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Contributed articles

Road Safety Policy & Practice

Automated vehicles supporting “Towards Zero” Initiative

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Key Findings

1. First public demonstration globally by Bosch of an SAE Level 3 automated vehicle.
2. Automation, driver monitoring, HMI, and connectivity concepts presented.
3. Highly automated vehicle prepared in Australia using local and global resources.
4. Bosch Australia are preparing for a future when HAD vehicles are mainstream.
5. Bosch Australia supporting community discussions for a “zero accident” future.

Abstract

Many of us talk about a future where there are zero accidents and all vehicles are automated or driverless. It sounds attractive but how easy is it to automate a vehicle that is suitable for all driving conditions? What are the considerations we must engineer into such a vehicle? This paper explores some of the technology and highlights many of the challenges that are being confronted by Bosch in the drive to achieve a zero accident future.

Keywords

Automated Driving; Bosch; ITS World Congress

Glossary

HAD – Highly Automated Driving
ITS – Intelligent Transport Systems
SAE – Society of Automotive Engineers
TAC – Traffic Accident Commission
ABS – Antilock Braking System
TCS – Traction Control System
ESC – Electronic Stability Control

EPS – Electric Power Steering
MRR – Mid-Range Radar
SVC – Stereo Video Camera
DMC – Driver Monitoring Camera
NRC – Near Range Camera
MPC – Multi-Purpose Camera
USS – Ultrasonic Sensor
Lidars – Light Imaging Detection and Ranging Sensor
HMI – Human Machine Interface

Introduction

Assuming that most road fatalities and injuries are the result of a failure by a driver to concentrate adequately on the task of driving their vehicles under the given conditions in which they happen to be at the time of the “incident”, the following question must be: Can automation of a vehicle lower or remove the risk of any “incident” occurring? If the implemented automation completes its tasks to an adequate level then logically the answer must be “yes”.

By an adequate level we mean that the vehicle must complete the tasks to the same level as a human driver when they are concentrating correctly and actively avoiding any incident from occurring. These tasks that are being referred to include all of the seemingly mundane tasks that are undertaken by vehicle drivers whenever the vehicle is in motion. This could be during a short drive to work, or to the shops, or to school, or wherever else the driver may travel, every day of every week of the year. Backing out of the driveway, looking left and right while indicating and operating the accelerator, brake and maybe the clutch if a manual gearbox is in use. Noticing that the vehicle up ahead is adjusting its own lane position and thoughit hasn’t yet indicated, is likely to turn right at any moment. Recognising that your neighbouringvehicle has a driver distractedby the behaviour of children in the back seat, and that the car behind you is clearly in a hurry and wants to overtake you, demonstrated by the way they have come up behind you so quickly and are sitting now only scant meters behind your vehicle as you try to keep to the variable speed limit.

As human drivers we are constantly adapting to an environment around us that is continuously changing and requiring a high level of observation and decision making while operating a significant piece of heavy machinery – your vehicle. Trying to automate these tasks, which we as humans are able to complete without incident most of the time, is not to be underestimated. Good automation of vehicles requires that we not only deal with the problems with which we as humans fail from time to time, but also with all of those other tasks that we do successfully complete (albeit with varying degrees of skill) on all other occasions.

Robert Bosch (Australia) Pty. Ltd. has been researching and developing solutions to the not insignificant challenge of zero accidents for many years now. It is not a challenge that can be completed in one fell swoop, but it requires many steps along a long path that also slowly allows human drivers to adapt to the changing levels of automation in their vehicles. Simple features such as automatic windscreen wipers, automatic transmissions and self-locking doors are early levels of automation in a vehicle that takes some of the increasing load of decision making off the driver, allowing the driver to concentrate on the important tasks of steering and speed control. At another level the complexity of contemporary vehicles has been increasing as the automotive industry strives to increase safety and implement other desired functionality into vehicles for public use.

But is the world ready for this level of technology? Are the legislative rules and regulations in place for vehicles being driven without hands on the steering wheels?

In October 2016 global automotive supplier Bosch presented an SAE level 3 Highly Automated Driving vehicle at the ITS World Congress in Melbourne. A right hand drive vehicle was prepared in Australia by a local team of Bosch engineers leveraging the skills and knowledge available globally in the Bosch organisation(see Figure 1), and supported by financial contributions from the Victorian Government through the TAC. For Bosch globally this was the first time that we had publicly demonstrated a vehicle of this level and complexity, presenting not only a vehicle that could supervise its own automation system, but also demonstrating concepts for driver monitoring and a human machine interface. This was an opportunity for members of both the industries involved in this sophisticated technology and the general public to experience how the technology may present itself to them in a vehicle, and to formulate informed opinions that will support the debates required for establishing legislative rules and regulations. It was also an opportunity for Bosch to gauge the reactions of the passengers to the implemented concepts.

Figure 1. Bosch Highly Automated Vehicle and Team

What does it take to automate a vehicle?

At a basic level, turning a modern vehicle into an automated vehicle is not so difficult. An electric power steering system allows for directional control, an interface to the drivetrain system allows for speed control, and ESC in the vehicle gives you the ability to generate braking pressure. The complexity really begins when one starts to specify the ”use” cases: i.e. Where would you like the vehicle to go? How fast would you like the vehicle to travel along that route? What precision of steering control would you like? For what types of obstacles do you want the vehicle to actively decelerate or avoid? What is the environment like in which you would like the vehicle to travel? Additionally each of the above systems needs to be integrated with each other so that priorities can be set. Under what circumstances does steering take priority over braking, or should they both occur simultaneously under some or all conditions? What level of redundancy do we need so as to be robust in all conditions should some part of one of the systems fail? The challenges are many and varied but in order to better understand the problems that need to be solved let's first begin with the environment.

Environment

In order for a vehicle to deal with all of the challenges that we can imagine for an automated vehicle we need to first understand what is happening around the vehicle. Is there anything close to the vehicle? Are there objects moving towards or away from the vehicle, longitudinally or laterally? What objects do we need to be concerned about? Is anything smaller than a tricycle okay to ignore? Should we consider the density of the object? Does the object have a shape that we can identify and classify? Are we on a known road and if so, does that road have clear line markings so that we know where the car should be placed on the road? Do the local road rules require the car to drive on the left or the right hand side of the road? How can we robustly detect all of the above conditions, and others besides, before we even begin automation of the vehicle?

Bosch's approach to this has been to develop sensing solutions for as many of the use cases as we can imagine(see Figure 2), which were implemented on the ITS World Congress 2016 Bosch demonstration vehicle.

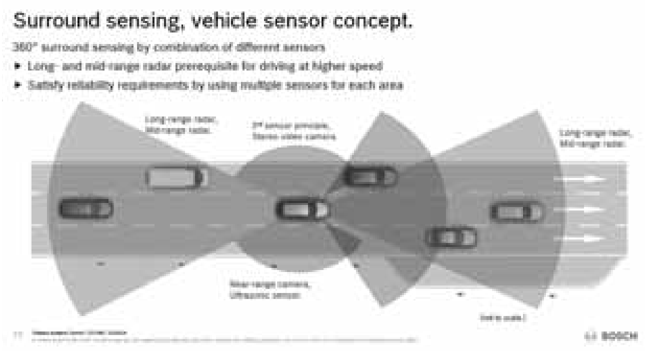

Figure 2. Bosch sensing solutions

Long range radars are facing forward and backward to allow the vehicle to sense as far ahead and behind as possible; up to 250 metres. Given that in some countries the speed limit is substantially higher than in Australia this gives a relatively early opportunity for detection of situational concerns.

A family of mid-range radars (MRR) are placed strategically around the vehicle. Typically this means one facing forward (MRR Front), one facing rearwards (MRR Rear), and one at each corner of the vehicle (MRR Corner). The features of these radars vary with regard to sensing distance and field of view, ranging from 30-150 metres and 12-150 degrees respectively.

Ultrasonic sensors (USS) are important for when the vehicle is manoeuvring at slow speeds. The latest generation is now able to measure out to six metres from the vehicle.

Light Imaging Detection And Ranging Sensors (or lidars as they are commonly known), nominated as the third sensing principle in Figure 2, are able to scan an object at a much higher density than a radar, giving a far more detailed view of an object than a radar would. These are also placed around the vehicle in a similar fashion to radars.

A range of vision systems are also used in the form of stereo video cameras (SVC), multi-purpose cameras (MPC), and near range cameras (NRC). In the same way that the radars vary in performance so do the cameras. The one big advantage of cameras is that they can see variation in colour. A good example is being able to see line markings on a road (something none of the other sensors can do). They are also able to recognise road signs including speeds (60km/h or 80km/h) and commands such as "STOP".

One might ask why we need lidars, radars and cameras to sense the environment around the vehicle. The answer is simple – definition, disparity and redundancy. We need to create a comprehensive and unambiguous 360° environment model. While each of the "sensors" might be able to detect the same objects, they note different features about the objects. Fusing this information together can create a far better understanding of what the detected object might be, but they can also be used to correlate with each other the existence of an object. For example, a lidar might detect dust as an object whereas the radar might well not detect it at all. The camera may be covered with dust and so therefore be of no use at that time. Now comes the tricky bit. What should the vehicle then do?

Driver Monitoring

Even though the vehicle may be automated the driver still needs to be considered. They are the one who will most likely define the destination and potentially the desired route, and in a level 3 vehicle as demonstrated at the ITS World Congress 2016, will need to be in control in non-automated driving situations. Additionally the driver can also be unpredictable. Will they be able to take over the driving task if needed? Are there times when the driver should not take over control? Is the driver impaired in some way or perhaps unwell?

Bosch has been developing driver monitoring and support functions for well over a decade now. In many vehicles we are now able to reliably detect if the driver is drowsy, but in an SAE Automated Level 3 or 4 vehicle we have to take this to a higher level, as in these vehicles the need will arise where the driver must be able to take control. We therefore want to detect the identity of the driver so as to be sure they are a registered driver of the vehicle. Are they awake or distracted? Are they impaired in some way such that they cannot, or should not, take control of the vehicle?

The demonstrated solution utilises a small specialised camera mounted behind the steering wheel with software that is able to detect both micro-sleeps and when the driver looks away from the road ahead for any more than a defined period during non-automated driving situations. In these cases audible warnings are presented in the vehicle designedto bring the driver back to the driving task should they need to be in control.

Decision Making

Consider the constant decision making that you do as a driver of a vehicle every second of your journey. Some decisions happen almost sub-consciously (think about the constant steering adjustments you make to maintain your vehicle position within a lane on the road), whilst other decisions require clear planning and execution (for example deciding which route to take to a certain destination and navigating your way there). The challenge for an automated vehicle is to execute the plan that you have given to the vehicle in a way that is safe, smooth, efficient, and appears to be entirely logical to you as the driver.

The developers of these systems need to cater for all driving scenarios and situations. Given that there are always driving scenarios that are somehow neglected, they need to also ensure that the vehicle can learn from its own experiences in the same way as humans do. What this means is that we are entering the realm of artificial intelligence to help us deal with all the potential situations and scenarios that exist in every day driving. Can the vehicle learn about regular driving routes and scenarios? Can it learn the driver's preferences and driveaccordingly? Can the vehicle adapt to unforeseen behaviour by other users of the roads in a manner that the driver might expect?

Bosch has been working together with selected universities and institutes in the field of robotics, artificial intelligence and deep machine learning for a number of years now. The advances in these fields of technology are racing forward at an exciting rate and show great promise for dealing with the tasks that may appear to us as drivers of vehicles as somewhat mundane and simple but are in fact relatively complex.

Verification and Validation

The number of "use" cases for automated vehicles to negotiate are enormous. To give you some idication of the challenges facing developers, Bosch have a catalogue of tests for ABS, TCS and ESC that run sometimes into the thousands, depending on vehicle variants and complexities. Just combining another system to these aforementioned ones, such as Electric Power Steering (EPS), multiplies the combination of tests at least ten-fold. What this demonstrates is that each time another system is added the complexity of testing is multiplied. Because we combine multiple systems for highly automated driving the number of test cases could be in the millions. Testing against all of these use cases, even in simulation, requires significant time and effort and is simply not possible without considering new and novel approaches to how an automated car can be proven to be adequately tested prior to release for the public to drive. As shown in Figure 3 below, the estimated expenditure in effort for validation will increase by a factor of 10^6 to 10^7.

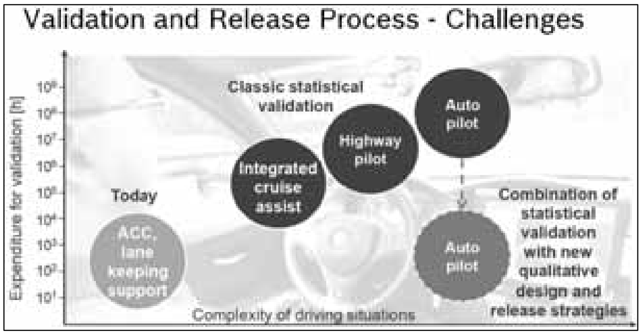

Figure 3. Verification and validation effort

One way for Bosch to deal with this challenge is to make each component in each development vehicle connected to the Bosch Cloud. By implementing this form of connectivity a big data approach can be utilised. Every moment that the vehicle is moving can be logged and used to statistically define both the durability concerns for the hardware in the vehicle, and scenarios with which the vehicle needs to deal with often, or seldom, and should be required to prioritise.

Human Machine Interface (HMI)

The HMI in a car is one of the most difficult features to engineer into a vehicle. No two people will ever agree on exactly how a particular solution should be engineered for use by the public. The HMI for an automated vehicle is very important. It must be intuitive and simple to use. It must give information to the driver in a way that is logical and unambiguous.

What we demonstrated at the ITS World Congress 2016 was just one concept developed by Bosch engineers and researchers. Two main interfaces were implemented: 1. A central screen that provides visual and audible information and cues and; 2. A steering wheel with HAD activation buttons and visual cues as shown in Figure 4.

Figure 4. Human Machine Interface concepts

Bosch is not suggesting that this is the way that all companies should implement their HMI solutions, but it is one approach that we think is possible for Level 3 & 4 vehicles. Clear instructions are given on the central display with requests for takeover of control well before the end of the section of road designated for automated driving. Lights on the steering wheel change colour depending on the state of the automation. In this case we used blue for manual control, white for automated control, and red for when the driver is requested to take control back from the automation.

Legal Issues

Through a process of consultation, discussion and risk management, limited permission was given by VicRoads for Bosch to drive our automated vehicle on public roads. Many of the discussions centred on understanding what risks may exist with the Level 3 HAD solution proposed by Bosch and how those risks were to be mitigated. Some of the requirements Bosch put in place included allowing only specifically trained drivers behind the steering wheel when vehicle automation was to be used, and then only for a limited period at any one time up to a defined total number of hours in any one day. Bosch needed to provide evidence of sufficient liability insurance in the case of an accident, and agree to provide recorded vehicle data in the case of an accident.

Discussion

While prototype vehicles can be catered for through specific permissions and requirements being put in place, all of this work did raise questions with regard to production vehicles and how the various states and territories in Australia might deal with the legal issues of allowing automated vehicles on the roads. Currently each of the Australian states and territories have either no requirements to date other than the existing regime of legislation dealing with the vehicles that are sold in Australia, or they have their own defined solutions. Fortunately at this time the requirements seem not to be too onerous for developers of solutions like Bosch. There is however a need to harmonise the guidelines and regulations before Australia is confronted with production vehicles capable of SAE level 3, 4 and 5 automation. The National Transport Commission (NTC) are currently developing national guidelines which we expect will support commonality in acceptance of automated vehicles into each of the states and territories.

Based upon the many discussions with members of the public to date, there are sections of the community who feelvery sceptical about HAD vehicles and how safe they might be. Equally we’ve met many individualswho are very enthusiastic about a future with HAD vehicles and how they believe their lives will change as a consequence. In either case, what has become clear to us is that public education with regard to how to behave around HAD vehicles is likely to be necessary. What should a driver of a non-HAD vehicle expect from HAD vehicles? What knowledge should a driver of a HAD vehicle have before they start activating the HAD system within their new HAD vehicle? And perhaps most importantly for the public, who takes responsibility in the event of an incident involving a HAD vehicle driving in HAD mode?

Fortunately the engineering solutions to the challenges of bringing an SAE level 3 or 4 vehicle into production are still being worked on and we have a little time to figure out answers to the questions above. Bosch is committed not only to the engineering solutions surrounding HAD implementation in vehicles, but also to helping the government agencies involved in the legal questions and difficulties, and to supporting public education in understanding the details of HAD vehicles and how they will affect our lives into the future.

Conclusions

SAE level 3 and 4 vehicles will soon be available in the vehicle showrooms. It may only be a few years before the first vehicles become available to the public where hands-off, unsupervised driving is possible on selected roads around the world including in Australia and New Zealand. The question that remains is not how willing we are to embrace the technology, but how willing we are to embrace the challenges that this technology will bring to our society.

Bosch are working on the technological solutions, and are demonstrating the such concepts outside of the automotive industry so as to develop the engineering skills locally in Australia in preparation for a future when HAD vehicles are mainstream. Bosch is also encouraging discussion and debate within the wider community to aid both community acceptance and readiness for this technology, and to receive feedback so that we can support development of the best solutions possible as we work towards a “zero accident” future.

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