Augmenting AV Awareness with I2V Information

Offer Grembek, Alex Kurzhanskiy, Aditya Medury, Pravin Varaiya, Mengqiao Yu

Automated vehicle (AV) safety rests on the proposition that if a vehicle can identify the objects in its field of view and if it can predict how each object will behave, it can safely drive itself. This project is concerned with the situation in which there are objects that are not visible to the AV. The driving context is that of an intersection, and the lack of visibility is due to other vehicles that obstruct the AV’s view. Such obstruction is commonplace in intersections.

Our objective is:
1. Inform a vehicle crossing the intersection about its potential blind zones; and
2. Inform the vehicle about the presence of agents (other vehicles, bicyclists or pedestrians) in those blind zones.

Achieving the first part of the objective would increase vehicle and intersection safety. Accomplishing the second part would improve vehicle and intersection efficiency: when a given blind zone is empty or the agent dynamics in that zone does not lead to a conflict, one can safely proceed at normal speed instead of disengaging, inching forward, or stopping and waiting.

Identifying Blind Zones

Blind zones are computed from static data comprising intersection geometry (intersection approaches and exits; subdivision into lanes; turn pockets; rail tracks; special lanes for transit and bicycles; crosswalks), permitted movements (e.g., left turn from the second lane from the left), and admissible movements that can be activated concurrently. Note that such admissible movements can be conflicting, as explained below.

Intersection geometry can be obtained from OpenStreetMap (OSM) or MapBox. For every movement, we establish a guideway – a bundle of all plausible object trajectories implementing this maneuver. There are vehicle, bicycle and pedestrian guideways. Places where guideways intersect, are called conflict zones. Conflict zones are areas where collisions or near misses may happen.

Figure 1, describes our Danville intersection test site in 4 panes:
1. Displays all possible guideways for this intersection.
2. Highlights the guideways that belong to one admissible movement combination. In this case, the movement combination corresponds to signal phases 2 and 6 – west-east and east-west movements,
as well as west-south, south-east, east-north and north-west right turns and the two west-east/east-west pedestrian crossings.

3. Intersecting highlighted guideways produces conflict zones, shown as cyan boxes. Here, white solid (vehicular traffic) and hollow (pedestrian traffic) arrows indicate movements that generate the conflict zones. For each state of the signal, there are several (usually, between 4 and 8) conflict zones that are active – where conflict is possible, even if there are no violations of traffic rules. So from the state of the signal we can automatically calculate which conflict zones to focus attention on.

4. Focusing on a single movement, say south-east right turn, during activation of signal phases 2 and 6, there will be only two conflict zones: one resulting from right turn intersecting with pedestrian crossing; and the other resulting from right turn intersecting with west-east movement.

Once the conflict zones are determined, we can compute **blind zones**. Each blind zone is computed for a given guideway (movement) with respect to a given conflict zone.

Consider conflict zones for the west-north left-turn movement resulting from its intersection with three straight east-west guideways (CZ1, CZ2, CZ3) and with west-east/east-west pedestrian crossing (CZ4), shown in Figure 2a. It is a case of permissive, but **not protected** left turn. Let us focus, for instance, on conflict zone CZ3, shown in red. CZ3 is the intersection of the west-north left-turning guideway G0 and third lane east-west guideway G3 (Figure 2b). For any point of guideway G0 upstream of CZ3, we can define a **vision zone** VZ (Figure 2b) through its heading, radius and angle. If at a given point of G0, VZ centered at that point intersects with guideways G1 or G2 before reaching G3, the view of G3 from that point is obstructed.\(^1\)

SAE J2735[^2] MAP message is used to broadcast the intersection layout.

### Presence of Agents in Blind Zones

If the presence of blind zones at a given intersection is established, we want to put detection into those zones to enable informing vehicles with obstructed vision about potential dangers. Referring to the above example, Figure 3 shows zones, where detection is required (desired) for the west-north left-turn movement. Here, we need to monitor the crosswalk and three east-west guideways. The extent of desired detection zones is determined by the assumptions about agent dynamics. For example, on the road with speed limit 40 mph (18 m/s), turning radius 10 meters and acceleration rate \(1.5 \text{ m/s}^2\) the detection zone

---

[^1]: We believe that occlusions are caused by queued-up (not by moving) vehicles. Queues may be formed upstream of conflict zones. Therefore, we check if the vision zone intersects guideways other than G3 upstream of any of its conflict zones.

[^2]: SAE J2735 Standard: [https://www.sae.org/standardsdev/dsrc](https://www.sae.org/standardsdev/dsrc)
should start 72 meters before the stop bar. This would give the left-turning vehicle 4 seconds to complete its maneuver starting at zero speed at its stop bar. Left-turn maneuver should not start in the presence of pedestrians at the crosswalk.

The presence of vehicles in the desired detection zones can be monitored using the set of approach and stop bar sensors that count vehicles entering and exiting the detection zone, thus roughly maintaining the size of the vehicle queue in that zone. SAE J2735 SPaT message is used to broadcast the current signal phases also providing the state of all lanes in terms of vehicles/bicyclists/pedestrians present in them, as well as any pre-emption or priority. SAE J2735 ICA messages are typically used in vehicle-to-vehicle communications: a connected vehicle issues this message if it violates the intersection. However, the combination of signal phasing and detector readings provide enough data to identify violation and for the roadside equipment to generate ICA message and broadcast it.

**Current Research and Next Steps**

Our research plan can be summarized as follows:

1. We are developing an algorithm to establish the minimal number of sensors needed to eliminate blind zones and their placement to guarantee safe operation.

2. Presently, we use PreScan to justify the need for detection in blind zones. Figure 4 presents a screenshot of the PreScan simulation of the collision scenario involving vehicles in guideways G0 and G3. G0 vehicle slowly makes permissive unprotected left turn and runs into the speeding at 40 mph G3 vehicle. This scenario is modeled after autonomous Uber car crash in Tempe, AZ in March 2017.³

---

Our next step is to evaluate the efficiency of detection and I2V in PreScan and see how information about agent activity in blind zones (as opposed to just informing about existence of such zones) improves AV’s and intersection’s operation.

3. We are developing software for intersection evaluation. It will help answer the following questions:
   • Does a given intersection have blind zones?
   • If yes, how probable are occlusions for given vehicle, bicycle and pedestrian flows?
   • What is the minimum viable detection setup for elimination of blind zones? This calculation can serve as a proxy for the cost of intersection instrumentation.
   • How much improvement in terms of safety and mobility does I2V instrumentation provide for a given vehicular, bicycle and pedestrian traffic pattern and a given portion of connected traffic?

4. We will build a prototype I2V system at an intersection in Richmond Field Station (RFS), a UC Berkeley test facility.