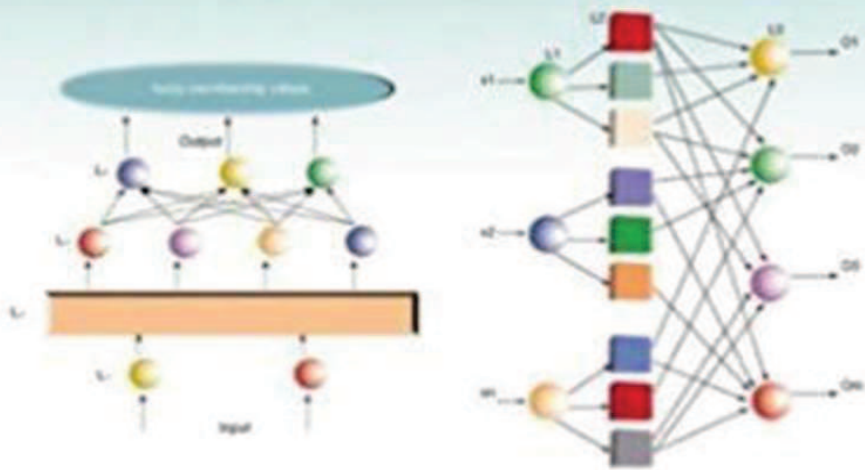


Computer Vision and Fuzzy-Neural Systems



ARUN D. KULKARNI

Computer Vision and Fuzzy-Neural Systems

ARUN D. KULKARNI

Complete guide to applying fuzzy-neural systems in computer vision

neural networks and fuzzy logic are trans- of computer vision, making it possible for applications to learn and make decisions, and visual data far more effectively. Now, Dr. Arun together the latest research and applications. world's first comprehensive tutorial and reference.

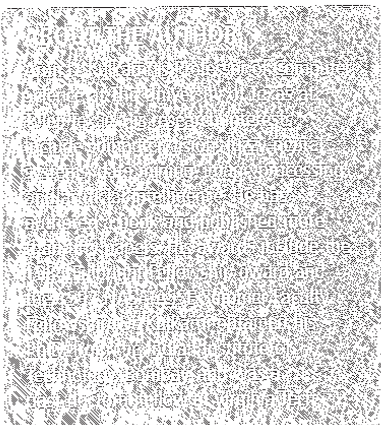
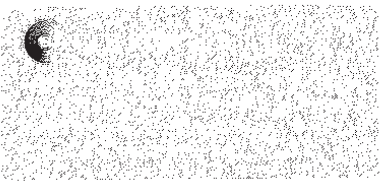
By reviewing the fundamentals of computer stages of a computer vision system. He shows traditionally have been implemented via que- then he introduces approaches that neural networks, fuzzy inference systems, and work models. Coverage includes:

techniques such as radiometric or geometric

tion, supervised and unsupervised classification, memories, and other techniques for improving performance

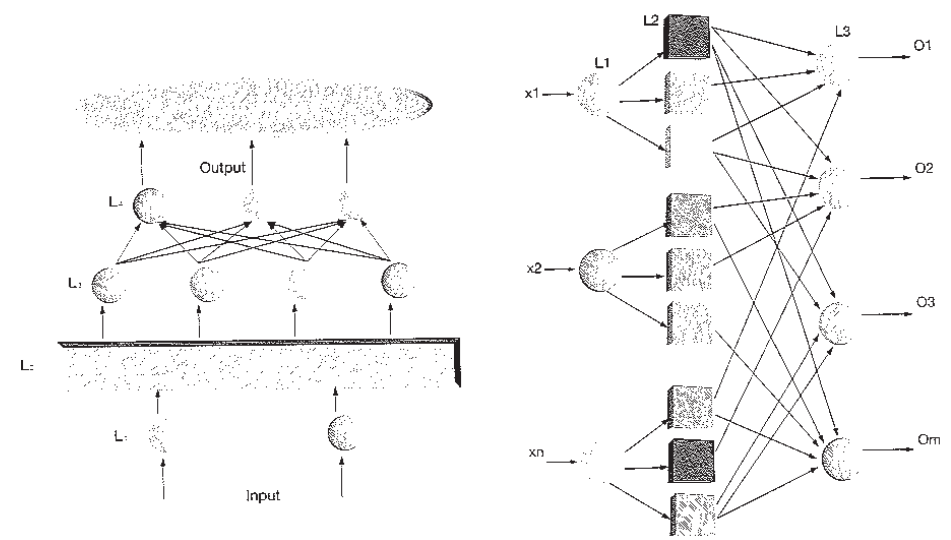
vision applications: remote sensing, medical precision, data mining, character recognition, and more

Computer Vision and Fuzzy-Neural Systems illuminates state-of-the-art technology through hands-on exercises, principles, and proven algorithms. It is an essential resource for every engineer, scientist, and programmer in computer vision and a wide range of related fields. It can also be used as a textbook for undergraduate- or graduate-level courses in computer vision.



Computer Vision and Fuzzy-Neural Systems

Computer Vision and Fuzzy-Neural Systems



PH PTR

ARUN D. KULKARNI

**COMPUTER VISION AND
FUZZY-NEURAL SYSTEMS**

Arun D. Kulkarni



Prentice Hall PTR
Upper Saddle River, NJ 07458
www.phptr.com



Library of Congress Cataloging-in-Publication Data

Kulkarni, Arun D., 1947-

Computer vision and fuzzy-neural systems / Arun D. Kulkarni.

p. cm.

Includes bibliographical references and index.

ISBN 0-13-570599-1

1. Computer vision. 2. Neural networks (Computer science) 3. Fuzzy systems. I. Title

TA1634 .K85 2001

2001016382

006.3'7--dc21

. CIP

Editorial/production supervision: *Vincent Janoski*

Acquisitions editor: *Bernard Goodwin*

Editorial Assistant: *Michelle Vincenti*

Marketing manager: *Dan DePasquale*

Manufacturing manager: *Alexis R. Heydt*

Cover design director: *Jerry Votta*

Composition: *PreTeX, Inc.*



©2001 by Prentice Hall

Published by Prentice Hall PTR

Prentice-Hall, Inc.

Upper Saddle River, New Jersey 07458

Prentice Hall books are widely used by corporations and government agencies for training, marketing, and resale.

The publisher offers discounts on this book when ordered in bulk quantities. For more information, contact Corporate Sales Department, Phone: 800-382-3419; Fax: 201-236-7141; E-mail: corpsales@prehall.com
Or write: Prentice Hall PTR, Corp. Sales Dept., One Lake Street, Upper Saddle River, NJ 07458.

All products or services mentioned in this book are the trademarks or service marks of their respective companies or organizations.

Figures 1.1, 1.7, 2.33, 10.1, 10.2, 10.3, 10.4, 10.5, 10.6, 10.7, 10.8, 10.9 are printed courtesy Space Imaging, Inc., copyright © 2000 by Space Imaging; Figures 6.29, 6.30, 10.15, 10.16, 10.40, 10.41, 10.42, 10.43, 10.44, 10.45, 10.52, 10.53, 10.54, 10.55, 10.56 copyright © IEEE, reprinted with permission; Figures 1.8, 2.20, 5.46a are printed courtesy John Green and Timothy Mathers, Eastman Kodak Company, Inc.; Figures 2.4, 2.28 are reprinted courtesy The MathWorks, Inc.

MATLAB® is a registered trademark of The MathWorks, Inc., 3 Apple Hill Drive, Natick, MA, 01760-2098, USA, Tel: (508)647-7000, Fax: (508)647-7101, email: info@mathworks.com; Web: www.mathworks.com.

All rights reserved. No part of this book may be reproduced, in any form or by any means, without permission in writing from the publisher.

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN 0-13-570599-1

Prentice-Hall International (UK) Limited, *London*

Prentice-Hall of Australia Pty. Limited, *Sydney*

Prentice-Hall Canada Inc., *Toronto*

Prentice-Hall Hispanoamericana, S.A., *Mexico*

Prentice-Hall of India Private Limited, *New Delhi*

Prentice-Hall of Japan, Inc., *Tokyo*

Pearson Education Asia Pte. Ltd.

Editora Prentice-Hall do Brasil, Ltda., *Rio de Janeiro*

This book is dedicated to the memory of my parents

CONTENTS

Preface	xi
1 INTRODUCTION	1
1.1 Introduction	1
1.2 Computer Vision	8
1.3 Neural Network Models	11
1.4 Fuzzy Logic Techniques	15
1.5 Fuzzy Neural Systems	18
1.6 Summary	23
1.7 Outline	23
References	24
Exercises	26
2 COMPUTER VISION FUNDAMENTALS	27
2.1 Introduction	27
2.2 Human Vision System	28
2.3 Perception	30
2.4 Input-Output Devices	39
2.5 Camera Models	42
2.6 Sampling and Quantization	45
2.7 Preprocessing Techniques	47
2.8 Image Transforms	48

2.9	Feature Extraction and Recognition	54
2.10	Summary	57
	References	57
	Exercises	58
3	FUZZY LOGIC FUNDAMENTALS	61
3.1	Introduction	61
3.2	Fuzzy Sets and Membership Functions	62
3.3	Logical Operations and If-Then Rules	67
3.4	Fuzzy Inference System	70
3.5	Defuzzification	80
3.6	Fuzzy Set Representation with a Cube	85
3.7	Hedges	87
3.8	Fuzzy Systems as Function Approximators	90
3.9	Extraction of Rules from Sample Data Points	93
3.10	Fuzzy Basis Functions	96
3.11	Design and Implementation of a Fuzzy Inference System	98
3.12	Summary	99
	References	100
	Exercises	101
4	NEURAL NETWORK FUNDAMENTALS	105
4.1	Introduction	105
4.2	Neuron Representation	108
4.3	Perceptron	113
4.4	Linear Networks	121
4.5	Single-Layer Networks with Nonlinear Transfer Functions	125
4.6	Backpropagation	128
4.7	Kohonen Feature Maps	134
4.8	Competitive Learning	138
4.9	Hopfield Networks	141
4.10	Counterpropagation Network	145
4.11	Summary	148
	References	148
	Exercises	151

5	PREPROCESSING	153
5.1	Introduction	153
5.2	Gray-Level Histogram	154
5.3	Point Operations	155
5.4	Filtering Techniques	162
5.5	Noise Removal Techniques	171
5.6	Mathematical Morphology	177
5.7	Edge Detection Techniques	181
5.8	Neural Network Models for Brightness Perception and Boundary Detection	192
5.9	Image Restoration	196
5.10	Geometric Corrections and Registration	209
5.11	Interpolation	212
5.12	Summary	219
	References	220
	Exercises	222
6	FEATURE EXTRACTION	227
6.1	Introduction	227
6.2	Segmentation and Shape Descriptors	228
6.3	Moment Invariants	234
6.4	Feature Extraction using Orthogonal Transforms	236
6.5	Neural Network Models for FT Domain Feature Extraction	246
6.6	Neural Network Model for WHT Domain Feature Extraction	253
6.7	Invariant Feature Extraction using ADALINE	256
6.8	Texture Features	260
6.9	Neural Network Models for Texture Analysis	267
6.10	Summary	272
	References	275
	Exercises	277
7	SUPERVISED CLASSIFIERS	281
7.1	Introduction	281
7.2	Discriminant Functions	285

7.3	Minimum Distance Classifiers	287
7.4	Bayes Classifier	288
7.5	Tree Classifiers	290
7.6	Neural Network Models for Classification	295
7.7	Fuzzy Neural Network Models	313
7.8	Summary	343
	References	344
	Exercises	347
8	UNSUPERVISED CLASSIFIERS	351
8.1	Introduction	351
8.2	Conventional Clustering Techniques	353
8.3	Self-Organizing Networks	364
8.4	Fuzzy C-Means Clustering	378
8.5	Fuzzy Neural Network Models for Clustering	382
8.6	Summary	388
	References	389
	Exercises	391
9	ASSOCIATIVE MEMORIES	395
9.1	Introduction	395
9.2	Discrete Autocorrelator	397
9.3	Discrete Bidirectional Associative Memory	400
9.4	Bidirectional Associative Memories with Multiple Input–Output Patterns	409
9.5	optimal Associative Memory	412
9.6	Selective Reflex Memory	413
9.7	Temporal Associative Memory	414
9.8	Counterpropagation Networks as Associative Memory	415
9.9	Fuzzy Associative Memory	417
9.10	Computer Vision Applications	420
9.11	Summary	421
	References	421
	Exercises	423

10	APPLICATIONS	427
10.1	Introduction	427
10.2	Remote Sensing	428
10.3	Medical Image Processing	441
10.4	Image Data Compression	452
10.5	Data Mining and Computer Vision	462
10.6	Biometric Applications	468
10.7	Character Recognition	476
10.8	Knowledge-Based Pattern Recognition	478
10.9	Stereo Vision	482
10.10	Summary	487
	References	488
	Exercises	493
	Index	495
	About the Author	509
	About the CD	514

PREFACE

Computer vision deals with extracting meaningful descriptions of physical objects from images. Computer vision has many practical applications such as remote sensing, medical image processing, robot vision, military reconnaissance, mineral exploration, cartography, forestry, etc. Recent developments in neural networks and fuzzy logic have changed the computer vision field dramatically. During the past few years there has been a large and energetic upswing in research efforts aimed at synthesizing fuzzy logic with neural networks. Neural networks provide algorithms for learning and are modeled after the physical architecture of the brain. Fuzzy logic deals with issues such as reasoning at the semantic or linguistic level and is based on the way brain deals with inexact information. Consequently, the two technologies complement each other. A variety of fuzzy-neural network models have been used in computer vision. This book deals with the topic of fuzzy-neural systems as applied to computer vision. The book provides exercises at the end of each chapter, and it can be used as a textbook for a course in computer vision at senior undergraduate or master degree level. The book also provides engineers, scientists, researchers, and students involved in computer vision a comprehensive, well-organized, up-to-date overview of recent techniques used in computer vision. The book is the outgrowth of my lecture notes in various classes that I taught at The University of Texas at Tyler. The material in the book is well tested in the classroom. It also has been published as journal articles and has been presented at various professional meetings.

Every effort has been made to produce a book that is easy to understand without oversimplification of the material. The mathematical level is well within grasp of a first-year graduate in a technical discipline such as engineering, computer science, or technology requiring preparation in classical set theory, discrete mathematics, matrix algebra, and computer programming. The textbook presents several worked-out examples along with MATLAB examples. All chapters contain exercises.

AUDIENCE

This book is intended for use as a textbook for courses in computer vision, pattern recognition, or image processing at either the senior undergraduate level or first year graduate level. It is also suitable for use as a self-study guide by researchers, professionals, or engineers who want to learn about recent advances in computer vision and fuzzy-neural systems. Many techniques described in the book are also useful in data mining.

ORGANIZATION

The book consists of ten chapters. Chapter 1 provides the overview of the book. Chapter 2 describes the fundamentals of computer vision. It describes various stages of a computer vision system. These stages can be implemented with conventional statistical techniques, neural networks, fuzzy inference systems, or fuzzy-neural network models. Chapter 3 and Chapter 4 describe fuzzy logic and neural network models, respectively. Chapter 5 describes pre-processing techniques such as radiometric or geometric corrections. Chapter 6 deals with feature extraction. Chapter 7 and Chapter 8 deal with supervised and unsupervised classification. Chapter 9 concerns with associative memories, and Chapter 10 presents various applications of computer vision. Topics such as remote sensing, medical image processing, data compression, data mining, character recognition, and stereovision are discussed in Chapter 10. The dependency chart for the chapters is shown in Figure P.1. The book covers material for two semesters in computer vision. Chapters 1 through 5 can be covered in the first semester and Chapters 6 through 10 can be covered during the second semester. For a one-semester course Chapters 1, 2, 3, 4, 5, 7, and 10 can be covered.

ACKNOWLEDGMENTS

The author is indebted to a number of individuals who, directly or indirectly, contributed to the text. In particular, I wish to express my thanks and gratitude to Professors S. C. Sahasrabudhe, B. L. Deekshatulu for introducing me the fields of image processing and pattern recognition, respectively. I am thankful to Professors George Whitson and Ron King for their valuable discussions in areas such as neural networks and clustering, and Dr. Rod Tabler and Professor. Joydeep Ghosh for reviewing the manuscript and for their helpful comments. I also would like to thank Mike Martin and Professor John Burch for their support and advise during this project. I have learned a lot from my students, and would like to thank many individuals who have worked with me in the course of their graduate programs: Viren Wasnikar, J. Zhao, P. Byars, Charles Cavanaugh, G. B. Giridhar, P. Coca, Nageshwar Rao, N. R. Baktula, V. K. Muniganti, Vijay Nagpurkar, John Taylor, Brian Koontz, I. Yazdapanhi, and many others.

I also would like to thank Space Imaging, Eastman Kodak, Sound and Vision Inc., Institute of Electrical and Electronics Engineers (IEEE), and The University of Texas at Tyler for giving permission to use their copyrighted images and figures in the book. Finally I would like to thank Bernard Goodwin, editor and publisher at Prentice Hall for his support and patience

during this project; Vincent Janoski, production editor for his help in coordinating the project; The MathWorks, Inc. customer service team for their continued support of use of MATLAB Toolboxes.

Last but not the least, I would like to thank my wife Vasanti and our children Himani, Prathit, and Shradha for their encouragement, support, and patience.

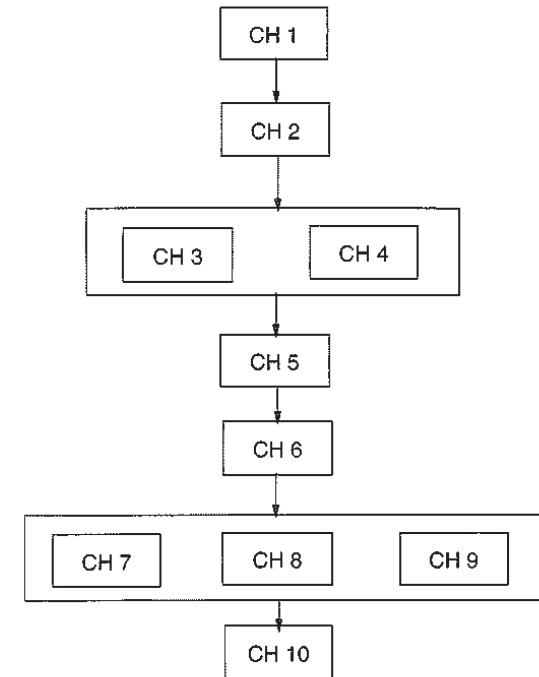


Figure P.1 Chapter dependency diagram

His research interests include computer vision, fuzzy-neural systems, data mining, image processing, and artificial intelligence. He has authored a book and published more than 50 referred papers. His awards include the 1984 Fulbright Fellowship award and the 1997 NASA/ASSE Summer Faculty Fellowship. Dr. Kulkarni obtained his Ph.D. from the Indian Institute of Technology, Bombay, and was a post-doctoral fellow at Virginia Tech. AUTHORS. Arun D. Kulkarni. No contact information provided yet. Daxwanger, W. A. and Schmidt, G.: Neural and fuzzy approaches to vision-based parking control, *Control Engrg. Practice* 4(11) (1996), 1607-1614. Google Scholar. 3. Kuo, R. J.: A robotic die polishing system through fuzzy neural networks, *Comput. Industry* 32(3) (1997), 273-280. Google Scholar. 4. Zadeh, L. A.: Roles of soft computing and fuzzy logic in the conception, design and deployment of information/intelligent systems, in: O. Kaynak, L. A. Zadeh, B. Turksen, and I. J. Rudas (eds), *Computational Intelligence: Soft Computing and Fuzzy-Neuro Integration with Applications*, NATO ASI Series F: Computer and Systems Sciences, Vol. 162, 1998, pp. 1-9. Google Scholar.