# 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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deciding the rules that ought to be applied in civil and criminal procedures Nagel also covers computer aided mediation and provides a new perspective on judicial decisions Then in Part IV he treats at length the process of judicial administration and how to improve its efficiency Of particular interest to court personnel will be the benefits to be derived from reducing delays and in the docketing and sequencing of cases **Computer Applications** ,1978 Bridge Design and Performance and Composite Materials National Research Council (U.S.). Transportation Research Board,1989 **API Series** ,1965 **Geotechnical Engineering, 1989** ,1989 9th International World Wide Web Conference Bozzano G Luisa,2000-05-11 These Proceedings contain the papers presented at The Ninth International World Wide Web Conference WWW9 held on May 15 19 2000 in Amsterdam the capital of The Netherlands Leaders from industry academia and government present the latest developments in Web technology and discuss the issues and challenges facing the Web community as it moves into the 21st Century **9th International World Wide Web Conference** ,2000-05-11 These Proceedings contain the papers presented at The Ninth International World Wide Web Conference WWW9 held on May 15 19 2000 in Amsterdam the capital of The Netherlands Leaders from industry academia and government present the latest developments in Web technology and discuss the issues and challenges facing the Web community as it moves into the 21st Century **Current Index to Statistics, Applications, Methods and Theory** ,1999 The Current Index to Statistics CIS is a bibliographic index of publications in statistics probability and related fields *Applications of Systems Analysis Models - A Survey* ABT Associates (Cambridge, Mass.),1968 **Proceedings of the Biennial Meeting of the Scandinavian Society of Forest Economics, Vantaa, Finland, 12th-15th May 2004** Scandinavian Society of Forest Economics. Meeting,2004

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