6

Time Series Prediction with the Self-Organizing Map: A Review

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Summary. We provide a comprehensive and updated survey on applications of Kohonen's self-organizing map (SOM) to time series prediction (TSP). The main goal of the paper is to show that, despite being originally designed as an unsupervised learning algorithm, the SOM is flexible enough to give rise to a number of efficient supervised neural architectures devoted to TSP tasks. For each SOM-based architecture to be presented, we report its algorithm implementation in detail. Similarities and differences of such SOM-based TSP models with respect to standard linear and nonlinear TSP techniques are also highlighted. We conclude the paper with indications of possible directions for further research on this field.

6.1 Introduction

Time series prediction (TSP) (or forecasting) is a function approximation task whose goal is to estimate future values of a sequence of observations based on current and past values of the sequence. This is a rather general definition, which makes no distinction between the nature of the time series data samples; that is, whether they are deterministic (chaotic) or stochastic, linear or not, stationary or not, continuous or discrete, among other characterizations. Anyway, TSP is a mature field, with well-established linear and nonlinear techniques and well-defined data transformation methods contributed from many scientific domains, such as statistics, economy, engineering, hydrology, physics, mathematics and computer science.

From the last fifteen years on, a growing interest in TSP methods has been observed, particularly within the field of neural networks [1, 2]. To some extent, this interest can be explained by the fact that, in its simplest form, the TSP problem can be easily cast as a supervised learning problem, in which the input vectors are formed by the current and past values of a certain time series and the target values are the corresponding (one-step-ahead) future values. This fact has allowed users to explore the function approximation and

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generalization abilities of some well-known supervised neural architectures, such as the Multilayer Perceptron (MLP) and the Radial Basis Functions (RBF) networks. Not surprisingly, the vast majority of applications of neural network models to TSP tasks are based exactly on these two architectures and their variants.

The *Self-Organizing Map* (SOM) [3, 4, 5] is an important unsupervised neural architecture which, in contrast to the supervised ones, has been less applied to time series prediction. We believe that this occurs because TSP is usually understood as a function approximation problem, while the SOM is commonly viewed as a neural algorithm for data vector quantization (VQ), clustering and visualization [6, 7]. Despite this view, the use of the SOM as a stand-alone time series predictor is becoming more and more common in recent years, as we shall review in this paper.

In a global perspective, the main goal of the paper is then to show that, despite being originally designed as an unsupervised learning algorithm, the SOM is flexible enough to give rise to a number of efficient supervised neural architectures devoted to TSP tasks. To our knowledge, this paper is the first of its type, since former surveys on neural networks for time series prediction (see, for example, [2, 8, 9, 10]) only report just a few SOM-based applications (or even none at all!). In this regard, the contributions of this review are manifold, as we provide a comprehensive list of references, give detailed description of architectures, highlight relationships to standard linear and nonlinear TSP techniques and indicate possible directions for further research on this field. We do not follow a chronological order of presentation of the SOM-based models for TSP, but rather an order that favors understandability of the concepts involved[1].

The remainder of the paper is organized as follows. In Section 6.2 a brief description of the SOM algorithm is carried out. Then, in Section 6.3, we present the basic principles of time series prediction and discuss some reasons to using the SOM for this purpose. Several SOM-based models for TSP are presented from Section 6.4 to Section 6.8. In Section 6.9 possible directions for further research on the field are suggested. The paper is concluded in Section 6.10.

6.2 The Self-Organizing Map

The SOM is a well-known unsupervised neural learning algorithm. The SOM learns from examples a mapping from a high-dimensional continuous input space $\mathcal{X}$ onto a low-dimensional discrete space (lattice) $\mathcal{A}$ of q neurons which are arranged in fixed topological forms, e.g., as a rectangular

[1] Matlab codes of most SOM-based TSP models described in this paper can be downloaded from http://www.deti.ufc.br/∼guilherme/competitive.html.