Automated Turn Signal Based on Trailer Dynamics

Development of a system for classification of complex semi-truck turns and lane changes using sensors and vehicle dynamics.

EE 448/449

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Introduction

Nearly all vehicles have turn cancelling systems which return the turn stalk to neutral after a turn is over. Semi-trucks, however, do not typically have such a system. Differences in the vehicle dynamics of hinged vehicles make most semi-trucks incompatible with the traditional mechanical solution found in passenger vehicles, which simply cancel the signal once the steering wheel straightens out.

The proposed mechanism uses signals available on the vehicle CAN bus as well as sensor systems to monitor the vehicle's progress through a turn. The available signals will allow our embedded solution to monitor vehicle yaw, turning path, and speed. This data about the vehicle's dynamics is enough determine the vehicle's turn status reliably.

Algorithm

The vehicle dynamics calculations take place on the Mbed development board at the front of the vehicle's cab. A typical 90˚ turn trajectory is shown in Figure 1.

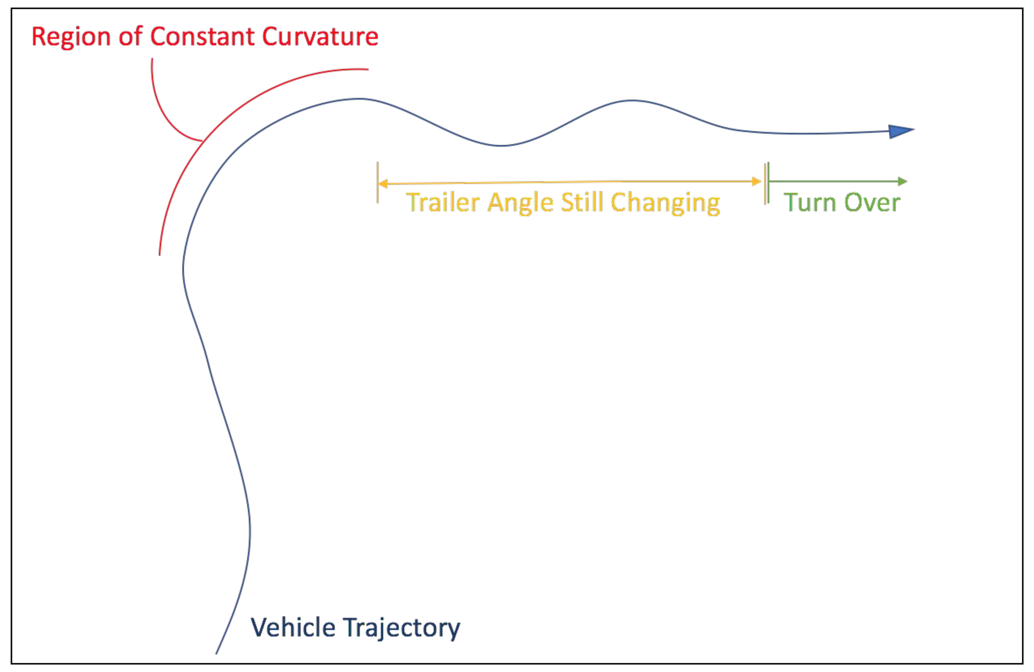


Fig. 1: Typical 90˚ turn trajectory

There are two main stages in the turn during which we prevent the signal from turning off that are shown in figure one in red and yellow: a region of constant curvature followed by a period of oscillation as the driver adjusts lane adjustment. There are two simple conditions that determine maneuver completion:

- the vehicle must have experienced "enough" yaw for the maneuver indicated by the driver
- the truck must have minimal change in its angle of trajectory.

To prevent early cancellation and meet these conditions we perform the checks shown below:

$$\left.\begin{matrix} k\int STWAngle * Vehicle\ Velocity\ dt \\ \dfrac{d(STW\ Angle)}{dt} \ \& \ \dfrac{d(Trailer\ Angle)}{dt} \end{matrix}\right\} \text{Check}$$

By using both velocity and steering wheel data we hope to capture a greater range of turns at many speeds and for drivers with different driving styles.

Edge Cases

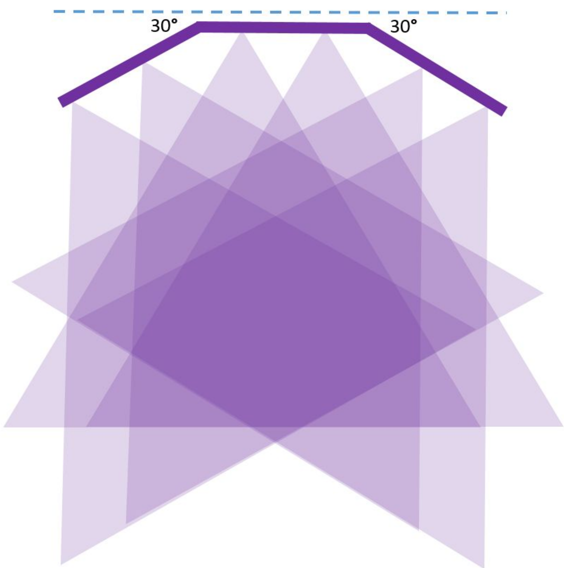
While this vehicle dynamics approach handles many edge cases and variability in turns, there are some maneuvers different enough from a typical in-city 90˚ turn and had to be identified and handled individually. The cases we addressed include:

- Preventing creep in integration value at low speeds
- Detecting and correctly handling lane changes
- Accounting for variability in driving style
- Handling turns both with and without turn lanes

Ultrasonics

The only input to our system not already available to us on the vehicle's CAN bus is trailer angle. We developed a ultrasonic sensor array to provide this information to our system.

Individually, the sensors we chose could read angles of surfaces at +/- 30˚ to the sensor. To achieve a greater range, we used three pairs of sensors on angled panels to measure a total trailer angle range of +/- 60˚ from center.



One of the limitations of this design is that it produces inaccurate measurements for trailers with front faces which are not flat. We recommend a solution that would pair this ultrasonic array with another sensor type, such as a non-contact hall effect sensor in the 5th wheel hitch. The ultrasonics would help the hall effect sensor to initialize and the hall effect sensor is far more accurate and works agnostic of trailer type.

Fig. 2: Ultrasonic mount on Kenworth test vehicle

Testing

Vector CANoe was used to log and replay recorded CAN data from all of our test drives. This let us edit our algorithm and see how it responds under certain circumstances offline before driving on-site.

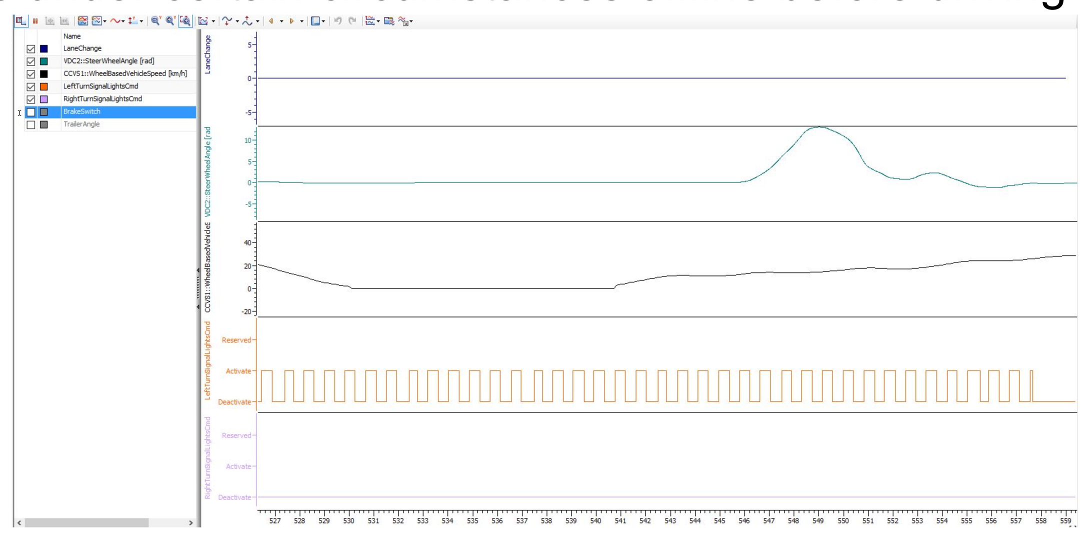


Fig. 3: Left-hand 90˚ turn data recorded and visualized in Vector CANoe

We used a 1-hour route through Renton with over 33 turn and lane changes as the initial test for our algorithm and ultrasonic sensors and their ability to handle different roads and turn trajectories. For further validation of our system's compatibility with different drivers, we tested the route around Renton with 3 different drivers.

Results

Initially, we tested our system exclusively on right and left 90˚ turns. Our system indicated only after the tractor and trailer were in the lane. We achieved our goal for 90% accuracy in this preliminary test.

For our validation runs in Renton, we added functionality to detect lane changes and turns both with and without turn lanes. In these tests, we were unable to reach our accuracy goal of 98%.

	# Maneuvers	Pre-Tuning	Post-Tuning	% Early
Driver 1	68	48%	63%	3%
Driver 2	52	54%	61%	7%
Driver 3	32	N/A	**90.6%**	3%
Driver 4	18	N/A	77.7%	0%

Overall, the results from our validation drive indicate that our system's performance is more dependent on driving style than we had anticipated. Our system still responds best to 90˚ turns, slight turns never reach the necessary integration threshold, and our trailer angle sensors occasionally need to be reinitialized.

A key success to note is that there were minimal early shut-offs, as shown in the table above. To ensure road safety, our system must not cancel the signal early.

As we tuned the system it became more accurate for some maneuvers and less accurate for others. With more time and driving data, a balance could be achieved that maximizes accuracy for the average driver. It worked the best for the driver with the least experience, suggesting that it could be especially useful for new drivers.