Granular Analysis of Traffic Data for Turning Movements Estimation

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ABSTRACT

The paper discusses the principles and the algorithm of granular analysis of data in a specific context of urban traffic monitoring and control (EIS). The proposed granular information processing enables extraction of information on the pattern of journeys from the detailed traffic counts. This facilitates progression from the local optimisation of traffic on individual crossroads to the more holistic optimisation of traffic in a road network. The proposed EIS makes use of readily available stop-line queue data, which is used for adaptive tuning of traffic signals, and adds a data processing layer referred to as granular analysis. It is argued that granular analysis is preferred to statistical data processing since it does not require any assumptions about statistical characterisation of traffic. The granulation algorithm has two distinctive features: (1) the information granules are formed by means of hierarchical optimisation of information density, and (2) the granules are created as hyperboxes thus being readily interpretable in the pattern space. The granular estimates of turning movements are calibrated using an HUTSIM micro-simulator.

Keywords: knowledge and information management; simulation; transportation

INTRODUCTION

Modelling of urban traffic represents a significant conceptual and computational challenge. This is because the atomic components of urban traffic, for example, individual vehicles, are controlled by drivers who take into consideration both local traffic conditions and global intentions of their individual journeys. Although the local traffic situation can be measured to some degree, the global journey intentions are generally known only to the drivers. Further-
more, the driver intentions information is a dynamic entity that is not approximated well by some static characterisation such as an "origin-destination matrix". What is needed is a real-time estimation of journey intentions that is economical to deploy and does not compromise the privacy of individual drivers. The first requirement points to the use of the existing traffic telemetry, and the second implies some statistical rather than vehicle-specific journey characterisation.

The estimation of dynamic origin-destination (O-D) matrices from traffic counts in a transportation network has received much attention in the last two decades. Conventionally, O-D flow matrices were considered only for a certain period of interest and thus were estimated with the average traffic count data for that period (Chang & Wu, 1994). A comprehensive review of research along these lines has been presented by Cascetta (1984) and Cascetta and Nguyen (1988). Such methods were static in nature and relied on some prior O-D information as well as "standard" driver behaviour to produce a reasonable result. At the other end of the spectrum are the O-D estimation models that are based on statistical analysis of detailed traffic counts on individual approaches to the intersection. The O-D estimation problem is formulated in this case as a problem of minimisation of the prediction error evaluated as a discrepancy between the expected and actual traffic counts on all approaches (Cremer & Keller, 1987; Nihan & Davis, 1987; Peytchev, 1999). Although this approach can, in principle, deliver accurate estimates of turning movements on the intersection, it depends critically on the extensive instrumentation of each intersection, for example, real-time measurements of the incoming and outgoing traffic.

In this paper, we propose an alternative method that preserves the benefits of real-time estimation of turning movements while avoiding the need for extensive instrumentation of intersections. We argue that the secondary effect of the right-turning traffic (in UK) on the traffic queue provides an adequate approximation of turning movements. The key to this analysis is the observation that the reduction of measurement information requires that the analysis is performed at a more aggregated (granular) level.

The rationale for information granulation is deeply rooted in human information processing, which can be characterised as a constant endeavour to extract and organise knowledge about the external world. It is this very ability to abstract detailed information into more general information granules which enable humans to be successful in dealing with complex systems. Zadeh (1979, 1996, 1997, 1999) promoted a notion of information granulation in the framework of fuzzy sets that are particularly well-suited for representing vague or imprecise data. However, other granulation frameworks such as sets (intervals) are quite appropriate in a broad range of situations and have long been used for representing physical reality (that is essentially analog) in digital computers. In a nutshell, information granules are treated as collections of entities (say numeric readings) that are grouped together because of their similarity, functional closeness, or any other criterion that captures a feature of "indistinguishability". Information granules give rise to hierarchies of cognitive entities. When forming information granules, one needs to reconcile two aspects. On one hand, information granules are conceptual constructs that do not need to have immediate physical counterpart. But, on the other...