ELSEVIER

CrossMark

Chinese Astronomy and Astrophysics 39 (2015) 368–379

CHINESE
ASTRONOMY
AND ASTROPHYSICS

Prediction of Length-of-day Variations Based on Gaussian Processes[†] [⋆]

LEI Yu[1,2,3△]   ZHAO Dan-ning[1,3]   GAO Yu-ping[1,2]   CAI Hong-bing[1,2]

[1] *National Time Service Center, Chinese Academy of Sciences, Xi'an 710600*

[2] *Key Laboratory of Time and Frequency Primary Standards, Chinese Academy of Sciences, Xi'an 710600*

[3] *University of Chinese Academy of Sciences, Beijing 100049*

Abstract Due to the complicated time-varying characteristics of the length-of-day (LOD) variations, the accuracies of traditional linear models for the prediction of the LOD variations, such as the least squares extrapolation model, the time-series analysis model and so on, cannot satisfy the requirements for the real-time and high-precision applications. In this paper, a new machine learning algorithm — the Gaussian process (GP) model is employed to forecast the LOD variations. Its prediction accuracy is analyzed and compared with those of the back propagation neural networks (BPNN), general regression neural networks (GRNN), and the Earth Orientation Parameters Prediction Comparison Campaign (EOP PCC). The results demonstrate that the application of the GP model to the prediction of the LOD variations is efficient and feasible.

Key words astrometry, time, methods: data analysis

1. INTRODUCTION

The LOD variation is an important parameter to characterize the earth rotation variation, it mirrors the rate variation of the earth rotation by indicating the difference between the astronomically defined one day and the LOD of 86400 seconds. As the so-called earth rotation parameters (ERP), both the LOD and polar motion (PM) are the parameters only with which can the transformation between the celestial reference system and the terrestrial

† Supported by National Natural Science Foundation (No.10573019)

Received 2014–07–02; revised version 2014–08–04

⋆ A translation of *Acta Astron. Sin.* Vol. 56, No.1, pp.53–62, 2015

△ leiyu@ntsc.ac.cn

doi:10.1016/j.chinastron.2015.07.008

reference system be realized, and are commonly applied to many research fields, such as the deep-space exploration, precise satellite orbit determination, astrogeodynamics, and so on[1]. The modern geodetic techniques, including the very long baseline interferometry (VLBI), global navigation satellite system (GNSS), and satellite laser ranging (SLR) etc., have been widely used in the routine monitoring of earth rotation variations, and provided the observational data of high time-space resolution and high precision. However, the acquisition of ERP using the modern geodetic techniques is often delayed for some days even two weeks because of the complicated data treatment procedure. The rapid prediction of ERP in real time, therefore, becomes a topic worth studying.

For the ERP prediction, it is a hard nut to forecast precisely the LOD variation, especially during the occurrence of an el Niño) event, while an amplified oscillation comes about in the LOD variation because of the variation of tropical monsoon. More and more attentions are paid to the high-precision real-time predications of the LOD variations. The LOD variations consist mainly of two parts, namely a tidal component and a non-tidal one, and the former can be accurately determined with the models given conventionally by the International Earth Rotation and Reference Systems Service (IERS)[2], while the seasonal variations of the latter, such as the annual term and semi-annual one, are caused by the angular momentum interchanges of the solid earth with the global atmosphere, ocean and underground water[3].

Many studies have been made on the ERP prediction, and various prediction models, put forward, including the extrapolation model of least squares (LS)[4], the combination of the LS extrapolation model and autoregressive (AR) model (LS+AR)[4−5], the Kalman Filter combined with atmospheric angular momentum (Kalman Filter+OAM)[6−7], the combination of the LS extrapolation model and artificial neural networks (ANN) (LS+ANN)[3,8−11], fuzzy-inference systems (FIS)[12], as well as the combination of the discrete wavelet transform (DWT) and autocovariance (AC) model (DWT+AC)[13], and so on. In order to compare the prediction results of various models, the Institute of Geodesy and Geophysics of Vienna University of Technology organized a global campaign of prediction comparison for the earth rotation orientation parameters in the period from 1st October 2005 to 28th February 2008, and the results of more than two years have shown that there is no such a model which is suitable to predict all components of ERP, and is simultaneously suitable to make the prediction for all time spans[14].

It is theoretically more rational to adopt non-linear methods for the prediction of the earth rotation variation because of its complexity and its non-linear irregularity caused by various excitation factors[8−11]. The ANN are the effective means to approximate the complex non-linear functions, many researchers have applied it to predicting the ERP and have obtained significant results[3,5,8−11]. But some shortcomings exist with the ANN, such as the difficulty of determining the network topological structure, the excessive learning in the training procedure, the rashness of the iterative procedure to sink into partial optimization,