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Fuzzy deep learning based urban traffic incident detection

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Abstract

Traffic incident detection (TID) is an important part of any modern traffic control because it offers an opportunity to maximise road system performance. For the complexity and the nonlinear characteristics of traffic incidents, this paper proposes a novel fuzzy deep learning based TID method which considers the spatial and temporal correlations of traffic flow inherently. Parameters of the deep network are initialized using a Stacked Auto-Encoder (SAE) model following a layer by layer pre-training procedure. To conduct the fine tuning step, the back-propagation algorithm is used to precisely adjust the parameters in the deep network. Fuzzy logic is employed to control the learning parameters where the objective is to reduce the possibility of overshooting during the learning process, increase the convergence speed and minimize the error. To find the best architecture of the deep network, we used a separate validation set to evaluate different architectures generated randomly based on the Mean Squared Error (MSE). Simulation results show that the proposed incident detection method has many advantages such as higher detection rate and lower false alarm rate.

Keywords: Automatic traffic incident detection; Fuzzy deep learning; Deep artificial neural network; Stacked auto-encoder model; Back-propagation algorithm; Fuzzy logic controller

1. Introduction

Traffic congestion is a key problem to cause driver frustration and air pollution in today's urban area (El Hatri & Boumhidi, 2017). One of the important parts of intelligent transportation systems is incident detection. Traffic incidents are the main cause of congestion, which subsequently increases travel delay and fuel consumption in major cities. Traffic incidents usually cannot be predicted which poses great challenge to traffic management centers. Therefore, early detection of incidents reduces the delay experienced by road users, fuel consumptions, gas emissions, and the probability of other collisions, as well as improves road safety and real-time traffic control (El Hatri, Tahifa, & Boumhidi, 2016). This paper focuses on developing an intelligent system able to determine the presence of an incident by using real-time traffic data. The objective is to help the officer manage and take action to clear the roadway as early as possible and to ensure that traffic return to normal safety conditions.

For the aforementioned reasons, automatic traffic incident detection techniques have been investigated quite a lot in the recent years. A number of incident detection approaches based on traffic behavior or mathematical models have been proposed for this task. However, earlier incident detection methods are limited in distinguishing recurrent and non-recurrent congestions, and the complexity of current approaches makes them insufficient to handle the real time task. This paper presents a new approach for detecting traffic incident, and compares its performance with established techniques. Different from traditional incident detection methods, both spatial and temporal traffic

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information are considered to find the potential incidents. Meanwhile, adaptive learning ability and short detection response time are achieved in the proposed method. Traffic incident detection can be viewed as a pattern recognition problem. The proposed method is based on fuzzy deep neural network learning. We selected this technique because it performs well to a wide range of classification problems and it is fairly robust to irrelevant features. The rest of the paper is organized as follows: the related works are discussed in Section 2. Fuzzy deep learning based approach is presented in Section 3. Network configuration and measures to evaluate detection performance are discussed in Section Section 4. Simulation results and analysis are given in Section Section 5. Finally, the paper is concluded in Section Section 6.

2. Related works

The problem of TID can be regarded as a task of classification, to determine whether or not an incident happens according to data gathered from traffic flow. Various automatic incident detection techniques have been released to address this problem, such as Support Vector Machine (SVM) (Yuan & Cheu, 2003), Fuzzy Logic (FL) (Rossi, Gastaldi, Gecchele, & Barbaro, 2015), and Back-Propagation Neural Network (BPNN) (Lu, Chen, Wang, & van Zuylen, 2012). All of the works cited suffer from drawbacks. The limitation of SVM comes from the choice of kernel function, the determination and tuning of several parameters. FL is based on human knowledge by determining fuzzy rules which are often set manually by experts. Thus, the detection performance is affected by subjective decisions. The Back-Propagation (BP) algorithm suffers from slow convergence and the possibility of getting caught in the local minimum. In any event, it is difficult to say that one method is clearly superior ever other methods in any situation. One reason for this is that the proposed models are developed with a small amount of specific data. The accuracy of TID methods is dependent of the traffic flow features embedded in the collected spatiotemporal traffic data. Thus we propose a novel TID method which considers the spatial and temporal correlations of traffic flow inherently. In general, the use of intelligent classification offers helpful techniques to deal with this kind of problem. Artificial intelligence refers to a set of procedures that apply reasoning and uncertainty in complex decision making and data analysis processes (Rossi, Gastaldi, Gecchele, & Barbaro, 2015). Among artificial intelligence methods, Artificial Neural Networks (ANNs) have been widely used in various research areas to solve problems including classification, traffic incident detection, function approximation, optimization, prediction, and so on (Chakraborty, 2012; de Oliveira & de Almeida Neto, 2014). ANN possesses a variety of alternative features such as massive parallelism, distributed representation and computation, generalization ability, adaptability and inherent contextual information processing (Azar, 2013). Several studies confirmed that neural network models can provide fast and reliable incident detection for several reasons. First, automatic incident detection can be cast as a pattern recognition problem. Neural networks are known to solve pattern recognition problems effectively (Kumar Basu, Bhattacharyya, & Kim, 2010). Second, neural networks are suitable for solving the problem when there is no mathematical model or explicit rules.

There are a variety of types of ANNs. Traditional process neural network is usually limited in the structure of single hidden layer. ANN with multiple layers was examined not as effective as ANN with single hidden layer in many applications. It is because the structure of process neural network would be very complex when extended to multiple hidden layers. However, for complex detection systems with rich amount of data, one single hidden layer usually would be not enough in describing complicated relations between inputs and outputs. Complexity theory of circuits strongly suggests that deep architectures can be much more efficient than shallow architectures, in terms of computational elements and parameters required to represent some functions. Deep learning is a type of machine learning method. It has been introduced with the objective of moving machine learning closer to one of its original goals: artificial intelligence. The concept of deep learning is derived from neural network research, therefore deep learning regarded as a new generation of neural networks (Chakraborty, 2012). It use multiple-layer architectures or deep architecture to extract inherent features in data from the lowest level to the highest level, and they can discover huge amounts of structure in the data. Recently, deep learning had attracted a lot of attention from both academic and industrial communities. It has been applied with success in classification tasks, natural language processing, object detection, traffic data prediction and so on (Deng, Ren, Kong, Bao, & Dai, 2016; Deng & Yu, 2013; Lv, Duan, Kang, Li, & Wang, 2015; Shin, Orton, Collins, Doran, & Leach, 2013). As traffic incident is complicated in nature, deep learning algorithms can represent traffic features without prior knowledge, which may have good performance for traffic incident detection.

The main contributions of this paper are the following. First, we present a novel fuzzy deep learning based incident detection method. Second, we propose the use of a stacked auto-encoder model following a layer by layer pre-training procedure to represent traffic flow features for incident detection. Third, to conduct the fine tuning step and adjust the parameters of the deep network, we propose the use of the back-propagation algorithm. Fourth, since fuzzy logic systems have demonstrated their ability in many applications, especially for the control of complex nonlinear systems that are difficult to model analytically (Azar, 2012), we propose the use of the fuzzy logic approach to adaptively vary the learning parameters where the objective is to reduce the possibility of overshooting during the learning process and help the deep network get out of a local minimum. The simulation results show that the proposed

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