L1, L2, Kalman Filter and Time Series Analysis in Deformation Analysis

Assoc. Prof. TOR Yam Khoon, Singapore

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ABSTRACT

This paper discusses the use of minimum norm (L1), least squares (L2), Kalman filtering, and time-series analysis (Box-Jenkins models) in extracting the true signals in deformation measurement and analysis, especially in the presence of outlying observations and environmental disturbances due to wind, rain and temperature changes.

Minimum norm, or the L1 method, and the least squares, or L2 method, with robust estimation techniques are the traditional methods used in pre-deformation analysis. The inherent weakness in these two traditional methods in dealing with continuous deformation measurement using motorized total station (also known as surveying robot) is the non-consideration of the correlation in the data, which is basically a time series.

The autoregressive and autocorrelation nature of the continuous monitoring measurements could be explored using the Box-Jenkins time series models. Filtering and prediction done using the sophisticated Autoregressive Integrated Moving Average (ARIMA) techniques or its subset is however not suited for automated real-time deformation analysis.

This study focused on the use of Kalman filter in filtering out outlying data and noisy data. The known systematic effect of pillar rotation, scale change and change in refraction as well as the horizontal directions, slope distances and zenith angles were modeled as the state vector in a forward Kalman filtering and backward smoothing. It is proven in this study that it is feasible to implement an automated real-time Kalman filter in deformation analysis. Test carried out on a 'stable' building at Nanyang Technological University, Singapore, and processed using Kalman filter confirm the 'movement' of the building of less than 1 mm.

CONTACT

Assoc. Prof. TOR Yam Khoon
School of Civil and Environmental Engineering
Nanyang Technological University
Block N1, #01a-06, Nanyang Avenue
Singapore
REPUBLIC OF SINGAPORE
Tel. + 65 6791 1744 Ext 4743
Fax + 65 6791 0676
E-mail: cyktor@ntu.edu.sg
Web site: http://www.ntu.edu.sg/cee