APPLICATION OF TRAFFIC CONFLICT TECHNIQUE FOR TRAFFIC SAFETY EVALUATION AT INTERSECTION BASED ON IMAGE PROCESSING

INTRODUCTION

Nowadays, the frequency and severity of crashes are two important data used commonly in assessing traffic safety on the road or at intersections. These datasets have two major disadvantages. First, the accident has already happened and has caused some particular damages. Secondly, the process of collecting these data usually takes from 3 years to 5 years to achieve enough reliable samples to analyze (OH et al, 2010).

Therefore, assessing traffic safety using traffic conflict techniques is considered a better option in the upcoming years (ZHENG ET AL, 2014). Besides, unlike collisions, the occurrence of traffic conflict is far more frequent and thus being able to analyze it will provide a deeper and wider insight into failure that can possibly cause an accident (SAYED ET AL, 2007). Based on that conclusion, conflict parameters are considered as an alternative to collision parameters when studying road traffic safety. Effective solutions could reduce human and material losses to the minimum by forecasting and analyzing conflict situations.

In an urban configuration, intersections are widely considered the most crucial area since they are the place where roads meet and conflicts occur. Thus, the safety of the whole traffic network can be improved if we can reduce collisions at intersections for that reason, studies related to traffic safety at intersections have always drawn attention among researchers both in the transportation field and in the other fields (POLDERS, BRIJS, 2015). Methods of road safety identification, diagnosis as well as assessment, and evaluation are constantly being developed and perfected (ZHENG ET AL, 2014).

Recently, with the development of image processing techniques, the applications of traffic image recognition and simulation techniques in traffic safety analysis at intersections has successfully provided some positive outcomes in both research and practice in developed countries around the world (HUANG ET AL, 2013). VISSIM technique and Surrogate Safety Assessment Model (SSAM) software and data collected through image processing are employed to evaluate the severe level of conflict points at signal-controlled intersections for cars and pedestrians (MAHMIUDET ET AL, 2018). In their study, Chai et al (2015), a framework to analyze traffic at intersections based on determining traffic behavior as well as safety of cars and pedestrians through image processing is proposed by manual traffic conflict points at the node. The comparison between SSAM and the Cellular Automata model in traffic safety assessment was also described in a study (SHIRAZI, MORRIS, 2015).

In Vietnam, with the characteristics of mixed traffic (i.e. cars, motorbikes and bicycles using the same infrastructure), the traffic safety analysis are often conducted based on the statistics of road accidents. In recent years, several intelligent transportation solutions have been installed at intersections. Real-time image processing techniques are used for real-time traffic regulation. However, they are mostly used to count the number of vehicles, estimate the traffic flow or the length of the queue (LE ET AL, 2005). In research of Dang et al (2016), another possible application of image processing techniques is proposed. This application aims to deal with traffic violation problems (e.g. lane violation, red light violation). These solutions, despite their contribution to traffic safety, lack a deep study on traffic conflicts, especially at signaled intersections. Against this background, this paper proposes another application of the image processing technique and the comprehensive fuzzy assessment methods to detect hazard levels of conflict points and its locations.
METHODOLOGY

Affiliations
Fuzzy comprehensive evaluation method (FCE), also called fuzzy synthetic evaluation (FSE), is used to analyze and assess the system relied on fuzzy logic field which has been published by Zadeh (1965). The FCE method has also been widely used in many kinds of scientific domains involving traffic safety evaluation. Applying the FCE method is presented as followed: Assuming that domain U = (u1, u2,...,um) denotes a set of assessment parameters. V = (v1,v2,...,vp) is used to appoint a diversity of evaluation level or command control. Thus, vk is a number that would express the link between evaluated factors and its consequences such as safety, less safety, and dangerous. This Fuzzy relation is demonstrated in matrix R from U to V:

Fuzzy Relation (1)

\[ R = \begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1p} \\ f_{21} & f_{22} & \cdots & f_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ f_{m1} & f_{m2} & \cdots & f_{mp} \end{bmatrix} \]

where \( f_{jk} \) denotes the membership degree \( j = (1,2...,m), k = (1,2...,p) \); \( R = () \) denotes a fuzzy set of attribute \( u_j \) and \( \sum f_{jk} = 1 \).

Evaluation of the traffic safety at a signal intersection based on conflict techniques and FCE methods would be implemented following 4 steps below:

Step 1: Construction of domain of conflict indicators based on given safety level (I, II, III, IV);
Step 2: Construction of fuzzy membership functions of the indicators, based on its domain;
Step 3: Calculation of the weight of the indicators;
Step 4: Determination of safety level based on the correlation coefficient.

Moving vehicles detection
The purpose of vehicle detection is to get the position of vehicles, and then calculate their velocity. In this paper, the vehicles are detected using the background subtraction method based on the Gaussian mixture model (LIU et al., 2013). The video frames are streamed from the camera, then, image pre-processing transformations such as image resizing and color to gray image conversion are performed to reduce the computational complexity. The background subtraction algorithm is applied to extract traffic vehicles from the image background, which are installed according to the mixture of Gaussians model. Moving object from the background is detected by calculating the absolute deviation of the intensity of the pixels between two consecutive frames. The intensity difference between two consecutive frames at the same position determines whether this pixel belongs to the background or the foreground object. The morphological operations are applied to the vehicles extracted to reduce noise. The edge detection algorithm is applied to localize a moving vehicle and separating the foreground object from the background. The rectangular boundaries are drawn around the moving object to separate from the image background.

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To achieve the identity of each vehicle, we use a Kalman filter to track each vehicle in a specific point in time. Basically, a Kalman filter is used to estimate states of a linear system where states are assumed to be Gaussian random variables. The Kalman filter algorithm comprises two steps: prediction and correction. In the prediction step, a state is estimated using a state equation. After that, the correction step takes current observations to adjust and update the estimated state in the prediction step. In this paper, to track multiple vehicles simultaneously, multiple Kalman filters, one for each vehicle, are used (JEONG et al, 2014). Each Kalman filter is represented as below:

\[ X_k = A x_{k-1} + w_k \]  
\[ Z_k = H x_k + v_k \]

Where \( x \) : the center position of the x-axis and y-axis, respectively

\( V_x, V_y \) : the velocity of the x-axis and y-axis. Matrix \( A \) represents the transition matrix, matrix \( H \) is the measurement matrix, and \( T \) is the time interval between two adjacent frames. \( w_k \) and \( v_k \) are the Gaussian noises with the error covariance and \( R_k \). The Kalman filter is processed as follows:

Update the state: \( x_k | k-1 = A x_{k-1} | k-1 \)

Predict the measurement: \( z_k | k-1 = H x_k | k-1 \)

Update the state error covariance:

\[ P_k | k-1 = A P_{k-1} | k-1 A^T + Q_k \]  
\[ (3) \]

\[ (4) \]

\[ (5) \]

To track multiple vehicles in complex transportation, matching between vehicles and measurements should be performed correctly. In this paper, we employ the data association method, which splits and merges the vehicles. The results of vehicle detection are shown in Figure 1.

At each time-point, the vehicle is manually selected based on the vehicle’s ID, from which, the coordinates and the speed of the vehicle were collected in pixels per meter (ppm) and distance of road in pixels to meters.

\[ V = m \times fps \times 3.6 \]

Where \( v \) is the vehicle’s velocity in pixel/s, \( m \) is a constant calculated by dividing the distance of the road where the camera is located in meters and in pixels.

**Figure 1. Vehicles detection**

**Source:** Search data.

**RESULTS**

Data collection was conducted at 2 signaled intersections in Hanoi, Vietnam: the first one is the Nguyen Chanh – Mac Thai To intersection, and the second one is the Van Cao– Lieu Giai – Doi Can intersection. The main reason for this selection is that the two intersections have many...
typical characteristics of Hanoi’s traffic conditions. For example signalized four-leg intersections, mixed traffic, lack of some pedestrians and cyclists, etc.

Traffic data was collected at non-rush hour on weekdays by cameras. The recorded video tapes are used to achieve the information involving traffic flows and traffic conflicts. The camera scenes essentially focused on an area of inside the intersections where conflicts occur frequently. Besides, we also measured the intersection’s geometric to calibrate the dimension in our image processing solution. Data of crossing geometric features were collected based on the measurement implemented by the Topcom GTS – 1002 total station. The processing of the video-data was implemented to achieve the value of different conflict parameters, including time to conflict (TTC), conflict speed (CS), and deceleration rate (DR), which are the factors of traffic conflict techniques commonly used as evaluation indicators.

The number of traffic conflict points recorded at two selected intersections are 319 samples. At each point, there are three conflict factors collected by recognizing the conflict and predicting the conflict position where two vehicles could collide if they remain at their speed and direction. The time to collision and the conflict speed are also measured. These parameters were indicated by cumulative frequency curves, as shown in figure 2 below:

**Figure 2.** Cumulative frequency curves of conflict parameters collected (a. DR, b. TTC, and c. CS)

![Cumulative frequency curves of conflict parameters](image)

Source: Search data.

The safety level of a conflict point is divided into 4 categories: safe (I), relatively safe (II), relatively unsafe (III) and dangerous (IV). Therefore, \( V = \{ I, II, III, IV \} \) and \( p = 4 \). These four categories are chosen as 15%, 40%, 60%, and 85% of the cumulative frequency level. The cumulative frequency level is collected through 319 conflict points at the two intersections. As shown in Figure 2, the conflict speed of 7.3 m/s to 7.8 m/s is the dominating one and having
78 samples. The ones with a speed between 9.25 m/s and 10.1 m/s are relatively rare, and they occur mostly when the traffic light is turning yellow from green. However, in terms of braking acceleration, the braking acceleration range from 4.7 m/s² to 5.1 m/s² has up to 22 cases (accounting for 7.01%). We observed that there are some points that have longer collision time or lower speed, but in fact, in terms of braking level, the requirement is higher. This shows higher collision risk when there is no timely reaction.

Data was recorded by video processing are input parameters that fuzzy comprehend evolution (FCE) would use to calculate the safety level of conflict points, which are divided into four levels, safe (level I), relative safe (level II), less safe (level III), dangerous (level IV). After analyzing, the result of this study was indicated following the table 1 as below:

| No | Conflict speed (m/s) | Time to collision TTC (s) | Deceleration rate DR (m/s²) | Correlation coefficient of different safety levels | Level of safety |
|----|----------------------|--------------------------|-----------------------------|---------------------------------|----------------|
| 1  | 6.68                 | 1.41                     | 2.36                        | 0.84                            | I              |
| 2  | 8.35                 | 1.26                     | 3.29                        | 0.10                            | II             |
| 3  | 7.53                 | 1.52                     | 2.48                        | 0.67                            | I              |
| 4  | 6.31                 | 0.84                     | 3.74                        | 0.30                            | II             |
| 5  | 8.91                 | 1.05                     | 4.23                        | 0.00                            | I              |
| 6  | 7.33                 | 1.10                     | 3.31                        | 0.00                            | II             |
| 319| 6.485                | 0.976                    | 3.32                        | 0.242                           | II             |

**Source:** Search data.

Parameters of conflict points were shown in 3-dimensional space and classified in 4 regions correlation 4 levels of safety.

**Figure 3.** Clustering follow by level of safety of conflict point

**Source:** Search data.

The heat map was also used to present the distribution and location of dangerous conflict points (level 4). Different colors correspond to different numbers of conflict occurring in the survey period. The red color expresses the areas having many dangerous conflicts, the yellow indicates less and there are some dangerous conflicts in green spaces.
**Figure 4.** Heat maps demonstrated location and concentration of conflict point (left: Van Cao-Lieu Giai-Doi Can, right: Nguyen Chanh-Mac Thai To)

Source: Search data.

At Nguyen Chanh - Mac Thai To intersection, the conflicts are evenly distributed in areas of the intersection, while in Van Cao - Lieu Giai - Doi Can intersection, hazardous conflicts improve traffic light signal control. To solve this issue, a new control scheme was considered to replace the current plan, in which 3 phases were installed to prevent conflicts that occur between vehicles going straight and turning left.

**CONCLUSION**

This paper presented the method of conflict analysis at an intersection using image processing technique and fuzzy comprehensive evaluation. Based on the vehicles detected from camera, the parameters extracted and analyzed by the traffic conflict technique. The results of the research describe point conflicts and it’s the location that provides the background of traffic at the intersection based on traffic conflict technique, and thus, will have an effective solution to solve some remaining problems. In the future, the study will be established a relation between conflict data and traffic accidents, so it has fully shown the role of conflict data set.

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Application of traffic conflict technique for traffic safety evaluation at intersection based on image processing

Resumo

Acidentes de trânsito ocorrem com frequência em cruzamentos por causa de conflitos entre veículos. Muitos pesquisadores têm avaliado a segurança no trânsito, porém a maioria deles são baseados em dados de acidentes que aconteceram e causaram danos, bem como danos econômicos. Recentemente, as técnicas de conflito fornecem visões gerais e soluções para evitar colisões precoces. Este artigo propõe um método de análise de conflitos utilizando técnica de processamento de imagem e avaliação abrangente. Com base na detecção de veículos, os parâmetros de conflito coletados de duas intersecções em Hanoi, Vietnã foram processados e avaliados por uma avaliação abrangente para dar o nível de segurança dos pontos de conflito. Os resultados experimentais mostram que os métodos propostos mostraram com sucesso a distribuição e localização de pontos de conflito perigosos de acordo com a situação real dos dois cruzamentos. Com base em nossos resultados, as autoridades podem considerar a reorganização do padrão de semáforos nesses cruzamentos para reduzir possíveis colisões.

Palavras-chave: Técnica de conflito de tráfego. Avaliação de segurança no trânsito. Processamento de imagens. Avaliação abrangente difusa.

Abstract

Traffic accidents occur frequently at intersections area because of conflicts among vehicles. Many researchers have been assessing traffic safety, however most of them are based on accident data that happened and caused injury as well as economic damage. Recently, conflict techniques provide general views and solutions to prevent early collisions. This paper proposes a method of conflict analysis using image processing technique and fuzzy comprehensive evaluation. Based on vehicles detection, the conflict parameters collected from two intersections in Hanoi, Vietnam were processed and evaluated by fuzzy comprehensive evaluation to give out the safety level of conflict points. The experimental results show that the proposed methods have successfully shown the distribution and location of dangerous conflict points according to the actual situation of the two intersections. Based on our results, authorities can consider reorganizing traffic light pattern at these intersections to reduce possible collisions.

Keywords: Traffic conflict technique. Traffic safety evaluation. Image processing. Fuzzy comprehensive evaluation.

Resumen

Los accidentes de tráfico ocurren con frecuencia en el área de intersecciones debido a conflictos entre vehículos. Muchos investigadores han estado evaluando la seguridad del tráfico, sin embargo, la mayoría de ellos se basan en datos de accidentes que ocurrieron y causaron lesiones, así como daños económicos. Recientemente, las técnicas de conflicto proporcionan puntos de vista generales y soluciones para prevenir colisiones tempranas. Este artículo propone un método de análisis de conflictos utilizando la técnica de procesamiento de imágenes y la evaluación integral difusa. Sobre la base de la detección de vehículos, los parámetros de conflicto recopilados de dos intersecciones en Hanoi, Vietnam, se procesaron y evaluaron mediante una evaluación integral difusa para dar a conocer el nivel de seguridad de los puntos de conflicto. Los resultados experimentales muestran que los métodos propuestos han demostrado con éxito la distribución y ubicación de puntos de conflicto peligrosos de acuerdo con la situación real de las dos intersecciones. Con base en nuestros resultados, las autoridades pueden considerar reorganizar el patrón de semáforos en estas intersecciones para reducir las posibles colisiones.

Palabras-clave: Técnica de conflicto de tráfico. Evaluación de seguridad vial. Procesamiento de imágenes. Evaluación integral difusa.