Application of Markov Chains to Analyze and Predict the Time Series

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Abstract

Markov chains are usually used in modeling many practical problems. They are also effective in modeling time series. In this paper, we apply the Markov chains model to analyze and predict the time series. Some series can be expressed by a first-order discrete-time Markov chain and others must be expressed by a higher-order Markov chain model. Numerical examples are given. The results show that the performance and effectiveness of the Markov chain model to predict the time series is very well.

Keywords: Markov chains, Time series analysis, Mathematical Modeling

1. Introduction

Markov chains are useful tools in modeling many practical systems such as queuing systems (Ching, 2001,and Sharma, 1995.), manufacturing systems (Buzacott & Shanthikumar, 1993.) and inventory systems (Ching, Fung & Ng, 2003,pp.291−298 and Nahmias, 1997). Applications of Markov chains in modeling categorical data sequences can also be found in (Ching, Fung & Ng, 2002, pp.87−199 and MacDonald & Zucchini, 1997). Time series occur frequently in many real world applications. If one can model the time series accurately, then one can make good predictions and also optimal planning in a decision process (Ching, Ng & Fung, 2008, pp.492−507).

In this paper, we apply the Markov chains model to analysis and predict the time series. Some series can be expressed by a first-order discrete-time Markov chain and others must be expressed by a higher-order Markov chain model. Numerical examples are given. The results show that the performance and effectiveness of the Markov chain model to predict the time series is very well.

2. Markov chain model

2.1 The first-order Markov chain model

We consider modeling a time series x_t by a first-order Markov chains having k states $E=\{1,2,\ldots,k\}$. A first-order discrete-time Markov chain having k states satisfies the following relationship:

$$P(x_{t+1}=i_{t+1}\mid x_t=i_t, x_{t-1}=i_{t-1},\cdots,x_1=i_1)=P(x_{t+1}=i_{t+1}\mid x_t=i_t),$$

where x_t is the state of a time series at time t and $i_t \in E$. The conditional probabilities

$$P(x_{t+1}=i_{t+1}\mid x_t=i_t)$$

are called the one-step transition probabilities of the Markov chain. These probabilities can be written as $p_{ij} = P(x_{t+1}=i\mid x_t=j)$ for i and j in E. The matrix $P=(p_{ij})_{k\times k}$ is called the one-step transition probability matrix. We note that the elements of the matrix P satisfy the following two properties:

$$0\le p_{ij}\le 1 \ \forall i,j \in E \text{ and } \sum_{i=1}^{k} p_{ij}=1, \forall j \in E$$

A first-order Markov chain model

$$\mathbf{x}_{t+1}=P\mathbf{x}_t \tag{1}$$

is then constructed for the observed time series.

We have the following well-known proposition for a transition matrix P. The proof can be found in (Horn & Johnson, 1985, pp. 508−511) and therefore omitted here.

Proposition 1. *The matrix P has an eigenvalue equal to one and all the eigenvalues of P must have modulus less than or equal to one.*

Generally one has the following proposition for a non-negative matrix, see for instance (Horn & Johnson, 1985, pp. 508−511).

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