Analysis of traffic data by considering nonlinearity and nonstationarity

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Summary. The paper focuses on characterization of real life traffic by analysis of flow volume and speed measured at different locations over a day. The analysis addresses the challenging issues of non-stationarity and non-linearity present in the traffic data by performing a nonlinear time series analysis. The work involves estimation of correlation and embedded dimensions, Lyapunov exponents, Kolmogorov entropy and development of bivariate phase space diagram for flow volume and speed. The results can be the basis for identification of appropriate model to predict and estimate traffic volume and speed.

Extended abstract.

Real-life traffic is characterised by traffic condition variables, such as traffic volume, traffic speed (averaged over space or time), density etc. and their evolutions over space and time. Traffic condition variables or traffic variables are measured by static or fixed detectors against time. Analysis and modelling of the traffic time-series datasets are essential for subsequent control of real-life traffic networks or traffic management.

Traffic time-series datasets such as traffic volume and speed as measured are affected by various factors. Some of these factors can be modelled such as traffic signal control and some are uncertain such as weather conditions or calendar events. Traffic time-series datasets are generally modelled as linear models to avoid computational complexity though the traffic time-series datasets as measured using fixed detectors are non-linear and non-stationary in nature. These nature of these datasets vary based on location, traffic control types and other factors. This study aims at exploring, comparing and contrasting the non-linear characteristics of the traffic volume and speed datasets from different location and time–periods. Also, the temporal evolution of the volume-speed relationship (known as fundamental diagram) from various sources will also be investigated to characterise congestion effects.

In this study three highway stations from San Diego and three urban stations from Dublin were used for analysis. The data considered for the highway stations were flow volume and flow speed ranged over a day and only flow volume were considered for the urban stations in the study. Figure 1 shows the flow volume time series ranged over a day. It can be noted from the time series plots that the highway locations has more fluctuations when compared the urban data.

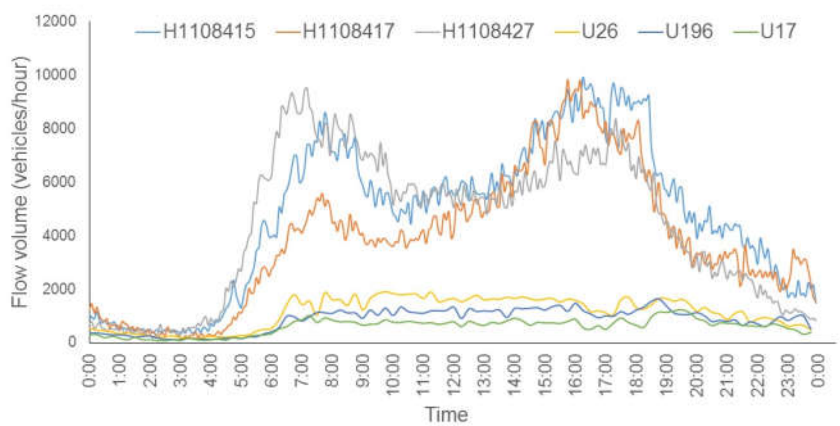

Figure 1. Plot for flow volume over a day. H1108415, H1108417 and H1108427 represent three highway measuring stations at San Diego and U26, U196 and U17 represents three urban measuring stations at Dublin.

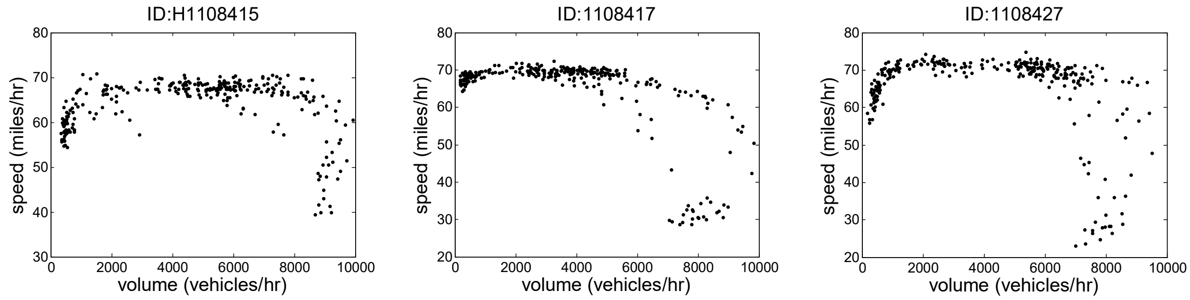

Figure 2. Plot of volume vs. speed curve for 3 highway stations at San Diego.

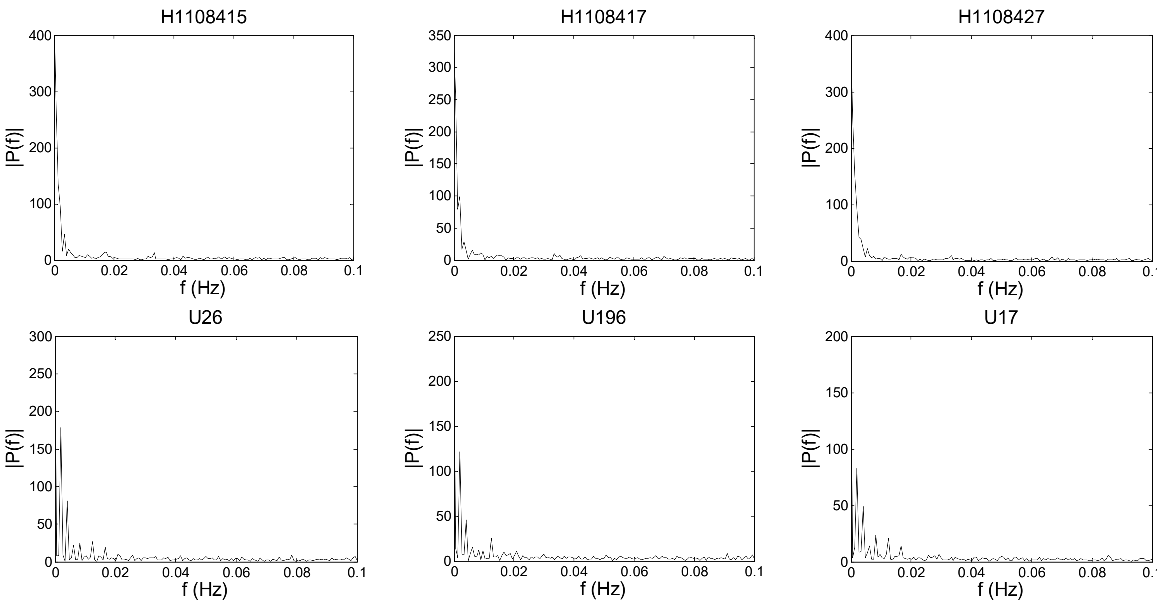

Figure 3. Fourier spectrum of the highway and urban volume data.

The fundamental diagram for the three highway stations were plotted in Figure 2. The figure indicated that with increase in flow volume, the speed got reduced. However, for very high volume, the network becomes congested and the relationship between volume and speed becomes chaotic in nature. The Fourier spectrum was then plotted in Figure 3. It can be noted from the Fourier spectrum that the energy decays rapidly for highway locations whereas there are evidence of periodicity for the data observed inside urban locations.

Since the traffic process is a highly non-stationary and non-linear process, a detailed analysis is needed to characterize the nonlinearity of the process. For this purpose, several nonlinear characteristics such as the correlation dimension and embedded dimension, Lyapunov exponents, Kolmogorov entropy were estimated for each of the volume time series data. The degree of nonlinearity was categorized by using the empirical mode decomposition (Huang et al., 1998).

Further, to understand the relationship between the flow volume and the average vehicle speed, a bivariate phase space diagram were constructed. Those information can be used to understand the traffic process at different locations and duration. Those information will be utilized to identify the appropriate model for prediction and estimation of traffic volume and speed by considering real world complexities.

Reference

Huang N.E., Shen Z., Long S.R., Wu M.C., Shih E.H., Zheng Q., Tung C.C., Liu H.H. (1998) The empirical mode decomposition method and the Hilbert spectrum for non-stationary time series analysis. *Proc. Roy. Soc. London*, **454A**, 903-995.