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A rear-end collision prediction scheme based on deep learning in the Internet of Vehicles

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HIGHLIGHTS

- We determine the factors that affect the probability of collision and quantify them.
- The proposed method of building BP neural network can simulate the numerical expression of computational intelligence.
- The dynamic optimization methods for each network parameter and the trained network to estimate collision probability are employed.

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ABSTRACT

Recently, the deep learning schemes have been well investigated for improving the driving safety and efficiency in the transportation systems. In this paper, a probabilistic model named as CPGN (Collision Prediction model based on GA-optimized Neural Network) for decision-making in the rear-end collision avoidance system is proposed, targeting modeling the impact of important influential factors of collisions on the occurring probability of possible accidents in the Internet of Vehicles (IoV). The decision on how to serve the chauffeur is determined by a typical deep learning model, i.e., the BP neural network through evaluating the possible collision risk with V2I (Vehicle-to-Infrastructure) communication, V2V (Vehicle-to-Vehicle) communication and GPS infrastructure supporting. The proper structure of our BP neural network model is deeply learned with training data generated from VISSIM with multiple influential factors considered. In addition, since the selection of the connection coefficient array and thresholds of the neural network has great randomness, a local optimization issue is readily occurring during the modeling procedure. To overcome this problem and consider the ability to efficiently find out a global optimization, this paper chooses the genetic algorithm to optimize the coefficient array and thresholds of proposed neural network. For the purpose of enhancing the convergence speed of the proposed model, we further adjust the studying rate according to the relationship between the actual and predicated values of two adjacent iterations. Simulation results demonstrate that the proposed collision risk evaluation framework could offer rationale estimations to the possible collision risk in car-following scenarios for the next discrete monitoring interval.

1. Introduction

With the current rapid economic growth, the population of vehicles is fast increasing, accompanied by a rising number of road accidents. Investigations and statistical data show that among all of the road accidents, those that involve vehicles account for 60%–70% of the total and are dominated by rear-end collisions [28]. These accidents concentrate in places where the vehicles could drive very fast and/or the external environment nearby is dull, such as on highways [49]. Hence, how to considerably reduce rear-end collisions, especially on highways, is essential for the driving safety of vehicles.

The Internet of Things (IoT), as the name implies, "things connected to the Internet", is an important aspect of the new generation of information technology. It has two meanings: first, the IoT is an extension and expansion of the network whose core and foundation is still the Internet. Second, the extension and expansion of the IoT can achieve the intelligent identification of goods, positioning, tracking, monitoring and management of a network based on information exchange and communication between any two items [9,39]. As a special case of the IoT, the

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IoV is quickly developing from a series of sensing technologies that offer information to chauffeurs and upload the filtered sensor data to centralized processing equipments to define performance metric functions and optimize them through exchanging sensor inputs among vehicles. In the autopilot system, these functions can achieve the maximum safety and efficiency of vehicles and reduce the environmental impact. In other words, the introduction of the IoV will definitely improve the road safety with advanced sensor technology [40], expanded environmental awareness and timely information exchange [8].

At present, the techniques that serve to ensure road safety can be mainly classified into passive safety and active safety. The former class attempts to alleviate harm against the drivers after the occurrence of accidents, which cannot avoid potential accidents in advance in most cases. To avoid road accidents before they occur, active safety techniques are receiving increasing attentions from the experts and researchers. This research focuses on active safety techniques by mainly studying the methods for risk-aware safety alerts and interventions [34] and automatic controls for the protection of people inside of vehicles in the cases of emergency [27]. The active safety technique that centers on collision warnings anticipates potential risks and actively informs the chauffeurs and passengers of oncoming dangers.

According to the benefits of an active safety system, the active safety early warning technique that collaboratively combines wireless communication, vehicular sensing and GPS localization techniques has become a hot topic in the IoV. The key to the early warning of dangers against a vehicle is to identify the potential safety hazards and the corresponding levels of risks. In fact, many studies have been conducted in the area of safety warning skills over the past few years [20,47]. Among these studies, the context-aware scheme for vehicular collision forecasting based on the deep learning of the internal/external environment is of great significance; this system mainly consists of the sensing layer, inference layer and application layer [30]. The sensing layer is responsible for the perception of information with regard to the environment, road, drivers and statuses of vehicles using wireless communication and proximity sensing techniques. The inference layer is mainly responsible for studying and deciding the present motion states of vehicles based on the messages collected at the sensing layer and then executing the corresponding actuators. The principle task of the application layer is to send the current state of a vehicle to other vehicles nearby. In [16], a dangerous context-aware system in the vehicular environment was proposed. In this system, various sensors are first used to obtain the status of the vehicles. Next, information is chosen based on a fuzzy logic model from the sensed information with regard to the vehicles' status as the decision information, which is then applied to determine whether the vehicle is truly in danger. Afterward, an alert will be issued to the driver if the vehicle is really endangered. In [5], Aswad et al. proposed an environment-aware driving assistant system on the highway. In their system, the status of the vehicles and nearby environment is first obtained with sensors. Afterward, the obtained status of the vehicle is compared with the expert database for risk evaluation. Finally, guidance is offered to the driver according to the matched pattern from the expert database. As a result, a vehicle that is in extreme danger will be subjected to an automatic control; if the vehicle is in a common danger, an audio/video alert will be issued to the driver, and if the vehicle is truly safe, then no information will be passed to the driver and vehicles. In [2], Al-Sultan et al. presented a context-aware system to discover the abnormal activities of a driver. When the system detects fatigue or drunk driving, it will issue warnings and inform the driver with regard to driving safety. This system will first sense the surroundings of the chauffeur and then perform analysis of the obtained information using the dynamic Bayesian network model to evaluate the activities of the driver. If the activities of the chauffeur are found to be abnormal, then warnings will be issued to the driver. Otherwise, the driver can continue driving normally. In [3], Woermdl et al. presented a context-aware system design that consists of a physical sensing component, an inferential decision component and a vehicular execution component. The physical sensing component is responsible for collecting the data sensed by different sensors and delivering the collected data to the inferential decision layer. Afterward, the inferential decision layer will infer the status of the investigated vehicle based on the dynamic Bayesian network model and send the result to the vehicular execution component. The vehicular execution component is designed to execute the corresponding actions according to the status of the vehicle delivered by the inferential decision layer.

Despite their ability to improve the driving safety, the aforementioned studies consider only one or few factors with respect to the vehicle itself, other vehicles, the driving environment and the driver. In addition, the forecasting accuracy of above proposals is still not sufficient. To address the above problems, this paper proposes a risk forecasting scheme that can predict the level of risk against the vehicles by jointly accounting for multiple factors that involve the vehicle itself, other vehicles, the driving environment and the driver. In the proposed system, the sensed data are fed into a Back-Propagation (BP) neural network for inferencing, and the decision results are used for further control over the vehicle.

In summary, the point of our study is to focus on the active safety-related warning techniques in the IoV based on deep learning models. To ensure the driving safety and improve the driving experience, this paper proposes a BP neural network-based collision probability forecasting scheme that jointly considers the effects of multiple influencing factors that involve the drivers, the environment, the vehicles and the road. Moreover, different levels of warnings can be issued to the driver based on the extent of the predicted risk to the vehicle.

The remainder of this paper is organized as follows: Section 2 reviews related studies on active safety systems. Section 3 describes the design principle of our proposed GA-optimized BP neural network, which is used for forecasting the collision probability while accounting for multiple collision-influencing factors. Section 4 demonstrates the utility of our raised model with simulations and the corresponding numerical results. Section 5 summarizes the content of this article.

2. Related work

The passive safety systems, for example, safety belts, body steel frame structure, airbags and other safety configurations, are indeed helpful for obtaining a safer driving environment in our daily life. In addition to passive safety agencies that effectively reduce personal injuries in an accident, active safety systems can remind and help the driver to prevent or mitigate crashes before accidents through an electronic stability system, warning system, Anti-lock Brake System (ABS) and so on. In recent years, significant work has been done to characterize algorithms and investigate hardware implementations for active safety systems. Although researchers have conducted a large number of experiments and obtained quite satisfactory results, they have not attempted to incorporate multiple influential factors, including subjective and objective factors, into the forecasting and control of possible collisions.

In general, active safety systems can be classified into three categories according to the following criteria: data collection or processing methods, safety state studying/determining schemes and active control maneuvers.

Upon data collection or processing, active safety systems could be designed with an on-board vision camera, inter-vehicle communication (IVC) transceivers, motion capture sensors and so forth.

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