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Automatic Generation of Fuzzy Rules From Data by Fuzzy Clustering and Particle Swarm Optimization

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***Abstract*—This paper focuses on building a rule based model for a water supplying network using particle swarm optimization and fuzzy clustering. There are various fundamental problems of water supply distribution networks namely distance, quantity, demand, elevation etc. Depending on these factors we get the water at receiving ends in terms of quantity, pressure etc. An algorithm is proposed to obtain desirable rule based model for the above problem using particle swarm optimization which can further help in simulation and deciding various factors of input so that required output can be obtained.**

Keywords: Fuzzy Expert System, Intermittent Water Supply, Continuous Water Supply, Particle Swarm Optimization, Fuzzy Clustering, Fuzzy Rule Based Model.

I. INTRODUCTION

Fuzzy expert system is a collection of membership functions and rules that are used to reason about data. It is a collection of membership functions and rules that are used to reason about data, oriented toward numerical processing. Fuzzy rule based models are now a days extensively used in various fields ranging from biotechnology and economics to agriculture. It helps to forecast the output of some input based on some rules. In some expert systems the fuzzy rule are generated by the experts in the area, but with the increase in number of variables and its linguistic values it become difficult for the expert to generate all the rules for the expert system. The reason behind this difficulty is that the number of rules increases exponentially with linguistic values and variables.

The no. of rules depends exponentially on no. of variables (both input & output). Fuzzy rules can be optimized and generated using an evolutionary algorithm called particle swarm optimization and fuzzy clustering. Particle Swarm Optimization (PSO) is an optimization algorithm proposed by Kennedy and Eberhart in 1995. It is easy to be understood and realized. It has been applied in many optimization problems. The PSO is more effective than traditional algorithms in most cases [1, 2].This paper is designing an algorithm for constructing a fuzzy rule based model for drinking water supply. In many of the developing countries like India drinking water system doesn't invariably operate upon continuous water supply due to many constraints like financial and resource availability. Therefore intermittent nature of supply over a period of eight hours or less is considered adequate to supply the drinking water. Water distribution networks simulation and modeling dates back to early 1970's when computers were in infant stage and modeling was mainly to static state. The single most important consideration in water distribution system operation and planning is to assure adequate level of service at all points in the system, under varying conditions of loading criterion. For determining the level of service, which include

1. Maintenance of flow rate, water quality and pressure
2. Management of storage in such a way , as to balance in supply and distribution

From operation point of view it's important to know the impact of any parameter like demand, distance, elevation etc on the output like pressure. Such knowledge would aid in developing control strategies to maintain the level of service. From the planning point of view, there is need to evaluate adequacy of storage of proposed networks, additions with respect to increase in total demand. Both these needs can be met by simulating the behavior of the system over a period of 24 hour- 48 hour under changing demand patterns

These are many existing models that are trying to simulate the flow and pressure in water distribution system. They are

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1. Steady state models
2. Extended period models

This paper is organized as follows: section II presents a basic overview of the evolutionary algorithm used .section III shows the training mode. Section IV presents an algorithm for designing a rule based model for the specified problem in this section. Section V presents the conclusion.

II. FUZZY CLUSTERING

In fuzzy clustering, data elements can belong to more than one cluster, and associated with each element is a set of membership levels. These indicate the strength of the association between that data element and a particular cluster. Fuzzy clustering is a process of assigning these membership levels, and then using them to assign data elements to one or more clusters. Areas of application of fuzzy cluster analysis include for example data analysis, pattern recognition, and image segmentation. The detection of special geometrical shapes like circles and ellipses can be achieved by so-called shell clustering algorithms. Fuzzy clustering belongs to the group of soft computing techniques (which include neural nets, fuzzy systems, and genetic algorithms).

III. OVERVIEW OF PARTICLE SWARM OPTIMIZATION (PSO)

PSO came into origin from the research of food hunting behaviors of birds. Researchers found that in the course of flight flocks of birds would always suddenly change direction, scatter and gather [3]. It is used to solve a wide array of different optimization problems. Their behaviors are Unpredictable but always consistent as a whole, with individuals keeping the most suitable distance. Through the research of the behaviors of similar biological communities, it is found that there exists a social information sharing mechanism in biological communities. There are many advantages of PSO over other optimization algorithms. The advantage of using trees is

a. Easy to produce rules based on tree structure
b. Rules easy to understand
c. The disadvantage of using tress to solve the problem
d. Accuracy decreases seriously when there are many classes
e. Only use information gain and consider only one attribute once
f. Easy to trap in local minimum

The advantage of using neural networks

a. High accuracy for float values

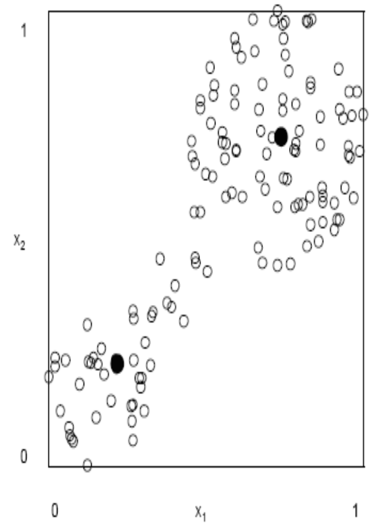

Figure 1: Example with two clusters, cluster center marked with to solid dots

b. The disadvantage of using neural networks
c. Easy to over fit
d. Rules hard to extract and hard to understand.
e. The advantage of GA
f. It has a fitness values to evaluate the population.
g. It updates the population and search for the optimum with random techniques.
h. Disadvantage
i. It is difficult to implement because of crossover and mutation.
j. System doesn’t guarantee success

The advantage of PSO is

a. Easy to represent the interaction between attributes
b. Consider several attributes once
c. Balance between local exploitation and global employment
d. PSO is easy to implement and there are few parameters to adjust.
e. All the particles tend to converge to the best solution quickly even in the local version in most cases.

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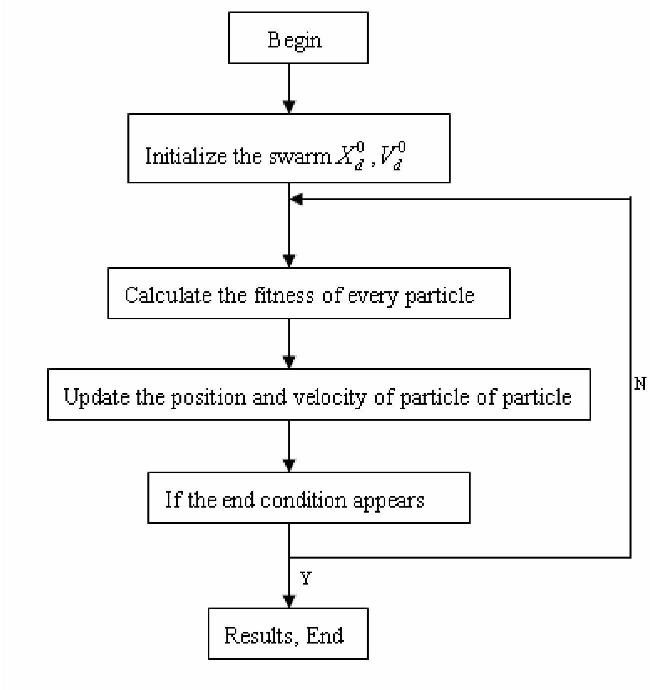

Figure 2: Flowchart of PSO

It has an ease of implementation and no gradient information is required. Each swarm of PSO can be considered as a point in the solution space. If the scale of swarm is N, then the position of the i-th (i=1, 2…N) particle is expressed as Xi . The "best" position passed by the particle is expressed as pBest [i]. The speed is expressed with Vi . The index of the position of the "best" particle of the swarm is expressed with g. Therefore, swarm i will update its own speed and position according to the following equations

VI=w*VI+c1*rand()*(pBest[i]-Xi)+c2*Rand)*

(pBest[g] -Xi) (1)

Xi =Xi + Vi (2)

Where c1 and c2 are two positive constants, rand( ) and Rand ( ) are two random numbers within the range [0, 1], and w is the inertia weight.

The PSO system combines two models: a social-only model and the cognition-only model [4]. These models are represented by the velocity update, shown in equation (1). The second term in the velocity update equation, c1*rand ()*(pBest[i]-Xi), is associated with cognition since it only takes into account the particle's own experiences. The third term in the velocity update equation, c2*Rand ( )*(pBest[g] - Xi), represents the social interaction between the particles. It suggests that individuals ignore their own experience and adjust their behavior according to the successful believes of individuals in the Neighborhood.

IV. THE TRAINING MODE

The single most important consideration in water distribution system operation and planning is to assure adequate level of service at all points in the system, under varying conditions of loading criterion.

EPANET is a software program that performs extended period simulation of hydraulic and

We will try to create the rules which will help to predict the output.

We have considered three parameters as input namely

1. Elevation of the tank calculated in meters

2. Demand calculated in LPM

3. Head in M

The nodes calculated .we used the result to train PSO. Input variable has 3 membership functions for each parameter like Elevation = {high, mid, low}, Demand= {more, average, less}, Head= {high, mid, low} and Output variable has Three membership function Pressure = {high, mid, low}.Then with the help of EPANET we calculated the pressure at the node in m. The table shows the result. water quantity behavior within pressurized pipe networks. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network during a simulation period comprised of multiple time steps. It is used for many different kinds of application in distribution system analysis.

Depending on the requirements we can select the parameters of input and with the help of fuzzy

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Sr.no	Elevation m	Demand Lpm	Head M	Pressure m
1.	136.19	224.98	137.19	1.00
2.	136.94	123.36	137.79	0.85
3.	137.69	93.84	138.09	0.4
4.	137.60	54.95	138.07	0.47
5.	137.42	31.2	138.19	0.77
6.	137.42	90.37	137.79	0.37
7.	137.80	54.9	137.93	0.13
8.	138.12	96.49	138.55	0.43
9.	138.74	178.01	140.04	1.30
10.	135.85	314.31	137.04	1.19
11.	134.86	277.03	136.25	1.39
12.	134.22	307.97	134.94	0.72
13.	137.07	133.77	137.35	0.28
14.	136.81	84.3	137.79	0.98
15.	137.92	2.93	138.02	0.10
16.	137.37	73.1	137.75	0.38
17.	137.15	105.32	137.49	0.34
18.	136.90	62.68	137.78	0.88
19.	137.06	64.58	137.83	0.77
20.	135.85	314.31	137.04	1.19

Table 1: Training Data

V. FUZZY RULE BASED MODEL FOR WATER SYSTEM

Let's consider a Tsk model for the above case. The shape of membership function for the input is taken to be Z, S and Triangular. The output is constant with parameters ranging from 0 ->1.

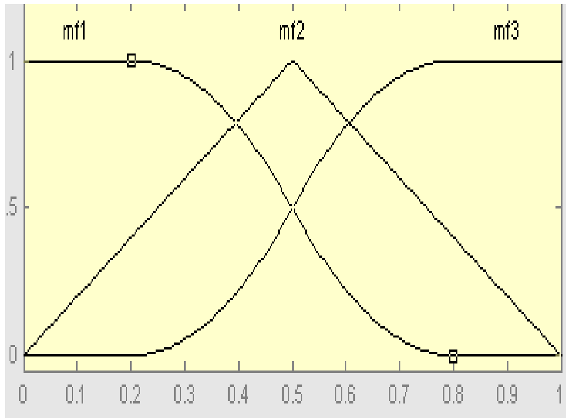

Fig 3. Membership functions for input variables.

The algorithm for fuzzy rule based model is

1. Assign membership function to all the input variables

2. Assign membership function to output variable

3. Calculate the max and min of each input parameter and output parameter

4. Using fuzzy clustering group the data according to membership function of input and output

5. Initialize Population size= 10

    Maximum iteration = 100

6. Initialize wmax = 0.9

    wmin = 0.3

    c1 = 2

    c2 = 2

7. Assign the value of pbest randomly

8. The value of Gbest is min error

9. Repeat step 11 till iter < maxiter & flag == 0

10. VI=w*VI+c1*rand()*(pBest[i]-Xi) +c2*Rand()

    *(pBest[g] –Xi

11. Xi =Xi + Vi

12. Assign the value of gbest as the consequent of the rules.

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VI. CONCLUSION

Eventually the no. of rules that should be generated taking the example into consideration should be 27, but with the help of the above given algorithm the no of rules generated will be 19.Weight is the degree to which these fuzzy rules are associated to the system.

The results can be viewed with surface view and rule view.

Fuzzy Rule	Weight
If Elevation is low and Demand is average and Head is mid then Pressure is High	0.012083
If Elevation is low and Demand is average and Head is mid then Pressure is mid	0.059149
If Elevation is Low and Demand is More and Head is Low then Pressure is mid	1.000000
If Elevation is Low and Demand is More and Head is Mid then Pressure is High	0.299574
If Elevation is Mid and Demand is Less and Head if Low then Pressure is Low	0.011400
If Elevation is Mid and Demand is Less and Head if Mid then Pressure is Mid	0.544908
If Elevation is Mid and Demand is Less and Head if High then Pressure is Low	0.158600
If Elevation is Mid and Demand is Average and Head if Low then Pressure is High	0.053223
If Elevation is Mid and Demand is Average and Head if Mid then Pressure is Low	0.442481
If Elevation is Mid and Demand is Average and Head if High then Pressure is Mid	0.080567
If Elevation is Mid and Demand is More and Head if Low then Pressure is High	0.152196
If Elevation is Mid and Demand is More and Head if Mid then Pressure is High	0.446221
If Elevation is High and Demand is Less and Head if Low then Pressure is Mid	0.006858
If Elevation is High and Demand is Less and Head if Mid then Pressure is Low	0.642849
If Elevation is High and Demand is Less and Head if High then Pressure is Low	0.344609
If Elevation is High and Demand is Average and Head if Low then Pressure is Low	0.022921
If Elevation is High and Demand is Average and Head if Mid then Pressure is Low	0.266195
If Elevation is High and Demand is Average and Head is high then Pressure is High	0.820300

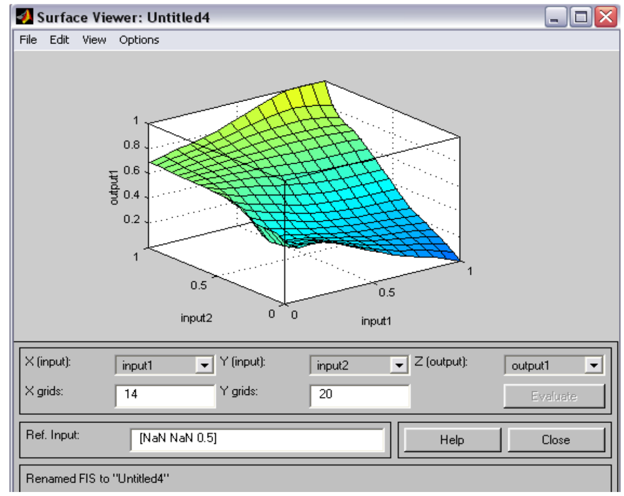

Fig 4. Surface View(input2,input1)-> output

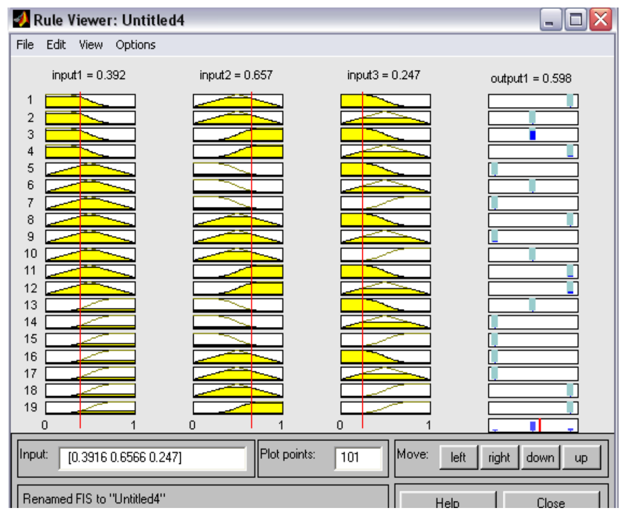

Fig 5. Rule View

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