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Wearable Vision Systems: Head/Helmet-Mounted Displays

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Wearable near-to-eye (NTE) visualization systems are being developed by consumer electronics and social media companies to enable compelling experiences in augmented and virtual reality (AR/VR). VR immerses viewers mentally in a place other than the one in which they are physically present. Negative physiological side effects often limit VR usage to 10 min episodic sessions. AR involves symbology and/or imagery superimposed over the real world perceived in real time. AR NTE display system types include see-through (such as motorcycle visors, pilot helmets, or eyewear) and non-see-through with symbol overlays (for visualizing the world via passive or active electro-optic band cameras, imaging radar/lidar systems, or computer scene generators). VR systems are non-see-through only. Also, unlike VR, AR imagery is required to be conformal to the physical world surrounding the viewer. Accurate tracking of position, head, and eye are needed for some VR and all AR applications.

This special section of *Optical Engineering* comprises several papers addressing wearable vision systems (WVS) implemented as head- or helmet-mounted display systems. The paper by Schmerwitz et al. analyzes the human factors of conformal AR NTE displays for pilots in which 3-D symbology representing relevant real-world objects is presented on a see-through display such that it inherits the same optical flow as the physical environment in which the aircraft is operating. If successfully integrated with pilot workflow, such an AR system increases safety and expands flight operations (commercial, medical, civil, military) to include a variety of degraded visual environments. The paper by Peinecke et al. reviews conformal counterparts for several aircraft related instruments. The paper by Fischler et al. demonstrates the challenges of integrating an NTE system into a high-performance aircraft. The paper by Arthur et al. reviews NTE vision system research at NASA focused on advancing the state-of-the-art in displays, head-trackers, and flight data to guide regulatory guidance development for the NextGen commercial aviation industry. The paper by Harding and Rash identifies the luminance contrast requirements for full-color NTE see-through displays based on a perceptual study of the quality of white symbology against natural static backgrounds. The work in these five papers can provide important lessons learned to similar navigation and WVS challenges for ground vehicle operators and pedestrians.

The paper by Huang addresses a challenge for projection systems—compact optics—by developing an ultrashort throw design based on a telecentric lens and optimized Koehler illumination. All NTE systems are projectors (of small real images to virtual ones beyond the eye's near point) and may benefit from future miniaturization of Huang's approach.

The paper by Adil et al. addresses a fabrication efficiency challenge of NTE systems in which an image is projected to one eye via reflection off a coated portion inside one half of a spherical visor or lens. A Shack-Hartmann wavefront sensor is used to determine the aberrations in the visor parts, and a neural network framework is exploited to align the two halves.

The current period of significant commercial investment in WVS for personal communications and entertainment is driving rapid advances in miniature optoelectronics components and product design. Key challenges include achieving performance in a NTE visualization system sufficient to compel users to tolerate shortcomings including latency, acuity, field-of-view, fashion, and donning/doffing. We hope that this special section will help the community to leverage consumer-driven advancements in the design of specialty applications including automotive, industrial, and military vision systems.

Darrel G. Hopper is a principal electronics engineer at the Air Force Research Laboratory. He received his PhD in physical chemistry Oklahoma State University with a dissertation in quantum molecular physics. He has chaired the DoD Special Technology Area Review (STAR) for Displays in 2004. Current interests include advanced helmet systems, ultrahigh resolution, 3D data visualization, gesture interfaces, and image processing. He is a Fellow of SPIE, Senior Member of IEEE and SID, and a Director of SID.

James E. Melzer is technical director for Advanced Projects at Thales Visionix, Inc. He received his SM degree from the Massachusetts Institute of Technology and a BS degree from Loyola University of Los Angeles. He has published over 50 papers and book chapters and holds five U.S. patents. His interests are in head-mounted displays, human visual and auditory perception, head-neck biomechanics, and invertebrate vision as a model for sensor designs.

Michael Browne is the general manager of the Vision Products Division at SA Photonics. He received his PhD from the University of Arizona's Optical Sciences Center, where his dissertation was on high-resolution displays and image intensifier systems. His interests are in wide-field-of-view high-resolution VR and AR displays, digital night vision systems, and person-machine interfaces.

Peter L. Marasco the technology advisor for the Air Force Research Laboratory, Sensors Directorate, Multispectral Sensing and Detection Division. He holds degrees in optical and electro-optical engineering from the University of Rochester, the University of Arizona, and the University of Dayton. In his career, he has authored 35 papers, holds 4 patents, and has been a member of SPIE for over two decades.