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Analysis of Forecast Models of Time Series Chaotic

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Abstract- Problems from different areas of science constitute chaotic time series. Predicting the behavior of these series has proved to be an important challenge, especially about machine learning methods such as neural networks and fuzzy systems. A chaotic series that has been studied over the years is the Mackey Glass series. This work proposes a numerical comparison between two computational methods, namely, a Radial Base Function Neural Network (RBF) and an Adaptive Neuro-Fuzzy Inference System (ANFIS). The tests were carried out considering several delay scenarios of the series and demonstrated that, in all, there is a superiority of prediction of the ANFIS method.

Keywords*-Time Series, Neural Networks, Fuzzy Systems, Mackey Glass, RBF, ANFIS*

I. INTRODUCTION

Understand the dynamics of certain systems makes it enables the realization of actions who's the goal is analyze, control, and predict specific signals. Chaotic signals are present in several areas of science, in medicine, for example, heart rate signals are used to predict cardiovascular diseases [1].

Predicting the evolution of chaotic systems has been the subject of several studies, especially since the advent of machine learning techniques, such as support vector machines, the various architectures of artificial neural networks and fuzzy systems [2]. The ANN's, despite presenting themselves as excellent predictors, [2] highlights that it is computationally heavy because of the return propagation through the internal memory time.

For in addition to models based on RNA's, the systems fuzzy has also if been presented as an alternative to predicts time series with chaotic behavior [3]. Among the models based on fuzzy logic is the ANFIS (Adaptive Neural Fuzzy Inference System) which, according to [4], It consists of an effective method when applied to forecasting problems.

In this context of forecasting, a chaotic series that has historically been the object of studies is the Mackey Glass series [5]. This series comes from an ordinary differential equation, which makes it possible to generate different temporal behaviors by changing just a few parameters of the generating equation [5].

Bearing in view that the series of Mackey Glass makes it possible to the generation of various scenarios and that the models based in ANN and in fuzzy logic have as methods effective predictions, is that this work proposes a comparison between an RNA/RBF model and a fuzzy/ANFIS system. The proposed comparison is performed checking the values of MAPE (Mean Absolute Error Percentage) for different chaotic scenarios in the series.

II. THEORETICAL REFERENCE

The theoretical subsidy necessary for the understanding and execution of this work consists, general, in two topics: Neural Network of Radial-Based Function and Adaptive Neuro-Fuzzy Inference System-ANFIS. Thus, such topics will be addressed in the following subsections.

A. Radial Base Function Neural Network-RBF

When in an ANN the activation function of its intermediate layer is radial based, this network is called a Radial Based Neural Network [6]. A function, according to [6], is said to have a radial basis when its image is exactly the functional value of the norm of its arguments. In mathematical terms the radial basis function can be defined as in equation (1).

$$f(x) = f(\|x\|) \qquad (1)$$

For [7] an RN-RBF Differs, for example, from an MLP for having only an intermediate layer with activation functions. In most cases, the activation functions are of the Gaussian type (Fig. 1)

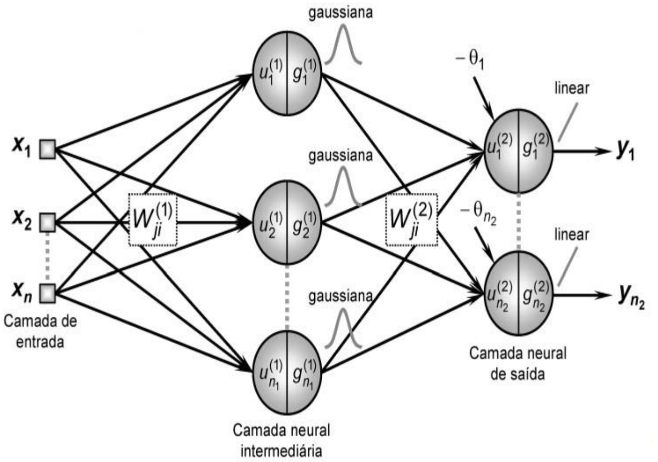

Figure 1. RBF Neural Network [7]

Reference [7] state that artificial neural networks, in general, are excellent computational methods for time series prediction, especially networks with radial basis functions. That is, it is a method that deserves prominence and performance analysis.

B. *Adaptive Neuro-Fuzzy Inference System-ANFIS*

A neuro adaptive diffuse inference system or adaptive network-based fuzzy inference system (ANFIS) is a type of artificial neural network that is based on the fuzzy inference system [8].

Reference [9] defines an system of interference Neuro-Fuzzy System-ANFIS as a structure composed of a combination of a diffuse inference system and a neural network. The topology of this structure can be seen in Fig. 2.

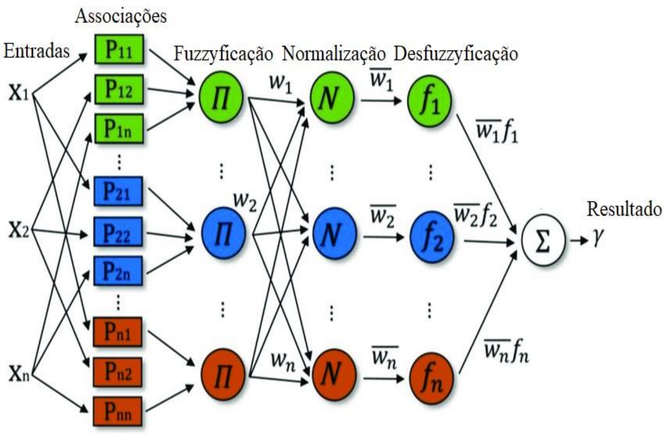

Figure 2. ANFIS system [9]

According to [8], this system can learn to approximate nonlinear functions and is considered a universal estimator.

III. MATERIALS AND METHODS

The problem analyzed here consists of comparing two systems designed to predict the Mackey-Glass chaotic time series that is generated by a differential delay equation (Equation (2)).

$$\frac{dx(t)}{dt} = \frac{0.2x(t-\tau)}{1+x^{10}(t-\tau)} - 0.1x(t) \quad (2)$$

The sequence of steps performed in this methodology were:

1. Solve the solution (2) using the Runge Kutta method and get x(t) with 3000 points.
2. Make the prediction of x(t) using 2000 points for training and 1000 for testing through the RBF.
3. Make the forecast x(t) using ANFIS.
4. Calculate the average percentage error of each method and compare the results for different values of τ (τ = 10 to τ = 24).

The metric used to compare the RBF with the ANFIS was the MAPE (Mean Percentage Absolute Error). This metric measures the error in percentage and is calculated according to Equation (3).

$$MAPE = \frac{1}{n}\left(\frac{\sum_1^n |actual - predicted|}{actual}\right) \quad (3)$$

The computer simulations were performed using the Matlab-simulink programming software and the results are shown in graphs in the following section.

IV. RESULTS

The results of the computer simulations were obtained considering two stages. In the first step, the solution of the differential equation (2) was verified for a τ = 24. To solve the equations, the fourth order numerical method of Runge Kutta was used. The results obtained in this step are shown in Figure 3.

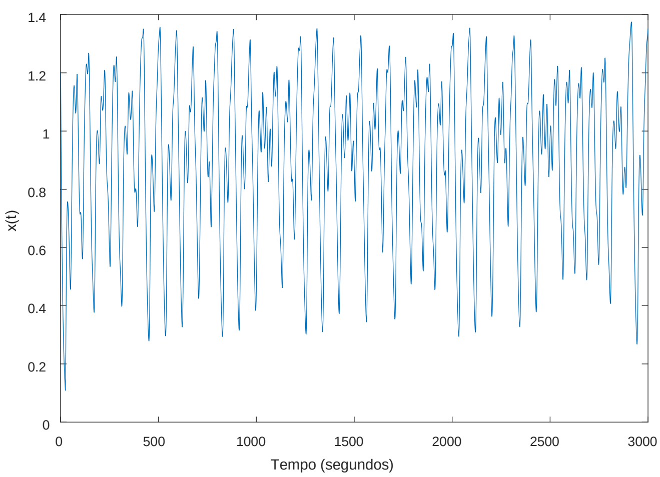

Figure 3. Mackey Glass chaotic series with 3000 points and τ = 24.

After solving the differential equation (2), the ANFIS prediction method was used. In time series prediction, we use known values of the series up to a point in time, t, to predict the value at some point in the future, t + P. By default, a mapping of sample data points D is created, sampled at each Δ units in time (x(t−(D−1)Δ),...,x(t−Δ),x(t)) to a predicted future value x(t+P). Following the conventional settings to predict the time series, D = 4 was defined in such a way that for each t, the training data form a four-column vector according to Equation (4).

$$w(t) = [x(t_{19}), x(t_{12}), x(t_6), x(t)] \quad (4)$$

In Fig. 4 it is possible to observe the test result for τ = 24 compared with the real values of the series.

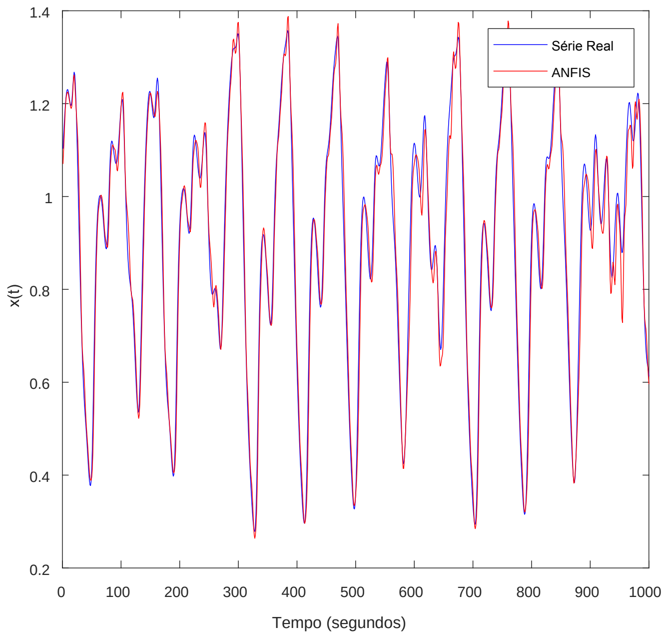

Figure 4. ANFIS test result for τ = 24.

The other prediction method used was the RBF neural network. In this application, the set of values of the series was separated into training and testing (2000 points for training and 1000 for testing). Figure 5 shows a comparison between the real values of the series and those predicted by the RBF for a value of τ = 24.

Observing Figures 4 and 5, it can be seen that the ANFIS method is significantly better for the specific case of τ = 24. However, it is not possible, with this result alone, to affirm the superiority of the method. In this sense, it was decided to extend the computational tests by varying the value of τ in an interval between 10 and 24. This interval was chosen with the purpose of leaving the value 17 in the center, because according to Cox (1994) the analyzed series has characteristics for τ > 17, that is, the set of delays chosen allows the analysis of chaotic and non-chaotic series. Figure 6 shows a comparison between the mean percentage error values obtained with the two analyzed methods.

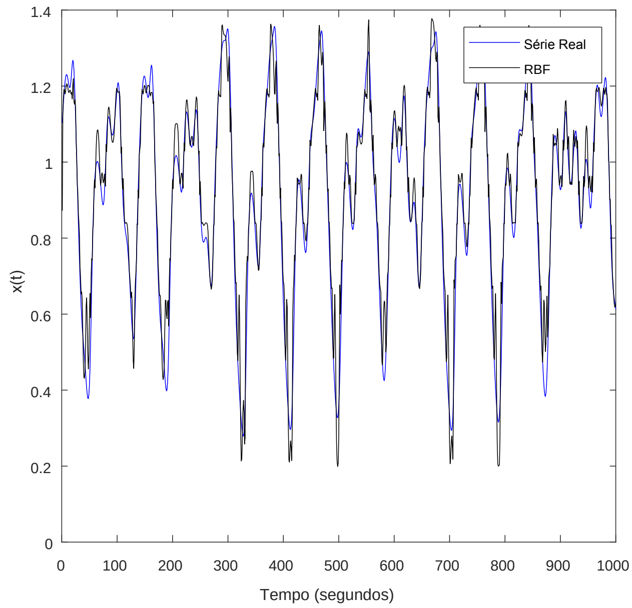

Figure 5. RBF test result for τ = 24

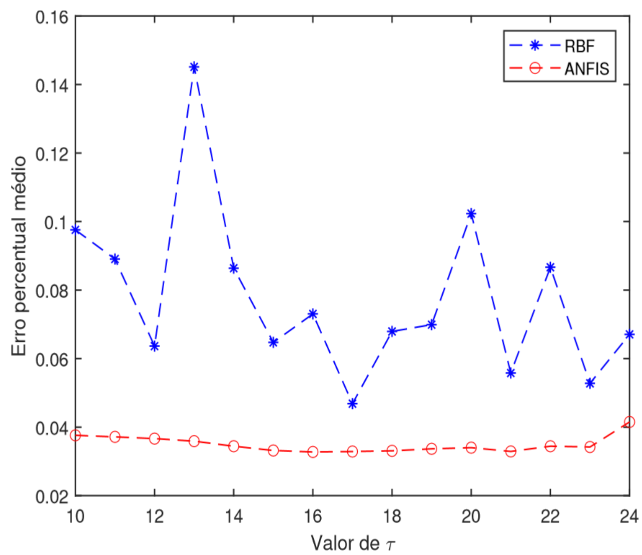

Figure 6. Average percent error for different scenarios of the Mackey Glass series

Observing Figure 6, the MAPE value in the different scenarios varied between 4% and 15% when using the RBF method. On the other hand, when using the ANFIS method, the MAPE values remained stable around 4%, which indicates a superiority, in terms of error, of the ANFIS method.

V. CONCLUSION

In this work, a comparison was made between two methods of forecasting chaotic time series. The series analyzed was that of Mackey Glass. The simulations were carried out considering several delay scenarios and the results obtained showed that both methods proved to be effective in predicting the data of the analyzed series. However, a superiority of the ANFIS method was noticed, since the errors generated were smaller in all analyzed scenarios.

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