Towards a Game Theoretic Approach to Model Pedestrian Road Crossings

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Abstract

The goal of this research is to introduce the fundamentals of a game theoretic approach to model pedestrian roadway crossings, as well as road users interaction strategies in such scenarios. For this reason, the most influencing factors in users decision and choice of strategy are employed to develop the model. This plays a central role in building a robust microsimulation model to simulate the trajectory, and movements, of traffic participants in roadway crossing scenarios, in which there is no traffic control and management systems to conduct the traffic and users movements.

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1. Introduction

Interactions of road users have always been a concern in traffic safety. During the interaction process, users intend to dominate the road space that they are moving towards. The priority competition is more complicated when heterogeneous users are interacting with one another in uncontrolled environments. Schönauer et al. (2012) developed a game theory to model the users behaviours in conflicting interactions, where factors like the probability of collision determine the users’ conflict resolving strategies. Johora and Müller (2020) extended the model by incorporating multiple cars to pedestrians interactions. However, the applicability of the proposed models is mostly restricted to specific types of road users, e.g., cars with cyclists and/or pedestrians. In this study, a game theoretic approach is formulated to model the interactions of pedestrians with a variety of users, like two-wheeler, passenger car, and heavy commercial vehicle. Such a user diversity provides a more robust model that can be applied in any traffic environment.

2. Conflict Resolution Model

A game of Stackelberg leadership competition is applied to determine the decision of users interacting at crossing and simulate their movements. A sub-game perfect Nash equilibrium (SPNE) is used to solve the game using backward induction method, i.e., the best response of the follower must be computed first to allow leader to maximise its payoff. The payoffs of strategies are classified as dis-utilities and utilities, and the formulations are presented in Table 1.
Table 1: Utility functions to compute payoffs of strategy pairs for users $i$ and $j$ in the game ($(x, y)$: agent’s position, $v$: speed, and $\text{Act}$: actual)

<table>
<thead>
<tr>
<th>Category</th>
<th>Metrics</th>
<th>Utility/dis-utility</th>
<th>Formula</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety level</td>
<td>Relative time to min. rel. distance (RTMD)</td>
<td>$S_{ij}$</td>
<td>$\text{RTMD}<em>{ij} = \frac{t</em>{min}^{i} - t_{max}^{j}}{t_{ij}}$</td>
<td>$\text{RTMD}_{ij} &lt; \text{RTMD}^{MM}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$1 - \exp(-\text{RTMD}_{ij} - \text{RTMD}^{MM})$</td>
<td>$\text{RTMD}^{MM} = 3\text{sec}$</td>
</tr>
<tr>
<td>Travel level</td>
<td>Delay</td>
<td>$D_{i}$</td>
<td>$1 - \exp(-\text{FFT}<em>{i} - \text{FFT}</em>{j})$</td>
<td>$\text{FFT}<em>{i} &gt; \text{FFT}</em>{j}$</td>
</tr>
<tr>
<td></td>
<td>Departure</td>
<td>$D_{i}'$</td>
<td>$1 - \exp(-\text{FFT}<em>{i} - \text{FFT}</em>{j})$</td>
<td>$\text{FFT}<em>{i} &gt; \text{FFT}</em>{j}$</td>
</tr>
<tr>
<td></td>
<td>Deceleration rate</td>
<td>$D_{i} - D_{i}'$</td>
<td>$1 - \exp(-\text{FFT}<em>{i} - \text{FFT}</em>{j})$</td>
<td>$\text{FFT}<em>{i} &gt; \text{FFT}</em>{j}$</td>
</tr>
<tr>
<td>Traffic environment</td>
<td>Group size</td>
<td>$F_{i} \cdot F_{j}$</td>
<td>$(-1, 0, 1)$</td>
<td>Pedestrian group size $= 2$</td>
</tr>
<tr>
<td></td>
<td>Approaching lane</td>
<td></td>
<td>$(-1, 0, 1)$</td>
<td>Pedestrian approaching lane</td>
</tr>
<tr>
<td></td>
<td>Right of Way</td>
<td></td>
<td>$[0, 1]$</td>
<td>Who gets priority</td>
</tr>
</tbody>
</table>

Utility of chosen strategy pair $S_{(\text{leader, follower})}$

**3. Data collection and Analysis**

A mid-block crossing in Surat city, India is selected for the video observation and data analysis (Golakiya and Dhamaniya, 2018). In the studied data-set, there is no real collision on the road, i.e., users could successfully solve all the conflicts by performing different evasive actions. The chosen strategies of users to avoid conflict and factors influence their decisions are of this study interest. For this purpose, a theoretical collision point (TCP) is assumed between interacting users, in which users would intersect at that point, if they would have not take evasive actions. A minimum time-to-collision was defined to capture the simultaneous arrival of the users at TCP. The application of the conflict detection procedure on data led to identification of 172 conflict events between pairs. The detection of conflict resolution strategies was performed manually and strategies are specified as: continue, deceleration, and deviation.

**4. Initial evaluation of the model**

To evaluate the performance of the model, one conflict event (CE) was chosen and the users’ payoffs were computed. In the CE, a pedestrian (P1) encounters a three-wheeler (3W), while approaching from the kerbside. Figure 1 shows the users’ real trajectories, where (P1) decelerated and 3W gained priority. The model assumes that user with lower time-to-TCP is the game leader (in this event 3W is leader and P1 is follower). The scenario is reproduced by applying the utility functions described in Table 1, and the game matrix is formed as Table 2. The SPNE of the game yields a similar result as the real scenario, where (P1) decelerates to let (3W) pass first.

**Figure 1: CE - green: traversed trajectories, cyan: trajectories after solving conflict**

**5. Discussion**

The presented methodology, when combined with the studied data-set, can provide insight into the users’ decision-making process, since a diverse range of road users interact at the mid-block crossing. To improve the accuracy of the proposed approach, another data-set will be additionally used for calibration and validation of the model.

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**References**

