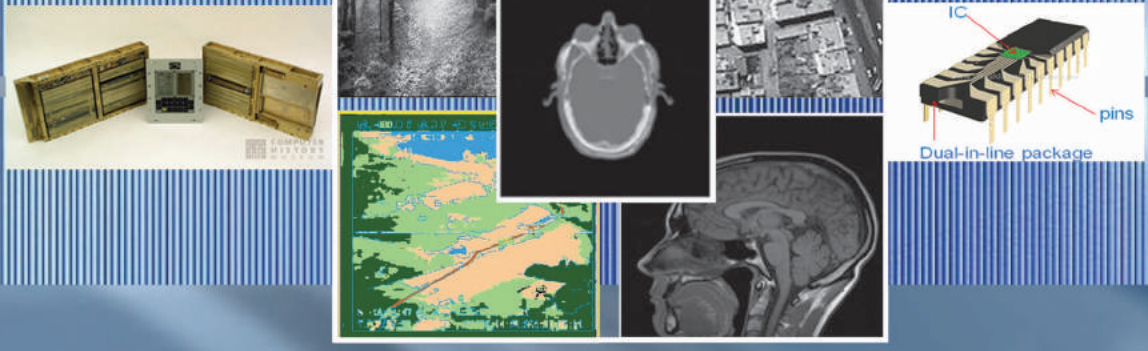
Image Processing and Computer Vision Algorithms for Defence Research

Jharna Majumdar



Defence Research & Development Organisation
Ministry of Defence, India

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Defence Research and Development Organisation
Ministry of Defence, New Delhi – 110 011
2017

DRDO MONOGRAPHS/SPECIAL PUBLICATIONS SERIES

IMAGE PROCESSING AND COMPUTER VISION ALGORITHMS FOR DEFENCE RESEARCH

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Cataloguing-in-Publication

Majumdar, Jharna

Image Processing and Computer Vision Algorithms for Defence Research

DRDO Monographs/Special Publications Series

1. Image Processing 2. Computer Vision 3. Algorithms

I. Title II. Series

004.932:623

ISBN 978-81-86514-91-7

Cover Design	*Printing*	*Marketing*
Rajesh Kumar	SK Gupta	Tapesh Sinha

Published by Director, DESIDOC, Metcalfe House, Delhi – 110 054.

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Preface

The practical aspects of implementing the theoretical book-based knowledge for real life problems related to DRDO projects was the major driving force to write this monograph. The monograph is expected to be of immense benefit for the young DRDO scientists to learn the basic theories and concepts of digital image processing coupled to variety of algorithms to process, analyse and interpret imagery. The hands-on exercises provided in this monograph are likely to enhance the confidence of DRDO scientists to take up challenging projects.

The monograph is distinctly different from the standard text books available in the market. It provides detailed technical explanation, mathematical derivations with numerical example for many of the image processing algorithms. The purpose has mainly been to assist the young DRDO scientists with a first-hand experience of implementation along with good understanding of the theory and algorithms for image processing through simple exercises. The information provided in the Monograph is not available in any standard text book.

The monograph has purposely focused more on examples chosen from the years' long experience. Open source software are available today, where enormous amount of results may be quickly generated simply using pull down menus where the user often is left in darkness about the algorithm details.

This eventually leads to a big dearth of trained manpower in the area of image and video processing. Many private industries and national laboratories of the country are running image and video processing divisions which spend huge amount of money to train the fresh recruits who, inspite of studying 'Digital Image Processing' as an elective subject in their curriculum, hardly know how to implement the algorithms for practical problems.

Dr Jharna Majumdar

Acknowledgements

My sincere thanks are due to the DS & DG (ECS), DRDO for the invitation to undertake this project to write a monograph on 'Image Processing and Computer Vision Algorithms for Defence Research'.

I am also thankful to the Director and staff members of CAIR, DRDO and ADE, DRDO where I had the immense opportunity to work on real life problems often through live trials where image exploration algorithm developed found practical applications.

Sincere thanks are due to Shri Gopal Bhushan, Director, Defence Scientific Information and Documentation Centre (DESIDOC), Delhi for his cooperation and efficient support received in bringing out this monograph.

A special thanks is due for Ms Alka Bansal and Ms Kavita Narwal, Monographs Division of DESIDOC for their excellent support and assistance in every possible way. My special thanks goes to my associate Venkatesh GM for helping me in developing the software codes.

Dr Jharna Majumdar

List of Acronyms

2D	2 Dimensional
A/D	Analog-to-Digital
ACCLAHE	Adaptively Clipped Clahe
ADC	Analog-to-Digital Converter
AHDL	Altera Hardware Description Language
AHE	Adaptive Histogram Equalisation
ALV	Average Local Variances
ALWHE	Average Luminance with Weighted Histogram Equalisation
AMHE	Adaptively Modified Histogram Equalisation
ASIC	Application-Specific Integrated Circuit
AVI	Audio Video Interleave
BBHE	Brightness Preserving Bi-Histogram Equalisation
BIDHE	Bilinear Interpolation Dynamic Histogram Equalisation
BMP	Windows Bitmap
BPDHE	Brightness Preserving Dynamic Histogram Equalisation
CAD	Computer Aided Design
CAN	Controller Area Network
CCD	Charged Couple Device
CCTV	Closed-Circuit Television
CD5	Chasys Draw Image
CDF	Cumulative Distribution Function
CF	Column Frequency
CGM	Computer Graphics Metafile

CGT	Contrast Gain Transformation
CL	Clip Limit
CLAHE	Contrast Limited Adaptive Histogram Equalisation
CLB	Configurable Logic Blocks
COM	Component Object Model
CPLD	Complex Programmable Logic Device
CPU	Central Processing Unit
CRT	Cathode Ray Tube
CT	Computer Tomography
DAC	Digital-to-Analog Converter
DCM	Digital Clock Managers
DDR2	Double Data Rate 2
DSIHE	Dualistic Sub-Image Histogram Equalisation
DSP	Digital Signal Processing
DVI	Digital Visual Interface
ECW	Enhanced Compression Wavelet
EDK	Embedded Development Kit
EER	Entropy Error Rate
EGPR	Edge Preserving Smoothing Filter
EM	Edge Mismatch
EPS	Encapsulated Postscript
ESSIM	Edge-Based Structural Similarity
Exif	Exchangeable Image File Format
FIFO	First in First out
FLIR	Forward-Looking Infrared
FMC	Fpga Mezzanine Card
FPGA	Field Programmable Gate Array
GIF	Graphics Interchange Format
GLCM	Gray Level Co-occurrence Matrix
GLG	Grey Level Grouping
GPIO	General Purpose Input/Output

HCI	Human Computer Interface
HDL	Hardware Description Language
HE	Histogram Equalisation
HPF	High Pass Filter
HS	Histogram Specification
HW-SW	Hardware-Software
IC	Integrated Circuits
IMINT	IMagery INTelligence
IOB	Input Output Block
ISE	Integrated Software Environment
ISNR	Improved SNR
JPEG	Joint Photographic Experts Group
JTAG	Joint Test Action Group
LCD	Liquid Crystal Display
LLMMSE	Local Linear Minimum Mean Squared Error Filter
LMS	Least Mean Square
LOG	Laplacian of Gaussian
LPF	Low Pass Filter
LUM	Linear Unsharp Masking
LVDS	Low-Voltage Differential Signaling
MAE	Mean Absolute Error
ME	Misclassification Error
MHE	Multipeak Histogram Equalisation
MMBEBHE	Minimum Mean Brightness Error Bi-Histogram Equalisation
MOS	Mean Opinion Score
MP	Mega Pixel
MP4	Mpeg-4
MPEG	Moving Pictures Expert Group
MSE	Mean Square Error
MUX	Multiplexer
NRE	Non Recurring Engineering

NTSC	National Television Systems Committee
ODG	Open Document Graphics
PAL	Phase Alternating Line
PAL	Programmable Array Logic
PBM	Portable Bitmap File Format
PCB	Printed Circuit Board
PDF	Portable Document Format
PDF	Probability Density Function
PGM	Portable Gray Map
PLA	Programmable Logic Array
PLD	Programmable Logic Device
PNG	Portable Network Graphics
PPM	Portable Pix Map
PROM	Programmable Read Only Memory
PSNR	Peak Signal-to-Noise Ratio
QM	Quality Metric
RAE	Relative Foreground Area Error
RAM	Random Access Memory
RF	Row Frequency
RMSE	Root Mean Square Error
RMSHE	Recursive Mean-Separate Histogram Equalisation
RN	Region Non-uniformity
ROM	Read Only Memory
SDRAM	Synchronous Dynamic Random Access Memory
SECAM	System Electronique Couleur Avec Memoire
SF	Spatial Frequency
SIMULINK	Simulation and Model-based Design
SNR	Signal to Noise Ratio
SOC	System on Chip
SPI	Serial Peripheral Interface
SPLD	Simple Programmable Logic Devices

SVG	Scalable Vector Graphics
SWF	Shockwave Flash
SysGen	System Generation
TIFF	Tagged Image File Format
TTM	Time to Market
UART	Universal Asynchronous Receiver Transmitter
UAV	Unmanned Air Vehicle
USARTS	Universal Synchronous/Asynchronous Receiver/Transmitter
USB	Universal Serial Bus
VFBC	Video Frame Buffer Controller
VHDL	VHSIC Hardware Description Language
VHSIC	Very High Speed Integrated Circuit
VLSI	Very-Large-Scale Integration
VSK	Video Starter Kit
WMF/EMF	Windows Metafile/Enhanced Metafile
WMV	Windows Media Video
WTHE	Weighted and Thresholded Histogram Equalisation
XPA	Xilinx Power Analyser
XPS	Xml Paper Specification
XPS	Xilinx Platform Studio

CHAPTER 1

Fundamentals of Digital Image Processing

1.1 INTRODUCTION TO DIGITAL IMAGE PROCESSING

A digital image is a two-dimensional (2-D) function f(x, y), that has been discretised both in spatial coordinates and amplitude. x and y are the spatial (plane) coordinates, and f is the amplitude for any pair of coordinates (x, y). A digital image is therefore composed of a finite number of elements, each of which has a particular location and value. These elements are called the intensity or brightness or grey level of the image at that point and referred to as picture elements, image elements, pixels or pels.

There are some arguments about where image processing ends and fields such as image analysis, image interpretation or computer vision starts.

The continuum from image processing to computer vision can be broken up into low-, mid-, and high-level processes.

EXAMPLE

Low-level Processing

Input: Image

Output: Image

Examples: Noise removal, image sharpening

Mid-level Processing

Input: Image

Output: Attributes

Examples: Object recognition, segmentation

High-level Processing

Input: Attributes

Output: Understanding

Examples: Scene understanding, autonomous navigation

Digital image processing (DIP) focusses on:

- Improvement of pictorial information for human visual perception
- Use of computer algorithms to perform processing on digital images
- Processing of image data for storage, transmission and representation for autonomous machine interpretation

Digital image processing allows a wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise and signal distortion during processing. Images are defined as two dimensions and hence digital image processing may be modelled in the form of multi dimensional systems.

1.2 HISTORY OF DIGITAL IMAGE PROCESSING[1]

Early 1920s: One of the first applications of digital imaging was in the Newspaper Industry by the name The Bart lane cable picture transmission service. By this services:

- Images were transferred by submarine cable between London and New York
- Pictures were coded for cable transfer and reconstructed at the receiving end on a telegraph printer

Figure 1.1. Early digital image.

Mid to late 1920s: Improvements in the Bart lane system resulted in higher quality images as:

- New reproduction processes based on photographic techniques
- Increased number of tones in reproduced images

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About the Book

This monograph covers the basic theories and concepts of digital image processing coupled to variety of algorithms to process, analyse, and interpret imagery. This book elaborates on image enhancement techniques, histogram equalisation and adaptive enhancement, spatial filters, image restoration and adaptive filters, edge and line detection techniques, and image segmentation. Various quality metrics for image processing algorithms are also provided along with hardware implementation of image processing algorithms. It provides detailed technical explanation, mathematical derivations with numerical example for many of the image processing algorithms. The purpose has mainly been to provide scientists, researchers, and students with a first-hand experience of image processing along with good understanding of the theory and algorithms for image processing through simple exercises.

About the Author

Dr Jharna Majumdar obtained her BTech in ECE and DIIT in Computer Technology from IIT, Kharagpur in 1969 and 1970, respectively. She received her PhD in Electrical Engineering in 1980. She has more than 30 years of professional career in the country and abroad. During 1983-1989, she worked as a Research Scientist at the Institute for Real Time Computer Systems and Robotics, Karlsruhe, Germany.

She joined DRDO at Centre for Artificial Intelligence & Robotics (CAIR), Bangalore in 1990 and worked in research areas related to robot vision. She later joined Aeronautical Development Establishment (ADE), Bangalore in 1995 and worked for the UAV programmme of ADE. She is presently working as Dean R&D and Professor, Computer Science and Engineering at Nitte Meenakshi Institute of Technology, Bengaluru.

Her research interests are: UAV image exploitation, automatic target recognition, change detection, multi sensor fusion, etc. She has 65 papers to her credit. She has received certificate of appreciation from the President, Stanford Research International, California. She is a member of IIPR, IEEE and Fellow of Aeronautical Society of India.

978-81-86514-91-7

Price ₹ 1400/-
US $38
UK £29

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Ministry of Defence, Metcalfe House, Delhi - 110054, India