HOW A LASER HUD CAN MAKE DRIVING SAFER

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Driving is a necessary part of daily life, yet, it remains dangerous. In the United States there are over six million car crashes, leading to over three million injuries and 40,000 fatalities every year. Combined, this accounts for more than $230 billion in societal cost in the United States alone.[1] A large portion of these crashes can be traced to the same root cause – driver distraction.

Safety and driver "infotainment" systems are not optimally integrated into cars today. Data critical to decision making is often displayed in multiple locations: on a center console LCD or in the instrument panel, for example. Often, the placement of safety and infotainment systems in the car makes it difficult for a driver to assimilate critical data quickly and safely. For example, current navigation systems require a driver to look away from the road while the car is moving.

In addition to this core technology integration problem, other new technologies in cars distract the driver even more. Cell phones and navigation systems are obvious culprits. Satellite and HD radio now stream complex information, such as real-time traffic data, song titles, and advertising, further contributing to driver distraction.

In order to mitigate the numerous effects of distractions within the car, it is vital to put critical information where the driver can use it without affecting focus on the road ahead. Audible alarms are useful supplements when used in conjunction with visual displays. But driving is an overwhelmingly visual task. To optimize a car's active safety systems, more than just audible alarms are necessary. The driver needs a visual interface that focuses his or her attention on the road ahead; one such solution is a head-up display (HUD).

THE RISKS OF DRIVER DISTRACTION

The risks of driver distraction are well-studied, and extremely clear. The easiest measure is by vehicle crash reports. Both domestic and international reviews prove that driver negligence contributes to 90% of all traffic crashes. [2] Nearly half of them are related to driver inattention, perceptual errors, or decision errors. [3]

Strictly speaking, driver inattention excludes fatigue, excessive speed, alcohol or drugs. Instead, "inattention" generally means that the driver was engaged in another activity besides driving to stay focused on the road. In fact, "inattention" can even mean the driver was looking down at the instrument panel, not the forward scene.

"Perceptual errors" represent a failure to see, rather than a failure to look. In most cases, this implies a driver was scanning the road, but did not recognize an obstacle, especially one that was moving into the vehicle's path. This error happens most often at intersections.

"Decision errors" are more like driving without looking. For example, pulling out into traffic from a hidden driveway, or turning into one. "Decision errors" also include running red or yellow lights, or running stop signs.

Fortunately, all three of these errors can effectively be mitigated with an active safety system centered on a HUD. The data from an instrument panel – chiefly, speed, RPMs and fuel level – can easily be viewed on the windshield. So the driver's attention never leaves the forward scene.

In the same way, active cruise control, lane departure warnings, and rear collision alerts delivered to a HUD can alleviate perception errors. Likewise, next-generation night vision systems will extend the sensory range of drivers. So distraction, perception and decision errors might all improve.

HUDs are critical to these improvements, as the following use case scenarios illustrate.

HUD FOR INSTRUMENT CLUSTER DATA

Adopted from the aerospace industry and Formula One racing, HUD, like many driver-friendly technologies, was repurposed in the automotive segment as a safety feature. General Motors first introduced HUD in the Oldsmobile Cutlass Supreme and Pontiac Grand Prix in 1988. HUD is now gaining momentum in the industry as new display technologies are capable of delivering brighter images, lower power, lower temperature, improved optics and smaller footprint systems. Images generated by integrated HUDs appear to float in space in front of the driver, using sophisticated optics and the windshield to generate a virtual image.

The most commonly viewed information in a vehicle is from the instrument cluster, where speed, tachometer, fuel, engine temperature, fuel gauge, turn indicators and warning lights provide the driver with an array of fundamental information. This information, at a minimum, is expected to be displayed in a vehicle with HUD.

HUDs may never replace the core instrument cluster in a driver's dash board. Physical gauges offer their own safety advantages by clearly indicating when they fail. But when an automobile is underway, it's far safer for a driver to use the HUD images as the primary telemetry.

Academic research supports this view. One recent study of natural driving patterns found that "total eyes-off-road durations of greater than two seconds significantly increased the near-crash or crash risk." [4] Likewise, the 2006 NHTSA study on rear-end collision avoidance systems found through eye tracking that almost 40% of drivers "appeared to be distracted within five seconds before the crash-imminent alert.” [5]

According to research conducted by the General Motors Safety Integration Center, studies have shown that drivers are much better at detecting events in the forward scene with a HUD than with a conventional instrument cluster display. [6] And younger drivers agree. For example, a reviewer on Epinions.com with a HUD-equipped 2004 Corvette reports:

> “The basic Corvette accelerates so smoothly and uneventfully that, as quick as the car does feel, the rate at which the digits on the head-up display (HUD) speedometer grow can come as a shock. Which is another way of saying that you need that HUD if you hope to stay out of trouble. […] I never use the conventional instruments. Highly recommended.” [7]

Other informal studies conducted by automotive OEMs have found that a majority of drivers would opt for HUD over a larger engine for the same total cost. Those surveyed stated that they liked the HUD the same or more after having used HUD for an extended period of time.

Simple math shows, traveling at 40 miles per hour equals 60 feet per second. Thus, three seconds is 180 feet, and five seconds is 300 feet. That’s a lot of ground to cover, while blind to the forward scene. HUD’s close this attention gap. This is an important way that HUDs make driving safer.

HUD FOR NAVIGATION SYSTEMS

Among the clearest applications for HUD is to supplement GPS navigation systems for turn-by-turn directions. Even the newest speech-capable navigation systems lack visual cues for the driver, except on a center console screen. The risk with this use case scenario is that the driver’s attention strays to the navigation unit’s display panel, and not on traffic movement, curbs or pedestrians. This distraction is listed as a cause of traffic accidents due to poor driver situational awareness. According to research conducted at the University of California at Berkeley, timing required to look at in-vehicle information takes a minimum of 2 seconds, drawing attention away from the road to look at dash mounted instrumentation and returning focus to traffic on the road.[8] Logically, looking at a complex map on an in-car navigation system will take longer. This same study finds that a HUD requires that the driver invest only a half second to gather critical information and make an informed decision.

To alleviate the danger of driver inattention, navigation systems can be made to project directional arrows on the lower portion of a windscreen via the HUD. These navigation symbols are bright enough to get the driver’s attention, yet don’t obstruct the rest of the driver’s visual frame. This is true even at night. Moreover, according to a study conducted at the General Motors North American Operations Safety Center, test results among the 24 drivers tested indicated a significant time advantage in detecting pedestrians while using a HUD.[9] These findings clearly suggest that HUDs enhance the driver’s ability to see forward scene events, and as a result, improve traffic safety.

What is critical is that a HUD be used to help the driver improve safety in the car while accessing complex turn-by-turn navigation instructions. Driving is complicated enough, without dangerous distractions. HUD can be part of a global solution that makes everyone safer on the road.

HUD FOR AUTOMOTIVE OBSTACLE DETECTION SYSTEMS

Automotive OEMs continue to develop technologies to improve driver situational awareness and safety inside, and around a vehicle. A growing number of automotive

OEMs are offering driver assistance technologies, also called automotive obstacle detection systems.

A variety of obstacle detection technologies, including ultrasonic, radar, lidar and camera-based systems, adaptive cruise control, night vision, rearview camera, park assist, lane departure warning, blind spot detection, lane keep and pedestrian protection can augment a driver's ability to avoid collisions. According to research conducted by the Royal Institute of Technology in Stockholm, obstacle detection systems require sufficient range to account for high vehicle speed, sufficient width to account for change in vehicle trajectory and peripheral vision to see objects moving in the periphery.[10] Quick and reliable data processing completes the system. One of the most effective ways to address the requirements of obstacle detection systems, especially where a driver is expected to make evasive maneuvers to avoid a collision, is to put data where it is most needed. In almost every case, clever human factors engineering combined with a HUD and obstacle detection technologies can improve the driver's visual and cognitive workload.

A great example of an improved automotive obstacle detection system is the combination of night vision technology with HUD.

More than 40 percent of vehicle crashes that result in fatalities occur after dark. In the dark, the ability for a human to process visual data is significantly impaired; visual acuity, contrast and depth and distance perception are affected in low-light conditions.[11]

HUD is very well suited for use with night vision technologies. Alternatives to using HUD include a center console LCD display or an instrument cluster mounted display. A collision may be unavoidable in nighttime driving conditions as a result of time required to glance down at a display mounted in a center console. That is because this implementation of night vision splits your attention between the road and the night vision display, somewhere on the dashboard. However, a HUD paints images directly where the driver's eyes need to be focused.

Night vision systems in combination with a bright, high contrast HUD projects images in the driver's field of view just slightly above the hood of a car. At night, this is dead space between the outside field of view and an instrument cluster – the perfect area to present information from beyond where a driver's headlights allow them to see.

Research and development is ongoing to use sophisticated image processing to improve detection and enhance the image quality of objects. These intelligent night vision systems can identify, for example a pedestrian or an animal on a dark road. The display can then apply a color scheme to highlight the object and provide an event based warning to alert the driver. That way, a pedestrian in the distance is always in the driver's field of view, both before and after headlights illuminate the pedestrian. [12] In brief, this means a driver doesn't have to shift his or her attention to make informed decisions about driving conditions in a dark setting, giving vastly improved night vision when combined with HUD.

Further, in 2003 Honda Motors experimented with image processing software to detect pedestrians, and enhance images, using color. [13] This system was deployed in Japan in 2004. Meanwhile, Ford has developed its own laser imaging system, one that cuts through weather.[14]

In combination with obstacle detection systems, HUD technology provides one of the best implementation solutions available to supplement active automotive safety systems. Safety technologies as disparate as lane departure warning, blind spot detection and adaptive cruise control can be vastly improved when implemented with HUD. Ultimately, consumers expect automotive safety should improve from generation to generation. However, with the ever increasing number of systems with which drivers are expected to interact, the very technologies that are intended to improve vehicle occupant safety can become a distraction that causes crashes. The use of HUD systems in conjunction with obstacle detection systems can deliver on the promise of safer drivers and fewer collisions.

COMPETITVE HUD TECHNOLOGIES

There are multiple display technologies that can be used in HUD systems, including emissive displays (OLED, CRT, VFD, etc.), digital micro mirror device (DLP®), backlit LCD, micro-displays (LCoS) and scanned laser displays. Each of these technologies has its strengths and weaknesses.

The majority of current HUDs use backlit LCDs. LCD technology has lent itself to effective use in HUD applications to date, but emerging technologies like scanned laser displays provide a variety of advantages over LCD in categories like brightness, color range, contrast and tolerance to windshield variations, all of which are important in human factors engineering for automotive OEMs.

LCD, DMD, and LCoS based display technologies share a common weakness in terms of the presence of glow in the projected image. This is a function of the display design, requiring that the entire display is illuminated to generate an image. Even in regions of the HUD image that are intended to be "see-through", backlighting has the effect of producing image artifacts that are especially pronounced in dark settings. While OLED does not share the problem of background glow, it is not very well suited for automotive applications because it does not generate adequate brightness for daylight use.

When each of these display technologies is compared in light of automotive HUD applications, the leading solution is a scanned laser display, as this technology often performs considerably better in terms of brightness, contrast, and sensitivity to windshield variations.

In support of the assertion that contrast and brightness are critical HUD features for daylight readability, the NHTSA recently reported, summer-time drivers frequently used a HUD's variable brightness control. [15] This particular government study was conducted in Michigan. In other parts of the country such as California or Texas where the sun may appear brighter, an important capability for HUD is to overcome daytime light. Scanned laser based HUDs achieve this most effectively.

Daytime readability is one measure of HUD reliability. Another is a HUD's contrast ratio, which is important for night time driving. In practical terms, contrast is a measure of light pollution. If the HUD produces excess light, this can "wash out" the forward scene, impairing night vision. Scanned laser displays provide significantly higher contrast.

Table 1. Display Technology Comparison

	Scanned Laser	LCD	Next Gen LCD	DMD	LCoS	OLED
Brightness	>10,000 cd/m²	1,000 cd/m²	>10,000 cd/m²	>10,000 cd/m²	~ 10,000 cd/m²	500 cd/m²
Contrast	10,000:1	100:1	2,000:1	>3,000:1	800:1	>2,000:1
Size	Variable	<60 x 30 mm	<80 x 40 mm	9 x 6.5 to 22 x 19 mm	15.24 x 20.32 mm	Variable
HUD Applicability	Superior	Marginal	Marginal	Poor	Poor	Poor

Source: Microvision, Inc.

MICROVISON'S SCANNED LASER DISPLAY ENGINE FOR HUD

The key to Microvision's scanned laser display is the Integrated Photonics Module (IPM™) and its proprietary Micro-Electro-Mechanical System (MEMS) device.

Scanned laser displays provide high brightness and contrast for a superior HUD system. The display engine uses low power laser or LED light directed onto a biaxial MEMS scanner. The MEMS device rapidly scans light horizontally and vertically to build an image. This image can be projected onto any surface. The IPM display engine is a simple and elegant solution to a complex problem. LCD, LCoS and DLP displays utilize an array of pixels that have 10^6 tiny elements to produce an image. Grating Light Valve (GLV) utilizes 10^3 pixel elements to diffract laser light using an array of tiny movable ribbons mounted on a silicon base. LCD, LCoS, DLP and GLV devices are very complex, low-yield technologies whose costs rise non-linearly with resolution. Microvision's IPM display engine paints a 2D image one pixel at a time. This simple architecture provides high yields and costs that rise linearly with resolution at the lowest cost-per-pixel.

The IPM display engine enables exceptional performance capabilities for a new generation of high-performance HUDs. Optical elements in Microvision's scanned laser display include:

- Pure laser light from tiny red, green and blue laser diodes that enable millions of colors,
- Pixel forming optics to collect and focus the laser light to form the optimum pixel profile at the scanned image plane,
- The MEMS scanner, which scans single-pixel laser light at video rates to form a 2D image, with the laser light source modulated in synchronization with the motion of the MEMS scanner,
- The exit pupil expander (EPE), which serves to increase the cone angle of the light from each pixel, thereby producing a large exit pupil, or eyebox, and
- Relay optics, which magnifies and relays the image to the viewer's eyes.

The EPE produces an array of "image windows", where the gaps between these windows are smaller than the eye pupil so that a large, uniform eye box can be produced.

Figure 1. LCD vs. Scanned Laser Display HUD

The image on the left is an LCD based HUD display engine. Notice the background glow. This image artifact is typical of backlit LCDs. The image on the right is a scanned laser display. Contrast is an order of magnitude better than LCD technology – a truly see-through image with no background glow. The laser light source is not illuminated where there is no image to project, unlike backlit LCD, which turns on the whole screen in order to produce an image.

The IPM provides automotive display manufacturers with the ability to create displays that achieve outstanding image contrast, intense brightness, high-resolution and excellent dynamic color range. Additionally, IPM based HUDs allow for electronic image alignment and warping, lowering the cost of HUD installation by automotive OEMs and simplifying windshield replacement by car dealers in the aftermarket.

CONCLUSION

Complete situational awareness is critical when driving a vehicle. To maximize safety, a driver must have instant access to important vehicle information without compromising attentiveness to road conditions. HUD technology is arguably one of the most effective ways to reduce driver distraction. Research has clearly shown that drivers are able to detect more events in the forward environment with a HUD than through use of conventional instrumentation and displays alone. For this reason, a vehicle with a HUD is a vast improvement over vehicles without HUD as reflected in overall vehicle safety. If driver distraction can effectively be addressed with HUD, the cost savings to individuals and industry can be significant.

For vehicle manufacturers, Microvision's scanned laser display is a cost effective and technically superior HUD that can vastly improve a driver's situational awareness. The image contrast, brightness, color palette and tolerance to windshield variation makes Microvision's IPM based display engine ideal for HUD applications. IPM based HUDs provide a compelling active safety feature. Driving is largely a visual endeavor, and keeping the driver's eyes focused on the road is the best way to address the problem of driver inattention as the principal cause of traffic collisions.

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