Predicted Relative Time-to-Collision: Evaluating Pedestrian Potential Risk at Non-Signalized Intersections

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Introduction

In the field of transportation studies, ensuring pedestrian safety at intersection is an issue of increasing urgency and global significance. Contemporary studies are capitalizing on cutting-edge technologies to assess the likelihood and severity of accidents, using real-time data from vision sensors [1]. Consequently, the research focus now is on developing proactive protection systems. Certain studies have used SSMs to predict conflicts between pedestrians and vehicles due to their advantages in simplifying complex interaction scenarios [2-3]. However, these studies expose the limitations of traditional SSMs that oversimplify the complex dynamics between vehicles and pedestrians, resulting in less accurate and inexplicable risk predictions. To better understand and predict the interactions between pedestrians and vehicles, some research studies have suggested using trajectory prediction to assess pedestrian risk potential [4-5]. Still, there exist a research gap on promoting an accurate and explicable evaluation matric to evaluate the potential pedestrian risk with the predicted trajectories.

In response to the outlined challenges, this paper introduces an innovative adjusted Surrogate Safety Measure (SSM), termed Predicted Relative Time to Collision (PRTTC), to evaluate the pedestrian potential risk. To evaluate the matric efficacy, a comprehensive framework integrating PRTTC with advanced computer vision and trajectory prediction technologies is developed. Within this framework, pedestrians are classified into distinct groups: kids, adults and cyclists. Specific evaluation criteria tailored to each category have been established to enhance the accuracy and reliability of risk evaluation. This adjusted SSM, PRTTC, aims to significantly improve proactive pedestrian protection systems by providing a more precise and dependable evaluation of pedestrian risk.

Methodology

The proposed framework for the evaluation of potential risks for pedestrians consists of three parts: (i) data collection and preparation, (ii) trajectory prediction, and (iii) potential risk evaluation. In **Data Collection and Prepossessing**, we extract and filter trajectories of kids, cyclists, adults, and vehicles from the raw video with computer vision technology. In **Trajectory prediction**, we use deep learning models, Trajectron++, to predict the trajectory of vehicles and pedestrians to determine possible collision points and calculate P-RTTC.

Lastly, in **Potential Risk Evaluation**, optimum threshold of P-RTTC value of each pedestrian classes for risk evaluation is obtained by enumeration method. The performance of the matric is evaluated with the risk level labelled dataset by observation with conflict rules [6].

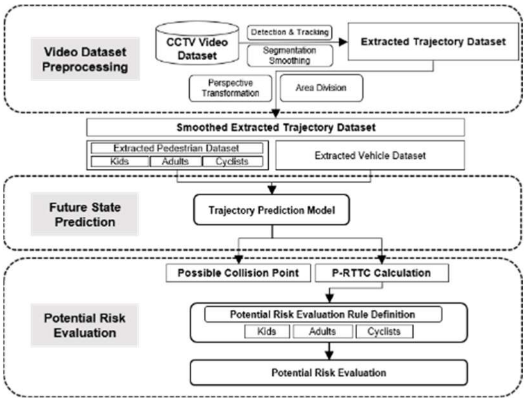

Figure 1. Framework for risk evaluation

Predicted Relative Time to Collision is defined as the predicted time difference that the vehicles and pedestrians reach the possible collision point. The formula is attached.

$$\widehat{\mathrm{Traj}}^{i}_{n+m,t} = \mathrm{Trajectron}\left(\mathrm{Traj}^{i}_{n,m}\right) \tag{1}$$

$$P^{i,j}_{j+m} = \mathrm{Intersect}\left(\widehat{\mathrm{Traj}}^{i}_{n+m,t}, \widehat{\mathrm{Traj}}^{j}_{n+m,t}\right) \tag{2}$$

$$P-RTTC = \mathrm{TBC}\left(\widehat{\mathrm{Traj}}^{i}_{n+m,t}, P^{i,j}_{j+m}\right) - \mathrm{TBC}\left(\widehat{\mathrm{Traj}}^{j}_{n+m,t}, P^{i,j}_{j+m}\right) \tag{3}$$

where $Traj^{i}_{j,m}$ represents the trajectory information of agent i from time n with m time length, $Trajectron$ represents the pretrained Trajectron++ model with predicted trajectory $\widehat{\mathrm{Traj}}$ as the output, $Intersect$ evaluates intersections between segments formed by connecting adjacent points within each trajectory. If segments intersect, it returns the collision point coordinates (x, y), $TBC(Time\ Before\ Collision)$ returns the time when next timestep's location in predicted trajectory $\widehat{\mathrm{Traj}}^{i}_{n+m,t}$ past the collision point $P^{i,j}_{j+m}$.

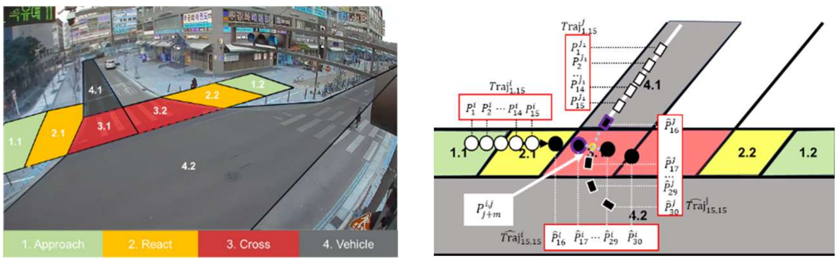

Figure 2. Area Division for study site & Trajectory Prediction for P-RTTC calculation

Result

The experiment was conducted at a real-world, non-signalized crosswalk. Pedestrian trajectory prediction over a 3-second future timeframe yielded Average Displacement Errors (ADE) of 0.68, 0.62, and 0.45 meters for kids, cyclists, and adults, respectively. Utilizing optimally tailored thresholds determined through ten-fold cross-validation, the evaluation result of PRTTC is shown in Table 1. These results demonstrate the robust performance of the

Predicted Relative Time to Collision (PRTTC) in enhancing pedestrian safety assessments in non-signalized intersections within 3-second's future.

	Accuracy	Precision	Recall	F1 Score	Threshold
All w/o	0.70	0.65	0.95	0.77	[-2,1.5]
All	0.81	0.78	0.88	0.81	*
Adult	0.79	0.76	0.93	0.83	[-0.5,0.7]
Kid	0.87	0.9	0.65	0.73	[-0.8,0.3]
Bike	0.82	0.76	0.89	0.78	[-0.3,0.5]

Table 1. PRTTC Evaluation Result on different pedestrian categories

Conclusion & Discussion

This study demonstrates that Predicted Relative Time to Collision (PRTTC), as an adjusted Surrogate Safety Measure (SSM), effectively evaluates pedestrian risks. The integration of PRTTC with advanced computer vision and trajectory prediction technologies within a comprehensive framework allowed for tailored risk evaluations among different pedestrian categories: kids, adults, and cyclists. Ultimately, PRTTC has proven to significantly enhance the efficacy of proactive pedestrian protection systems by providing a more accurate and reliable potential risks evaluation.

In addition to serving as a metric for assessing future potential risks—which aids in transmitting warning signals to pedestrians and activating vehicle brakes at non-signalized intersections—decision-makers and urban planners can leverage PRTTC to gain valuable insights into potential collision scenarios. This utility is particularly evident in understanding and mitigating high-conflict situations, even when pedestrians successfully evade imminent dangers.

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