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Accurate freeway travel time prediction with state-space neural networks under missing data

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Abstract

Accuracy and robustness with respect to missing or corrupt input data are two key characteristics for any travel time prediction model that is to be applied in a real-time environment (e.g. for display on variable message signs on freeways). This article proposes a freeway travel time prediction framework that exhibits both qualities. The framework exploits a recurrent neural network topology, the so-called state-space neural network (SSNN), with preprocessing strategies based on imputation. Although the SSNN model is a neural network, its design (in terms of input- and model selection) is not "black box" nor location-specific. Instead, it is based on the lay-out of the freeway stretch of interest. In this sense, the SSNN model combines the generality of neural network approaches, with traffic related ("white-box") design. Robustness to missing data is tackled by means of simple imputation (data replacement) schemes, such as exponential forecasts and spatial interpolation. Although there are clear theoretical shortcomings to "simple" imputation schemes to remedy input failure, our results indicate that their use is justified in this particular application. The SSNN model appears to be robust to the "damage" done by these imputation schemes. This is true for both incidental (random) and structural input failure. We demonstrate that the SSNN travel time prediction framework yields good accurate and robust travel time predictions on both synthetic and real data.

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1. Introduction

There is an increasing need for Advanced traffic information systems (ATIS's) that can provide road-users and traffic managers with accurate and reliable real-time traffic information (Abdel et al., 1997). The potentially beneficial effects of ATIS's (in terms of individual and collective cost- or time savings) have been studied extensively in the past decade (e.g. Khattak et al., 1995; Arnott et al., 1991; Mahmassani and Liu, 1999). Although these studies clearly show the heterogeneity of possible responses to ATIS among different groups of drivers (e.g. commuters, non-commuters) under different (traffic) circumstances, they generally do emphasize two things. The first is that for traffic information to have beneficial effects, it should be based on *predictions* rather than on current or past traffic conditions (Chen et al., 1999). Secondly, the *reliability* of traffic information greatly influences driver response (Mahmassani and Liu, 1999; Van Berkum and Van der Mede, 1993). In a real-time setting, the reliability of traffic prediction models is among other things a function of the sensitivity of the models used to unreliable and/or incomplete input data.

In this article we present a neural network based travel time prediction framework that is both accurate and capable of dealing with (i.e. robust to) missing or corrupted input data. The model is aimed at short-term travel time prediction on freeways, typically for generating messages (expected travel times) on variable message signs (VMS's) on strategic locations (e.g. bifurcations) on a freeway network, or for real-time en-route travel information services such as RDS-TMC.[1] The framework consists of a recurrent neural network travel time prediction model, in conjunction with a preprocessing layer which utilizes simple imputation schemes to remedy input failure.

The article is outlined as follows. In the next section we will give an overview of the state-of-the-art in freeway travel time prediction. Thereafter, we present a novel recurrent neural network topology specifically designed for freeway travel time prediction: the so-called state-space neural network (SSNN). Subsequently, we will address the robustness of the SSNN model under missing or faulty input data and show results of the SSNN travel time prediction model on both synthetic and real data.

2. The freeway travel time prediction problem: state-of-the-art

Travel times on freeways are (certainly in congested conditions) the result of complex traffic processes, which are governed by stochastic and non-linear interactions between individual drivers. Evidently, *predicting* travel times for vehicles departing on a particular freeway route is as complex as predicting the underlying traffic processes vehicles will encounter, which—based on

[1] Radio data signal—traffic message channel.