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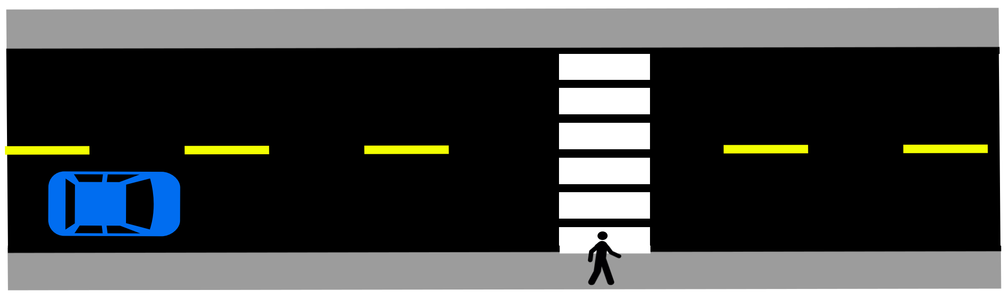
Modeling Pedestrian - AV Interaction at a Mid-Block Intersection

1 Problem Formulation

Consider the problem of an autonomous vehicle attempting to drive past an unsignalized, "mid-block" crosswalk. A pedestrian is simultaneously walking towards the intersection.



In this case, what should the autonomous vehicle do? Should the vehicle always stop as soon as a pedestrian is observed near a cross-walk? Can the AV make the decision to speed up and cross before the pedestrian is in the intersection? If so, how can it communicate intent to the pedestrian? Likewise, can it interpret signals from the pedestrian to understand whether the pedestrian is set on crossing?

Uncontrolled mid-block intersections, like the one shown in Fig. 1, pose the ambiguity of right of way. These laws are dictated on a state-by-state basis. While several states (e.g. Minnesota, Georgia, Maryland) have "must-stop" rules for uncontrolled intersections, other states have "must yield" rules. For example, vehicles in Arkansas must yield once a pedestrian is in any portion of the roadway, while vehicles in Alabama require motorists to yield to a pedestrian either on the same half of the road or approaching from the opposite side of the roadway.

Given this ambiguity, there is a clear need to study the interaction between the pedestrian and the autonomous vehicle. Most human drivers and pedestrians do not know the explicit laws of their state, but safely navigate pedestrian interactions nonetheless.

Several research questions can be posed for the following situation:

- Can we come up with a mathematical formulation describing this situation?
- Can we superimpose this mathematical model with real-world data of pedestrian intersection crossings?
- Can this formulation, combined with real-world data, be used to predict realistic interaction scenarios?
- Can we design control policies for the vehicle that maintain a high standard of safety while also enabling robust traffic flow

2 Prior Work

There is a wide body of literature segmenting the work on pedestrian behavior. In terms of purely modeling the dynamics of pedestrian motion, Batkovic et al. [1] presented a mathematical model to predict pedestrian motion over a finite horizon, with a focus on low computational complexity for autonomous driving. Karasev et al. modeled pedestrian behavior as intent using a Markov Decision Process [3].

Another segment of the literature is focused on developing predictive models for pedestrian crossing. These approaches typically study the parallel issues of pedestrian crossing behavior or driver yielding behavior and date as early as 1975 [4]. Schroeder and Rouphail [11] explored factors associated with driver yielding behavior at unsignalized pedestrian crossings. Using logistic regression, the authors found that drivers are more likely to yield to assertive pedestrians who walk briskly in their approach to a crosswalk. Kadali and Perumal [8] studied the "gap acceptance" behavior of pedestrians at mid-block crosswalks through a video graphic survey, and found that the gap accepted by crossing was explained by factors such as crossing direction, vehicle speed, and pedestrian age. Yannis et al. [13] also found that gap acceptance was influenced by the size of the oncoming vehicle and the presence of other pedestrians. Gap acceptance models were also proposed by [12]. Lee and Aty [6] studied interactions in the form of crashes, and found crashes were linked with higher daily traffic.

Another branch of literature specifically studies the interaction between pedestrians and autonomous vehicles. A review of these studies was conducted by [9]. Rothenbucher et al. [10] studied the interaction between pedestrians and driverless vehicles by constructing a car seat costume to disguise a driver. The authors noted that pedestrians overall managed interactions at crosswalks effectively, but later mentioned increased uncertainty about the car's behavior. To improve the issue of trust, several researchers have developed external interfaces to more clearly broadcast the intent of the autonomous vehicle [7], [5].

Several real-world studies of AV-pedestrian interaction noted that once a local population learned a vehicle was programmed to be perfectly safe, pedestrians would regularly take advantage of the AV and walk in front of it. [**?**]. This illustrates an issue with automated driving in that an overly conservative crossing algorithm will often be taken advantage of or cause confusion among pedestrians. Camara et al [2] attempted to model the natural negotation for priority between a pedestrian and an AV at an intersection using game theory.

3 Proposed Research

References

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