Intersection Decision Support Project Seeks to Prevent Broadside Crashes

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The Intersection Decision Support (IDS) project addresses the application of infrastructure-based and infrastructure-vehicle cooperative systems to address intersection safety. The Infrastructure Consortium (IC) comprises the US Department of Transportation (DOT), California DOT (Caltrans), Minnesota DOT, and Virginia DOT.

The project's mission is to investigate key enabling technologies, conduct naturalistic driving data collection, perform driver modeling, develop an integrated IDS simulation approach, and look at the applicability of a large set of already- or nearly-available “commercial off the shelf” systems toward meeting IDS requirements. We will also investigate the use and usability of roadside-mounted dynamic message signs.

The IDS team comprises members of the Infrastructure Consortium, as well as researchers from PATH, the University of Minnesota ITS Institute, and Virginia Polytechnic Institute (Virginia Tech Transportation Institute).

Each institution and State brings its own expertise and focus to the national problem:

- California focuses on systems integration and the left turn across path problem, particularly in urban areas. PATH's funding for the project is from the FHWA and Caltrans.
- Minnesota focuses on lateral direction crashes when minor roads intersect major arterials, particularly in rural areas.

• Virginia focuses on near-term deployable approach warning for traffic signals and signs.

This effort culminates in engineering, testing and designing for a set of end-of-program demonstrations, probably in early 2005, and thereafter one or more approaches may be selected for Field Operational Test (FOT). An FOT will be a real application on a real site.

The PATH technical focus is left turn movements. In particular, we are concentrating on preventing crashes that occur when a driver makes a left turn onto a cross street, and is either hit head-on by an oncoming vehicle traveling in the opposite direction, or hit broadside by a vehicle traveling on the cross street. Figure 1 shows the first scenario, dubbed Left Turn Across Path/Opposite Direction (LTAP/OD). Figure 2 shows the second, Left Turn Across Path/Lateral Direction (LTAP/LD).

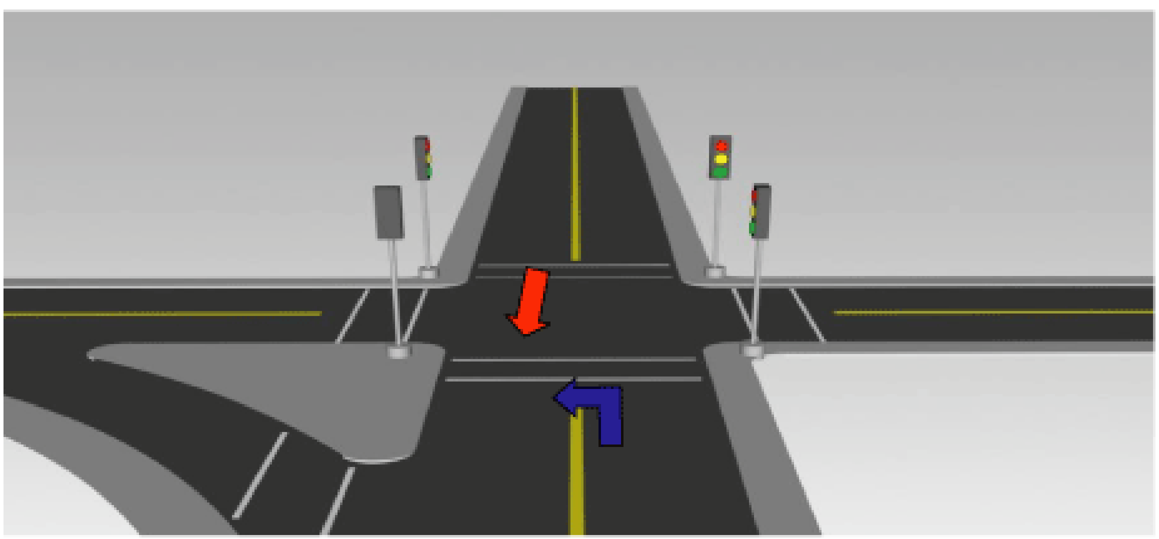

Figure 1 - LTAP/OD scenario

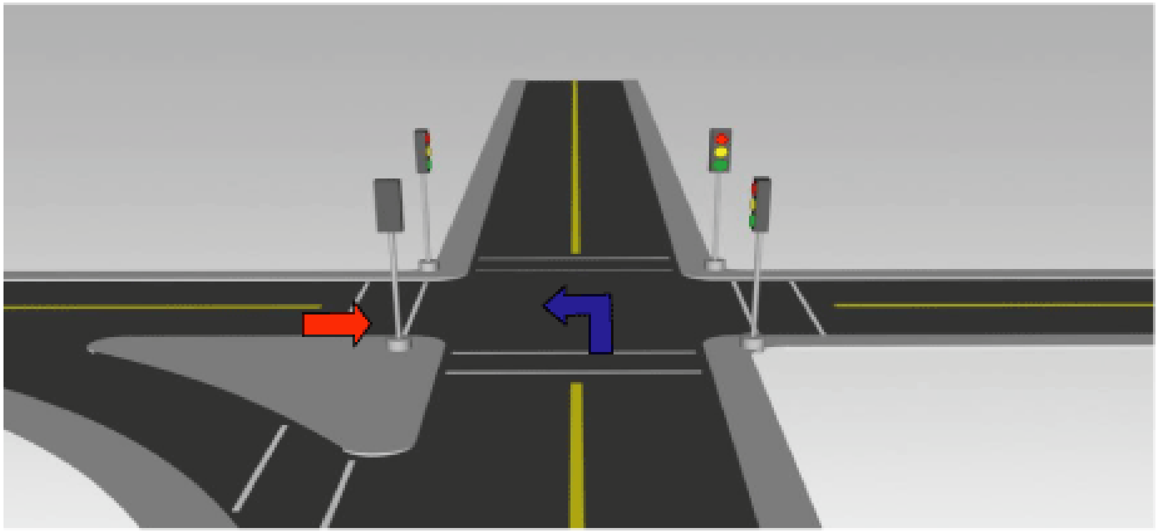

Figure 2 - LTAP/LD Scenario

The LTAP/OD scenario represents 27.3% of intersection crashes, and cuts across all causal factors. Likewise, the LTAP/LD scenario represents 15.9% of all intersection crashes. Even when delimiting the LTAP/LD to urban areas, we believe that our specific solution approaches may affect between 30 and 40% of all intersection crashes in the U.S.

At a quarterly technical review meeting held at PATH's Richmond Field Station headquarters in March, working components of the LTAP/OD scenario were described and demonstrated to the IC partners. We are preparing for a national demonstration to be held at the FHWA Turner Fairbank Highway Research Center in McLean, Virginia, as part of the National Intelligent Vehicle Initiative meeting, to be held 25 - 26 June, 2003.

The system demonstated in March can operate on one or both of two modes: as an infrastructure-based LTAP/OD intersection collision warning system that uses a flashing road sign to warn the driver of an approaching hazard; or as a cooperative LTAP/OD collision warning system, with “cooperation” enacted by a wireless system that sends state information about the hazard, collected at the roadside or even from other vehicles, to the driver. A PATH video (viewable at www.path.berkeley.edu/PATH/Research/Featured/032703) shows a working prototype of the infrastructure-based system. The major differences between this prototype and the system we will demonstrate nationally are that by June we will tune our timing algorithm using tests on human subjects, fuse data sources other than the lidar in the video (by including automotive radars and loop detector inputs), and make our controlling computer interact with a state-of-the-art (2070) Advanced Traffic Controller so that traffic engineers can see the near term deployment path.

Key components of the system include:

Component 1 - development of operating principles and algorithms.

Figure 3 illustrates our basic architecture. Inputs to the algorithm are: Subject Vehicle (SV) sensor measurements, Principal Other Vehicle (POV) sensor measurements, and traffic signal phase information. The output of the algorithm is a warning signal that triggers either a roadside mounted Driver-Infrastructure Interface (DII – the flashing road sign), or an in-vehicle display. For the SV and POV sensor measurements, sensor data processing is necessary to refine the measurements by means of filtering and tracking to form a system level description of vehicle states by means of multiple sensor data fusion, and to derive vehicle motion parameters such as range and speed by means of statistical parameter estimation.

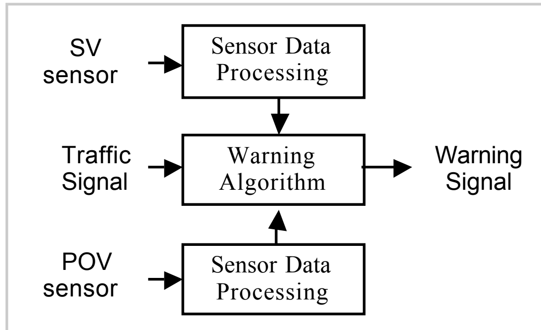

Figure 3 - Algorithm Architecture

Vehicle motion parameters, together with traffic signal phase information, are further processed in a warning algorithm, based on a decision-making criterion to decide whether or not to turn on the DII. The criterion is that if POV's time-to-intersection (T2I) falls in a critical time gap, which is a safe time gap required by SV to make a left turn, the algorithm will trigger a warning; otherwise, no warning should be given. T2I is defined as the time that SV or POV needs to get into the intersection. The basic warning timing based on this criterion is illustrated in Figure 4.

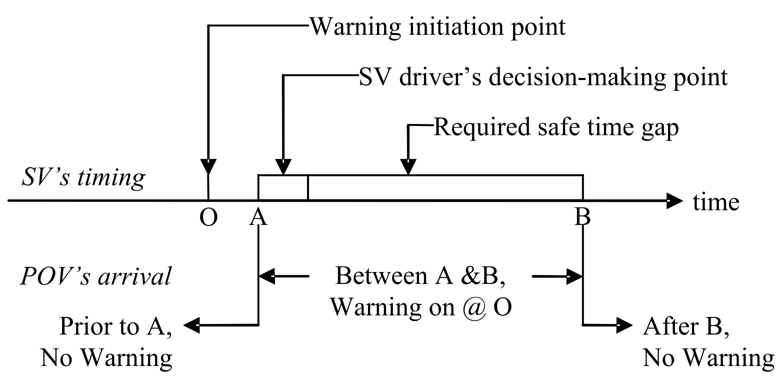

Figure 4. - Basic Warning Timing

In Figure 4, the warning initiation point (O) is the time point that the DII turns on. This point can be selected during the time interval when SV driver is gathering information from environment soon before reaching the intersection. The SV driver's decision-making point is distributed in a time interval because of the diversity of situations and driver's capabilities. The required safe time gap is bounded by point A and B. As shown in the timing, if POV's T2I at point O is shorter than OA or longer than OB, no warning should be given; otherwise a warning should be issued at O. Once the DII is triggered, it stays on until the POV passes the intersection. In a practical system, the traffic signal phase and possible queues of subject vehicles and other vehicles will make the timing more complex, and functionality will be increased to predict, potentially, gap, stops and conflicts. However major characteristics have been addressed in this basic timing.

A diversity of sensors can be used to detect POV and SV. Embedded micro loops, micro-wave radars, and laser scanners (lidars) are commonly used. Embedded loops are widely deployed in actuated traffic signal control systems. Radars and lidars are used in adaptive cruise control and collision avoidance systems. Embedded loops are inexpensive but do not provide continuous trajectory. Radars and lidars provide continuous trajectory but may not work in some circumstances. It is of great value to test these sensors in a demo system to see which sensors or what combinations best fit the IDS needs.

Component 2 - driver interface.

This involves a two-pronged effort: the roadside-mounted DII, and a communication means to enable an in-vehicle device.

The most important DII criteria is that it must be instructive to the driver of the SV; it must tell the driver to do something.. In the present case, that of a LTAP/OD, the instruction is to abort a turn intended or in progress on the grounds that an unseen POV threatens to collide with the SV.

Other criteria include:

- Placement: the sign must be placed where the driver's eyes would likely be directed and where an imminent turn could be stopped.
- Look: the DII must to show a familiar icon within the array of possible signs approved within the MUTCD.
- Temporal facility I: The DII must be 'off', and thus invisible, until needed.
- Temporal facility II: The DII must be able to be turned on suddenly.
- The DII must have its own power, in order to respond to a trigger signal delivered either by hard wire or by wireless.
- The DII must be able to compete with the gamut of distracting visual features of an intersection.: thus it must exhibit salience and attention-getting qualities along with its familiar instructional quality.

We considered a number of option including speed limit signs with variable speed indicators, in-pavement flashing signals to supply a visual barrier, and augmented traffic signal approaches (e.g. Left turn red arrow).

The most generally useful of the solutions proved to be a modestly refined (to become active) left-turn prohibition sign (MUTCD R3-2), illustrated in Figure 3. The sign is to be placed just above eye level at opposite corner of the intersection. (For the LTAP/OD case, it will be on the left-hand far corner, whereas for the LTAP/LD case, it could be placed on either intersection. Optimization for exact placement has not yet been thoroughly investigated.) These are the ones of the candidate locations that the driver of the SV is most likely to scan in advance of a turn (which also include overhead at the signal, or in before the intersection).

Figure 5. Left Turn Prohibited Sign Adapted to Active DII

We have designed the sign to be self-luminous when active (using LEDS) and thus to be neutral and icon-free when not. An additional refinement, that we project will increase its salience and attention getting qualities, will be to arrange for the red circle/slash that covers the left turn arrow, to be continuously active during the 'on' phase. The circle/slash will, periodically (at 1-4 Hz), increase in scale from the standard size shown in geometrical specifications for the R3-2 to a 50% increase in the thickness of the elements. This latter activity will, we conjecture, make the sign especially visible amongst the distracters that can be found at any intersection for the reason that the motion inherent in its elements and the looming nature of that motion, should be especially suited to signaling the fastest and most sensitive pathways in the visual nervous system.

With regard to the roadside-vehicle communication necessary to enact an in-vehicle driver interface, we have developed a "State Map" concept wherein information from the roadside is transmitted to a computer, either at the roadside or within the vehicle. In either case, a LTAP/OD IDS algorithm – probably the same or similar version – can operate at either locale. The critical enabling technology is Dedicated Short Range Communication (DSRC), and the concomitant development of protocols to allow safety critical information to be transmitted to ad hoc and ever-changing networks of cars within the intersection.