Optical Methods for Shape Measurement

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In industry, there is a need for accurately measuring the 3-D shape of objects to speed up and ensure product development and manufacturing quality. There are a variety of applications of 3-D shape measurement, such as: control for intelligent robots, obstacle detection for vehicle guidance, dimension measurement for die development, stamping panel geometry checking, and accurate stress/strain and vibration measurement. Moreover, automatic online inspection and recognition issues can be reduced to the 3-D shape measurement of, for example, body panel paint defects and dent inspection.

The principles of triangulation, structured light, and interferometry have been in existence for decades. However, it is only with the recent availability of advanced and low cost computers, electro-optical elements, and lasers that such techniques have reached the breakthrough point to be commercialized, and ever increasingly be applied in industry. To make it even more acceptable in industry and to strive to achieve 10^{-4} to 10^{-5} accuracy, there are still some challenges that need to be addressed, such as: the shading issue, the specular surface headache, accurate data patching from different view directions, geometric parameter determination and calibration, absolute phase measurement, local and global coordinates tracking and transforming, real-time computing, sensor planing, and optimization. This special section is designed to promote research activity and to serve as a forum both for academia and industry.

This special section includes a variety of development and application examples such as: optimization of an optical system which results in one part in 20,000 accuracy, new techniques using a diffraction grating or defocus to overcome the shading issue, direct digital wavefront reconstruction combined with wavelength scanning to attack the absolute phase measurement issue, and development of a self-calibration method to increase measurement accuracy and practical use.

The first group contains overview papers in which Chen, Brown, and Song provide an overview on various 3-D optical methods, then focuses on the structured light method while Shang et al. furnish recent progress on surface profiling using shearography.

The second group consists of new approaches and devices. Tiziani, Wegner, and Steudle describe a confocal method and its applications on macro/micro shape and surface defect measurement. Techniques to obtain absolute phase values are presented by Yamaguchi, Yamamoto, and Yano and Marron and Gleichman using wavelength scanning and by Gilbert and Blatt employing a color grating technique. Takeda et al. and Ditto and Lyon address the shading issue by using a co-axial/image plane optical system or diffraction grating configuration. Wagner, Osten, and Seebachler developed digital wavefront reconstruction with wavelength scanning to calculate absolute phase. de Groot, de Laga, and Stephenson devised a new configuration that can be used to desensitize the optical measurement system. Coggrave and Huntley achieved 2×10^{-5} accuracy (desirable in industry and making the optical 3-D technique more acceptable in industrial metrology) by optimizing the optical system using a LCD. Sciammarella gives the detail advances and new approaches in holographic moiré contouring while Mermelstein, Geldkhun, and Shirley put forward a new acousto-optic accordion fringe interferometer. Wang, Wu, and Wee utilized a facet model to extract shape with CT measurement. Brown and Pryputniewicz employed new methodology for measuring static and dynamic shape of micro-electro-mechanical systems. Lastly, Lu, He, and Liu proposed an effective algorithm to remove carrier fringes.

The third group concerns calibration, which is important for accurate measurements. Hung et al. and Kowarschik et al. present a geometric transform method which does not require that the parameters of the imaging and projection system be known. Schreiber et al. developed a self-calibration method and eliminated the usage of markers with photogrammetry. Zhou et al. developed a calibration methodology for a 4DI measurement system.

The fourth group deals with developing technologies to measure the shape or defects of specular surfaces. Höfling, Aswendt, and Neugebauer used a diffusive screen on which the fringes are projected and Zhang and North employed a retroreflective screen.

The fifth group emphasizes applying advanced and novel methods to the real academic and engineering world. Lilley, Lalor, and Burton developed a device and method for human body shape measurement. Beraldin et al. put together an eye-safe digital 3-D sensing system for space application. Ettemeyer and Furlong and Pryputniewicz developed systems that can be used for both geometric shape and strain measurement. Accurate strain/stress measurement requires the geometric shape of the object. Reich, Ritter, and Thesing and Osten developed advanced optical 3-D measurement systems combining photogrammetry and fringe projection to measure the geometric shape of complex automotive components; Osten not only measures shape but also deformation and provides a novel, complete application example as the closing mark for this special section.

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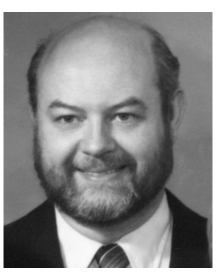

Gordon M. Brown received his BS in mechanical engineering from General Motors Institute in 1958 and his MS in nuclear engineering from the University of Michigan in 1959. He joined Nuclear Sciences Dept., Bendix Aerospace Systems Division in 1962 where he developed radiation detection instrumentation. In 1967 he joined GCO, Inc. where he developed holographic nondestructive testing and optical equipment and invented the holographic tire tester, first as director of holographic engineering and then as director of manufacturing. He joined the Ford Research Laboratory in 1973 where he developed optical equipment for online testing of automotive structures and developed and headed up the Computer Aided Holometry Laboratory, retiring in 1995. He has also run his own company, Optical Systems Engineering, since 1982 where he develops optical based test/measuring equipment for industry. He received the ASNT Achievement Award in 1970, the SPIE Dennis Gabor Award in 1993 for invention of the holographic tire tester and the development of Computer Aided Holometry and the Henry Ford Technology Award from Ford Motor Company in 1994. He is a Fellow of SPIE and OSA. He has 55 publications, 6 issued patents, 25 Ford Research Laboratory technical reports, 62 technical presentations (35 invited). He has been a SPIE Annual Meeting Laser Interferometry Applications Conference Co-Chair since 1991, and a session chair 22 times since 1983. He has reviewed many manuscripts for *Optical Engineering, Applied Optics, Optics Letters, Experimental Mechanics, and The International Journal of Analytical and Experimental Modal Analysis.*

Frank Chen received BS and MS degrees in engineering mechanics from Dalian Technology University in China and a PhD degree in mechanical system engineering from Oakland University, Rochester Hills, Michigan. He was an assistant professor with Tongji University, Shanghai, China, from 1985 to 1989 and was an instructor of applied optics for university professors and college teachers sponsored by the U.S. National Science Foundation in 1997. He is currently a research engineer with Advanced Vehicle Technology Division, Ford Motor Co., an adjunct professor with Oakland University, and a PhD advisor with the University of Michigan. He was the recipient of the Science and Technology Significant Contribution Award and the Science and Technology Achievement Award of the National Education Committee of China in 1988 and 1989, respectively, and the Ford Customer Driven Quality Award and Ford Innovation Award in 1995 and 1997, respectively. He holds one patent and has three patents pending. He has published more than 45 papers in the fields of applied optics and automotive engineering. He is a chapter coauthor of *Advanced Photomechanics*, published in 1992 by Academic Press, China. He has been included in America Marquis Who's Who in Science and Engineering.