Human Computer Interaction (HMI) in autonomous vehicles for alerting driver during overtaking and lane changing.

CS5760: Topic Assignment 2
Topic Paper

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Abstract:

Autonomous vehicles are about to reach a different level in their proposed systems. These levels vary with the part of technology that is been used in vehicle to keep the driver away from driving physically. Since this field is huge and under development, this paper will be focusing on role of human-machine interface in some of the safety alert systems used while over taking, lane changing and on sharp turns. Over taking and lane changing is the critical part in vehicle automation. The role of driver in this scenario, changes as the level of automation changes, from taking full control over vehicle to supervision. Though automation in automobiles has increased security and decreased environmental issues, it causes driver to be less active generating passive fatigue. This passive fatigue can lead to failure in responding quickly if needed. This led automation to keep driver active even though he/she is not required to take up full control all the time.

Introduction:

The National Highway Traffic Safety Administration (NHTSA) has defined automated vehicles as the vehicles in which some of the controlling functions are carried out without direct input of human driver.

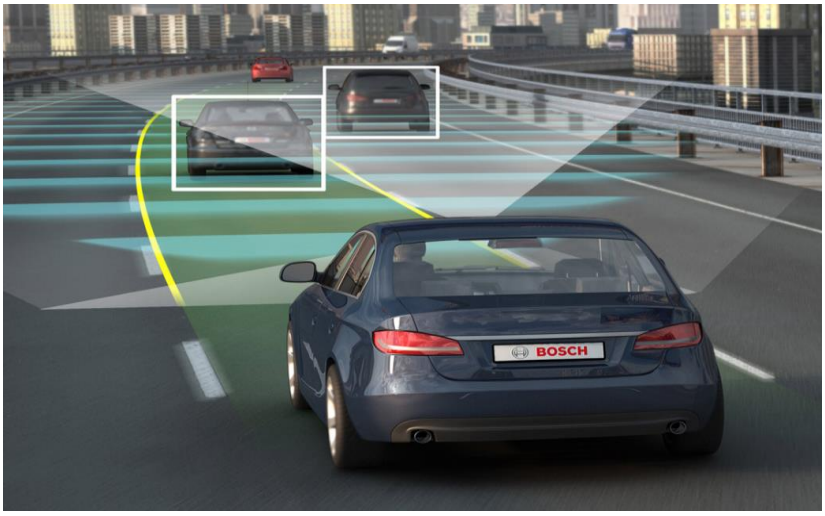

Fig.1: Imaginary vision of an autonomous car

Autonomous vehicles are cable of sensing environment using various techniques viz. IR and Ultrasonic rays, image processing, global positioning system, RADAR etc. The controller is designed to gather data from all inputs and analyze it thoroughly to find the perfect path for vehicle along with obstacles. Controller should be capable of locating other cars on road travelling in same directions as well as in opposite directions with their respective speeds in order to avoid mishaps.

Depending on the automation used, there are different levels of automation.

Level 0: Driver has complete vehicle control and systems may issue warnings.

Level 1: Driver should be capable of taking control at any time during the journey.

Level 2: Driver is responsible to detect obstacles which are not detected by system and take action to avoid mishaps. Control of the vehicle is given to driver as soon as s/he takes or initiates any action.

Level 3: Drivers can take their attention off and focus on other tasks only in limited environments.

Level 4: Driver should take control of vehicle only in severe environmental conditions otherwise vehicle should be driven by the system.

Level 5: Driver has only one task of selection destination.

Though Level 5 prototype is developed, only Level 1 automation is used widely in almost all types of vehicles. It features, Cruise control, Parking assistance and lane keeping assistance. In the Level 1 automation, user has only two interactions with the system one of them is to set the system on and other being taking control back from the system. Suggestions can be provided to user about present scenario to help user take control back.

Tesla and google have developed a Level 3 models. Tesla's model was upgraded recently to fully controlled version in all scenarios. Since, Level 1 and 2 automations are widely used and Level 3 yet to come in picture, this paper will try improvising the techniques being used currently with some new ideas.

Background:

Usability in cars is supposed to test the system for comfortable and ease of use. Resistance by individuals to give away control to system can be a possible issue in future for autonomous cars. This needs to be solved by increasing reliability in system. Artificial intelligence does not deliver its best results in chaotic conditions. This might introduce a delay in taking decision, leading to an accident. Sensors provided to the vehicle are not able to give perfect data sometimes, which may cause failure in detection. This can be avoided by keeping user in communication loop and running self-tests if problem occurs.

Driver needs to pay attention all the time in Level 1 and Level 2 automation which in widely in use. This can be decreased by giving updates to driver. Currently, in Level 1 automation, display

is changed to rear view only when vehicle is in reverse gear. Similar technique can be added in the form front view in certain scenarios discussed later.

Lane changing assistance is dependent on markings on road. Sometimes these markings fade away. Because of solar reflection sometimes processor cannot detect correct markings. This may lead to mishaps. To avoid this an alerting system should be improved making sure that user gives full attention to the vehicle during such scenarios.

The basic issue in increasing automation is letting driver know the capabilities and limitations of the automated system to have an awareness of any situation where it might need to interrupt the automated operation.

As human computer interaction is point to point communication between system and driver it becomes necessary to design extremely active, user friendly and attracting interface. In autonomous vehicles, drivers tend to get busy in other tasks due to system controls but HMI needs to develop situational awareness in drivers.

Proposed alerting systems in described scenarios:

1) While overtaking
   Overtaking is an important part of driving especially when it comes to autonomous driving. Decision making algorithms are implemented in overtaking. It requires identification of obstacles, vehicles and lane tracking. Most crucial part in taking decision of overtaking, determining and finalizing path for it is mainly dependent on relative velocities of other vehicles and obstacle. Within a moment whole scenario can change if other cars are not automated with similar system or introduce some error in decision. It may cause fatal mishaps. As far as Level 1 and Level 2 of automation are considered, it needs driver to be attentive all the time. This level of attention can be reduced to certain point by adding up some combinations of regular HMI techniques in it.

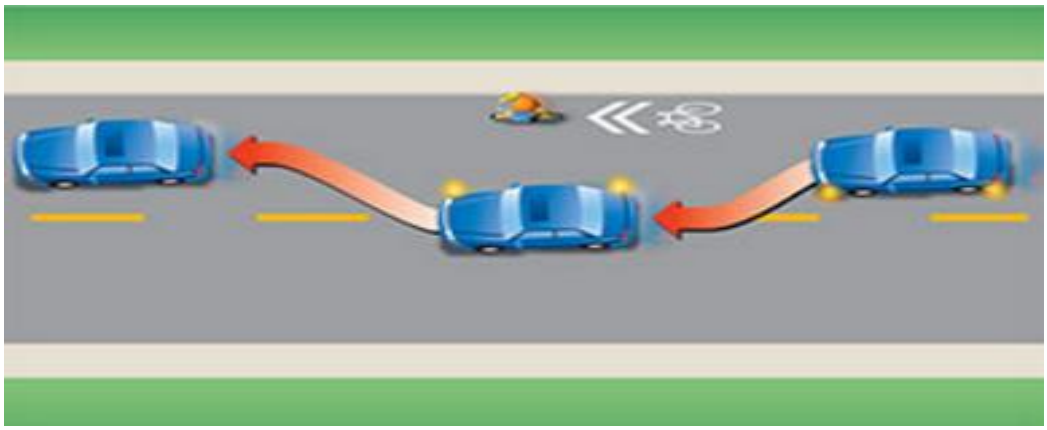

Fig.2: Overtaking the other vehicle

Fig.2 shows overtaking picturization where calculating relative velocity is necessary along with changing lane in order to avoid collision.
While overtaking after changing current lane, the part which can be seen as crucial is calculating relative velocity of the vehicle that is being taken over and increasing velocity of vehicle that is taking over previous vehicle. Driver is required to pay attention at all the times during this scenario.
To keep the driver in the loop all the calculations being made at the backend can be communicated to driver with help of HMI.

Using Graphical Display: We can have a dashboard GPS display to shift to “new” mode while initiating overtaking or lane change. This display will continuously show the live streaming of road map along with detected obstacles as well as other cars. The controller can also input lane status to the display. This can include current lane and available lanes on both the sides of vehicle with highlighted nearest cars in front of the vehicle and behind the vehicle along with their distance from vehicle.
We can have box which can show the operating radius of the vehicle which is the space occupied by the vehicle if turned in all directions. This will give driver an idea of the distance required is all the direction while taking over another vehicle. If the system is not judging the path correctly and getting closer to any of the vehicle that vehicle can be highlighted with a flashing color on display which can win attention of driver.

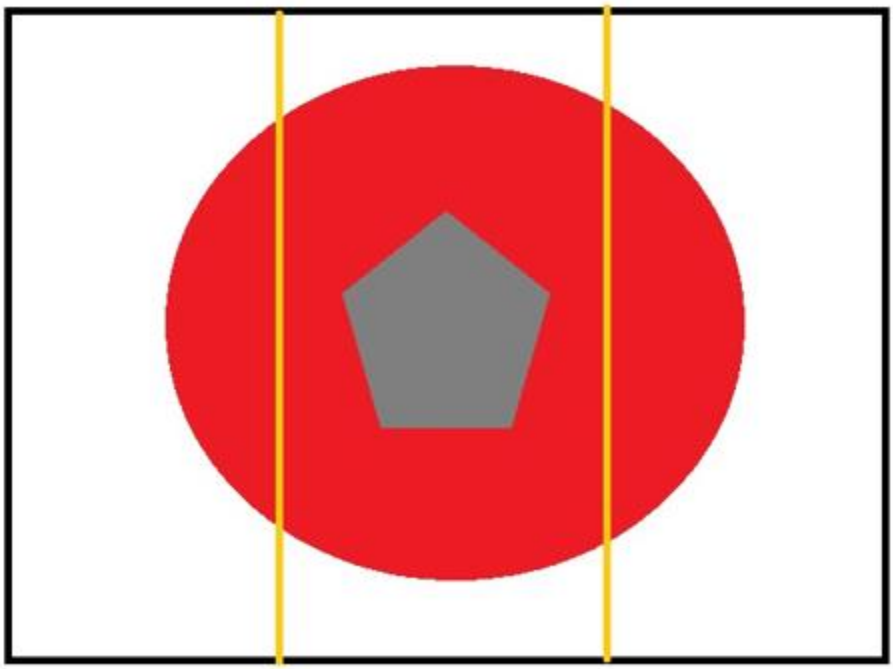

Fig.3: Operating radius of vehicle

Fig.3 shows the operating radius of the vehicle which can be added to graphical display. Grey pentagon is vehicle whereas yellow lines are lane separators. Operating radius is

nothing but the space occupied by vehicle if it is turned in any direction. This space is shown by red color in the diagram.

Voice message: In addition to display, for complete safety we can add a voice message declaring an alert or an alarm for taking charge of the vehicle. We can set a dynamic or adaptive threshold distance from nearest vehicle, which, if crossed, triggers an alarm to driver for taking total control.

Vehicle will be shifting from automated mode to normal mode as soon as driver takes the control which in-turn will give an accelerator and brake in diver's command as well.

The first accident occurred to Tesla's robotic car was due to failing to apply brakes along with loss of detection by cameras due to sunlight. Sunlight can cause failures in image processing greatly.

This again can be avoided by adding up an HMI technique to alert the driver. While sending out a voice message through infotainment systems the pitch and volume level should be mainlined such that driver will give full attention to it. Current tasks on infotainment system must be paused while sending out a message in order to avoid a conflict in message and music.

Scenarios described above can be considered as practical cases where driver needs to take the control. But, assigning control to driver should not be complicated task. Usability plays important role while changing the controller of vehicle. If only one way is kept to take the control of car for driver such as moving steering or pressing brake pedal, it will not incorporate 100% usable system.

This is because in stressful conditions one human cannot respond in same way as that of other. If someone reaches for steering wheel, then other can reach out for brake. Sometimes it is even possible to press accelerator pedal by mistake or hold the joystick. Therefore, as far as usability is concerned, not only single operation mentioned above but also any of the above operations mentioned above should be able to assign control to driver.

2) While changing lanes:

Change of lanes often occurs while taking diversion, changing speed, over taking another vehicle etc. Identification of lane is an important part in this. Lane separators can be used to detect the lane by image processing. Availability of the lane on both the sides is also a parameter that needs to be considered while changing lane. The first accident caused to robotic car was due to lit up sky, which could not detect some part of the obstacle. Same is the case in this situation. If reflections limit the ability of the system to detect the lanes, system should issue an alert message immediately to the driver in order to avoid an accident.

Along with availability of lane, detection of other obstacles in that lane is also required to change the lane. Sometimes it may incur crossing road and entering in wrong way. Keeping driver attentive can be achieved by keeping him/her informed. Lane change assist along with alert message would be an impressive idea in Level 2,3 of autonomous vehicles. This will ensure that user is aware of situation by sending feedback message.

While changing the lanes calculation of relative velocity is of comparatively less important than keeping the vehicle in new lane. This makes it necessary to have system that will share the scenarios with driver.

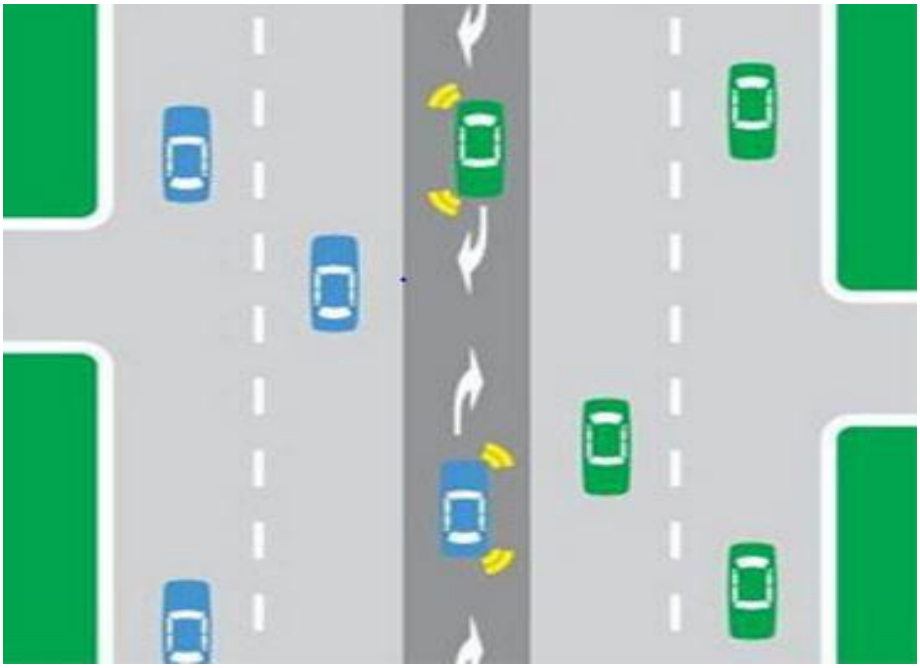

Fig.4: Lane changing scenario while taking diversion

Though graphical display of lanes and nearby vehicles is not required for this case, and only voice alerting message in sufficient, we can have system based on user priorities If user demands graphical display then graphical display along with distances on either side of the vehicle and front clearance as well as back clearance can be provided on display. This is on user demand.

In case of system failure, user needs to pay attention on track. Apart from this system can alert user with voice commands saying “lane not detected clearly” or “unclear obstacle in path” after by warning tune. This may result in gaining driver’s attention which can result in increase in reliability and comfort of user.

Fig.4 elaborates lane changing scenario while taking diversion. We must monitor vehicles coming from opposite side as we need to cross the road. This time proximity alert message can play an important role.

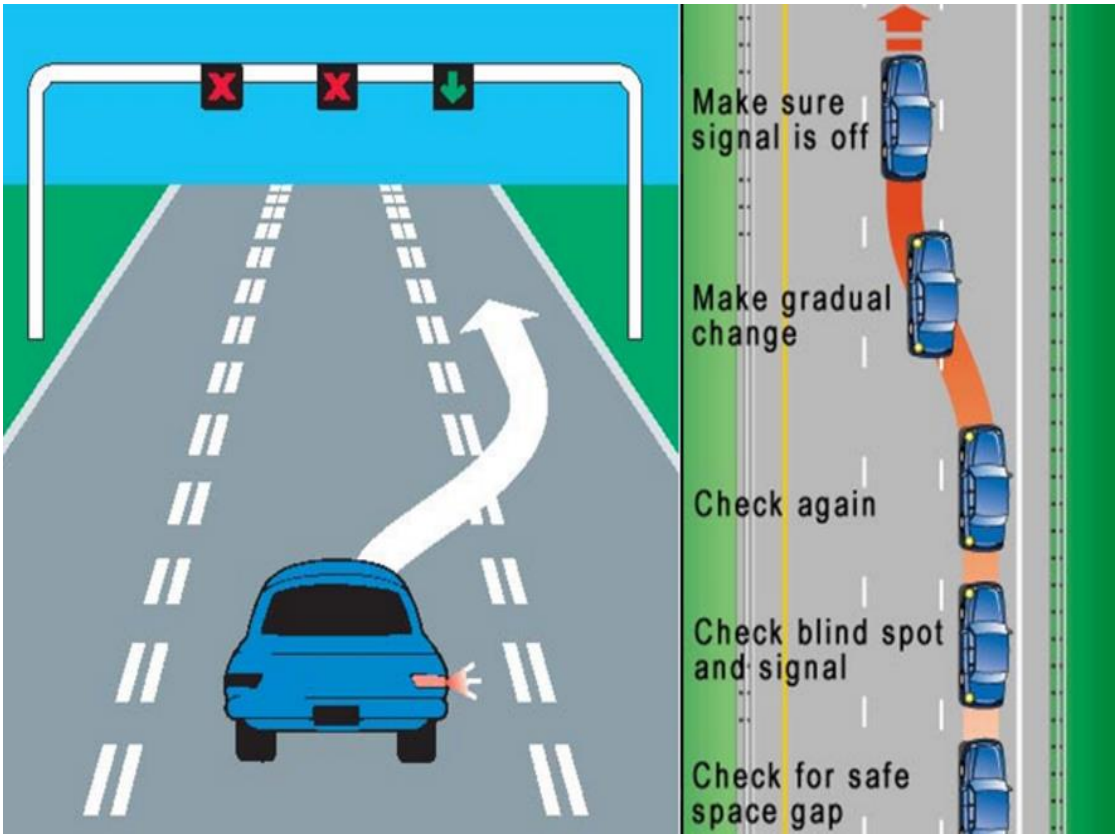

Fig.5: General lane changing scenario.

While handing control over to the driver similar methods can be used. Such as pressing accelerator pedal or brake pedal. Moving steering wheel or joystick. Here considering voice input to system is debatable option. Voice input can be treated as HMI but considering that there are many people talking with each other in car, sometimes, talking can be considered as a signal when it includes certain messaging words. Moreover, speech recognition algorithm needs to be trained for every new user. It can be a good option but it needs prevention from false detection. So, it need a switch that makes voice recognition on or off. And in critical cases like overtaking and lane assistance that switch can introduce a delay or inactivity if driver forgets to turn in on leading mishaps.

Another display element can be added while alerting lane change status. It can simply be flashing button on screen along with low volume siren, which will ask for attention. This element should be enough large, visible as far as sighting of driver is taken into account and bright in color that it will ask for the attention of driver when turned on.

Fig.5 shows general lane changing scene where only vehicles on same side need monitoring in order to proceed.

Heuristic evaluation:

It is carried out to identify the problems in human machine interface. Jacob Nielsen's principles are widely used in industry for checking HMI. Discussion below heads to highlighting need of HMI in autonomous cars and basic features needed to include in it.

- Visibility of the system: User should be aware of actions taken by the system. Present scenarios should be communicated with user. In Level 1 or 2 communication of alerting level should be increased with the help of improved display. So, user can be aware of actual space available for overtaking.
- User control and freedom: Driver is kept in the loop for present scenarios but when driver is required to act (feedback given by system or identified before feedback is given), he/she will be free to choose the way for taking charge of that vehicle.
- Aesthetic Design: Design should be enough good to make user feel better and comfortable. During the long journeys, it becomes hectic to keep an eye of display every time. So, along with display system should be integrated with voice commands which can get users attention easily in hard times.
- Recognition rather than recall: Minimize the user's memory load. Since voice commands are provided in the design, driver does not need to spend time on identifying the blinking objects on the screen. In tough situation, driver can rely on voice commands if got confused by graphical display parameters.
- Error prevention: Prevention is always better than cure. Here, this principle can be modified a bit before applying it. We are not preventing any error occurring in the system but, helping to avoid mishap by popping up alert message which can occur if the driver is not attentive of system failure (complete or partial) by keeping the driver aware during long, hectic and boring journeys by voice commands and smart graphical display.
- Help users recognize, diagnose and recover from errors: user should not find error message obscure. He/she should be able to take required action within specified time limit. So, we need to keep the message as simple as possible as given in the example. This can help in reducing delay in understanding message and taking required action.

Challenges:

1. HMI signals should not take much time. As these signals ask for taking control over the vehicle, they should be provided in time. They, neither should be too late nor should be too early (false alarm).
2. Multiple conflicts should be given priority dynamically. If there is a situation of overtaking, the vehicle is close to end of last lane as well as vehicle on the side which is taken over. Then priority must be given to an alert message of nearby vehicle's distance as far as it is on straight road. If same situation occurs on mountain road, then there might be a danger of vehicle falling from higher elevations which is more fatal than collision with other

vehicle as we have airbags for human safety. So, priority should be given to alert message of lane.

3. The voice command from the system should be loud and clear.
4. The voice command can be generated in multiple languages as user is not bound to understand one common language.

Conclusion:

Robotic cars are going to play important role in near future. They are capable of reducing poisonous emissions in environment. Autonomous cars have increased safety due less human errors. They can be seen as future in time saving aspect too. But, it can be seen from the discussion above that autonomous cars of Levels 1,2,3 still need driver to pay attention in certain situations. Sometimes only attention is not enough, driver might need to take the control over system. During such scenarios, it becomes necessary to literate the driver with ongoing actions and problems. This can be achieved by improved HMI techniques such as graphical display and voice commands which can keep the drive in the loop. A new element can be added to graphical display as operating radius of the vehicle. This parameter can show the space that can be occupied by vehicle if turned in any direction. This makes it possible to identify the objects in area of operation of vehicle. Handling control to driver should have multiple ways that can make it possible to take control in minimum time. Passive fatigue of driver should be eliminated by adding up voice commands after alerting tone. Autonomous vehicles being developed more day by day, it becomes urgent to establish the two-way communication between drive and system. It is important to keep driver as much alert as possible with different outputs from the HMI in harsh conditions.

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