Traffic Accident Prediction based on CNN and Time of Commuting after Accident

Sibo Wang *

School of Artificial Intelligence, Tianjin Normal University, Tianjin, 300000, China

* Corresponding Author Email: 2130330013@stu.tjnu.edu.com

Abstract. To address the challenges associated with traffic accident detection and the subsequent impact on commute times, a method combining CNN and Linear Regression models is proposed. Initially, this approach involves classifying specific accident data using images and detailed accident records. The images are then categorized into binary groups—accident and non-accident. Post-accident detection does not necessitate high-speed detection or extensive data processing; CNN are sufficiently capable for this purpose. Traffic accidents are an inevitable part of daily driving and can lead to significant delays in commuting. In rare cases, accidents may result in participants falling into a coma, further delaying rescue efforts. The proposed method aims to enhance road safety and traffic efficiency by promptly identifying accidents and minimizing the disruption caused to commute times through advanced technological solutions. By leveraging CNN for image analysis and Linear Regression for data modeling, this approach seeks to streamline accident detection processes, thereby improving overall traffic management and safety measures. This methodological framework underscores the importance of integrating cutting-edge technology to mitigate the adverse effects of traffic accidents on daily commuting.

Keywords: Traffic accident detection; CNN; random forest.

1. Introduction

Although brings significant advantages over traditional information and communication (ICT) technologies for Intelligent Transportation Systems (ITS), these applications are still very rare. Although there is a continuous improvement in road and vehicle safety, as well as improvements in IoT(Internet of Things), the road traffic accidents have been increasing over the last decades [1]. Traffic accidents are a major public health concern worldwide. Statistics indicate that approximately 1.3 million deaths and 50 million injuries are caused by road accidents each year [2]. China is a country prone to traffic accidents. According to statistics, from 2010 to 2015, the number of deaths from car accidents was more than 200,000 [3]. And it is estimated that more than 50% of the population is concentrated in cities, also this number will increase year by year [4]. These accidents not only harm those involved but also affect people’s quality of life in terms of both traffic mobility and personal safety [4]. Currently, there are no highly effective methods to prevent the occurrence of traffic accidents and when the vehicle is driving on the highway, once there is congestion, it will seriously affect the traffic capacity, so travel times can range from half an hour to several hours [5]. Therefore, it's not always possible to avoid accidents, but this paper proposes a method to provide early warnings when traffic accidents occur.

In the past, to reduce the response time to road traffic accidents, traffic departments installed numerous surveillance cameras at key points such as intersections or bridges. The traditional method of manually monitoring these feeds to provide timely updates on road conditions has become costly due to the volume of video data generated [6]. This paper aims to utilize a convolutional neural network (CNN) model to determine whether a traffic accident has occurred. A random forest algorithm is sufficient to handle the large but simple commuting data related to traffic accidents. If an accident is detected, relevant organizations can then inform people who have already entered the affected area or warn those who have not yet entered to alter their routes in advance.

2. Methods

2.1. Data Source

These data collected 900 images of traffic accidents and 900 images of vehicles with non-traffic accidents, as well as a amounts of data on the start, end and site of traffic accidents (1048575). In the validation data set, there are 200 photos of car accidents and 200 photos of non-car accidents. Although most of data collection come from America, but in America the situation of traffic is like that in China (drive on the right and similar driving situation in big cities). So, it has similar reference value in China.

2.2. Variable Description

This paper used a summary including 105485 information of traffic accidents Description. This is a summary where traffic accidents happened and how long the accidents will be solved based on linear regression model. After manually removing extremely meaningless data, the cause of accident was extracted using a regular expression extracting the cause mentioned in the description. Try to capture the reason part of the description by finding the keywords ("due to", "because of" "etc.). The cause of the accident was classified into predefined categories based on the extracted cause section. For example, the keyword "lane blocked" corresponds to the "Lane Blocked" category, "accident" corresponds to the "Accident" category, and so on. If there is no match to any keywords in the description, it is classified as "Other". The results are shown in Figure 1.

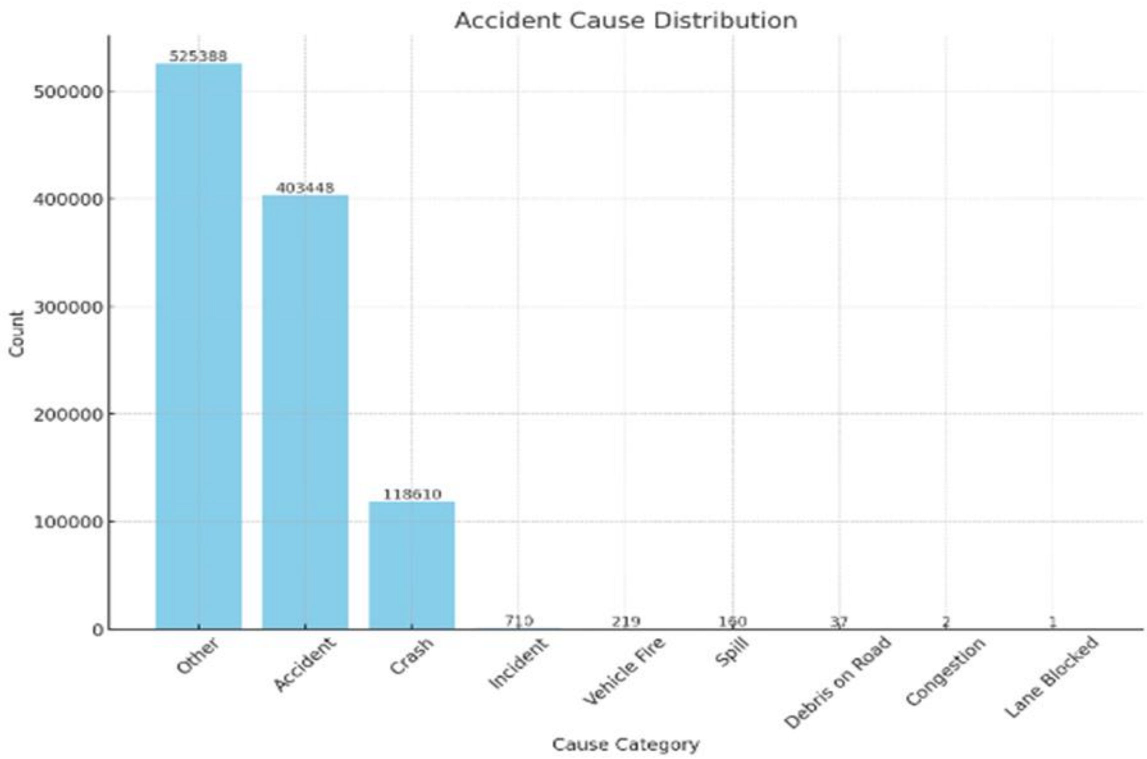

Fig. 1 The number of car crashes in each type

According to this figure 1, Accident and Crash show that they occupy a lot of a large number of other accidents. However, the highest proportion is in the other category, so it can be concluded that the specific classification of many accidents still has great difficulties. Then count each accident and how long it took and turn the unit into "seconds" for statistics. The results are shown in Figure 2.

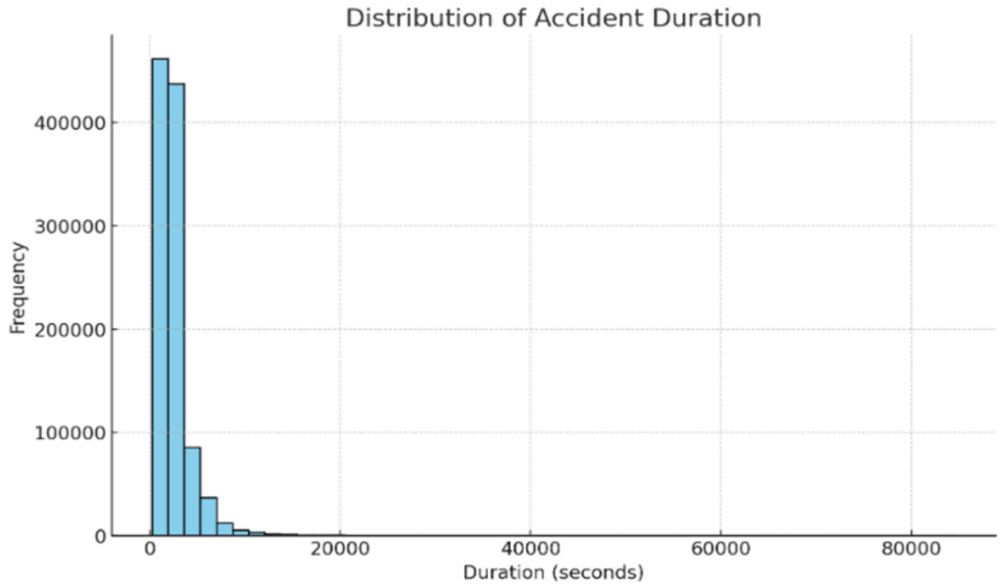

Fig. 2 Time consuming of all data after cleaning (in seconds)

As the data in the picture, regardless of the accident, the distribution of their duration is concentrated. The average time was calculated using the program, yielding the following table 1.

Table 1. Average time of nine cause category

Cause Category	Average Duration
Accident	0 days 00:48:23.425936942
Congestion	0 days 00:52:00
Crash	0 days 00:47:45.000126479
Debris on Road	0 days 00:58:51.666666667
Incident	0 days 01:16:12.627118644
Lane Blocked	0 days 00:30:00
Spill	0 days 01:05:33.375000
Vehicle Fire	0 days 01:17:03
Other	0 days 00:45:44.917022322

From the data, Incident, Vehicle Fire and Sill are more time-consuming types but occur less frequently. But Accident, Crash and Other, the three crash types with the highest proportion, are relatively less time consuming. This may be due to the higher complexity and severity of the former, which requires more resources and time to deal with.

In the target detection task, a single feature map with different sizes can affect the detection accuracy [8]. These pictures of traffic accidents are in different resolution ratio. In order to better train the model, this program set the resolution of the picture to 128×128. The environment of test is: windows10, CPU: AMD Ryzen 7 5800H, GPU: GPU NVIDIA GeForce RTX 3060, python 3.11.5, torch 2.1.2. This paper used a few index to estimate the function of CNN in the question being discussed.

Accuracy: Refers to the ratio of the correct number of samples to the total number on the validation or test set.

$$Accuracy = \frac{Number\ of\ Correct\ \Pr edictions}{Total\ Number\ of\ \Pr edictions} \tag{1}$$

Loss: The loss function is a function used to measure the difference between the model predicted value and the true value used in this program is dichotomous cross-entropy loss.

$$Binary\ Cross\ Entropy\ Loss = -\frac{1}{N}\ \sum_{i=1}^{N}[y_i \log(p_i) + (1 - y_i)\log(1 - p_i)] \tag{2}$$

2.3. Method Introduction

2.3.1. CNN

The CNN come up in 1988 by Yann LeCun. CNN includes five parts called input layer, convolution layer, pooling layer, full connection layer and output layer, as shown in Figure 3.

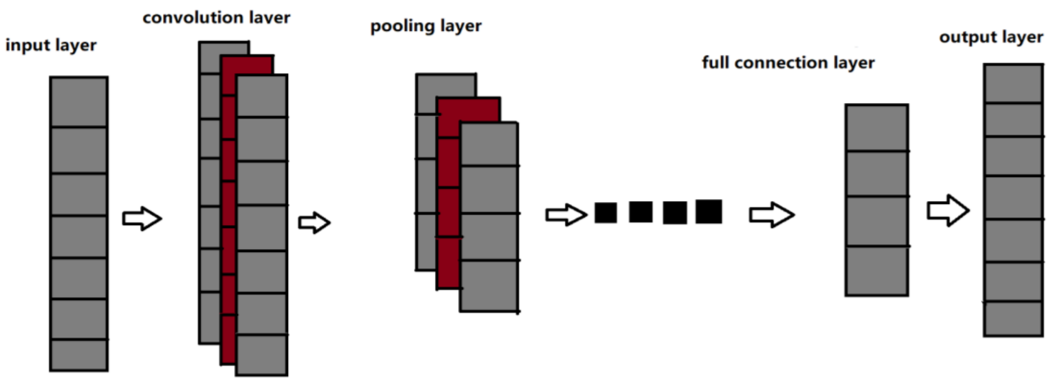

Fig. 3 Architectural structure of CNN

Owing to the program begin after the traffic accidents happened, so it need not a high-speed detection model, just answer to a few pictures after traffic accidents. The first step is detecting whether the traffic accidents happened or not, then calculate the time of commuting. So, this study used convolutional neural network model (CNN) to deal with these two problems.

CNN is a model can process images which are static and classifies images. In this study used a simple method called 'binary classification'. To achieve the purpose just need check whether the traffic accidents happened or not. So it can reduce amount of calculation of program and speed up the effect of warning.

Inside, convolutional layer used to convolutional calculation and local sensing of the input data for feature extraction. The polling layer is used to reduce the size of the fault prediction model, and thus improve the computation speed and reduce the feature dimension, at the same time it can keep the important characteristics of the traffic accidents detection data. The fully connected layer is used to integrate extracted eigenvalues into vector output and implement different tasks according to different purposes.

The accident is input into a pre-trained CNN model to predict the cause of the accident and the CNN model is used as an auxiliary tool to quickly predict the possible cause of the accident. This anticipation is intended to provide a preliminary direction for accident investigators and provide reference for subsequent accident site improvement and management [9].

The convolutional layer is calculated as follows:

$$y_{ij}^{l} = \sigma\left(\sum_{m=1}^{M} \omega_{m,j}^{l}\, x_{i+m-1}^{0} \;+ b_j^{l}\right) \tag{3}$$

The pooling layer is calculated as follows:

$$P_{ij}^{l} = \max\left(Y_{i\times T+r,j}^{l-1}\right) \tag{4}$$

2.3.2. Random forest algorithm

Random Forest is an integrated learning algorithm proposed by Leo Breiman in 2001 [10]. Its core idea is to reduce the risk of overfitting and improve the performance of the overall model by building multiple decision trees [6]. In this study, the random forest model is used to predict the accident duration. The classified features were transformed into numerical features by using one-hot encoding and using the training set to train the model. The model was then predicted on the test set, and its performance was evaluated by calculating the mean square error (MSE) and the R2 score. The information provided by the more important features is more helpful for the classification judgment [5].

This study extracts and transforms the information from the accident description into categorical features, which are then used to predict the accident duration. The use of the random forest algorithm enables the model to handle complex nonlinear relationships and to improve the accuracy and stability of the predictions by integrating multiple decision trees. The following below is a schematic structure of the random forest Figure 4.

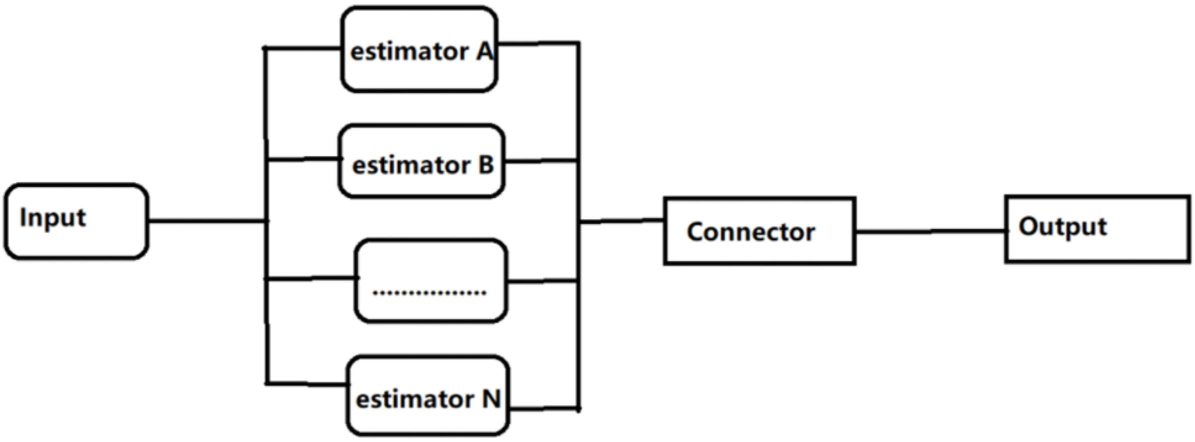

Fig. 4 Architectural structure of linear regression model

3. Results and Discussion

3.1. Model Results

The base model of picture classification used in this study is the CNN model, however a separate CNN model cannot satisfy the dichotomous problem of whether a car accident occurs. This creates overfitting problems. No matter how to adjust the basic parameters, this program can not improve the overfitting problem very well. So in order to first added dropout to prevent the overfitting phenomenon, but the effect was not ideal. So kernel_regularizer was added to this basis and L2 regularization was used to prevent overfitting. After this operation, the overfitting phenomenon is greatly reduced. After many attempts, the learning rate was finally set at 0.005. After 30 iterations, the model was basically formed. The results are shown in the figure 5 and figure 6.

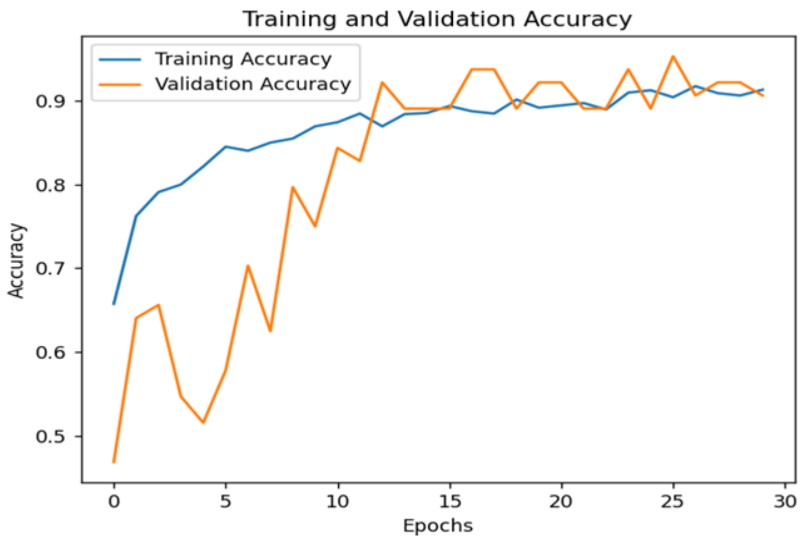

Fig. 5 Trends in the accuracy of the training and the validation

Fig. 6 Loss function for the training and test sets

As can be seen from Fig 5, the accuracy of training and validation basically shows a steady upward trend. As can be seen from Fig 6, the loss function of training and verification basically shows a downward trend. These two pictures show that the model training works better and reality is as showed. The highest validation accuracy reached 0.949.

3.2. Results of Detection

The last test used a total of 20 car crash photos and non-car crash photos. Some come from the Internet, some come from real photography. The identification results are shown in the following figure 7.

Fig. 7 Identification of traffic accidents (Pictures are from the Internet and real shooting [9])

From Fig 7, the author can intuitively see whether the program has identified the accident. Due to the complex and small number of images actually tested, the identification of images is partially biased.

In the training set, there are many types of crashes, such as rear-end collisions, rollover, car debris and side collisions. The collected pictures of car accidents basically correspond to the types included in the training set. In this program the type of rear-end collisions and car debris were detected very well. Conversely, the category side collisions were not identified with high accuracy.

4. Conclusion

Although this paper uses a random forest model to predict the passage time after a crash, the combination of the convolutional neural network and the random forest is not good. CNN model often fail to accurately identify what type of crash occurred. So it was decided that after the program detected the car accident, manually to identify what type of car accident had happened

Although this paper gave a simple method in traffic accidents and commuting time after traffic accidents, there are still many problems and deficiencies. The absence of Chinese traffic accidents data and the different condition of a country between China and America caused this model can not totally suited to China. And the purpose of the model is to detect whether a car traffic accidents has occurred or not, so it has not the ability to directly tell people which category of accidents happened then send out warning. It still needs people hand out the warning after the detection of program. In the later study, add more Chinese traffic accidents data is the most important part. And it needs a more powerful model and method to solve the problem that the program needs people to distinguish between different traffic accidents.

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