ANALOG AND DIGITAL HOLOGRAPHY WITH MATLAB®

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Preface

Although the concept of holography has been known for decades, the field has seen significant development due to the availability of moderately priced lasers in the market for holographic applications. Also due to the advances in computer technology and computational processes, gathering and processing the experimental data has become much more tangible. Holography is a useful technique because it is the only truly three-dimensional imaging method available. It is used in a plethora of fields, such as 3D nonintrusive testing of cracks and fatigue in equipment, high-axial and lateral-resolution 3D topography of surfaces, 3D particle image velocimetry, 3D stress and deformation measurement, 3D microscopy of transparent phase objects for biomedical imaging, and holographic displays for the entertainment industry, just to name a few. For these reasons, digital and analog holography, along with their many variations (i.e., holographic interferometry, holographic microscopy, holographic tomography, multiwavelength digital holography, phase-shifting holography, compressive holography, coherence holography, computer-generated holography, etc.) have become the methods of choice for various metrological applications in 3D imaging.

This book begins with a brief introduction of the history of holography, types of holograms, and materials used for hologram recording, followed by a discussion of the basic principles of analog and digital holography and an in-depth explanation of some of the most famous fringe-deciphering techniques for holographic interferometry. Besides the traditional topics already mentioned, other related topics are discussed—dynamic holography, non-Bragg orders, and compressive holographic tomography—as well as a nonholographic technique for 3D visualization, i.e., transportation of intensity imaging. Furthermore, the latest topics in the field of holography are discussed for the first time here: compressive holography, coherence holography, nonlinear holography, and polarization holography. The last chapter is dedicated to the progress in holographic and nonholographic 3D display technologies.

Multiple holographic techniques are presented, and readers may master their basic concepts through in-depth theory and applications. This book is a comprehensive study in the sense that traditional and up-to-date topics concerning holographic imaging and displays are presented. The focus is not so much the theory of these 3D imaging techniques, which exists in many references and will be briefly mentioned in this book, but rather the programming side, namely, the exact code that is needed to perform complex mathematical and physical operations. The code associated with each section help the reader grasp the mathematical concepts better through changing and adapting the parameters. Programming these complex equations is tedious and not straightforward; supplying the code with the text makes it easier for students and experienced researchers to concentrate on performing the experiment and simply changing the parameters in the code to get their results.

Because MATLAB® has become the programming language of choice for engineering and physics students, we decided to use this fantastic tool for our code examples. A few authors suggest the use of MATLAB for optics-oriented books, but none is adequate for use in practical situations. There are many books about analog and digital holography, but this book is more practical in terms of MATLAB code and examples because it includes all of the different techniques and codes in a single volume. A supplemental CD-ROM is included, which has a detailed version of the code and functions, as well as typical test images, so that readers do not need to perform the experiment to use the code in the book.

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Logan Williams
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List of Acronyms and Abbreviations

2D-SRNCP	Sorting by reliability, following a non-continuous path
AgBr	Silver bromide
AgCl	Silver chloride
AgH	Silver halide
AgI	Silver iodide
AH	Analog holography
AHI	Analog holographic interferometry
AO	Acousto-optic
AOM	Acousto-optic modulator
API	Application program interface
AR	Active retarder
AS	Angular spectrum
$BaTiO_3$	Barium titanate
BC	Branch cuts
BLU	Backlight unit
BMA	Block-matching algorithm
BS	Beamsplitter
BSO	Bismuth silicon oxide
CAD	Computer-aided design
CCD	Charge-coupled device
CGH	Computer-generated holography
CH	Coherence holography
CL	Collimating lens
CO_2	Carbon dioxide
CPAS	Compensated phase-added stereogram
CRS	Cathode ray sphere
CRT	Coherent raytrace
CRTs	Cathode ray tubes
CS	Compressive sensing
CsH	Compressive holography
DBS	Direct binary search

DC	direct current (zero order)
DCT/IDCT	Discrete cosine transform/inverse discrete cosine transform
DFD	Depth-fused display
DFT	Discrete Fourier transform
DH	Digital holography
DHI	Digital holographic interferometry
DHI-SM	Digital holographic interferometry with spatial multiplexing
DHM	Digital holographic microscopy
DHT	Digital holographic tomography
DL	Delay line
DLP	Digital light processing
DMD	Digital micromirror device
DND	Diffractive nanodevice
DOE	Diffractive optical element
DPSI	Digital phase shifting interferometry
DS	Diffraction specific
DSCP	Diffraction-specific coherent panoramagram
EASLM	Electrically addressable spatial light modulator
EBL	E-beam lithography
ED	Error diffusion
ESPI	Electronic speckle pattern interferometry
fft	Fast Fourier transform
FK	Fresnel–Kirchhoff
FOV	Field of view
FP	Full parallax
FPA	Focal plane array
FPGA	Field programmable gate array
FZP	Fresnel zone plate
GLV	Grating light valve
GPU	Graphical processing unit
GS	Gerchberg and Saxton
GVF	Gradient vector field
GWS	Guided wave scanner
H&D	Hurter–Driffield
HC	Holocamera
HDTV	High-definition TV
HMD	Head-mounted display
HOE	Holographic optical element
HORN	Holographic reconstruction
HPO	Horizontal parallax only
HTh	Hard thresholding
HWP	Half-wave plate
IR	Infrared
ITO	Indium tin oxide

$KNbO_3$	Potassium niobate
LCD	Liquid crystal display
LCOS	Liquid crystal on silicon
LCP	Left circularly polarized light
LED	Light-emitting diode
LEM	Lumped-element model
LID	Laser induced damage
$LiNbO_3$, LN	Lithium niobate
LP	Linear polarizer
LUT	Look-up table
MAC	Multiplication and accumulation
MEMS	Microelectromechanical systems
MO	Microscope Objective
MWDH	Multi-wavelength digital holography
MWDH-SH	Multi-wavelength digital holography with spatial heterodyning
MWDHM	Multi-wavelength digital holographic microscopy
MWDHM-SH	Multi-wavelength digital holographic microscopy with spatial heterodyning
Nd:YAG	Neodymium-doped yttrium aluminium garnet
NLS	Nonlinear Schrödinger
NMRS	Numerical mean square error
OALCD	Optically addressed LCD
OL/ETL	Offset diverging lens and electrically tunable lens
OPEN-GL	Open Graphics Library
OR	Orthoscopic
PAS	Phase-added stereogram
PBS	Polarized beamsplitter
PC	Phase conjugate
PDLC	Polymer-dispersed liquid crystal
PE	Phase enhanced
PMMA	Poly(methyl methacrylate)
POCS	Projection onto constrained sets
PP	Ping-pong
PR	Photorefractive
PR	Patterned retarder
PS	Pseudoscopy
PSDH	Phase-shifting digital holography
PSDH-WP	Phase-shifting digital holography using a wave plate
PSF	Point spread function
PSH	Phase-shifting holography
PTP	Photothermoplastic
PUMA	Phase unwrapping via maximum flow/min-cut
PZT	Piezoelectric transducer

QWT	Quarter-wave plate
RCP	Right circularly polarized light
RGB	Red, green, and blue
RHS	Right hand side
RIP	Restricted isometry propoerty
RMSE	Root-mean-square error
ROACH	Referenceless on-axis complex hologram
RPT	Regularized phase tracking
RS	Rayleigh–Sommerfeld
SADBS	Simulated annealing direct binary search
SAW	Surface acoustic wave
SBN	Strontium–barium niobate
SCF	Spatial coherence function
SF	Spatial filter
SHOT	Single-beam holographic tomography
SHOT-MT	Single-beam holographic tomography using a multiplicative technique
SHOT-RTT	Single-beam holographic tomography using a Radon transform technique
SIP	Shutter in panel
SLM	Spatial light modulator
SMV	Super multiview
SNR	Signal-to-noise ratio
SOP	State of polarization
SVEA	Slowly varying envelope approximation
TCH	Tomographic compressive holography
TCH-MT	Tomographic compressive holography using a multiplicative technique
TeO_2	Tellurium dioxide
TIE	Transport of intensity equation
TIR	Total internal reflection
TMP	Tree-matching pursuit
TV	Total variation
TWIST	Two-step iterative shrinkage thresholding
USAF	United States Air Force
UV	Ultraviolet
VA	Visual acuity
VPO	Vertical parallax only
VR	Virtual reality
VW	Viewing window
WRPM	Wavefront recording plane method

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