturalists to artists.
- ❑Each insect in a colony seems to have its own agenda and yet the group as a whole is highly organized.
- ❑Ants' behavior is unsophisticated and they collectively perform complex tasks. Ants have highly developed sophisticated sign based stigmergy.
- ❑Ants deposit a trail of *pheromones - chemicals whose smell can inform or influence the behavior of other ants* - along the route they travel in search of food.

Introduction

- ❑When a food source is found, the ant that discovered it communicate this information to its peers, who thus follow that insect's *pheromone trail*.
- ❑As more and more ants travel to the food source the pheromone track becomes thicker and thicker attracting more and more ants who in turn deposit their own pheromone and so on.
- ❑When *confronted to the obstacle* on the preferred path, the ants *quickly switch to the next most efficient line to the food*.
- ❑A high level of pheromone on the right path gives the ant stronger stimulus and has higher probability to turn right.



Travelling Salesman Problem

Five cities 1,2,3,4,5 and the distances between are given in table.

Answer 15 1-2-3-4-5-1 (un symmetric tsp)

1	0	2	5	7	1
2	6	0	3	8	2
3	8	7	0	4	7
4	12	4	6	0	5
5	1	3	2	8	0

Differential Evolution (DE)

- Proposed by Storn and Price – 1995, is a simple, powerful population based stochastic search technique.
- It is an efficient and effective global optimizer in the continuous search domain.
- It has been successfully applied to diverse fields – mech. Engg., communication, pattern recognition

- DE uses parameter vectors as individuals in a population
- The key element distinguishing DE from other population-based techniques is differential mutation operator and trial parameter vectors.

- DE generates new parameter vectors by adding the weighted difference between two parameter vectors to a third vector
- For each target vector $x_{i,G}$, $i = 1,2,\ldots,NP$, a mutant vector is generated according to:

$$\underline{v}_{i,G+1} = x_{r1,G} + F\,(x_{r2,G} - x_{r3,G})$$

where $\underline{v}_{i,G+1}$ is a mutant vector; $r1,r2,r3 \in \{1, 2, \ldots, NP\}$, random integer mutually different and different from index i then NP≥4; F is a real and constant factor $\in [0, 2]$ which controls the amplification of the differential variation

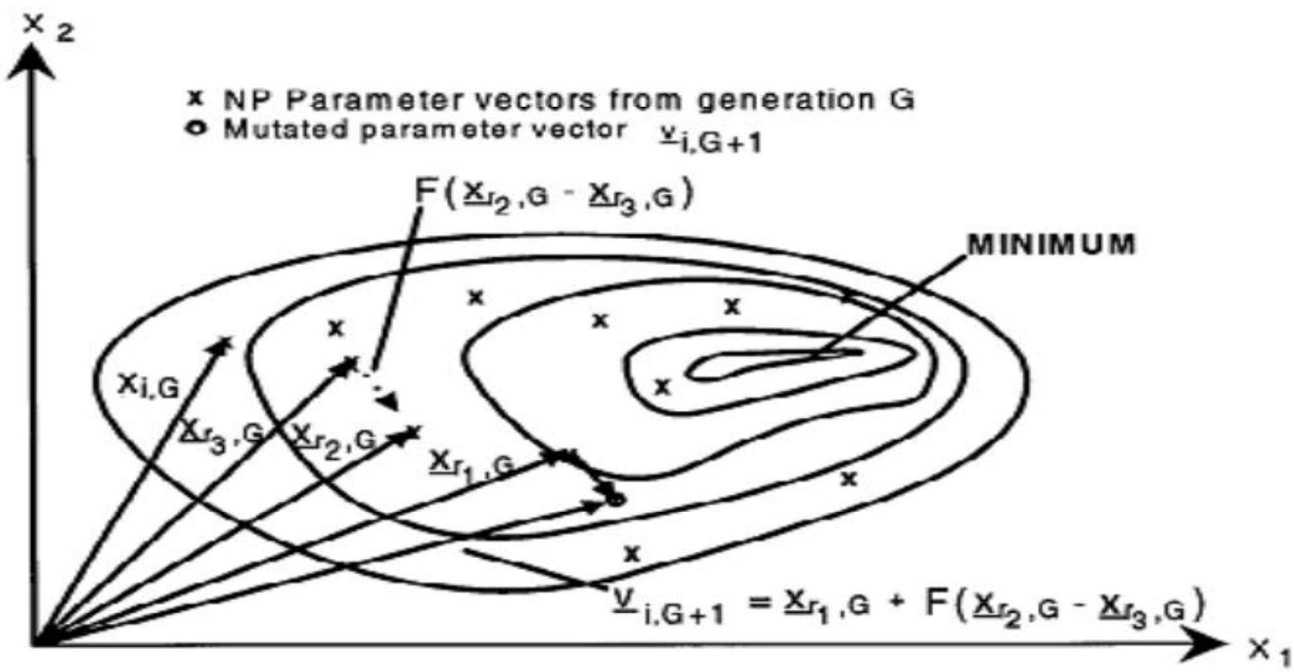


Fig. An example of a two-dimensional cost function showing its contour lines and the process for generating $\underline{v}_{i,G+1}$ by different vectors.

Feature Extractions

- Statistical Features
- Structural Features
- Image Transformations
- Hybrid Topological Features

Classification

- Artificial Neural Network
- Support Vector Machines
- Hidden Markov Models
- Quadratic Discriminant Functions
- Nearest Neighborhood Classifier
- Deep Learning & Convolution Neural Nets

Exchange Currency Rate

INTRODUCTION

Feature Extraction from Raw Data

- Data Available

  1. Average of daily figures (rupees/pounds/yens per unit dollar) of one month ($x_m, m = 1, 2, \ldots M$)

  2. M_1 = No of months for which data is available for training.

  3. M_2 = No of months for which data is available for testing.

  4. $M = M_1 + M_2$ = No of months for which total data is available.

Feature Extraction

- Each x_m is normalized using the maximum value of x_m to obtain xn_m (0 to 1).
- Input is taken from 12th month onwards for the purpose of training so that features from the previous11data can be extracted.
- For $(m+11)^{th}$ the month $(1 \le m \le M_{1-11})$ mean and variance values are computed as

$\overline{x}n_{m+11}$ = Mean of xn_m to xn_{m+11}

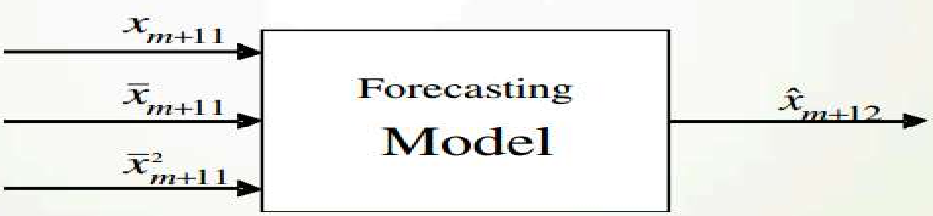
$\overline{x}^2 n_{m+11}$ = Variance of xn_m to xn_{m+11}

- The inputs to the model for any $(m+11)^{th}$ month are

$$xn_{m+11} \quad \overline{x}n_{m+11} \quad \overline{x}^2 n_{m+11} \qquad (1 \le m \le M_1 - 11)$$

- The estimated output of the model is given by $\hat{x}n_{m+12}$ as the model predicts for $(m+12)^{th}$ month.

The input-output of the nonlinear model is

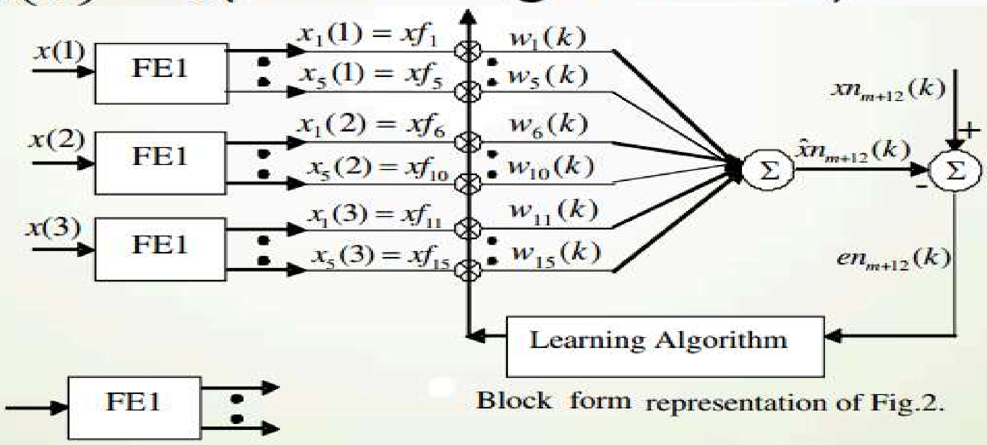


$$en_{m+12}(k) = x_{m+12}(k) - \hat{x}_{m+12}(k)$$

$$\hat{x}_{m+12}(k) = \sum_{j=1}^{J} xf_j(k).w_j(k)$$

$w_j(k) = j$th weight at kth iteration.

$w_i(o) = 0$(Initial weight at k=0)



Block form representation of Fig.2.

Proposed Nonlinear model for forecasting

THANK YOU

Related Journal Publications (2011 Onwards)

- T. Panigrahi, G. Panda and B Mulgrew, “Error Saturation Nonlinearities for Robust Incremental LMS over Wireless Sensor Networks," ACM Transaction on Sensor Network, 11(2), article no. 27, 2015.
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❖ N. K. Rout, D. P. Das and G. Panda, Computationally efficient algorithm for high sampling frequency operation of active noise control, Mechanical systems and signal processing, Elsevier, 56-57, pp:302-319, 2015.

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❖ N. K. Rout, D. P. Das and G, Panda, Particle Swarm Optimization based Nonlinear Active Noise Control under Saturation Nonlinearity, Applied Soft Computing, Elsevier, 41, 275-289, April 2016.

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