

Vision Technology Based Traffic Safety Analysis Using Signal Data

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Abstract

Recent vision technology allows traffic engineers to analyze traffic safety based on image processing applications. Vehicle trajectory data including vehicle position and speed are extracted and converted into traffic conflicts related variables. These variables are analyzed to find correlations with crash data and geometric design variables and included in the statistical analysis process to evaluate the safety of intersections. In this paper, signal timing information data is included in the analysis process to investigate if there are any correlations with traffic conflict data. For example, traffic conflicts happen more frequently in a certain movement at certain signal time phase. The goal of this paper is to develop a method for vision technology-based traffic safety analysis process using traffic signal data to identify crash prone movement and signal to time at a given intersection. The proposed technique is demonstrated in real-world video data collected in an intersection. This paper is expected to provide more insight and technique in traffic safety evaluation.

Keywords: traffic safety, image processing, vision technology, vehicle detecting, safety evaluation

1. Introduction

While the majority of traffic accidents are caused by drivers' error, traffic accidents occur for various reasons including driver-related factors, vehicles related factors, and environmental related factors including traffic conditions. A significant number of traffic accidents have been found to occur at intersections [1-3]. An intersection is a point where traffic flows running in different directions. Vehicles merge, diverge, and intersect each other at an intersection. Usually, an intersection with heavy traffic is controlled by a signal. The signalized intersection has the advantage of smoothly controlling the vehicles approaching from different access roads through the signaling device.

Conventional road safety assessments evaluated safety based on historical accident data. However, in order to collect accident data for statistical analysis, significant time, and cost are required [4]. Therefore, safety evaluation based on conflict data has been developed and utilized in many countries. Recent image detection technology has been developed to obtain vehicle trajectory information based on image data at an intersection [5-7].

Vehicle trajectory data including vehicle position and speed are extracted and converted into traffic conflicts related variables. These variables are analyzed to find correlations with crash data and geometric design variables and included in the statistical analysis process to evaluate the safety of intersections. In this paper, signal timing information data is included in the analysis process to investigate if there are any correlations with traffic conflict data. For example, traffic conflicts happen more frequently in a certain movement at certain signal time phase. The goal of this paper is to develop a method for vision technology-based traffic safety analysis process using traffic signal data to identify crash prone movement and signal to time at a given intersection.

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2. Data Collection and Analysis

Video data were collected from an intersection in Korea and vehicle trajectory data were processed and extracted (Fig. 1). Right turn on red is permitted in this intersection and cycle length of the intersection was 140 seconds.



Fig. 1 Data collection at an intersection

Different types of conflicts were identified. In this study, merging conflicts with right turn vehicles (Fig. 2) and conflicts between vehicles moving in the same direction (Fig. 3) were collected and analyzed. The severity of conflicts was calculated based on the vehicle position and speed data. Also, the conflict data were analyzed based on the timing data of the intersection signal to find the correlations between the conflict and signal timing. Fig. 4 demonstrates the workflow in this research.

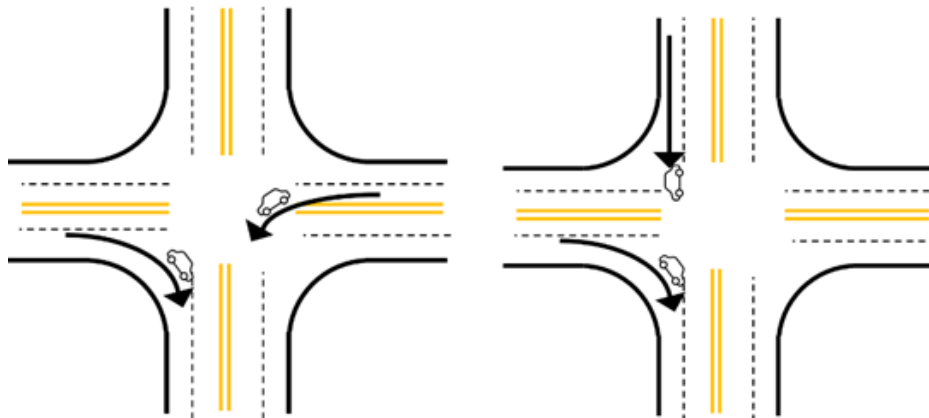


Fig. 2 Example of conflicts in merging traffic

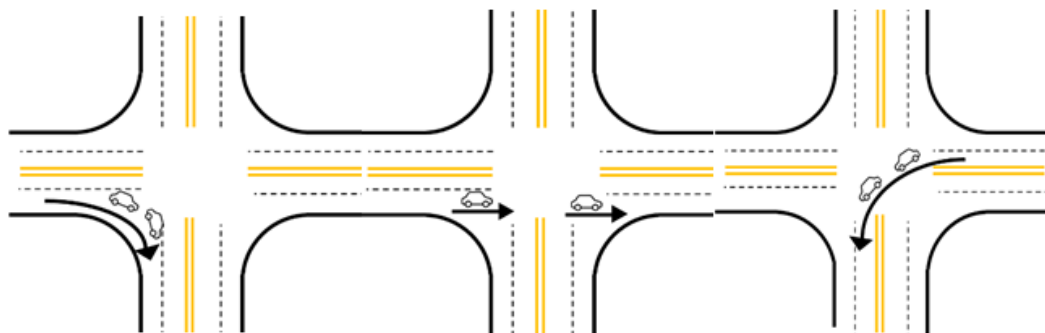


Fig. 3 Example of conflicts between vehicles moving in the same direction

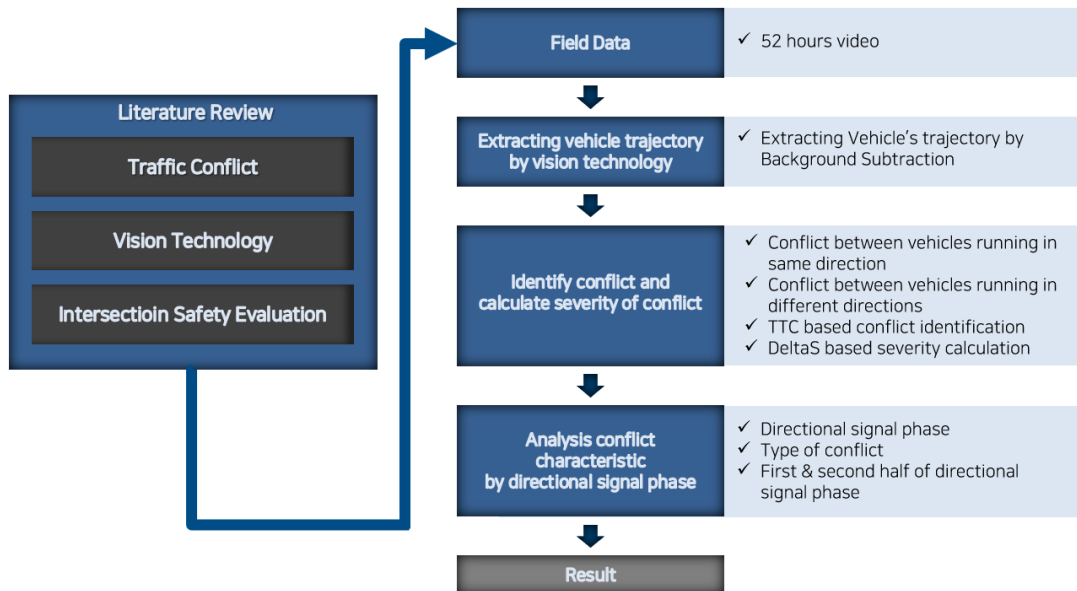


Fig. 4 Research workflow

3. Results

Conflicts between the vehicles moving in different direction were analyzed as shown in Fig. 4. It was found that a significant number of conflicts occurred in signal phase two and four. Most of the conflicts were conflicts between left-turning vehicles and through vehicles (Fig. 6). However, conflicts between right-turning vehicles and through vehicles were relatively spread out in the entire signal timing period.

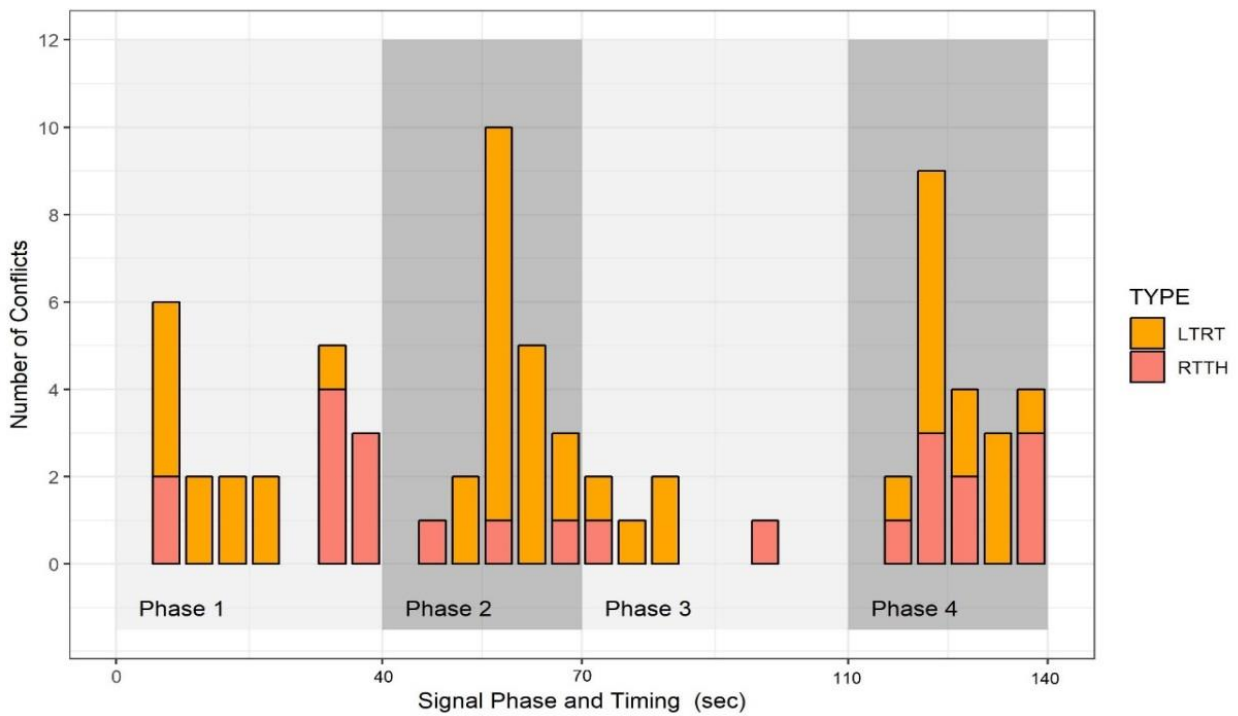


Fig. 5 Conflicts between the vehicles moving in a different direction

A total of 69 conflicts occurred between vehicles. Among those 69 conflicts, there were 46 conflicts between left turning and right turning vehicles, and 23 conflicts between through moving vehicles and right turning vehicles. Of the 46 conflicts that occurred between the left turning and the right turning vehicles, the largest number of conflicts, 18 cases occurred during phase 2, representing about 39%. Subsequently, 13 and 11 conflicts occurred in phase 4 and phase 1, respectively, and the lowest level of conflict occurred in 4 cases in phase 3.

A total of 23 conflicts were found between through moving vehicles and right turning vehicles. This number is only 33 percent of the conflicts occurred between the left turning and the right turning vehicles. Considering the total number of through moving vehicles, it is clearly seen that conflicts occurred more often between the left turning and the right turning vehicles compared to conflicts between the through moving vehicles and the right turning vehicles.

Fig. 5 demonstrates conflicts between the vehicles moving in the same direction. It is clearly seen that most of the conflicts occurred in phase 3 while there were almost no conflicts during phase 1 and phase 2. Also, more conflicts occurred in the middle and later part of phase 3 which implies that there might be correlations between the conflict and signal phase and timing.

It has been known that vehicle speed and its standard deviation have correlations with accident and traffic conflict. It is believed that the speed of the vehicle affects the accident severity as well in the event of a collision. The greater the variation in the speed of the vehicle, the greater the probability of an accident.

It was assumed that the difference was coming from the speed difference of vehicles. For example, vehicles passing the intersection during the latter half of phase tend to have higher speed than vehicles passing the intersection during the first half of phase since vehicles in the queue at the intersection were gradually dissipated during the first half of phase, therefore vehicles have lower speed during the first half of phase meaning less chance of having conflicts.

To verify the hypothesis average vehicle speed and its standard deviation were calculated for the vehicles passing the intersection in the first half and the latter half of each phase. If the average speed of vehicles passing the intersection during the latter half of phase is statistically higher than the speed of vehicles passing the intersection during the first half of phase, it is likely that it may affect the frequency and the severity of the conflict.

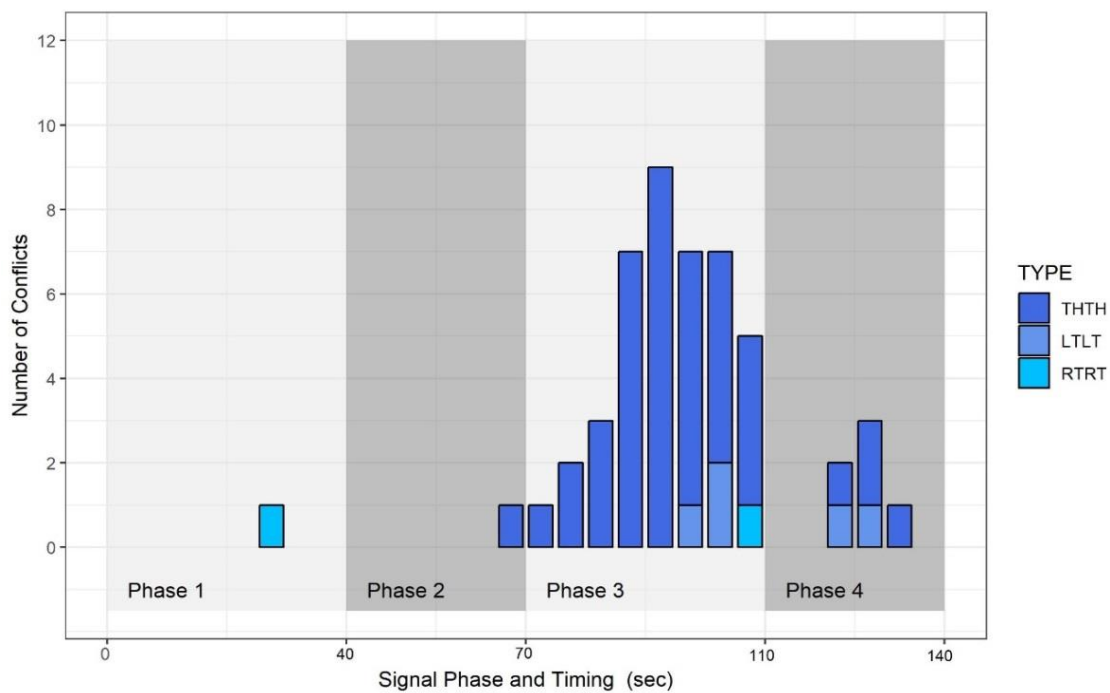


Fig. 6 Conflicts between the vehicles moving in the same direction

4. Conclusions and Future Work

Recent vision technology allows traffic engineers to analyze traffic safety based on image processing applications. Vehicle trajectory data including vehicle position and speed are extracted and converted into traffic conflicts related variables. These variables are analyzed to find correlations with crash data and geometric design variables and included in the statistical analysis process to evaluate the safety of intersections. In this paper, signal timing information data is included in the analysis

process to investigate if there are any correlations with traffic conflict data. For example, traffic conflicts happen more frequently in a certain movement at certain signal time phase.

In this paper, signal timing information data is included in the analysis process to investigate if there are any correlations with traffic conflict data. Also, vehicle speed and its standard deviation are analyzed based on the assumption that traffic characteristics might be different between vehicles passing the intersection during the latter half of phase and vehicles passing the intersection during the first half of phase.

First, the number of conflicts were compared based on the directional signal phase. It was found that the number of traffic conflicts by directional signal phase varies depending on the directional signal phase. Secondly, the characteristics of conflicts were compared by conflict type. The results show that conflicts between vehicles running in different directions have different characteristics by conflict type. Thirdly, the characteristics of conflicts were analyzed by the first and second half of directional signal phase for the left turn and right turn vehicle conflicts. It was found that the conflict characteristics do not differ between the first half and the second half of the phase. Finally, the characteristics of conflicts were analyzed by the first and second half of directional signal phase for through and right turn vehicle conflicts. The results show that the conflict characteristics differ according to the first half and the second half of the phase.

Underlying assumption on this analysis was that vehicles passing the intersection during the latter half of phase tend to have higher speed than vehicles passing the intersection during the first half of phase since vehicles in the queue at the intersection were gradually dissipated during the first half of phase, therefore vehicles have lower speed during the first half of phase meaning less chance of having conflicts. Conflicts between the vehicles moving in a different direction at the selected intersection were analyzed. Also, conflicts between the vehicles moving in the same direction at the selected intersection were analyzed as well. It was found that there was a significant difference between the two conflicts. Additionally, the conflicts were different between the directional movements of the vehicle.

It was found that a significant number of conflicts occurred in signal phase two and four. Most of the conflicts were conflicts between left-turning vehicles and through vehicles. However, conflicts between right-turning vehicles and through vehicles were relatively spread out in the entire signal timing period. Also, it was found that conflicts occurred more often between the left turning and the right turning vehicles compared to conflicts between the through moving vehicles and the right turning vehicles. Additionally, more conflicts occurred in the middle and later part of phase which implies that there might be correlations between the conflict and signal phase and timing.

As shown in this paper, traffic conflicts happen more frequently in a certain movement at certain signal time phase. The goal of this paper is to develop a method for vision technology-based traffic safety analysis process using traffic signal data to identify crash prone movement and signal to time at a given intersection. More robust statistical analysis is required to investigate the correlations between traffic conflicts and signal timing.

As limitations of this study, video data were collected at only one intersection. It is necessary to analyze more video data collected from multiple intersections to compare the results from this study and compare with the results from other intersections to verify the conclusion. Also, it is necessary to analyze additional factors affecting the characteristics of conflicts in addition to the factors considered in this paper. In this study, the proposed image detection method extracts the vehicle trajectory using the background subtraction method. However, this method generates false data when the target vehicle is covered from other objects such as shadows, signal poles, and adjacent vehicles. Therefore, it is necessary to develop a video detection method and a data analysis method that handles these problems more efficiently.

The preliminary experimental results from this study show that the proposed method has the potentials to be utilized as a part of a vision-based traffic safety analysis tool. Also, it has the potentials to identify possible factors and characteristics in

traffic accidents which have been not analyzed in the conventional traffic safety analysis. Since the outcome of the paper is based on the limited data set, the proposed method is not proven to be applied to other intersections. However, the proposed method is believed to provide some insight into more efficient safety analysis. More extensive studies may be conducted in the future to demonstrate the effectiveness of the proposed method in much greater testing scale.

Conflicts of Interest

The authors declare no conflict of interest.

Acknowledgments

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