Electronic Image Display

Equipment Selection and Operation

Electronic Image Display

Equipment Selection and Operation

Jon C. Leachtenauer

SPIE PRESS
A Publication of SPIE—The International Society for Optical Engineering
Bellingham, Washington USA

Library of Congress Cataloging-in-Publication Data

Leachtenauer, Jon C.
Electronic image display : equipment selection and operation / Jon C. Leachtenauer.
p. cm. – (SPIE Press monograph ; PM 113)
Includes bibliographical references and index.
ISBN 0-8194-4420-0
1. Information display systems. I. Title. II. Series.

TK7882.I6L43 2003
621.3815'422—dc21 2003054304

Published by

SPIE—The International Society for Optical Engineering
P.O. Box 10
Bellingham, Washington 98227-0010 USA
Phone: (1) 360.676.3290
Fax: (1) 360.647.1445
Email: spie@spie.org
Web: www.spie.org

Printed in the United States of America.

PDF ISBN: 9781510607835

To my wife, Mary Ellen, who has patiently awaited completion of this project, and to Amy, Caroline, Paul, Jon, and Eleanor.

Contents

Supplemental Materials: http://spie.org/Samples/Pressbook_Supplemental/PM113_sup.zip

Preface

This book provides guidance on maintaining image quality in the selection and operation of electronic displays. The book is intended for anyone who must perform critical information extraction tasks using electronically displayed continuous-tone imagery, particularly in medical and military applications. It is also of value to managers and operations and maintenance personnel associated with such tasks, as well as supporting procurement personnel. The book is written at multiple levels such that a variety of users can find the information needed to perform their jobs. At a minimum, the individual user can determine how to select and evaluate a viewing system. For those readers interested in proceeding further, the rationale for recommendations is provided, using both image examples and results of empirical studies. Five of the chapters cover the fundamentals of display operation, the human visual system, and image quality measurement. Measurement procedures are provided for those readers who have access to measurement instrumentation, and alternatives are provided for those without such access. A CD is included that contains a wide range of test targets.

The book begins with an overview and examples demonstrating the importance of maintaining image quality in the display process. The display chain is defined and briefly reviewed. A road map for readers with differing needs is provided. Chapter 2 introduces light and color measures and measurement. Chapter 3 provides a brief overview of electronic display operation. Both CRT and flat-panel display technologies are covered, although the emphasis is on CRT technology. The operation of common display controls is demonstrated with graphs and image examples.

Chapters 4 and 5 discuss physical and perceptual display quality measures. Physical measures include measures of resolution, contrast, and noise, both spatial and temporal. Perceptual measures are rating scales and performance measures used to rate the absolute or relative perceived quality of a display. Chapter 6 provides information on the performance of the human visual system. A brief description of the physiology of the eye is followed by a discussion of visual system capabilities—spatial, contrast, and color. The effects of individual differences are also described (including aging effects). The chapter ends with a review of visual performance models, with emphasis on the Barten model used as the basis for the NEMA/DICOM display calibration process. Subsequent chapters draw on the literature using these measures to illustrate the effects of display quality parameters.

The next three chapters of the book (7–9) provide guidance in display selection, covering luminance and spectral measures, resolution measures, and temporal/spatial measures. Each section begins with a listing of the recommended performance parameters and criteria values for both monochrome and color displays. The parameters are defined, the selection criteria are provided, and the measure-

ment procedures are described at both the perceptual and physical levels. Sources of performance information and their interpretation are discussed. Results of studies on key quality measures are provided where available. These studies are drawn from both the surveillance/reconnaissance and medical literature. Numerous figures are provided showing both measurement definitions and image examples to illustrate the effect of the key quality measures. Many of the desired performance measures are not routinely provided by vendors and require sophisticated equipment for measurement. Equipment and measurement procedures are defined for organizations that have either the capability of acquiring and operating such equipment or of specifying measurement performance requirements to vendors. For individuals or organizations without such capabilities, simplified procedures and tools are provided. Many of the tools are perceptual.

The operating environment is a critical factor in maintaining image quality. Recommended procedures are provided in Chapter 10 with emphasis on the control of room lighting. Chapter 10 also covers monitor selection, setup, and maintenance. Monitor luminance compensation techniques to account for the performance of the human visual system and procedures for generating the necessary look-up table are described. Monitor performance degrades with age, so the effects of the aging process are explained. Procedures for periodic quality assessment are defined.

Since software manipulation of an image is an important part of the image chain, Chapter 11 covers pixel processing operations including tonal, color, spatial filtering, and geometric manipulation. The proper sequence of operations is defined and alternative methods of processing discussed. A final chapter provides guidance on hard-copy capture and presentation. Digitizer properties are described, and guidance on digitizer selection and operation is provided. The process of transferring displayed soft-copy images to presentation media such as prints and transparencies is discussed. Printer calibration and look-up table generation procedures are defined to best emulate the originally displayed image on the presentation media. A brief section on electronic projection displays is also included.

Jon C. Leachtenauer
September 2003

Acknowledgments

I have learned from many people over my career. My work in the field of display technology began at the Boeing Company. I would particularly like to thank Dr. Jim Briggs, Mr. John Booth, Mr. Richard Farrell, Dr. Conrad Kraft, Dr. Charles Elworth, and Mr. Richard Schindler.

The idea for this book came from two projects I worked on at the National Exploitation Laboratory (NEL) and the National Imagery and Mapping Agency (NIMA). Both projects were directed at developing guidelines for the display of imagery on soft-copy displays. I was fortunate to work with the staff of the National Information Display Laboratory (NIDL) and Eastman Kodak Company. I would like to thank Mr. Michael Grote, Dr. Ron Enstrom, Mr. Michael Brill, Mr. Albert Pica, Dr. Jeff Lubin, and Dr. Dennis Bechis of the NIDL. I would also like to thank Mr. John Mason, Mr. Matt Pellichia, and Mr. Jim Leuning of Kodak. At NIMA, I would like to thank Mr. Art Cobb.

I deeply appreciate the valuable editing help supplied by Ms. Ellen Schwartz. Review comments provided by Dr. Peter Barten of the Barten Consultancy and Dr. James Florence of ELCAN Optical Technologies were invaluable. I would also like to acknowledge Ms. Margaret Thayer of SPIE, who has been very helpful in guiding me through the publication process.

Finally, I am grateful for the help and support of many other people that have contributed to my knowledge and understanding over the past 45 years. In particular, the staff of NIMA and predecessor organizations have made my career a rewarding experience.

List of Acronyms

ACM	alternating-current matrix
ACR	American College of Radiology
AFC	alternative forced choice
AMLCD	active-matrix liquid crystal display
ASICS	application specific integrated circuits
CCD	charge coupled device
CD	compact disc
CD ROM	compact disc, read-only memory
CIE	Commission Internationale d'Eclairage (International Commission on Illumination)
CL	command level
Cm	contrast modulation
CMYK	cyan/magenta/yellow/black
CPU	central processing unit
CR	computed radiology
CRT	cathode ray tube
CSF	contrast sensitivity function
CT	computed tomography
CTF	contrast transfer function
DAC	digital-to-analog converter
DCS	dynamic color separation
DCT	discrete cosine transform
DICOM	Digital Imaging and Communication in Medicine
DPCM	delta pulse code modulation
dpi	dots per inch
DQE	detective quantum efficiency
DR	dynamic range
DRA	dynamic range adjustment
DROC	differential receiver operating characteristic
DSIS	double-stimulus impairment scale
DSCQS	double-stimulus continuous quality scale
EIA	Electronic Industries Association
FED	field emissive display
FFT	fast Fourier transform
FOV	field of view
FROC	free response operating characteristic
GSD	ground-sampled distance
HDTV	high-definition television
HSB	hue/saturation/brightness

HVS	human visual system
I/O	input/output
IDEX	Image Display and Exploitation
IEC	integrated exploitation facility
IT	information technology
JND	just-noticeable difference
JPEG	Joint Photographic Experts Group
LCD	liquid crystal display
Lmax	maximum luminance
Lmin	minimum luminance
LUT	look-up table
MPEG	Motion Pictures Experts Group
MRI	magnetic resonance imaging
MTF	modulation transfer function
MTFC	modulation transfer function compensation
NC	noise criterion
NEMA	National Electrical Manufacturers Association
NEQ	noise-equivalent quanta
NIDL	National Information Display Laboratory
NIIRS	National Imagery Interpretability Ratings Scale
NIMA	National Imagery and Mapping Agency
NIST	National Institute of Standards and Technology
NPS	noise power spectrum
NS	not (statistically) significant
NTSC	National Television Systems Committee
OLED	organic light-emitting diodes
PAC	picture archiving and communications
PACS	picture archiving and communications system(s)
PC	personal computer
PDP	plasma display panel
PM	photomultiplier
ppi	pixels per inch
RAM	random access memory
RAR	resolution addressability ratio
RER	relative edge response
RGB	red/green/blue
ROC	receiver operating characteristic
SAR	synthetic aperture radar
SCS	sequential color separation
SMPTE	Society of Motion Picture and Television Engineers
SNR	signal-to-noise ratio
SQS	subjective quality scale
STN	supertwisted nematic
TN	twisted nematic
TSD	theory of signal detection

TTA	tonal transfer adjustment
TTC	tonal transfer correction
UCS	uniform chromaticity spacing
USAF	United States Air Force
UV	ultraviolet
VESA	Video Electronics Standards Association