Optical Engineering

OpticalEngineering.SPIEDigitalLibrary.org

High-Speed 3-D Optical Metrology and Applications

Song Zhang
Rongguang Liang
Lianxiang Yang

High-Speed 3-D Optical Metrology and Applications

Song Zhang
Iowa State University
Department of Mechanical Engineering
Ames, Iowa 50011
E-mail: song@iastate.edu

Rongguang Liang
University of Arizona
College of Optical Sciences
Tucson, Arizona 85721
E-mail: rliang@optics.arizona.edu

Lianxiang Yang
Oakland University
Department of Mechanical Engineering
Rochester, Michigan 48309
E-mail: yang2@oakland.edu

Recent innovations in computational and electronic technologies have drastically enhanced the three-dimensional (3-D) optical metrology field in terms of measuring speed and accuracy, as well as expanded applications. High-speed 3-D optical metrology is a platform technology that could benefit numerous scientific studies and engineering concerns including but not limited to manufacturing, medical sciences, robotics, etc.

Lately, a number of novel high-speed 3-D optical metrology methods have been developed, and these technologies have been applied to fields ranging from medicine, computer science, robotics, biometrics, homeland security, agriculture, and biology, to automotive, manufacturing, and entertainment industries. For example, Microsoft Kinect has penetrated 3-D optical metrology into our daily lives; real-time 3-D metrology techniques have permitted *in situ* inspection in the electronics industry; and high-speed 3-D sensing devices have enabled better robotic navigation.

This special section assembles a good number of high-speed 3-D optical metrology technologies, as well as a few representative applications. Active high-speed 3-D shape measurement based on fringe projection requires generating and projecting fringe patterns rapidly. T. Bell and S. Zhang summarize their contributions using the digital light processing (DLP) platforms; C. Casey et al. discuss the modified composite pattern illumination method; S. Heist et al. present their recent innovation of using an LED matrix; L. Lu et al. use triangular patterns for high-speed 3-D shape measurements; M. Schaffer et al. summarize their work using statistical patterns; and T. Wakayama and T. Yoshizawa present yet another rapid fringe pattern generation using spatiotemporal modulated laser light.

High-speed 3-D optical metrology not only requires high-speed pattern generation, but also high processing speeds and better system design. Parallel computing is apparently one of the preferred methods. C. Brauer-Burchardt et al. discuss the method of using geometric constraints to reduce the required number of patterns for 3-D shape reconstruction and thus improve measurement speeds, and K. Zhong et al.'s paper discusses the parallel architecture for high-speed measurements.

There are various ways of improving the measurement accuracy. One obvious method is to improve calibration, which was discussed in Y. Zhang's paper. Q. Xue et al. presented the idea of improving the center detection method for accuracy improvement; V. Marin et al. discuss an interesting but important aspect to increase the accuracy of triangulation through system design optimization.

Data received from high-speed 3-D sensors can benefit numerous application areas. This special section includes some critical areas of applications. 3-D facial recognition in biometrics, for example, can be greatly benefited from high-quality 3-D data captured from 3-D sensors. W. Luo et al. present their facial recognition methods based on advanced mathematical tools: Ricci flow and mass transportation. N. Burns and J. Watson use in-line holograms to measure marine organisms, and D. Serrano-García et al. apply 3-D optical metrology for dynamic temperature fields measurements.

We appreciate the authors who submitted their novel methods or applications to this special section, as well as the tremendous support from SPIE.

Song Zhang is an associate professor of mechanical engineering at Iowa State University. He received his PhD degree from Stony Brook University in 2005. His major research interests include high-speed 3-D optical sensing and 3-D sensing information processing. He has authored or coauthored over 100 research articles. He is the recipient of the NSF CAREER award in 2012 and is a Fellow of SPIE.

Rongguang Liang is an associate professor at the College of Optical Sciences, University of Arizona. Prior to that, he was a senior principal research scientist at Carestream Health Inc. and a principal research scientist at Eastman Kodak Company. He has been working on optical design for 15 years in the fields of biomedical imaging, digital imaging, display, and 3-D imaging. He is a topical editor of *Applied Optics* and a Fellow of SPIE.

Lianxiang Yang is the director of the optical laboratory and a professor in the Department of Mechanical Engineering at Oakland University, Michigan. Prior to joining Oakland University, he was an R&D scientist at JDS-Uniphase, Canada, a senior engineer at Dantec-Ettemeyer AG, Germany, a senior research fellow at University of Kassel, Germany, and a lecturer and associate professor at Hefei University of Technology, China. He has multidisciplinary research experiences including optical metrology, experimental strain/stress analysis, nondestructive testing, and so on. He is an associate editor of *Optical Engineering* and a Fellow of SPIE.