EMERGENCY LANE KEEPING (ELK) SYSTEM TEST DEVELOPMENT

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ABSTRACT

LDW and LKA systems are becoming more prevalent on modern vehicles, however their current simple implementation leads to frequent activation and intervention. Drivers report this indiscriminate intervention as annoying and perceive it to be unnecessary, which leads to system deactivation and the loss of any potential safety benefit in critical situations.

This paper focuses on developments relating to actively intervening Lane Support Systems (LSS), namely Emergency Lane Keeping (ELK) systems. It describes the findings of analyses of relevant European real world collision data and the development of representative test scenarios, methodology and evaluation criteria.

The aim of developing ELK test methodology is to encourage LSS that intervene less frequently but more effectively to prevent collisions occurring in critical lateral control situations. This was promoted by linking intervention to the associated threat thus encouraging vehicle technology that discriminates between event types and their criticality. A benefit of interpreting the threat is the ability to minimise the frequency of corrective inputs thus reducing the driver perception of unnecessary intervention and maximising driver acceptance of such systems. Therefore, similar to Autonomous Emergency Braking (AEB), the demanding requirement for a system to be default on at the beginning of every journey can be made to maximise the potential benefit in every day driving

Relevant real world crash data from European sources was studied to identify the common features of lateral control collisions such as run-off road, head-on collisions with oncoming vehicles and collisions with overtaking vehicles. Test scenarios, methodology, metrics and controls were developed for evaluating ELK systems. Evaluation criteria were also developed to encourage effective intervention in the real world.

The oncoming and overtaking testing scenarios require the use of a partner vehicle to trigger the ELK system intervention. The test target specified for use is the Global Vehicle Target (GVT), an impactable 3D car target according to ISO 19602 Part 1. It was intended that a representative road edge would also be developed to achieve repeatable testing across various locations, however it proved more challenging than initially anticipated to replicate the attributes of a real road edge and work continues in this area.

Although the testing methodology is grounded in real world data, certain compromises were required relating to the steering input and how the lane departure was generated in order to achieve a repeatable and reproducible results. However the results of initial testing indicate that it is possible to differentiate between system performances, particularly at higher lateral velocities.

The test procedures have been proposed to Euro NCAP for adoption, and will be implemented in the star rating scheme from 2018. Integration of the procedures into consumer testing will help to guide development of system design in future vehicles.

INTRODUCTION

Lane Departure Warning (LDW) and Lane Keep Assist (LKA) systems are becoming more prevalent on modern vehicles. These systems typically determine the position of the vehicle relative to the lane markings via image processing of data gathered by a forward facing camera sensor. In the event of the vehicle straying across a lane marking, an LDW systems issues a haptic or audible warning to the driver advising them of the incident, whilst an LKA system intervenes to adjust the vehicle heading, minimising the departure and returning the vehicle back towards the driving lane. Intervention is typically via the Electric Power Assisted Steering (EPAS) system adjusting the steering angle, however differential braking is also an effective alternative.

Current production LKA systems function in different ways. Some require a fully marked lane in order to operate whereas others will perform with a single lane marking. On some vehicles LKA is coupled with a lane centring guidance function and the LKA function cannot be independently tested. The majority of current systems are tuned to operate at speeds in excess of those typically found in urban areas to reduce activation rates, but are not discerning of the lane marking type and intervene whenever a marking is crossed whilst travelling at speed. It is this indiscriminate intervention, which drivers often perceive as unnecessary and annoying, that leads to system deactivation and any potential safety benefit in critical situations being lost.

This paper focuses on developments relating to actively intervening Lane Support Systems (LSS), namely Emergency Lane Keeping (ELK) systems. It describes the findings of analyses of relevant European real world collision data and the development of representative test scenarios, methodology and evaluation criteria.

AIM

The aim of developing ELK test methodology is to encourage LSS that intervene less frequently but more effectively to prevent collisions occurring in critical lateral control situations. This is promoted by linking intervention to the associated threat thus encouraging vehicle technology that discriminates between event types and their criticality, such as benign crossing of lane markings versus critical events such as run-off road, head-on collisions with oncoming vehicles and collisions with overtaking vehicles. In non-threatening lane departure events the vehicle may still issue a subtle warning to act as a reminder of lane marking crossing to the driver.

An Insurance Institute for Highway Safety (IIHS) study (IIHS, 2010) identified lane support systems as having the potential to prevent or mitigate 23 per cent of fatal crashes, greater than the potential of Forward Collision Warning (FCW), side view assist and adaptive headlights. It was noted that there was significant potential for effectiveness in single vehicle run-off road crashes, many of which end in death (Jermakian, 2011). However Highway Loss Data Institute (HLDI) findings to date (HLDI, 2012) have found that in some cases the fitment of LDW systems has led to higher claims rates in some cases, whilst approaching half of owners driving vehicles with the systems have reported them providing false or unnecessary alerts. In excess of a quarter describe the systems as annoying, describing their function as being akin to a ‘turn signal nanny’.

A benefit of interpreting the threat associated with lane departure events is the ability to minimise the frequency of corrective inputs thus reducing the driver perception of unnecessary intervention and maximising driver acceptance of such systems. Therefore, similar to Autonomous Emergency Braking (AEB), the demanding requirement for a system to be default on at the beginning of every journey can be made to maximise the potential benefit in every day driving.

REAL WORLD CRASH DATA

Analysis of UK accident data revealed that one quarter of police reported collisions are classified as single vehicle, head-on, or lane change incidents, accounting for 27 per cent of all fatal and serious injuries.

In depth analyses of accident data from countries including the UK, Germany and France identified that ELK relevant collisions are characterised by the following parameters:

- Collisions typically occur on rural single carriageway roads with speed limits in the range of 35 to 50mph (60 to 80km/h).
- Half of collisions occur on straight roads and half on gentle bends.

- A variety of markings are present across the various member states: solid or dashed white lines or no edge marking.
- The majority are single vehicle events with one in ten collisions including a second vehicle.
- Two thirds of events occur during daylight and one third during darkness.
- Typically the vehicle involved gently drifts from the lane with a shallow departure angle.
- In cases where the driver is distracted, the drift is often with a constant steering wheel angle.

The ELK test scenarios were generated based on the above findings. Another type of run-off road collision identified was that occurring with higher lateral velocities typically on smaller radius curves as a result of the driver failing to recognise the tightness of the approaching bend, entering at excessive speed and/or failing to steer appropriately. In these cases the lateral velocity rises rapidly because of the road geometry and they are subsequently outside of the scope of ELK. Curve approach or speed warning could be a more appropriate countermeasure for these cases.

TESTING METHODOLOGY

Scenarios

The ELK element of the 2018 Euro NCAP LSS test protocol comprises of the following test scenarios:

1. Running off the road to the near side.
2. Side collisions with an overtaking vehicle.
3. Head-on collisions with an oncoming vehicle.

For the running off road scenario there are three near side lane boundaries sub-scenarios: a solid marking, a dashed marking and the paved road edge (see Figure 1).

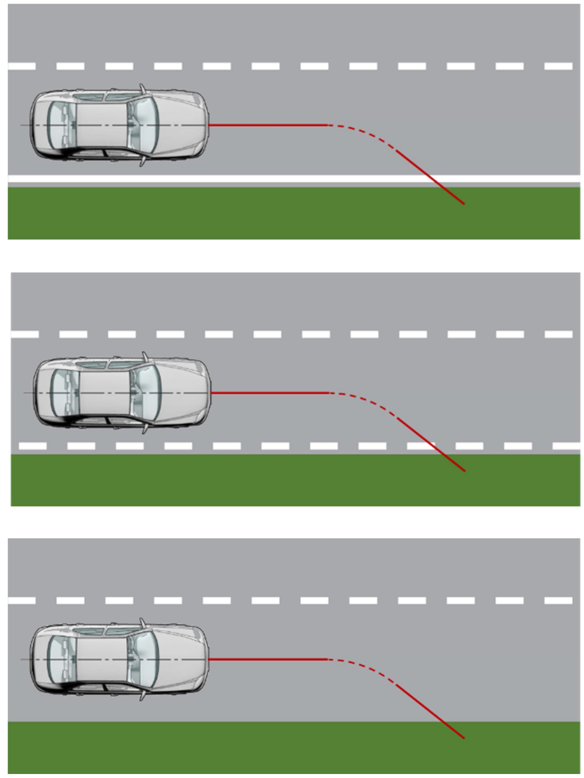

Figure 1. Running off road to the near side sub-scenarios

For the side collision with an overtaking vehicle scenario there are two sub-scenarios: a target vehicle travelling at the same speed as the test vehicle positioned centrally in the adjacent lane in the blind spot, and a target vehicle travelling centrally in the adjacent lane approaching from behind travelling at a slightly higher speed and overtaking. In these scenarios the lane change manoeuvre is synchronised such that the leading edge of the vehicle target would collide with the rear axle line of the test vehicle in case of no ELK system intervention (see Figure 2).

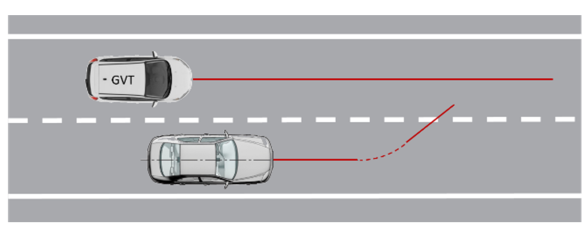

Figure 2. Side collision with overtaking vehicle scenario

For the head-on collision with an oncoming vehicle the lane change manoeuvre is synchronised such that the test vehicle crosses the central dashed lane marking into the path of the oncoming target vehicle and would collide with an overlap equivalent to ten per cent of the width of the test vehicle in case of no ELK system intervention (see Figure 3).

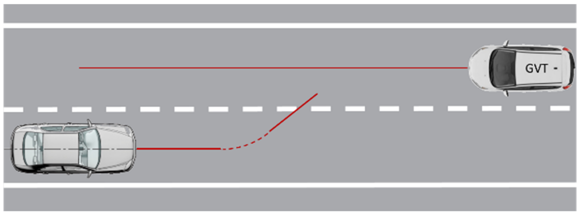

Figure 3. Head-on collision with oncoming vehicle scenario

Metrics

The running off road to the nearside and side collisions with an overtaking vehicle are tested at lateral velocities of 0.2 to 0.5 metres per second. The side collisions with an overtaking vehicle with intentional lane change are completed at lateral velocities of 0.5 to 0.7 metres per second. The head-on collision with an oncoming vehicle scenario is tested at lateral velocities of 0.3 to 0.6 metres per second reflecting the greater lateral distance that a vehicle will drift before colliding with the impact partner. All tests are performed in 0.1 metres per second increments.

All scenarios are initiated with the test vehicle travelling in lane at 45 miles per hour (72km/h) parallel to the lane boundary. In the side collision with an overtaking vehicle in the blind spot and the head-on collision with an oncoming vehicle the target vehicle also travels in lane at 45 miles per hour (72km/h) parallel to the lane boundary. In the side collision with an overtaking vehicle travelling at a higher speed sub-scenario the target vehicle travels at 50 miles per hour (80km/h) parallel to the lane boundary.

The lateral velocities, relative to the longitudinal direction of the test lane, are generated by gently steering the vehicle towards the lane boundary through on fixed radii paths of varying arc lengths. All three test scenarios are completed replicating unintentional drifting out of lane. A path radius of 1200m is used to replicate unintentional drifting to maintain the yaw rate below one degree per second at the test speed thus prevent the system operation from being suppressed. The side collision with an overtaking vehicle scenario is also completed with an intentional lane change manoeuvre where the indicator is applied and a radius of 800m is used.

Once the appropriate lateral velocity is established relative to the lane boundary the vehicle then continues to travels on a straight path towards the impact location ahead of ELK system intervention.

Target

The test target specified for use is the Global Vehicle Target (GVT) impactable 3D car target according to ISO 19602 Part 1 (see Figure 4). This document specifies the properties of an omni-directional multi-purpose vehicle target that will allow it to represent a passenger vehicle in terms of size, shape, reflection properties, etc. for testing purposes.

Figure 4. Global Vehicle Target (GVT) according to ISO 19602 Part 1

Road Edge

The running off the road to the near side scenario required the definition of a suitable road edge to ensure repeatable and reproducible testing across the various Euro NCAP test laboratories. Given the need to understand how vehicle sensors systems interpreted real road edges in order to be able to replicate them on the test track, members of the European Automobile Manufacturers (ACEA) and the European Association of Automotive Suppliers

(CLEPA) worked together to identify the relevant typical attributes of real road edges and methods for reproducing them on the test track. Three key attributes of various types of road edges were identified:

- A height difference to the paved surface, positive or negative.
- A colour contrast.
- A textural difference.

Individually, vehicle manufacturers and suppliers set about obtaining and evaluating candidate methods and materials for replicating road edges. The main challenge of assessing the materials was the identification algorithms are trained via a machine learning process involving exposing said algorithm to many examples of road edges and allowing it to develop and improve its own capability to recognise them. Subsequently the understanding of the key details that require replicating was limited and a process of trial and error was required.

A limited number of potential candidate materials and installations were identified and IDIADA hosted an evaluation workshop on behalf of Euro NCAP in October 2016 allowing vehicle manufacturers and suppliers the opportunity to assess and develop them. The outcome of the workshop was that all vehicle systems recognised the various real road edges evaluated, and all of the candidate materials and installations evaluated were recognised by at least some of the vehicle systems, however consensus could not be reached on a material or installations that would be suitable for all systems.

In order to proceed it was agreed that 2018 testing will be performed against different types of road edges present at the Euro NCAP test laboratories, and work will continue to define a representative road edge.

Control

The specification of the test scenarios tends to robotic control of the test vehicle in order to achieve the necessary guidance and synchronisation with the test target. Careful consideration must be given to the managing the test vehicle control in order to facilitate the operation of the ELK system and subsequent adjustment of the vehicle heading without overriding the intervention.

Criteria

The maximum departure permitted in the running off the road to the near side solid and dashed marking sub-scenarios is 0.3m beyond the inner edge of the marking defining the lane. For the road edge sub-scenario the maximum permitted departure off the paved surface is 0.1m. These figures were based on the typical width and position of the road edge markings and common tyre widths of modern vehicles, the intention being to maintain at least half of the width of the tyre on the paved surface in order to be able to exercise control over the vehicle path.

The pass requirement for the side collisions with overtaking vehicles and head-on collisions with oncoming vehicles is for the ELK system to intervene and avoid the collision. In case of imminent collision between the test vehicle and target indicating that the ELK system would fail to prevent a collision occurring, it is permitted to end the test at the last moment and take avoiding action to avoid a high speed collision with the vehicle target to maintain a safe working environment. In the side collision with an overtaking vehicle scenario, it is proposed that evasive action may be taken to avoid imminent collision with the test target if the test vehicle fails the test as a result of straying more than a specified distance beyond the lane boundary. At the time of writing this figure has yet to be finalised. In the head-on collision with an oncoming vehicle scenario it is permitted to take evasive action if the test vehicle is on a collision course with the car target at a time to collision of 0.8s. Development testing has demonstrated that this leaves adequate time to take avoiding action in both cases.

The results of initial testing indicate that it is possible to differentiate between system performance, chiefly on the grounds of departure distance from the lane and collisions with the target vehicle in the higher lateral velocity tests.

LIMITATIONS

The ELK test method and scenarios have been designed to replicate the real world lane departure collision population in order to encourage systems that address the most common types. However in order to achieve a repeatable and reproducible test method some aspects of the typical real world crashes have had to be adapted for the test track.

One example of this is all of the test scenarios are completed on straight road markings, whereas the real world data suggested approximately half of all collisions occur on gentle bends. This compromised is tolerated based on straight road markings being available on many test tracks whereas as curves to a particular specification would likely require installing. The lateral velocities achieved on gentle curves can be readily replicated by steering between straight lane markings.

Another is the steering behaviour of a distracted driver compared to the input used in the test scenarios. Drivers whose focus is elsewhere than on the road tend to hold a fixed steering wheel angle for the duration of their distraction, generally resulting in the vehicle tracking around a constant radius curve for a period of time. Throughout this period the lateral velocity continues to build, compared the initial direction of travel. However in order to test ELK systems in a discernable fashion a method of evaluating at discrete lateral velocities was desirable. With a constant radius curve test method, the severity of the test is ever increasing and governed by the timing of the ELK intervention, namely earlier intervention limits the extent to which the lateral velocity can develop, leading to potentially inconsistent testing. When using robotic control to initiate the manoeuvre there is the need to relinquish control at some in order for the ELK system to intervene. Therefore, for testing purposes, an three step test manoeuvre comprising of an initial straight line approach followed by a constant radius curve to establish the lane departure angle and therefore the lateral velocity, followed by another straight line path to depart the lane was used to establish consistent departure velocities. The robotic control systems can then be set to open loop once the final straight line path is established ahead of ELK intervention.

The real world fixed steering wheel angle issue also affects the head-on collision with oncoming vehicle scenario. The larger lateral distance between the initial vehicle paths and the impact position results in greater lateral velocities building as the departing vehicle travels across the central lane marking and into the path of the oncoming vehicle. The lateral position of the path of the oncoming vehicle is also orientated nearer to the central lane marking to modulate the time to collision between crossing the central lane marking and the collision occurring similar to that in real world collisions.

CONCLUSIONS

LDW and LKA systems are becoming more prevalent on modern vehicles, however their current simple implementation leads to frequent activation and intervention. Drivers report this indiscriminate intervention as annoying and perceive it to be unnecessary, which leads to system deactivation and the loss of any potential safety benefit in critical situations.

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