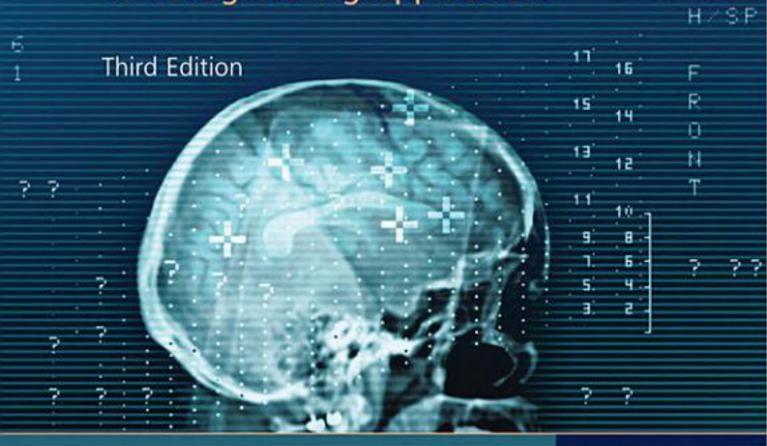
Timothy J. Ross

1 28

Fuzzy Logic

With Engineering Applications



WILEY

FUZZY LOGIC WITH ENGINEERING APPLICATIONS

Third Edition

FUZZY LOGIC WITH ENGINEERING APPLICATIONS

Third Edition

Timothy J. Ross University of New Mexico, USA



This edition first published 2010 © 2010 John Wiley & Sons, Ltd

First edition published 1995

Second edition published 2004

Registered office

John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at www.wiley.com.

The right of the author to be identified as the author of this work has been asserted in accordance with the Copyright, Designs and Patents Act 1988.

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, except as permitted by the UK Copyright, Designs and Patents Act 1988, without the prior permission of the publisher.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Designations used by companies to distinguish their products are often claimed as trademarks. All brand names and product names used in this book are trade names, service marks, trademarks or registered trademarks of their respective owners. The publisher is not associated with any product or vendor mentioned in this book. This publication is designed to provide accurate and authoritative information in regard to the subject matter covered. It is sold on the understanding that the publisher is not engaged in rendering professional services. If professional advice or other expert assistance is required, the services of a competent professional should be sought.

Library of Congress Cataloging-in-Publication Data Ross, Timothy J.

Fuzzy logic with engineering applications / Timothy J. Ross.-3rd ed. p. cm.

Includes bibliographical references and index. ISBN 978-0-470-74376-8 (cloth)

1. Engineering mathematics. 2. Fuzzy logic. I. Title.

TA331.R74 2010

620.001'511313-dc22

2009033736

A catalogue record for this book is available from the British Library.

ISBN: 978-0-470-74376-8

Set in 10/12pt Times Roman by Laserwords Pvt Ltd, Chennai, India Printed in Singapore by Fabulous Printers Pte Ltd

This book is dedicated to my brother Larry, my cousin Vicki Ehlert and my best friends Rick and Judy Brake, all of whom have given me incredible support over the past 5 years. Thank you so much for helping me deal with all my angst!

CONTENTS

	About the Author	Xiii
	Preface to the Third Edition	XV
1	Introduction	1
	The Case for Imprecision	2
	A Historical Perspective	3
	The Utility of Fuzzy Systems	6
	Limitations of Fuzzy Systems	8
	The Illusion: Ignoring Uncertainty and Accuracy	10
	Uncertainty and Information	13
	The Unknown	14
	Fuzzy Sets and Membership	14
	Chance Versus Fuzziness	16
	Sets as Points in Hypercubes	18
	Summary	20
	References	20
	Problems	21
2	Classical Sets and Fuzzy Sets	25
	Classical Sets	26
	Operations on Classical Sets	28
	Properties of Classical (Crisp) Sets	29
	Mapping of Classical Sets to Functions	32
	Fuzzy Sets	34
	Fuzzy Set Operations	35
	Properties of Fuzzy Sets	37
	Alternative Fuzzy Set Operations	40
	Summary	41
	References	42
	Droblams	42

viii CONTENTS

3	Classical Relations and Fuzzy Relations	48
	Cartesian Product	49
	Crisp Relations	49
	Cardinality of Crisp Relations	51
	Operations on Crisp Relations	52
	Properties of Crisp Relations	52
	Composition	53
	Fuzzy Relations	54
	Cardinality of Fuzzy Relations	55
	Operations on Fuzzy Relations	55
	Properties of Fuzzy Relations	55
	Fuzzy Cartesian Product and Composition	55
	Tolerance and Equivalence Relations	62
	Crisp Equivalence Relation	63
	Crisp Tolerance Relation	64
	Fuzzy Tolerance and Equivalence Relations	65
	Value Assignments	68
	Cosine Amplitude	69
	Max-Min Method	71
	Other Similarity Methods	71
	Other Forms of the Composition Operation	72
	Summary	72
	References	73
	Problems	73
4	Properties of Membership Functions, Fuzzification,	
•	and Defuzzification	89
	Features of the Membership Function	90
	Various Forms	92
	Fuzzification	93
	Defuzzification to Crisp Sets	95
	λ-Cuts for Fuzzy Relations	97
	Defuzzification to Scalars	98
	Summary	110
	References	111
	Problems	112
	Trodens	112
5	Logic and Fuzzy Systems	117
	Part I Logic	117
	Classical Logic	118
	Proof	124
	Fuzzy Logic	131
	Approximate Reasoning	134
	Other Forms of the Implication Operation	138
	Part II Fuzzy Systems	139
	Natural Language	140
	Linguistic Hedges	142

	CONTENTS ix	
Fuzzy (Rule-Based) Systems	145	;
Graphical Techniques of Inference	148	3
Summary	159)
References	161	
Problems	162	2
6 Development of Membership Functions	174	ļ
Membership Value Assignments	175	,
Intuition	175	,
Inference	176	
Rank Ordering	178	
Neural Networks	179	
Genetic Algorithms	189	
Inductive Reasoning	199	
Summary	206	
References	206	
Problems	207	
7 Automated Methods for Fuzzy Systems	211	
Definitions	212	
Batch Least Squares Algorithm	215	
Recursive Least Squares Algorithm	219	
Gradient Method	222	
Clustering Method	227	
Learning From Examples	229	
Modified Learning From Examples	233	
Summary	242	
References	242	
Problems	243	,
8 Fuzzy Systems Simulation	245	5
Fuzzy Relational Equations	250	
Nonlinear Simulation Using Fuzzy Systems	251	
Fuzzy Associative Memories (FAMS)	255	
Summary	264	
References	265	
Problems	266)
9 Decision Making with Fuzzy Information	276)
Fuzzy Synthetic Evaluation	278	3
Fuzzy Ordering	280)
Nontransitive Ranking	283	3
Preference and Consensus	285	
Multiobjective Decision Making	289	
Fuzzy Bayesian Decision Method	294	
Decision Making Under Fuzzy States and Fuzzy Actions	304	
Summary	317	1