

Development of Unequally-Spaced Traffic Measurement Prediction Model

By

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ABSTRACT

This paper presents the development of unequally-spaced or irregularly observed traffic measurement prediction model. Traffic measurements from detectors are usually observed or assumed to be equally-spaced (e.g., every 30 seconds and 1 minute) for transportation research. However, some traffic measurements may not be observed or assumed to be equally-spaced especially in arterial street and ITS applications. Continuous-time Kalman filtering may be used for modeling unequally-spaced traffic measurements especially for arterial street incident detection purpose.

I. INTRODUCTION

There are many prediction models utilizing traffic measurements such as percent occupancy, traffic count, and speed from detectors. These prediction models are used for many applications in traffic research including incident detection on highways. However, these models have a common assumption: equally-spaced data measurements. In fact, traffic or transportation data sets are unequally-spaced in some occasions. For example, data missing from mal-functioned detectors and irregular field data due to weather condition. Unequally-spaced data sets may then be modeled by continuous-time Kalman filtering models.

II. UNEQUALLY-SPACED MEASUREMENTS IN TRANSPORTATION

RESEARCH

There are some instances in transportation research to run across the unequally-spaced data measurements. For example, mal-functioned detectors on highway provide missing traffic counts, percent occupancy, and speed over time. If missing data collection occurs randomly over time, this data set is irregularly observed data set. Another example is irregular field data collection due to weather condition. For example, a retro-reflectivity data collection on pavement marking materials in regular time-based requires dry pavement condition to avoid measurement device damage and correct data reading. However, in locations where an adverse weather (e.g., rain and snow) condition is frequent, field trip to data collection is frequently delayed, resulting in irregular data collection sets. Other example in transportation research is a data aggregation problem on highways especially in arterial streets (Lee and Taylor 1999).

For example, incident detection strategy on signalized arterial streets is to aggregate traffic measurements in a certain time interval. This time interval should be as short as possible for a quick incident detection. However, it is not useful to collect and aggregate traffic measurements in less than cycle length due to high fluctuations of the measurements. If it is aggregated in 30 seconds for the cycle length of 75 seconds, percent occupancy may be more than 90 percent for the first 30 seconds (red interval) and less than 30 percent during next 30 second (green interval), and so on.

III. LITERATURE REVIEW

There are not direct study on unequally-spaced measurement prediction in transportation research. The only study would be travel time forecasting for ADVANCE project in Chicago, USA (Sen, Thakuriah and Liu 1993). A strategy for short-term travel time forecasting for in-vehicle navigation systems was developed as part of ADVANCE study. Travel time data was reported by probe vehicles but consecutive reports would not be the same over time. An irregularly spaced data-based design was suggested but resulted in no results.

IV. UNEQUALLY-SPACED MEASUREMENT PREDICTION MODEL

Dealing with unequally-spaced measurements is sometimes referring to dealing with missing data over time. The one technique using the EM (Expectation-Maximization) algorithm allows a partition of missing data and the rest of observed data in the model (Shumway 1988). However, this method may be useful for missing data sets over time in a regular basic sample interval rather than unequally-observed measurements. One

literature states “Unequally spaced observations differ from equally spaced observations with some missing observations in that there is no basic sampling interval. (Jones 1993, page 56).” Therefore, measurements without a basic sample interval (i.e., data aggregation in a signalized urban arterial streets) can be better modeled by considering a continuous time process.

IV. 1 Continuous-Time State-Space Model

A general model that may describe a special cases of interest in the same way that linear regression does is the state-space model. State-space model is expressed in two equations: State-Space Equation and Measurement Equation. General forms of these equations in terms of continuous-time process are below.

State-Space Equation

$$\mathbf{x}(t) = \Phi(t; t - \delta t)\mathbf{x}(t - \delta t) + \mathbf{w}(t)$$

where

$$\mathbf{w}(t) \approx N(0, \mathbf{Q}(t))$$

Measurement Equation

$$\mathbf{z}(t) = \mathbf{H}(t)\mathbf{x}(t) + \mathbf{v}(t)$$

where

$$\mathbf{v}(t) \approx N(0, \mathbf{R}(t))$$

$\mathbf{x}(t)$ is the state-space variable that we are interested in such as traffic count, percent occupancy, and speed from detectors. This state-space is unknown true value that should be estimated through noisy measurements ($\mathbf{z}(t)$) from detectors. $\Phi(t; t - \delta t)$ is state transition

matrix that transforms the state from time t to $t-\delta t$ where δt is time step of length. $H(t)$ is an observation sensitivity matrix at time k . $w(t)$ and $v(t)$ are noisy terms with error covariance of $Q(t)$ and $R(t)$ with the assumption of normally distribution. If a system process is dynamic, Q and Φ are varying over time. Also, if the process is unequally-spaced, then these terms are also dependent of time step of length.

Recursive process produces the predicted estimates and the filtered estimates over time.

Detailed process can be refered in the literature (Grewal and Andrews 1993).

For the unequally-spaced measurement estimates can be done by obtaining time-interval dependent terms in state-space equation. For a simple AR(1) process, Q and Φ may be expressed below for time-interval dependent parameters (Jones 1993).

$$\Phi(\delta t) = \exp[-\alpha_0(\delta t)]$$

$$Q(\delta t) = \sigma^2 [1 - \exp(-2\alpha_0\delta t)]$$

This model is very useful and potential for many traffic engineering studies and ITS applications. One great potential application may be incident detection on signalized arterial streets because of the nature of traffic measurements.

V. CONCLUSIONS

It is frequent for traffic researchers to run across the traffic measurements that we may not simply assume an euqllly-spaced over time in many traffic research. It is particular true for conducting research on signalized arterial streets and ITS applications. However, there is no study available investigating an unequally-spaced traffic measurements. This paper presents a prediction model for unequally-spaced measurements by investigating

continuou-time Kalman filtering. This model is very useful and a great potential for many traffic engineering studies and ITS applications.

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