



DIGITAL IMAGE PROCESSING

Rafael C. Gonzalez

University of Tennessee Perceptics Corporation

Richard E. Woods

Perceptics Corporation



ADDISON-WESLEY PUBLISHING COMPANY

Reading, Massachusetts · Menlo Park, California · New York Don Mills, Ontario · Wokingham, England · Amsterdam · Bonn Sydney · Singapore · Tokyo · Madrid · San Juan · Milan · Paris



Library of Congress Cataloging-in-Publication Data

Gonzalez, Rafael C.

Digital image processing / by Rafael C. Gonzalez, Richard C.

Woods.

p. cm.

Includes bibliographical references and index.

ISBN 0-201-50803-6

1. Image processing—Digital techniques.
 I. Woods, Richard C.

II. Title.

TA1632.G66 1992

621.36'7-dc20

91-30866

CIP

Copyright © 1992 by Addison-Wesley Publishing Company, Inc.
All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the publisher. Printed in the United States of America.

1 2 3 4 5 6 7 8 9 10-MA-95949392



CONTENTS

Chapter 1	napter 1 INTRODUCTION		1
1.	1 Back	ground	1
		al Image Representation	6 7
		Fundamental Steps in Image Processing	
1.		ents of Digital Image Processing Systems	10
		Image Acquisition	10
		Storage	14
		Processing	15
		Communication	16
		Display	16 17
1.5		Organization of the Book References	
	110101		18
Chapter 2 DIGITAL IMAGE FUNDAMENTALS		21	
2.1	1 Elem	Elements of Visual Perception	
	2.1.1	Structure of the Human Eye	22
	2.1.2	Image Formation in the Eye	24
	2.1.3	Brightness Adaptation and Discrimination	25
2.	2 A Sin	A Simple Image Model	
2.3	3 Samp	ling and Quantization	31
	2.3.1	Uniform Sampling and Quantization	31
	2.3.2	Nonuniform Sampling and Quantization	38
2.4	4 Some	Some Basic Relationships Between Pixels	
	2.4.1	Neighbors of a Pixel	40
	2.4.2	Connectivity	41
	2.4.3	Labeling of Connected Components	42
	2.4.4	Relations, Equivalence, and Transitive Closure	43
		Distance Measures	45
		Arithmetic/Logic Operations	47
2.5	5 Imagi	ing Geometry	51
	2.5.1		52
	2.5.2		56
		Camera Model	61
		Camera Calibration	67
	2.5.5	0 0	68 71
2.6		Photographic Film	
	2.6.1	Film Structure and Exposure	71



- 2.6.2 Film Characteristics
- 2.6.3 Diaphragm and Shutter Settings
- 2.7 Concluding Remarks

References

Problems

IMAGE TRANSFORMS Chapter 3

- 3.1 Introduction to the Fourier Transform
- 3.2 The Discrete Fourier Transform
- 3.3 Some Properties of the Two-Dimensional Fourier Transform
 - 3.3.1 Separability
 - 3.3.2 Translation
 - 3.3.3 Periodicity and Conjugate Symmetry
 - 3.3.4 Rotation
 - 3.3.5 Distributivity and Scaling
 - 3.3.6 Average Value
 - 3.3.7 Laplacian
 - 3.3.8 Convolution and Correlation
 - 3.3.9 Sampling

3.4 The Fast Fourier Transform

- 3.4.1 FFT Algorithm
- 3.4.2 Number of Operations
- 3.4.3 The Inverse FFT
- 3.4.4 Implementation

3.5 Other Separable Image Transforms

- 3.5.1 Walsh Transform
- 3.5.2 Hadamard Transform
- 3.5.3 Discrete Cosine Transform
- 3.5.4 The Haar Transform
- 3.5.5 The Slant Transform
- 3.6 The Hotelling Transform
- 3.7 Concluding Remarks

References

Problems

Chapter 4 IMAGE ENHANCEMENT

4.1 Background

- 4.1.1 Spatial Domain Methods
- 4.1.2 Frequency Domain Methods



DOCKET

Explore Litigation Insights



Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time** alerts and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.

