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Superfast 3-D Shape Measurement with Binary Defocusing Techniques

Song Zhang, Yajun Wang, Laura Ekstrand, Ying Xu, and Yuanzheng Gong

Summary

High-speed, high-resolution 3-D shape measurement has become increasingly important, with broad applications including medicine, homeland security, and entertainment. Techniques such as structured light, stereovision, and LIDAR have led the way in this field. In recent years, we have made some progress, developing an unprecedented 60 Hz system utilizing a digital fringe projection and phase-shifting method and simultaneously achieving 40 Hz 3-D shape acquisition, reconstruction, and display. However, a conventional digital fringe projection system requires the computer to generate sinusoidal fringe patterns to be sent to the projector. Because 8 bits are usually needed to represent high-contrast sinusoidal patterns, the data-throughput from the computer to the projector is very high. Therefore, a hardware bottleneck must be overcome to further improve the system's speed.

Our recent effort focuses on investigating a new route to eliminate this speed bottleneck. We have developed a technique that generates sinusoidal patterns by properly defocusing binary ones. Because this technique coincides with the operation mechanism of the digital-light-processing (DLP) technology, it leads to three major breakthroughs: (1) it doubles the speed of a real-time 3-D system without significantly increasing its cost; (2) it allows tens-of-kHz 3-D shape measurement with an off-the-shelf DLP projector; and (3) it achieves kHz phase shifting for superior high-speed, high-quality 3-D shape measurement with the DLP Discovery platform.

However, it is difficult for this technique to generate high-quality sinusoidal patterns with large depth range or to realize a multiple-wavelength phase-shifting (MWPS) algorithm. To conquer these challenges, we have developed a passive error-compensation technique and an active optimal pulse-width modulation method (OPWM). The former solves the depth range problem, while the latter provides the opportunity to realize an MWPS technique with its increased depth-measuring range. This paper will explain the principles behind all these technologies, show experimental results, and discuss their advantages and disadvantages.