NORTH AMERICAN LIGHTING

A KOITO Group Company

A Case for Integrating Sensors into Headlights

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INTRODUCTION

There are over 40 companies developing and testing autonomous vehicles with a vision for a safe and convenient future in mobility [1]. Each of these companies is taking a slightly different approach to safety, but all have in common the need to attach a suite of sensors to the vehicle for obstacle detection. These sensors need a suitable location on the vehicle to give a clear view of the environment.

Autonomous vehicle developers have experimented with several approaches to sensor placement. The roof of the vehicle is a common selection since it affords a 360° view around the vehicle. The bumpers and sides of the vehicle are also common locations.

There are conflicting factors to consider when choosing a suitable location for sensors. The location must provide a surround-view of the environment with no blind spots. It must be convenient and inexpensive to install supporting infrastructure such as power and data cables, and heat management systems. Most importantly, the location must provide early detection of obstacles for safety.

It should be noted that environmental sensing is a requirement for Advanced Driver Assistance Systems (ADAS) as well as autonomous vehicles. SAE International defines 6 levels of driving automation from fully manual driving (Level 0) to full automation (Level 5). These levels are described in Fig. 1. Starting with Level 3, the automated system must have the environmental detection capabilities to perform most driving tasks, so a full suite of sensors is required. Even for Level 2 features like Adaptive Cruise Control (ACC), forward-facing sensors to measure the distance to the preceding vehicle are needed. Therefore, sensors are required not only for Level 5 fully autonomous vehicles, but also for Level 2 vehicles with basic ADAS features.

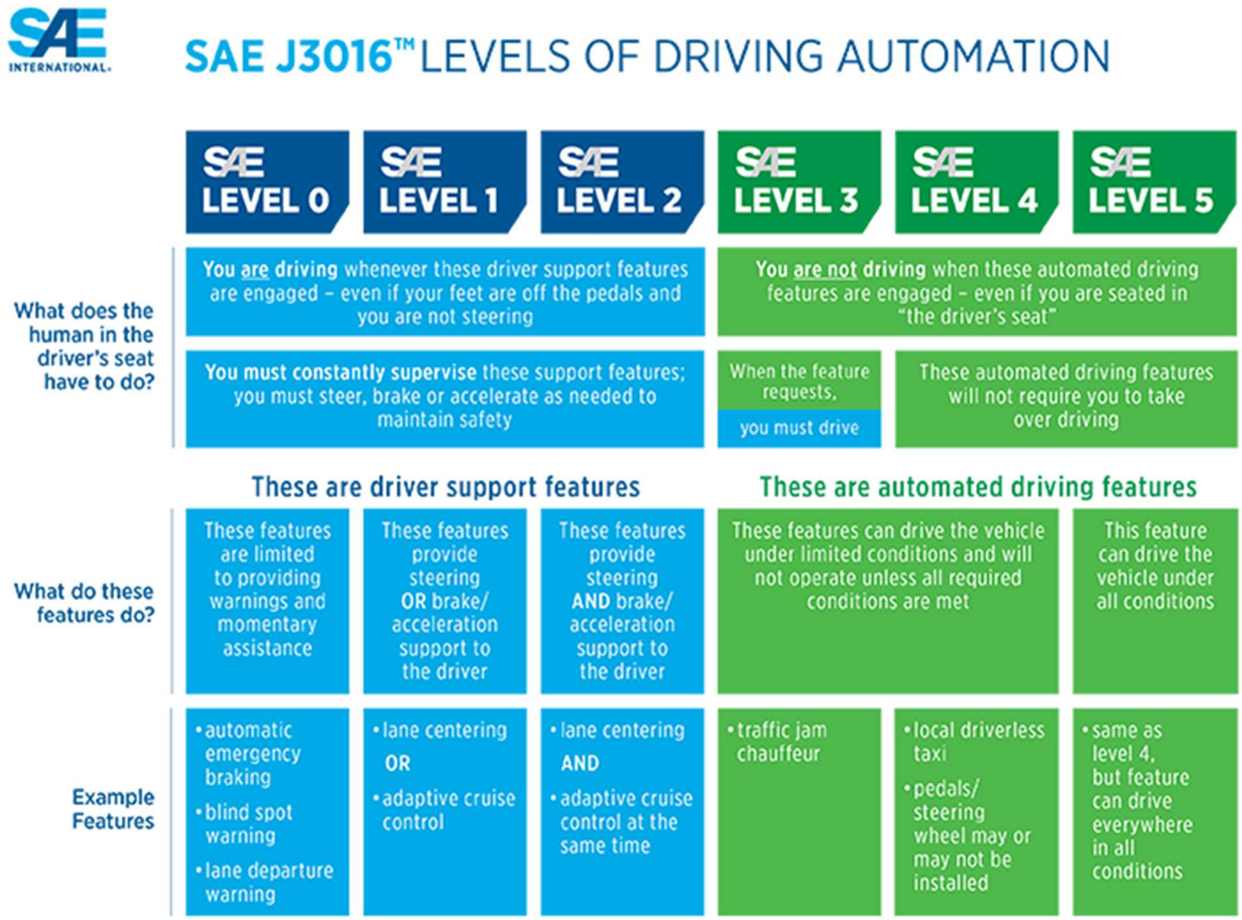


Fig. 1. SAE International Levels of Driving Automation

https://www.sae.org/news/press-room/2018/12/sae-international-releases-updated-visual-chart-for-its-%E2%80%9Clevels-of-driving-automation%E2%80%9D-standard-for-self-driving-vehicles

In this white paper, we propose the headlights as the most suitable location for sensor placement for ADAS and autonomous vehicle applications. The paper explains in detail how the headlights meet all the requirements for sensor placement and provide the earliest obstacle detection. It also presents simulation data showing the safety benefits of the headlight location and discusses the results. Finally, it explains why NAL, a headlight manufacturer, is well-positioned to design and manufacture sensor-integrated headlights.

PROBLEMS WITH SENSOR PLACEMENT

Autonomous vehicles need sensors, but sensor placement is awkward. Sensors have been placed in several locations on the vehicle including the roof, bumper, and sides, but each of these comes with drawbacks.

Some test vehicles are equipped with a sensor suite on the roof of the vehicle. For example, Waymo [Fig. 2] and Voyage [Fig. 3] are two prominent autonomous vehicle developers who have taken this approach. The roof of the vehicle is an attractive position for the sensor suite because it offers a 360° vantage around the vehicle. However, the bulky sensors are highly visible, and journalists have commented on their unsightly appearance [2] [3]. In addition, there remains a blind spot in the immediate vicinity of the vehicle that could be crucial in parking lots and other low-speed situations [Fig. 4].

Fig. 2. Waymo

https://www.wired.com/story/waymo-google-arizona-phoenix-driverless-self-driving-cars/

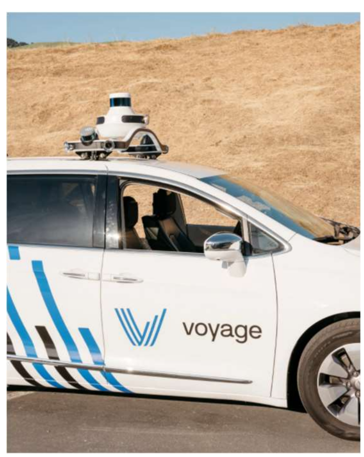


Fig. 3. Voyage

https://www.nytimes.com/2020/05/12/technology/self-driving-cars-coronavirus.html

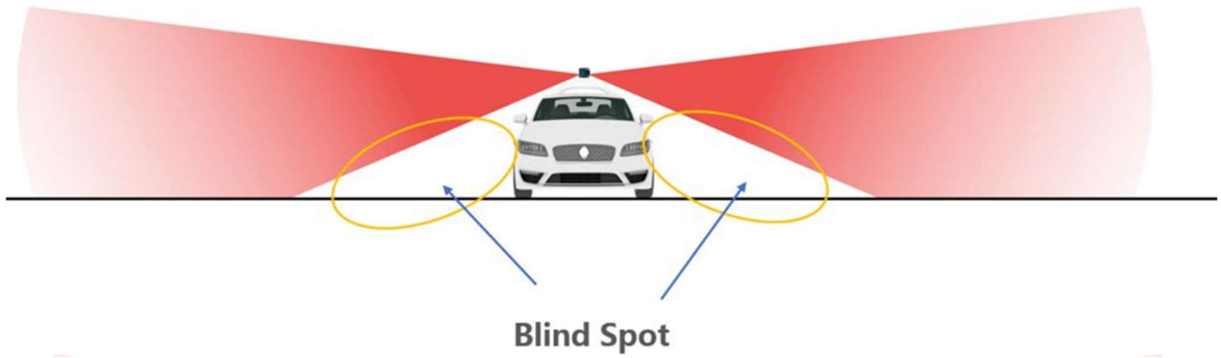


Fig. 4. Blind spot close to the vehicle

https://highways.today/2020/05/12/robosense-blind-spot-detection/

The bumper is another common location for sensors. Modern vehicles equipped with parking assist features often have ultrasonic sensors in the bumper [Fig 5]. This may be a suitable location for these inexpensive sensors, but when the high-cost sensors required for autonomous driving are installed into the bumper, this begins to defeat the purpose of the bumper - to protect the expensive parts of the car [4]. The need to run power and data cables to the bumper further increases the cost.

Fig. 5. Parking sensors in the bumper

https://www.cartoq.com/parking-sensors-reverse-cameras-or-both-which-is-safest-and-most-useful/

Some autonomous vehicle developers have tried positioning the sensors on the sides of the vehicle, either near or in place of the sideview mirrors [Fig. 6]. This location also requires expensive cabling to support the power and data requirements of the sensor. In addition, space is limited, making it difficult to install thermal management systems needed to keep the sensors cool during operation.

Fig 6. Side sensors

Photo by Sean O'Kane / The Verge

https://www.theverge.com/2017/1/8/14206084/google-waymo-self-driving-chrysler-pacifica-minivan-detroit-2017

THE SOLUTION – HEADLIGHT INTEGRATION

We propose a solution to sensor placement for autonomous vehicles – integration into the headlights. The headlights offer a wide field of visibility around the vehicle, electronic and heat management infrastructure, protection from the environment, and styling flexibility. Most importantly, there are safety benefits to installation into the headlights.

Let us close our eyes for a moment and imagine a car. And let's imagine ourselves walking around the car, viewing it from different angles. We'll notice that no matter which viewpoint we take, at least one lighting element, a headlight or a taillight, is always visible. This is because automotive lighting is designed to be visible from any angle around the vehicle, and by this virtue the lighting elements collectively have the vantage points for a 360° view around the car. They also have a view directly downward toward the ground, so that there are no blind spots.

Headlights already have the infrastructure needed to support headlights. Power cables to supply electricity and data transmission lines are in place, and more can be added alongside these as needed. Modern headlights are also equipped with thermal management systems that can also be used to cool the sensors. Furthermore, headlights have existing polycarbonate outer lenses which will serve to protect the sensors from impact and from the elements, and there are even existing headlight washer systems that can help keep the view clear for optical sensors like LiDARs and cameras.

Headlights are also a suitable place to hide the sensor suite to preserve style. Protruding sensors on the roof or on the side of the vehicle can draw unwanted attention and take away from a vehicle's brand image. By integrating the sensors into the headlight, the overall aesthetics of the vehicle design are maintained.

In these aspects, the headlights offer a solution to the issues that developers have in sensor placement on autonomous vehicles.

SAFETY VALIDATION

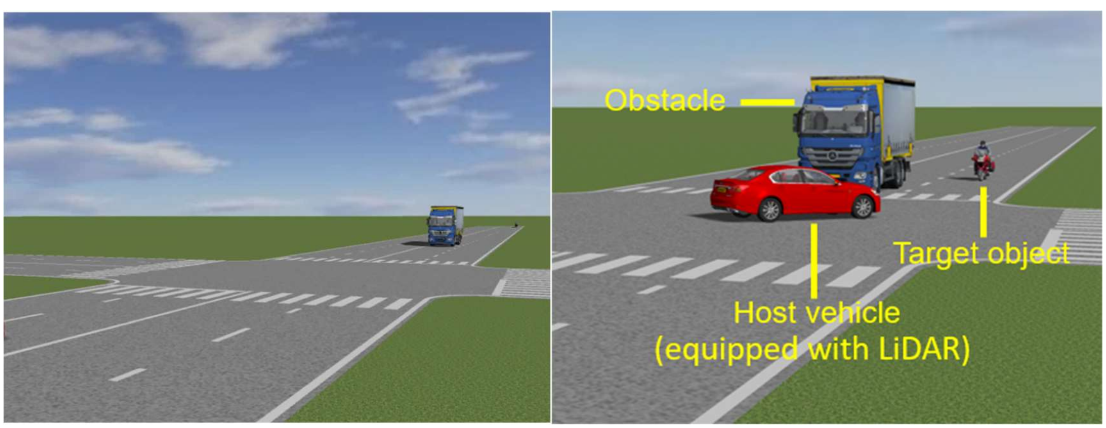
Safety is the most important criteria in evaluating sensor placement. In this section, we evaluate the safety benefits of placing the sensors in the headlights through 3D and 2D simulations. In order to have a positive contribution to safety, sensors must allow early detection of an obstacle, and detection of the obstacle for as much time as possible. The sensors must also be able to detect pedestrians of varying heights even when the view is partially obstructed. The simulations were designed to discover whether the headlight sensor position can meet these requirements.

The simulation presented here is based on research conducted by Koito's R&D Team, and presented at SIA Vision, 2018 under the title "Simulation of Detection Performance by LIDAR Location in Automated Vehicles" [5].

3D Simulation

We conducted a 3D simulation study on the effect of sensor location on detection time in various driving scenarios. We selected 16 driving scenarios in which an occluded obstacle is on a collision course with a host vehicle equipped with a sensor. This type of scenario was chosen for its high degree of danger and requirement for early detection of the obstacle.

Fig. 7 shows an example of one of the simulation scenarios. In the scenario, the host vehicle is turning to the right in front of a large truck, which obscures the view of an oncoming motorcycle. Fig. 7(a) shows the starting situation, and Fig. 7(b) shows the moment collision is imminent.



(a) Starting situation (b) Collision imminent

Fig. 7. Example of a simulation scenario.

Fig. 8 shows all 16 simulation scenarios. The host vehicle is shown in red, and the target obstacle to be detected is circled in red.

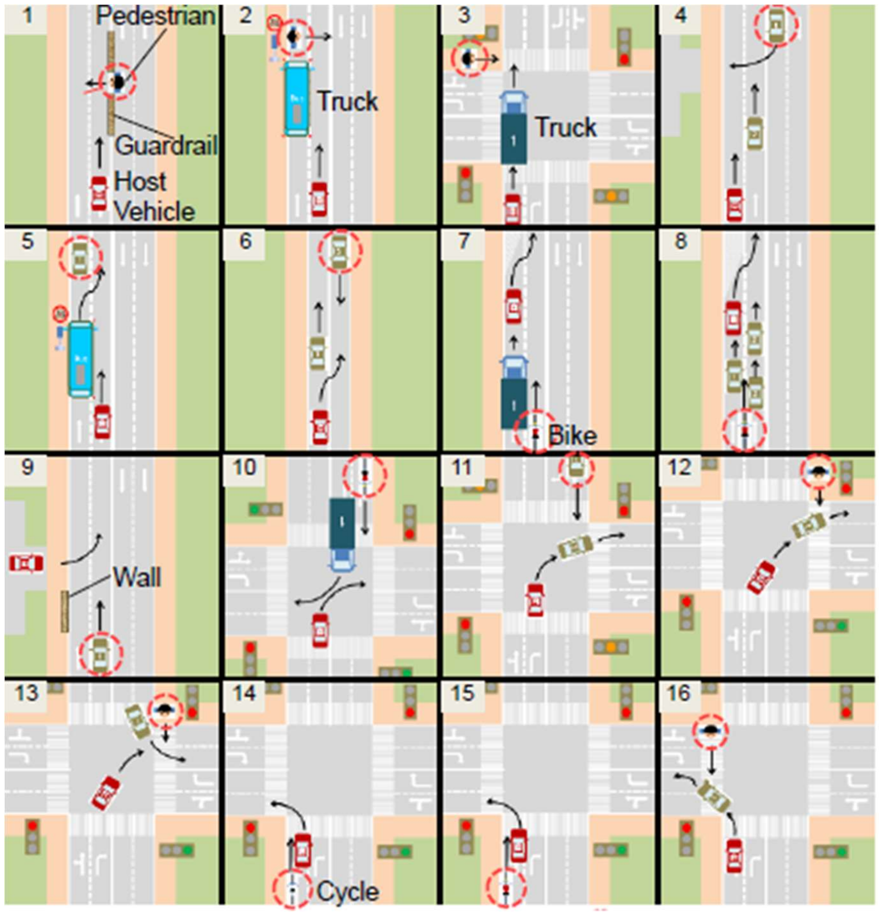


Fig. 8. Driving simulation scenarios

LiDAR Simulation

A rotating LiDAR was simulated to represent our sensor. The specifications of the LiDAR were chosen based on typical LiDAR sensors available on the market today. The LiDAR had 16 vertical channels with an extra horizontal channel in the middle, as shown in Fig. 9. The angular resolution was 1.33° for all channels except for the middle channel, which gave double the angular resolution of 0.67° because it was placed between two channels. The total vertical field of view was 20°. The simulated data collection rate was 10Hz, and the maximum range was set at 100m. Table 1 outlines the LiDAR specifications.

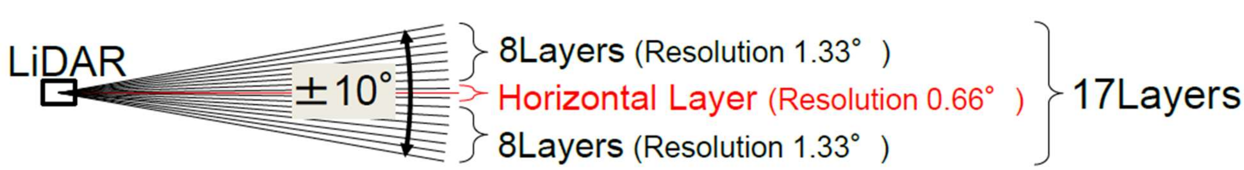


Fig. 9. Simulation LiDAR diagram

Table 1. Simulation LiDAR specifications

Specification	Value
Field of View (H)	360°
Angular Resolution (H)	0.2°
Field of View (V)	±10.0° (20°)
Angular Resolution (V)	1.33° (0.67° in the center)
Range	100m
Data collection rate	10Hz

LiDAR Locations

The LiDAR sensor was placed in three different locations for the simulation. The first location was in the headlamp, in order to test our proposal of sensor-integrated headlights. The second location was on the roof, representing the sensor bubble on the roof of common test vehicles today. The third location was in the bumper, and includes sensors on the sides of the vehicle to achieve a 360° view. Fig. 10 shows the LiDAR locations and resulting fields of view.

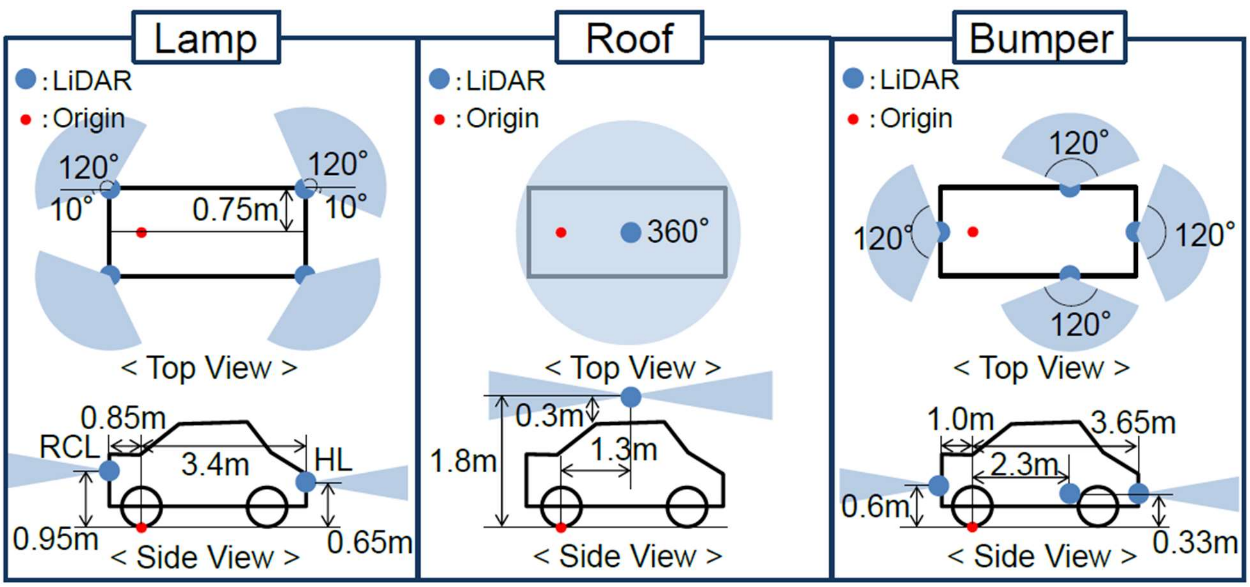


Fig. 10. LiDAR locations and respective fields of view

Evaluation Criteria

Suitable evaluation criteria to compare the safety of the sensor locations were needed. We defined two parameters to be evaluated: First Detection Time, and Total Time of Detection. First Detection Time is the time of first detection of an obstacle after the scenario simulation is started. Detection occurs when at least one LiDAR beam has reflected off the target and returned to the LiDAR sensor. Total Time of

Detection is the cumulative time that obstacle detection occurs, excluding any times where detection is interrupted for any reason. Chart 1 illustrates the definitions of the two parameters.

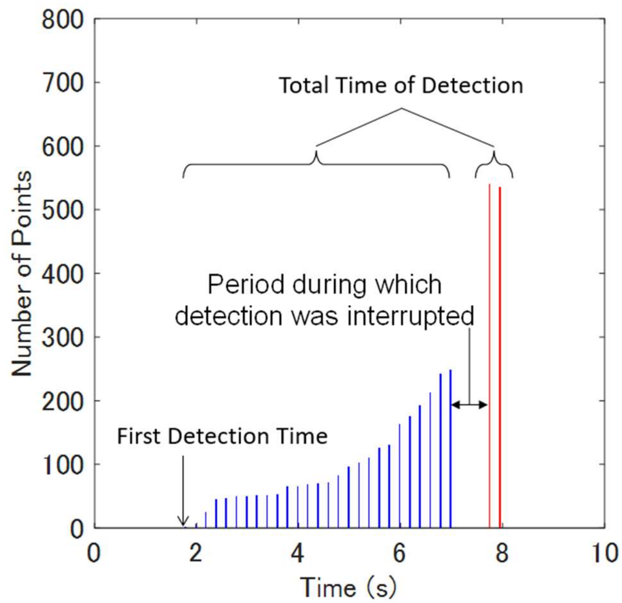


Chart 1. Definition of parameters "First Detection Time" and "Total Time of Detection"

Target Obstacles

Six types of target obstacles for detection were included in the simulations. Those obstacles and their dimensions (LxWxH) are shown in Fig. 11. Scenarios 1, 2, 3, 12, 13, and 16 involve pedestrians. For these scenarios, the simulation was studied with an adult and a child.

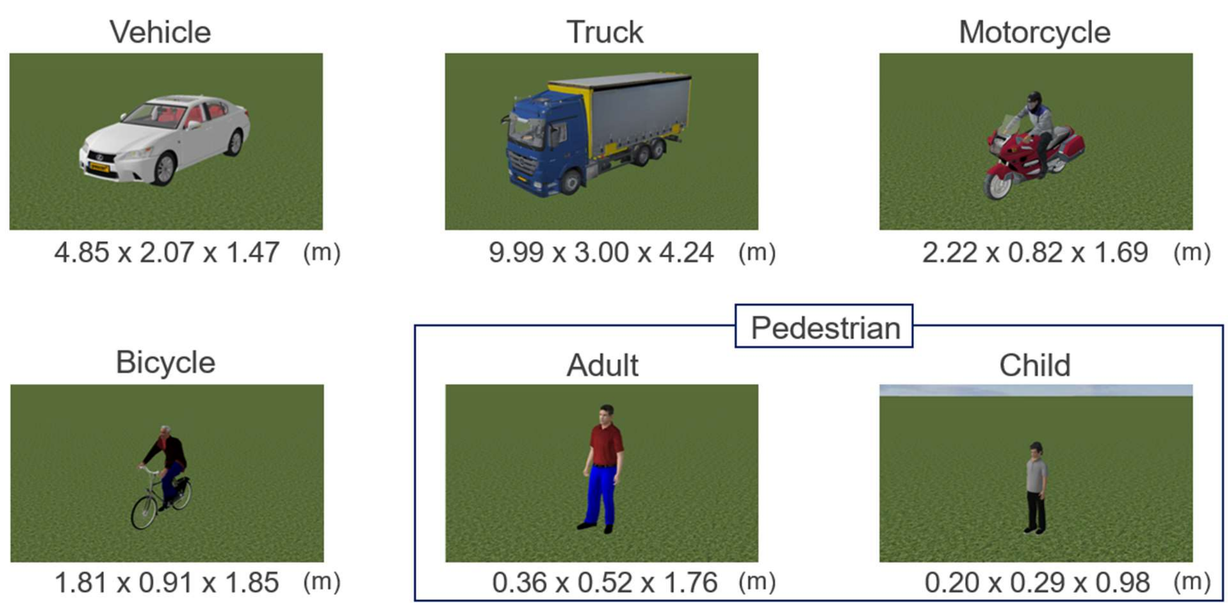


Fig. 11. Target obstacles and dimensions

Results

For the driving scenarios, the First Detection Time and Total Time of Detection were measured for each sensor location and compared. The average for all 16 scenarios was also calculated for comparison. Table 2 shows the results. The best result for each scenario, that is, the earliest First Detection Time and the longest Total Time of Detection, are highlighted in green. This table shows the results for adult pedestrians for those scenarios with pedestrians.

Table 2. Simulation Results

Scenario	First Detection Time			Total Time of Detection		
	Lamp	Roof	Bumper	Lamp	Roof	Bumper
1	4.3	4.2	4.0	5.6	5.7	4.8
2	6.7	9.3	8.3	1.6	0.8	1.3
3	4.1	7.2	5.1	6.0	2.9	4.7
4	5.3	5.4	5.2	4.8	4.7	4.9
5	4.4	4.7	4.6	4.4	1.5	3.2
6	7.0	7.1	7.0	3.1	3.0	3.1
7	2.4	5.2	6.2	7.5	4.9	3.9
8	2.2	1.0	8.2	7.8	9.1	1.9
9	7.7	8.3	8.0	2.4	1.8	2.1
10	4.8	8.6	7.9	2.5	1.5	2.2
11	4.8	4.9	4.8	5.3	5.2	5.3
12	0.0	0.0	0.0	7.8	10.1	7.0
13	0.0	0.0	0.0	8.8	10.1	8.1
14	0.0	0.0	0.0	10.0	10.1	10.1
15	2.7	2.9	2.7	7.3	7.2	7.4
16	0.0	0.0	1.2	8.5	10.1	6.8
AVG.	**3.5**	**4.3**	**4.6**	**5.8**	**5.5**	**4.8**

Overall, First Detection Time was earliest from the lamp location. The lamp location detected the obstacle earliest in 13 out of the 16 scenarios, the roof location detected the obstacle earliest in 5 scenarios, and the bumper location detected the obstacle earliest in 8 scenarios. The average First Detection Time was 3.5 seconds from the lamp location, compared to 4.3 seconds and 4.6 seconds from the roof and bumper locations, respectively.

Overall, Total Time of Detection was longest from the lamp location. The lamp location detected the obstacle for the longest time in 8 out of the 16 scenarios, the roof location detected the obstacle for the longest time in 6 scenarios, and the bumper location detected the obstacle longest in 5 scenarios. The average Total Time of Detection was 5.8 seconds from the lamp location, compared to 5.5 seconds and 4.8 seconds from the roof and bumper locations, respectively.

In the scenarios with pedestrians, the Total Time of Detection was shorter for a child than for an adult in all cases. The decrease was most drastic from the roof location, and less drastic for the lamp and bumper locations. Chart 2 shows plots of the Total Time of Detection for an adult and child from the three locations, for the scenarios with pedestrians.

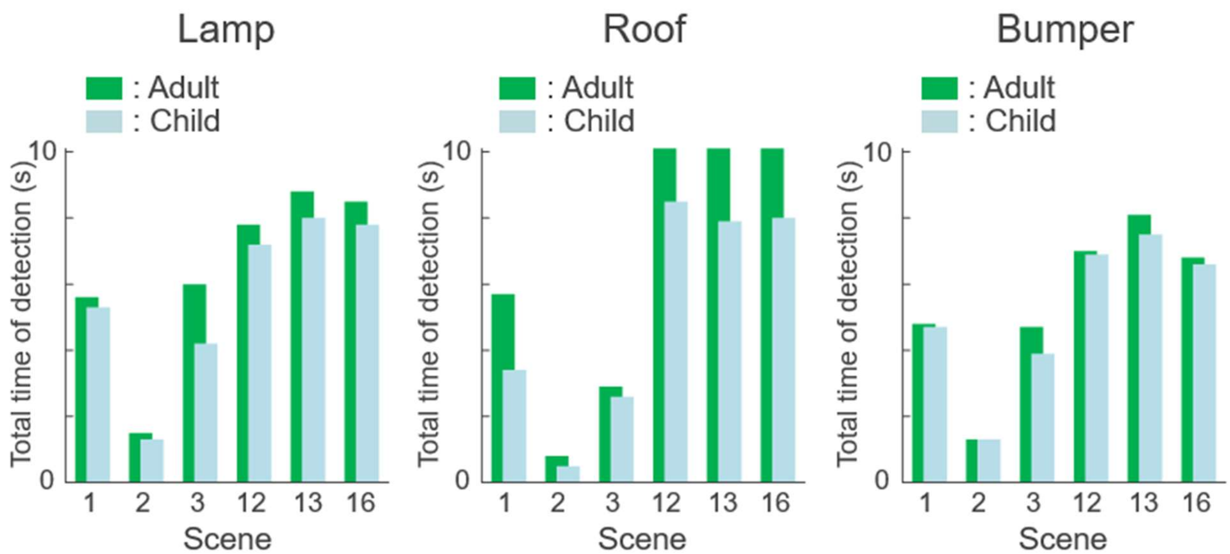


Chart 2. Total Time of Detection comparison for an adult and child from 3 LiDAR locations

2D Simulation

The results of the 3D simulations showed that detection performance depends on LiDAR location. To investigate this further, we examined how the detectable region changes when the LiDAR position is varied in the horizontal and vertical directions.

Horizontal LiDAR Position

A driving scenario was created to determine the effect of horizontal LiDAR position on the detectable region. In the scenario, a host vehicle was following a preceding vehicle, and a pedestrian was located somewhere along a Pedestrian Existence Line on the side of the road. A top view of the scenario is shown in Fig. 12(a). The Point P represents the point separating the detectable and undetectable regions. At points along the Pedestrian Existence Line closer to the host vehicle than Point P, a pedestrian is detectable. At distances farther than Point P, a pedestrian is undetectable. Fig. 12(b), shows a top view of the LiDAR location.

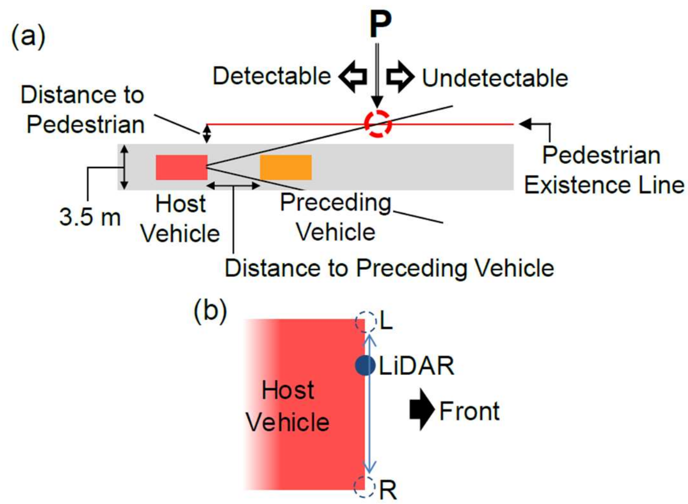


Fig. 12. (a) Scenario for evaluating horizontal LiDAR position, (b) horizontal LiDAR position

The host vehicle was 4.85m in length and 1.84m in width, and the LiDAR was positioned between 0m and 0.92m from the center to either side (+/- 0.92m from center). The distance between the host vehicle and the preceding vehicle was set at 5m, 10m, 20m, 30m, 40m, and 50m. The width of the road was 3.5m, and the pedestrian was positioned 1m off the side of the road. These conditions are summarized in Table 3. The same LiDAR configuration was used as for the 3D simulation.

Table 3. Conditions for 2D Horizontal Simulation

Vehicle Dimensions (Host Vehicle and Preceding Vehicle)	4.85m (length) x 1.84m (width)
LiDAR Position	-0.92m to +0.92m (the center is 0m)
Distance between Host Vehicle and Preceding Vehicle	5m, 10m, 20m, 30m, 40m, 50m
Width of Road	3.5m
Pedestrian Distance to Road	1m

Vertical LiDAR Position

A separate driving scenario was created to determine the effect of vertical LiDAR position on detectable height. Two versions of the scenario were created. In the first scenario, a host vehicle was facing a pedestrian standing at a Pedestrian Existence Line some distance away. A side view of the scenario is shown in Fig. 13(a). Points P_1 and P_2 are the points where the LiDAR beams intersect the Pedestrian Existence Line, and represent the highest and lowest points, respectively, along the height of the pedestrian that are detectable. The LiDAR position was varied along the height of the vehicle, between Points A and A'. The distance to the pedestrian was set at 5m.

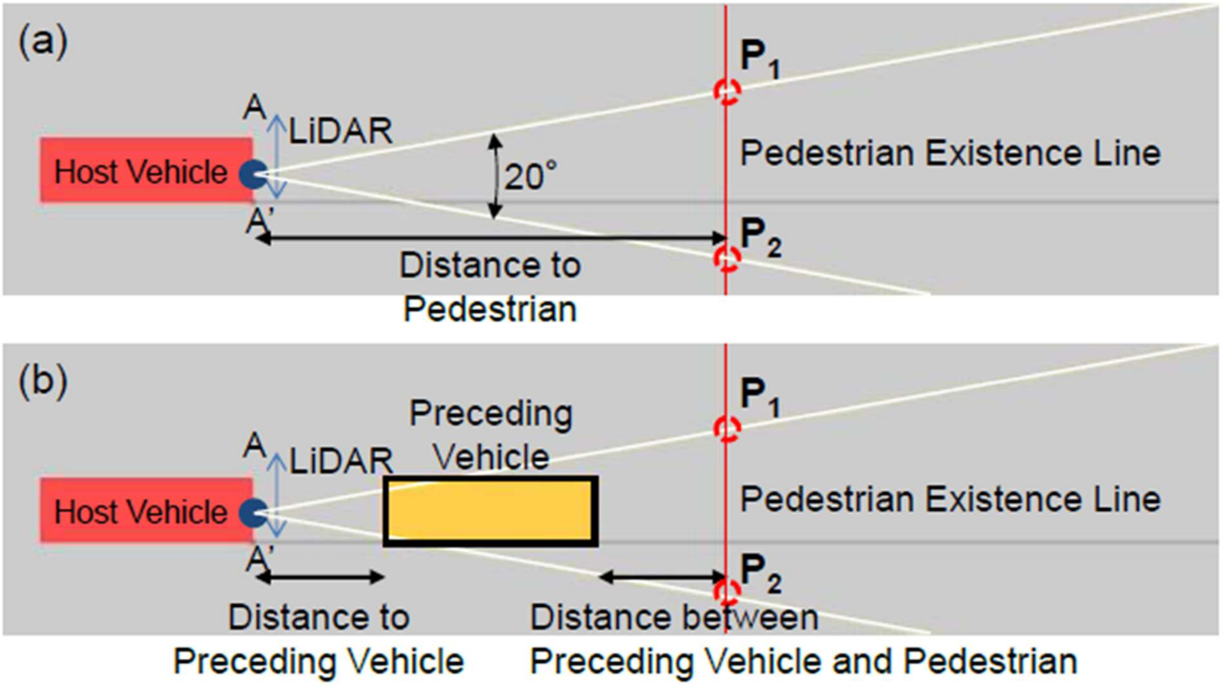


Fig. 13. Scenario for evaluating vertical LiDAR positions. (a) without a preceding vehicle, (b) with a preceding vehicle

In the scenario with a preceding vehicle shown in Fig. 13(b), a preceding vehicle was placed between the host vehicle and the Pedestrian Existence Line. The distance between the host vehicle and the preceding vehicle was set at 3m, and the distance between the preceding vehicle and the pedestrian was also set at 3m. The preceding vehicle had a length of 4.85m, making the total distance between the host vehicle and the pedestrian 10.85m. The scenario conditions for both versions are summarized in Table 4. The same LiDAR configuration was used as for the 3D simulation.

Table 4. Conditions for 2D Vertical Simulation

Vehicle Dimensions (Host Vehicle and Preceding Vehicle)	4.85m (length) x 1.47m (height)
LiDAR Position (height from ground)	0m to 2m
Distance between Host Vehicle and Pedestrian (no Preceding Vehicle)	5m
Distance between Host Vehicle and Preceding Vehicle	3m
Distance between Preceding Vehicle and Pedestrian	3m

Results

For the horizontal position evaluation, the position of Point P representing the farthest point where a pedestrian is detectable was plotted for different LiDAR positions, and for different distances to the preceding vehicle. This was done for both the left and the right sides of the vehicle. The plots are shown in Chart 3.

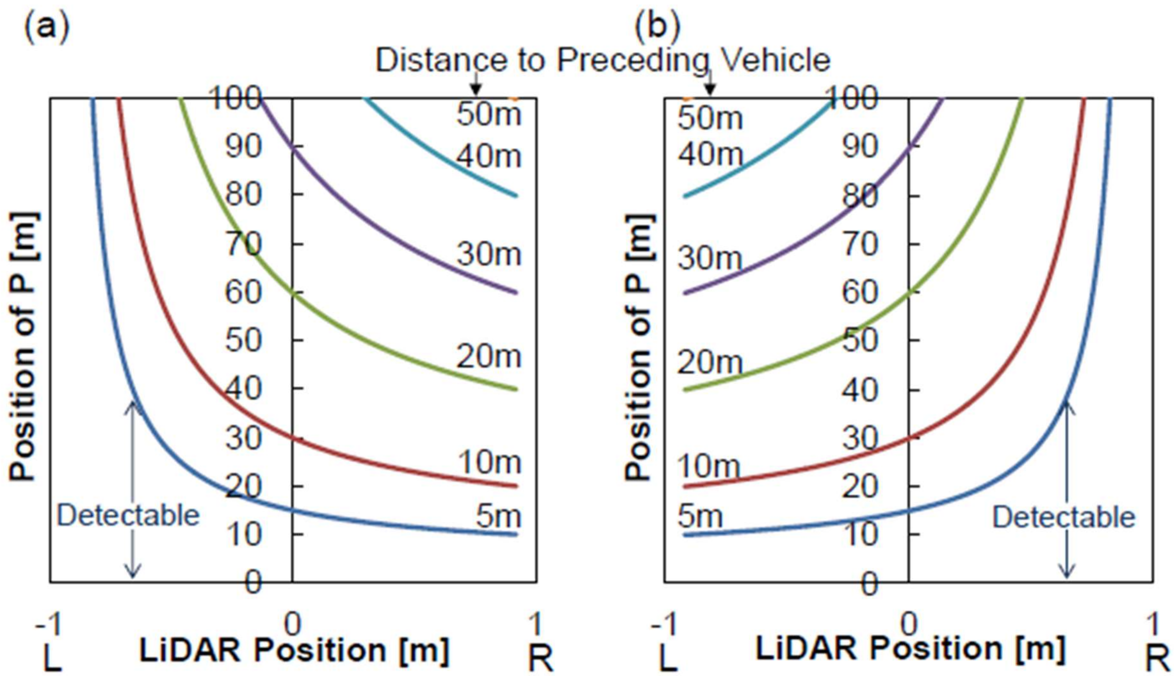


Chart 3. Position of Point P (detectable pedestrian location) by LiDAR position for various distances to preceding vehicles. (a) Left side, (b) Right side.

The results show that the detectable range increases as the LiDAR position moves towards the edge of the vehicle (to the left for the left side, to the right for the right side). As the LiDAR position approaches the edge of the vehicle, the detectable range increases rapidly. The increase is most drastic when the preceding vehicle is closer to the host vehicle. The results of the left and right scenarios are symmetric, as expected.

For the vertical position evaluation with no preceding vehicle, the heights of Points P_1 and P_2, representing the highest and lowest detectable points long the height of a pedestrian, were plotted against LiDAR height. Chart 4 shows the plot, with representations of a typical child and adult shown for reference.

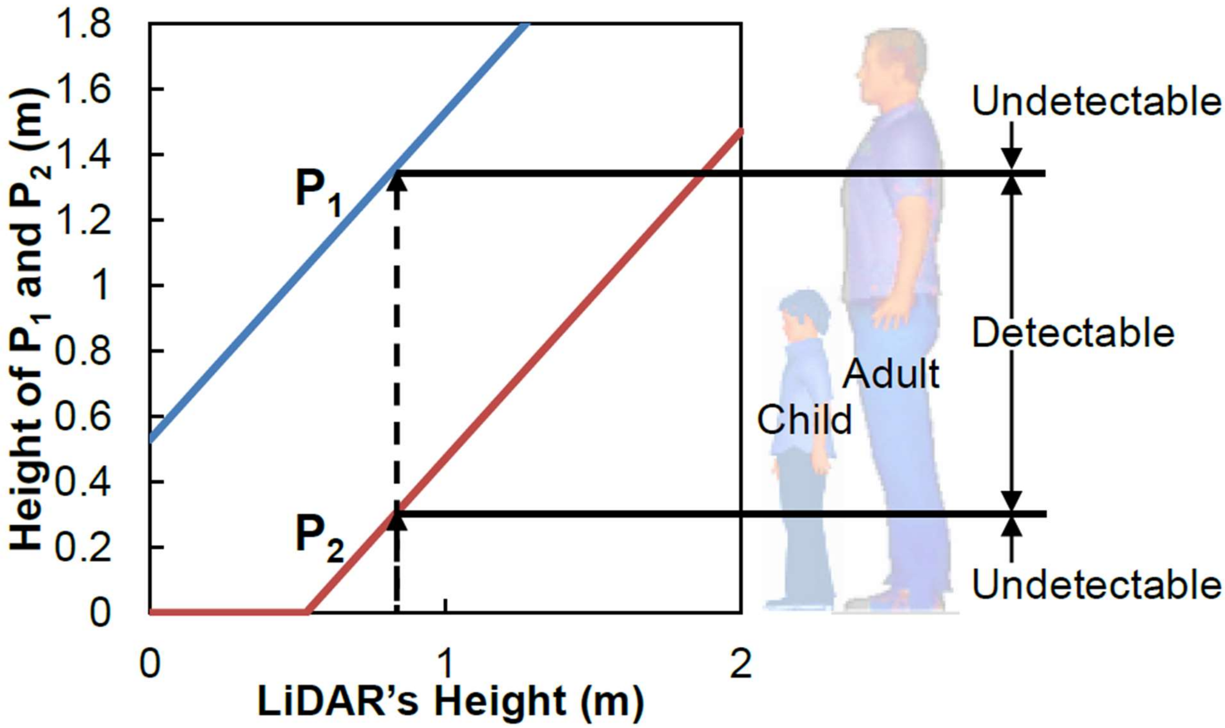


Chart 4. Height of Points P_1 and P_2 vs LiDAR position (height), no preceding vehicle

As the LiDAR height increases from the ground (0m), the detectable area of both the child and the adult increases. When the LiDAR height reaches about 0.5m, the detectable area reaches a maximum for both pedestrians. After that, as the LiDAR height continues higher, the detectable area of the child begins to decrease as the legs move into the undetectable area. At a height of about 1.8m, the child is fully out of the detectable area, and no longer visible.

To understand how LiDAR height affects detectability of the adult and child, we plotted the ratio of the detectable area to the total height against the LiDAR height for both pedestrians. These plots are shown in Chart 5.

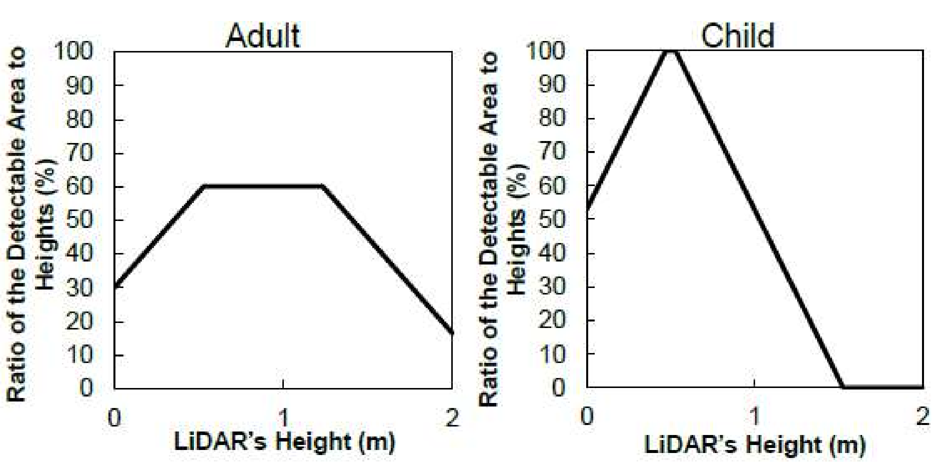


Chart 5. Ratio of detectable area to pedestrian height for an adult and child.

The ratio of the detectable area to total height for an adult reaches a maximum between LiDAR heights of about 0.5m and 1.2m. For a child, the ratio of the detectable area to total height reaches a maximum at about 0.5m, which is the only LiDAR height at which the entire child is detectable.

Chart 6 shows the heights of Points P_1 and P_2 plotted against LiDAR height for the case when a preceding vehicle is present.

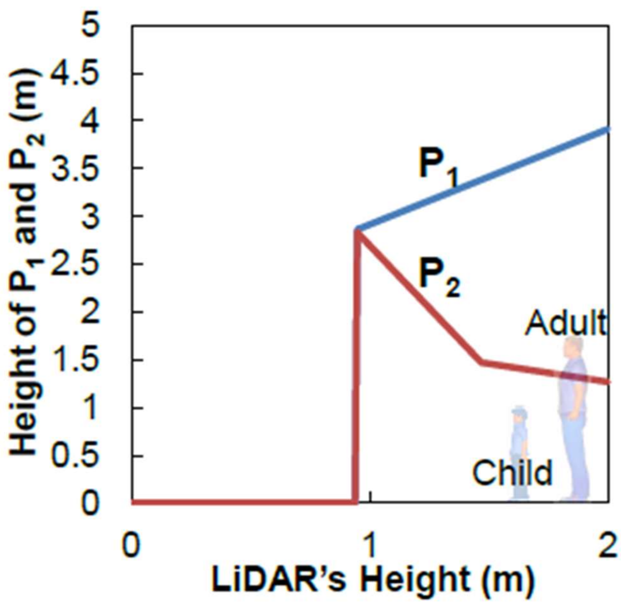


Chart 6. Height of Points P_1 and P_2 vs LiDAR position (height), with preceding vehicle

For LiDAR heights up to 1m, the preceding vehicle completely obstructs the LiDAR's view and no area of either pedestrian is detectable. At a LiDAR height of close to 2m, the adult is detectable, but only the shoulders and head are visible. The child is not detectable at any LiDAR height.

Discussion

3D simulations showed that the LiDAR sensor in the headlight position first detected the target obstacles in most of the driving scenarios. On average, obstacles were detected 0.8s faster than on the bumper and 1.1s faster than on the roof. In the context of driving safety, this earlier detection is significant. Aptiv CEO Glen De Vos wrote in a blog that if a driver is afforded an extra half-second to respond to a driving situation, 60% of accidents could be avoided [6].

The simulations also showed that the LiDAR sensor in the headlight position detected target obstacles for the longest amount of time. A longer detection time is desirable because it allows for more redundant detections of the obstacle, increasing the probability of a successful detection, and because it allows more time to perform object-recognition processing. Object-recognition processing is still a time-consuming process even with today's technology, and there remains a critical tradeoff between speed and accuracy [7]. Therefore, allowing more time for the recognition process is critical for improving safety. Placing

LIDAR sensors in the headlights provides a longer amount of time to recognize objects that could present a safety hazard.

2D simulations showed that a preceding vehicle can obstruct the view of a LiDAR placed in the horizonal center of the vehicle. When the LiDAR was placed in the center of the vehicle, the detectable range was about 90m when the preceding vehicle was 30m in front of the host vehicle. As the distance to the preceding vehicle closes to 20m, 10m, and 5m, the detectable range drastically reduces to 60m, 30m, and 15m, respectively. This shows that a preceding vehicle severely obstructs the view of a LiDAR placed in the horizontal center of the vehicle.

When the LiDAR is moved toward the edge of the vehicle, the LiDAR can see around preceding vehicles and detect pedestrians at long range. Even when the preceding vehicle was at a close distance of 5m, the detectable range was over 100m. This shows that placement of the LiDAR towards the edge of the vehicle, in the headlight position, reduces obstruction by preceding vehicles in detecting pedestrians.

For the vertical LiDAR position without a preceding vehicle, the ratio of detectable area to pedestrian height for an adult was highest at a LiDAR height between about 0.5m ant 1.2m. For a child the ratio was highest at 0.5m. Therefore, a LiDAR height of 0.5m is best for detecting as much of adult and child pedestrians as possible. This is about the same height off the ground as a headlight.

When there is a preceding vehicle obstructing the LiDAR, the LiDAR was mostly ineffective at all heights. Only at the high height of 2m was the adult only partially detectable, and the child was not detectable for any height. Therefore, the headlight position is not suitable for detecting a pedestrian who is directly behind a preceding vehicle, and other sensor positions may be needed to augment the detection ability for this situation.

Overall, the simulations showed that the headlight position offers faster detection and longer detection times than roof or bumper positions. The 2D simulations showed that the horizonal and vertical position of the headlight is advantageous for detecting pedestrians, in some cases even when a preceding vehicle is obstructing the view. However, in the case that a pedestrian is directly in front of a preceding vehicle, the obstruction cannot be overcome, and another sensor location may be needed.

FEASIBILITY

The advantages of placing sensors in the headlights is now clear, but can headlight manufacturers take on the challenge of manufacturing sensor-integrated headlights?

In fact, North American Lighting's expertise in headlight manufacturing also makes the company well-suited to sensor manufacturing. With headlights becoming more complicated over the years with more electronic components, NAL's expertise in electronics has become highly developed. NAL is also familiar with the strict durability testing requirements for headlights to meet the demanding requirements of the automotive industry. Finally, NAL has made strategic investments in two sensor companies to develop partnerships that are increasing NAL's technical expertise in sensors. For all these reasons, NAL is well-positioned to leverage its technical expertise to manufacture sensor-integrated headlights.

Headlights have become increasingly complicated in recent years. Once comprising only a dozen parts or so, added functionality has caused the number of parts to balloon to over 200. The development of more efficient lighting sources has contributed to this, as LEDs require electronic components for power and control. There are also new headlight features that have added complexity, such as adaptive front lighting, which turns the headlight to follow road curvature, and adaptive driving beam, which selectively dims the high beams to avoid glare to other drivers.

In keeping up with this increasing headlight complexity, NAL has gained expert-level technical acumen in designing, manufacturing, and testing electronic components. NAL also has the equipment required for testing procedures, which include shock and vibration testing, durability testing, and thermal cycling. The testing requirements for sensors are similar to those for headlights and can be completed using the same equipment in most cases. With similar quality requirements and testing procedures, NAL has the technical expertise and the equipment to manufacture and test both sensors and headlights that meet a high standard of quality.

NAL's parent company, Koito Manufacturing Co., Ltd., has recently made two strategic investments into sensor companies. On June 25th, 2019, Koito announced a $24M investment into BrightWay Vision, an Israeli company developing gated camera technology for vision in inclement weather [8]. Then on February 5th, 2020, Koito announced a $50M investment into Cepton Technologies, a California-based LiDAR developer [9]. This investment activity is part of Koito's plan to build strategic partnerships with sensor companies.

With these investments, Koito gained partnerships with and partial ownership of technology companies with a high level of expertise in their respective fields. Koito and its subsidiary NAL can incorporate this expertise and knowledge into headlight development, increasing the potential for building successful sensor-integrated headlights.

KEY TAKEAWAYS

- Sensor placement for autonomous driving is awkward, but headlights can offer a suitable solution.
- Advantages of headlight include 360° surround view, support from existing electronic infrastructure and heat management systems, protection from the elements, and styling freedom.
- Simulations have confirmed the safety advantage of sensors in the headlight location over the roof and in the bumper. Simulations have also confirmed the advantage of the headlight location in detecting pedestrians, in some cases even when an obstructing vehicle is present.
- NAL has expertise in complex headlight systems that utilize electronic components. This expertise is directly applicable to sensor development. NAL also has the appropriate testing equipment.
- NAL's parent company, Koito, has created strategic partnerships with sensor companies through investments. These partnerships will provide the expertise and knowledge needed to build sensor-integrated headlights.

CONCLUSION

Autonomous vehicles require sensors to be placed on the vehicle, but choosing a location is difficult. The roof is a common choice, but this location has a blind spot in areas close to the vehicle, and a large dome bubble on the roof is undesirable from an aesthetics point of view. The bumper and sides of the vehicle have also been considered, but there are cost considerations of running cables to these locations, and space constraints make heat management an issue.

We propose placing sensors inside the headlight. The four corner locations of the lighting offer a 360° view around the vehicle with no blind spots. Also, the headlights are already equipped with the electronic infrastructure and heat management systems to support sensors. From a stylistic perspective, the headlights can serve to hide the sensors, preserving vehicle aesthetics.

Simulation results confirm a safety benefit to installing sensors in the headlights. In a study of 16 simulated scenarios comparing sensor locations in the headlight, on the roof, and in the bumper, the headlight location detected targets earlier and for a longer time than other locations. This earlier and longer obstacle detection directly improves safety.

North American Lighting is well-positioned to become a sensor provider. As headlights have become increasingly complex over the years, NAL has developed expertise in electronic components. NAL's skill in manufacturing and testing these electronic components are directly applicable to sensor manufacturing.

NAL also has strong partnerships with sensor technology companies. Through strategic investments into these companies, NAL has access to the technical expertise needed to meet the challenge of manufacturing sensor-integrated headlights.

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