https://doi.org/10.17221/480/2020-AGRICECON

Nonlinear analysis and prediction of soybean futures

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Citation: Yin T., Wang Y. (2021): Nonlinear analysis and prediction of soybean futures. Agric. Econ. – Czech, 67: 200–207.

Electronic supplementary material

Supplementary Material S1

Artificial neural network (ANN) and chaotic artificial neural network (CANN)

The prediction model of artificial neural network (ANN) includes two important models, namely RBF (radial basis function) neural network model and BP (back propagation) neural network model. RBF neural network (RBF model), which is also called radial basis function neural network and proposed by Moody and Darken (1989), is a three-layer feed-forward network with a similar structure of multiple layers of forward networks with a single hidden layer. RBF neural network is a kind of local approximation network with three typical network structures: input layer, hidden layer and output layer. And back propagation neural network (BP model), including input layer, hidden layer and output layer, is using minimum variance learning method (Rumelhart et al. 1986; Yang and Tseng 1996). At the same time, it is a kind of supervised learning neural network, which contains three or more layers of neural networks. The specific structure of RBF model and BP model have been mentioned in many literatures, so it will not be repeated here.

The prediction model of chaotic artificial neural network (CANN) is the prediction model obtained by reconstructing the phase space of time series on the basis of artificial neural network. The inherent chaotic characteristics of time series can be grasped by phase space reconstruction. Accordingly, two models are constructed, namely RBF-CHAOS model and BP-CHAOS model.

The RBF-CHAOS model can be constructed by following steps:

Step 1: The embedding dimension m is obtained by phase space reconstructing of time series, and then take the embedded dimension m as the input number of RBF network, and let the output number as 1.

Step 2: Take the radial basis function form as:

$$w_j\left(\left\|\overrightarrow{h(t)}-\overrightarrow{k_j}\right\|\right)=\exp\left(-\frac{\left\|\overrightarrow{h(t)}-\overrightarrow{k_j}\right\|}{c^2}\right),\ j=1,2,\ldots,n \tag{1}$$

where: c – the width value; $\overrightarrow{h(t)}\in R^m$ – the input vector of the network; $w_j(.)$ – a radial basis function; $\|\cdot\|$ – norm; k_j – the center of the radial basis function.

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The BP-CHAOS model can be constructed by following steps:

Step 1: The embedding dimension m is obtained by phase space reconstructing of time series, and then take the embedded dimension m as the input number of BP network, and let the output number as 1.

Step 2: Take input and output of layer nodes respectively as:

$$L = \sum_{j=1}^{n} u_j c_j - b,$$

$$x_{i+1} = \frac{1}{1 + \exp\left(-\sum_{j=1}^{n} u_j c_j + b \right)}, \; j = 1, 2, \ldots, n \tag{2}$$

where:

$c_j = \dfrac{1}{1 + \exp\left(-\sum_{i}^{m} w_{ij} x_i + h_j \right)}$ – the output of hidden layer;

w_{ij} – the connection weight from the input layer to the hidden layer; h_j – the threshold value of hidden layer node; u_j – the connection weight from the hidden layer to the output layer; b – the threshold of the output layer.