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# Chaotic local weighted linear prediction algorithms based on the angle cosine

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**Abstract**

This paper expounds the limitations of the Euclidean distance as the measure between points similarity. According to the limitations of the original algorithm presented, chaotic local weighted linear forecast algorithm based on the angle cosine is proposed, which replaces Euclidean distance by cosine in the measurement of the similarity between phase points. In the process of parameters identification in the linear fitting, replace the Euclidean distance by the module and angle of vector as the optimal object. This algorithm overcomes the disadvantages of chaotic local prediction algorithm based on the Euclidean distance, and has obtained good effect in power load forecasting which is sensitive to the climate.



*Keywords:* Chaos time series; Angle cosine; Load forecast; engineering

## 1. Introduction

Chaos time series prediction is an important application field and study hotspot of chaos theory. It not only can be used to determine the dynamic system engineering model, detection and identification of chaos, are also widely used in all fields of natural science and social science, such as hydrological, electric engineering power load, sunspots and stock market forecast, which has important practical value and meaning.

Chaos time series prediction is based on the theory of phase space reconstruction. Based on the theory of phase space reconstruction, chaotic time series forecasting method can be divided into global method and local method. The former uses all the past information to predict the future value.[1] Because of the complex structure of the attractor, it's usually difficult to fit the global dynamic equation. The idea of the latter is that first find adjacent points of prediction benchmark under the sense of Euclidean distance. Then use the adjacent points as the data basis of chaotic sequence forecast to identify the parameters of the forecast model. Farmer and Sidorowich have proved that in the same embedded dimension, the local model works better than the global one, and that its calculated amount is significantly reduced.[2]

## 2. The principle of weighted first order local prediction method

The so-called first-order approximation is to fit the small field around the L$^{th}$ point using $x_{L+1} = a + bx_L$. Set the field of reference point $x_L$ as $x_{L1}, x_{L2}, \ldots, x_{LM}$, then it can be expressed as: [3]

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$$\begin{bmatrix} x_{L1+1} \\ x_{L2+1} \\ \cdots \\ x_{LM+1} \end{bmatrix} = ae + b \begin{bmatrix} x_{L1} \\ x_{L2} \\ \cdots \\ x_{LM} \end{bmatrix} \tag{1}$$

Where, $e=[1,1,...,1]_M'$. The value of a and b, which reflect the trend of the phase point in the phase space, can be got using the least square method. The concrete process of solving prediction is that after the determination of the reference field, use a and b to find out the linear evolutionary value of different points in the reference field. Then get the summation and the mean value of the evolutionary value to obtain the predictive value. In the process, there is an obvious question that how to determine the number of points in the scope of reference field. If the number is too much, the prediction effect will be impacted. Usually choose M = M + 1, M for embedded dimension.

On the basis of the phase space reconstruction and determination of the reference field, adding weight first order local method calculation weights of phrase points according to their Euclidean distance from the reference phrase point. Use the first-order polynomial to fit the trend of phase point in the phase space, which combines the advantages of weighted zero order local prediction method with that of first order local prediction method.

The specific algorithm is shown as below:

(1)Reconstruct the phase space of power load sequence, and get:

$$X(t)=\{x(t),x(t+\tau),...,x[t+(m-1)\tau]\} \tag{2}$$

Where, t=1,2,..,L. m is the embedding dimension, τ is the delay time, and $L=N-(m-1)\tau$.

(2)Calculate the Euclidean distance between the reference points and other phase points, and confirm the reference filed: $x_{Li}$, i=1,2,…M

(3)Compute the weights of the phrase points, according to the Euclidean distance:

$$p_i=\frac{e^{-a(d_i-d_m)}}{\sum_{i=1}^{M} e^{-a(d_i-d_m)}} \tag{3}$$

Where, di is the distance from $x_{Li}$ to $x_L$, and dm is the minimum among $d_i$, a=1;

(4) Calculation linear fitting parameters a and b using the least square method;

(5)The prediction value is $x_{L+1}=ae+bx_L$, where $e=[1,1,...1]_M'$.

The core of the local method is to choose the reference field which is similar with the center point, and conduct the prediction according to the evolution rule of phase points in the field. In the algorithm above, Euclidean distance is used as the measure of the similarity, while in high dimensional phase-space, it's difficult to reflect the similarity between the phase points accurately. Due to this, angle cosine is adopted to measure the similarity instead of Euclidean distance. Besides, in the process of calculating linear fitting parameters, take the phase points as the phasor, and the module and the angle of the phasor as the optimal object. The improved algorithm makes the similarity more assured, and selects better fitting parameters, so as to increase the prediction accuracy.

## 3. Improved algorithm

Suppose the power load sequence as $\{x(t), t=1,2,...,N\}$, carry out the phase-space reconstruction, and get the phase-space $X=\{x_1,x_2,...,x_L\}$.

The angle cosine between α and β is defined as: