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Fuzzy logic-based incident detection system using loop detectors data

Riccardo Rossi *, Massimiliano Gastaldi, Gregorio Gecchele, Valeria Barbaro

[a] *University of Padova - Department of Civil, Environmental and Architectural Engineering, Via Marzolo 9, Padova 35131, Italy*

Abstract

Vehicle loop detectors or other equipment installed on cross-sections are commonly used for monitoring traffic flow conditions on road network. For operational analysis it is crucial to distinguish between low level of service related to oversaturated conditions and generated by extraordinary events as incidents. In case of incident it is fundamental to have a prompt response in order to activate any requested countermeasure, such as rescue activation and traffic detour. This paper introduces a control system which recognizes incidents from vehicle loop detectors data (system control), and identifies the optimal position of loop detectors (system design).The system was developed using fuzzy logic concepts and calibrated using data from micro simulation experiments. Micro simulation approach is justified from the impossibility to get the requested data from on-field observations. The analysis has been focused on a two-way four-lane freeway basic segment; traffic flow variables (Density, Space Mean Speed and Flow Rate) were estimated with reference to the set of consecutive time intervals (one-minute long) belonging to the whole observation time period (3 hours). Simulated data were obtained running the model several times (10 runs) for each traffic volume class adopted in the analysis (1,000, 2,000, 3,000, 3,500 vehicles/hour), with different random number seeds. Calibration dataset was used to determine the knowledge base of each FIS using the open-source software FisPro, and the remaining data (validation dataset) to evaluate the performance of the system. The main finding of the study is that the detection system, despite its simplicity, shows excellent False Alarm Rate and satisfactory Mean Time To Detection.

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Keywords: Automatic Incident Detection; Fuzzy Logic; Loop Detectors; Microsimulation

* Corresponding author. Tel.: +39-049-827-5563; fax: +39-049-827-5577.
E-mail address: riccardo.rossi@unipd.it

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1. Introduction

In urban areas recurring congestion occurs during morning and/or evening peak periods because of the oversaturated traffic flow, with conditions that are generally easy to forecast. Another type of congestion is nonrecurring congestion, which occurs because of rapid capacity drop, due to unexpected reasons, that can be generally identified as incidents. Incidents may be accidents, disabled vehicles on the road, spilled loads, temporary maintenance and construction activities, signal and detector malfunctions, and other special and unusual events that disrupt the normal flow of traffic and cause motorist delay.

Whatever the reason is, congestion increases fuel consumption and emission due to increasing speed differentiation in addition to decreased travel speed and increased travel time. It is not easy to reduce these negative effects in recurring congestions, however it is possible in nonrecurring congestions through efficient traffic management systems, in particular by accurate detection of incidents.

Traffic management systems detect incidents by automatic or non-automatic methods. Automatic Incident Detection (AID) methods are more common: they analyse traffic data and quickly detect incidents, using different types of sensors and techniques (e.g. image-processing, detector/sensor based incident detection algorithms, probe vehicle data).

Wide literature on methods and applications is available on this topic, in this paper a fuzzy logic-based approach for detecting incident is presented. Fuzzy logic is an effective method to deal with complex non-deterministic problem. This paper introduces fuzzy theory into the automatic incident detection algorithm and uses fuzzy linguistic to describe the variation law of traffic parameters.

The paper is organized as follows. Section 2 presents a broad summary of different incident detection algorithms. In the third section of the paper the proposed Fuzzy Logic-Based Incidents Detection System is presented. The evaluation of the proposed system, tested with simulated data set, is provided in Sections 4 and 5. Finally results are evaluated in the last section.

2. Related Works

Automatic algorithms refer to those algorithms that automatically trigger an incident alarm when traffic condition data received from traffic sensors satisfy certain preset conditions; non-automatic algorithms or procedures are based on human witness reports (i.e., driver-based “sensors”). Automatic detection of incidents may be performed by different methods. Some techniques based on video processing have been adopted to detect traffic incidents (Michalopoulos et al., 1993), however they are sensitive to outdoor environmental factors (e.g. static shadows, snow, rain, and glare). The inductive loop detector (ILD) is the most commonly used sensor in traffic surveillance and management applications, which can collect the traffic data stably and does not suffer the outdoor environment impact.

Different algorithms based on data from fixed in-road sensors have different data requirements, principles, and structural complexity. Traditional incident detection algorithms have been grouped into seven categories in terms of their principles: 1) comparative algorithms; 2) statistical algorithms; 3) time series algorithms; 4) filtering/smoothing algorithms; 5) traffic modelling algorithms; 6) artificial intelligence algorithms; and 7) image processing algorithms (Parkany and Xie, 2005). All of these algorithms use loop detector or loop-emulating data collected at points along the roadway and all are applied to freeways.

Comparative algorithms are well-known algorithms, which compare the value of observed traffic parameters (i.e., volume, occupancy or speed) to pre-established thresholds and prompt an incident alarm when the value exceeds these thresholds. Comparative algorithms include the decision tree (DT) algorithms, also called California algorithms (Payne, 1976; Payne and Tignor, 1978; Levin and Krause, 1978) the pattern recognition (PATREG) algorithm (Collins et al., 1979), and the APID algorithm (Masters et al., 1991).

Statistical algorithms use statistical techniques to determine whether observed detector data differ statistically from estimated or predicted traffic characteristics, such as the standard normal deviate (SND) algorithm (Dudek et al., 1974) and Bayesian algorithm (Levin and Krause, 1978; Tsai and Case, 1979).

Time series algorithms employ time series models to predict normal traffic conditions and detect incidents when detector measurements deviate significantly from model outputs. Techniques used to predict time-dependent traffic