Computer-Generated Phase-Only Holograms for 3D Displays

"Phase-only Fresnel holograms," which can be displayed on a single SLM without the need for lenses or complicated optical accessories, substantially simplifies 3-D holographic display systems.

Exploring essential concepts, theories, and formulations of these phase-only Fresnel holograms, this book provides comprehensive coverage of modern methods for generating such holograms, which pave the way for commercial products such as compact holographic projectors, heads-up displays, and data security enhancement.

Relevant MATLAB codes are provided for readers to implement and evaluate the theories and formulations of different methods, and can be used as a quick start framework for further research and development.

This is a crucial and up-to-date treatment of phase-only Fresnel holograms for students and researchers in electrical and electronic engineering, computer science/engineering, applied physics, information technology, and multimedia technology, as well as engineers and scientists in industry developing new products on 3-D displays and holographic projection.

Peter Wai Ming Tsang received his Ph.D. degree in electrical and electronic engineering from The University of Hong Kong in 1987. He is currently an Associate Professor with the Department of Electrical Engineering, City University of Hong Kong. Dr. Tsang is actively engaged in research on digital holography and three-dimensional technology, focusing on developing methods for generation, processing, and display of hologram. Apart from research findings reported in international journals, conferences, invited talks, he is also an inventor of 28 patents. Dr. Tsang has served as Guest Editor/Associate Editor for the *IEEE Transaction on Industrial Informatics*. He is currently an Editor of the *ICT Express* (Elsevier). He also served as Topical Editor of the *Applied Optics*, OSA from 2013 to 2019.

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A MATLAB Approach

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Preface

According to experts and researchers, holography is likely to be the ultimate solution to 3-D display technology. In simple terms, holography is a method of capturing the full optical field of a 3-D scene in a 2-D complex image. When a hologram is illuminated with a coherent beam, the scene is reconstructed as a visible 3-D image.

With the advancement of computing and display technologies, it is now possible to generate a digital Fresnel hologram of a 3-D object scene numerically. Theoretically, if a high-resolution spatial light modulator (SLM) that is capable of displaying a complex-valued hologram is available, the image represented by the hologram will be reconstructed as a visible 3-D image that can be observed visually or projected onto a 3-D surface. However, in practice, existing SLM devices can only display either the magnitude or the phase component of a hologram, and a pair of SLMs has to be integrated with a precise and complicated optical arrangement in order to display a complex-valued hologram.

An effective solution to the current problem in holographic display is to generate a phase-only hologram instead of a complex hologram, so that it can be displayed with a single SLM. Such an approach will lead to significant simplification in the holographic display system, as well as enhancement of the brightness of the reconstructed image. On the downside, the quality of the hologram and its reconstructed image will be jeopardized. Although research on overcoming this issue began in the 1960s, it was not until recently that computationally efficient methods were developed for generating phase-only holograms at a video rate of over 25 frames per second.

Most of the modern methods for generating phase-only holograms are reported in individual journal articles. Due to the limited space available, the content of these papers is usually presented in a succinct fashion, focusing more on the theory than the practical aspects. This type of scholarly presentation can be adequate for an experienced researcher, but may present difficulties to someone new to the field who needs to acquire the knowledge within a short time frame, or someone who wants to get a full picture of the state of the art (such as an undergraduate student, a postgraduate student, or an engineering practitioner).

This book is intended to provide comprehensive coverage of modern methods for generating digital phase-only Fresnel hologram for 3-D displays – a kind of hologram that enables 3-D images to be displayed on a single SLM without the need for lenses or complicated optical accessories. The research findings related to this technology will have a significant impact, leading to substantial simplification of the 3-D holographic

display system, paving the way for commercial products such as compact holographic projectors, heads-up displays, and data security enhancement.

The book is aimed at various readers, including serious researchers, academics, engineers, postgraduate students, and undergraduate students taking courses in digital holography. It includes essential theories and formulations presented in a succinct and readable manner, avoiding material that is less relevant to the main theme. MATLAB code is provided for readers to verify and evaluate the theories and formulations whenever applicable and selected programs can also be found online here: www.cambridge.org/pwmtsang. I hope that this book is a good companion for everyone in the course of conducting impactful research and developing contemporary products on 3-D holographic display systems.

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Again, I am thankful for all of you reading this book.