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A Fuzzy-Preconditioned GRBFN Model for Electricity Price Forecasting

Satoshi Itaba, Hiroyuki Mori*

[a]*Dept. of Network Design, Meiji University, Nakano-ku Tokyo 164-8525, Japan*

Abstract

This paper proposes a fuzzy-preconditioned ANN (Artificial Neural Network) model for electricity price forecasting. The deregulated electric power systems have been widely spread to trade electric power through electric power markets. The market players are interested in gaining the inside track to maximize the profits and minimize risks in advance. One of the most important tasks is how to forecast a complicated time series of electricity price that affects transmission network congestion. In practice, it is hard to forecast electricity price with the spikes due to the high nonlinearity. In this paper, GRBFN (General Radial Basis Function Network) of ANN is proposed for electricity price forecasting. It is an extension of RBFN of ANN in a way that the optimal parameters of the Gaussian functions are determined by the learning process in RBFN. To improve the model accuracy of GRBFN, FCE (fuzzy c-Elliptotypes) is introduced into GRBFN as a fuzzy precondition technique. FCE is an extension of FCM (fuzzy c-means) and plays a key role to classify input data into fuzzy clusters. The use of FCE contributes to the improvement of model accuracy for spikes of electricity price that bring about much higher price. This paper makes use of DA clustering to evaluate a better initial solution of the parameters of the Gaussian functions. Also, EPSO of evolutionary computation is used to evaluate better weights between neurons. The proposed method is successfully applied to real data of electricity price.

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Keywords: artificial neural network;RBFN; GRBFN; time-series forecasting; global clustering; DA clustering; fuzzy clustering; fuzzy c-Elliptotypes; evolutionary computation; EPSO; electricity price; power markets; spikes

* Corresponding author. Tel.: +81-3-5343-8292; fax: +81-3-5343-8113.
E-mail address: hmori@meiji.ac.jp

Nomenclature

d_{rk}	eigenvectors of Fuzzy Scatter Matrix
e	cost function to be minimized in GRBFN
f	cost function to be minimized in DA clustering

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g	cost function to be minimized in Fuzzy c-Elliptotypes
g_{best}	best solution of swarm
h_{nk}	output of Gaussian function at the hidden layer
i	particle number
j	cluster number
N_F	number of clusters in Fuzzy c-Elliptotypes
k	cluster number
l	element number
M	fuzzy index
m	element number
N_D	number of clusters in DA clustering
n	number of data
$N(0,1)$	standard Gaussian random numbers with mean of 0 and standard deviation of unity
p_{nk}	attribute in probability that data n is assigned to cluster k in DA clustering
p_{best}	best solution of particle i
$rand(\ )$	standard uniform random numbers
s_j^t	location of particle i at iteration t
S_{lm}	Fuzzy Scatter Matrix
t_n	teach signal
u_{nk}	attribute in FCE
v_k	center of cluster k
v_j^t	speed of particle i at iteration t
r_{iq}^*	weights of particle i (q = 0, 1, 2)
w_k	weights between neurons at the hidden and output layers
x_n	data n
x_n^l	*l-th* element of data n
y_n	output at the output layer
z_{nk}	distance between data and center
β	temperature parameter
μ_k	center of *k-th* Gaussian function
σ_k^2	width of *k-th* Gaussian function
$\Delta\mu_k$	variation of center of *k-th* Gaussian function
$\Delta\sigma_k^2$	variation of width of *k-th* Gaussian function
τ, τ'	learning rates
$\cdot^*$	muted parameters of $\cdot$

1. Introduction

As a result of deregulated power systems, power markets have been open to purchase and sell electricity in each country. There is high probability that they are faced with risks and may lose their profits. A lot of financial products such as long-term contracts, future transactions, *etc.* have been developed to hedge risk in power markets. Under such circumstance, electricity price forecasting is one of fundamental tools. However, the behavior of electricity price includes very complicated factors such as randomness, nonlinearity, periodicity, uncertainties, *etc.* In particular, it is well-known that a time series of electricity price often has jump phenomena called spikes that correspond to several ten times higher prices instantaneously. In conjunction with power markets, transmission networks are often faced with network congestion that bring about higher electricity prices to market players. They are interested in the maximization of profits and the minimization of risks under such environment. As one of tools to solve the challenge, more advanced forecasting methods are required for the complicated time series of electricity price. Compared with the statistical methods such as ARIMA (Autoregressive Integrated Moving Average) model [1, 2], ANN (Artificial Neural Network) of intelligent systems has better performance due to the good nonlinear approximation function for nonlinear systems. Wang and Ramsay applied MLP (Multi-layer Perceptron) of ANN to