Driver Safety Enhancing Automotive Head-up Displays

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Automotive Head-Up Displays (HUDs) enhance driver safety. By contrast, conventional head-down displays (HDDs) can divert the driver's attention from the forward scene, delaying the driver's reaction to an unexpected collision threat. A wealth of automotive industry research indicates that HUDs increase eyes-on-the road time, significantly improving response to unanticipated road events. In addition, HUDs reduce visual re-accommodation between external targets and head-down driving. In combination with active vehicle safety telltales, HUDs can reduce the number of missed warnings. HUD technology is both a safety enhancing technology and comfort and convenience feature. Critical user performance issues influence the design of HUDs from a visual and cognitive standpoint. While automotive HUDs have been in use since the late 1980s, newer technologies address user performance issues by standardising symbology and improving the colour palette, contrast, brightness, visual clutter, virtual image distance and field of view. By addressing these issues, next-generation HUDs can lighten a driver's mental workload and more effectively deliver relevant information.

Next generation HUDs further enhance driver safety and convenience with wide field-of-view, full colour images that are artifact free, high contrast and day light readable

Key to safer driving is "eyes-on-the-road"

In typical driving, the vast majority of a driver's visual attention – roughly 85 to 90 percent – is on the road ahead. The more time a driver spends looking at the road, the more likely the driver is to catch time-critical events. Human factor studies have quantified this effect. According to the US National Highway Transportation Safety Administration, HUDs improve response times by one quarter to one second. While such small time periods may not seem significant, at 100 km/h, this represents 7 to 28 m reduced stopping distance. In addition to improvements in reaction time, HUDs also improve driver behaviour under both low and high mental workloads where the probability of detecting forward roadway events is greatly improved compared to conventional HDDs. A Volvo investigation of forward collision warning systems measured how quickly and efficiently distracted drivers reacted to a visual warning display placed in various locations in a vehicle. From both performance tests and user preference ratings, the warning indicator on the windshield (HUD) proved to be the best for forward collision warning, with almost one quarter of a second improvement in average brake reaction times and fewer missed warnings. HUDs also moderate distraction by driver convenience technologies like navigation systems. Increasingly, navigation systems include audio prompts and speech-to-text functionality to enhance the user interface. However, the safest navigation systems will incorporate HUDs for eyes-on-the road visuals, audible prompts and speech-to-text recognition.

Design Attributes That Optimise HUD Safety

Standardised symbology & rich colour palette

The first automotive head-up displays introduced in the late 1980s were monochromatic blue/green systems. HUD technology has advanced considerably since that time. With the advent of full colour display technologies, HUD can differentiate data using visual colour cues to indicate conditions that require varying degrees of response. Research suggests that carefully designed standardised HUD symbology can eliminate informational ambiguity. When combined with the depth of a full colour system, standard symbols can further refine the stimulus features of the HUD by allowing separation of critical data inputs spatially and by colour (eg, bright red for high priority warning symbols).

Greater Brightness & Contrast Ratios

While colour HUDs provide a much better visual stimulus than monochromatic systems, many colour systems can produce distracting image artifacts in the driver's field of view. For example, HUDs that use liquid crystal display (LCD) technology generate a background glow in the driver's field of view that is particularly pronounced at night. This is a side effect of having to flood illuminate the LCD array to produce an image that is bright enough to be daylight readable. Daytime readability is a critical design consideration for HUDs as up to 75 percent of driving occurs during the day. It is important to achieve the appropriate levels of luminance contrast for day and night use of the HUD so that images have the brightness and contrast necessary to be viewable in all lighting conditions without obstructing the forward view.

Minimal Visual Clutter

Poor design of HUD symbology and layout can become an attention trap that slows the processing of external events. This can be particularly problematic with older drivers who have a wide range of cognitive capabilities. Human factors design of HUD symbology and spatial layout must minimise or eliminate features that interfere with the task of detecting hazards while driving, otherwise known as visual clutter. Use of standard symbology overlays on the road where turn-by-turn navigation information is embedded within the driving scene can reduce visual clutter. Another approach would display critical data (such as active vehicle safety warnings) only when necessary, leaving the forward driving scene unobstructed for most driving conditions.

Virtual Image Distance

The typical distance at which HDD information is viewed is approximately 760 mm. Comfortable HUD virtual image viewing distances are between 2 and 4 m from the driver's eyes, reducing visual re-accommodation demands for drivers to view critical automotive information. Studies indicate that older drivers benefit most from this aspect of HUDs, eliminating the need to look through the near-field lens of bifocal correction spectacles to read the instrument cluster. This also provides significant time savings for drivers who do not need to wear glasses.

Wide Field of View

Another limitation of many HUD implementations is a narrow field of view (FOV.) Visual clutter can occur by placing too much information in the HUD eye box, sometimes making it difficult to distinguish common data from critical alerts. Studies find that a 20 degree or greater horizontal FOV could reduce visual clutter and improve driver response time. Further, wide FOV HUDs combined with simplified and universal visual cues and standard symbology can vastly improve driver safety, particularly in poor visibility driving conditions.

HUD technology comparisons

HUD improves the prospect of automotive safety. Various HUD solutions have their strengths and weaknesses. Flood illuminated LCD, DLP™ and liquid crystal on semiconductor (LCoS) systems lack the contrast and brightness demanded by HUD applications. Organic light emitting diode (OLED) systems provide good contrast, but lack the brightness for daytime HUD applications. Holographic laser light engine displays using LCoS arrays achieve reasonable brightness, but like all flood-illuminated systems, present image artifacts that affect contrast. Microvision is working with automotive suppliers to deliver automotive laser based HUDs, providing a scanning engine sub-system based on the ultra-miniature PicoP™ display engine. The scanning engine sub-system may be integrated by Tier 1 suppliers into HUD product packaging suitable for automotive manufacturers. Microvision's automotive grade PicoP display engine offers HUD designers an exceptional display solution that can aid a driver's situational awareness. The image contrast (>10,000:1 FOFO), brightness (>10,000 cd/m2) and rich colour palette (roughly 200 percent of the colour gamut of standard monitors) make Microvision's technology a compelling active safety feature. As driving is largely a visual endeavour, keeping the driver's eyes focused on the road is the best way to address problems of driver inattention. Microvision's PicoP display engine provides a practical approach to address critical design limitations inherent in many competitive HUD technology solutions.

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