

Vladimir Kovalevsky

Image Processing with Cellular Topology



Springer

Image Processing with Cellular Topology

Vladimir Kovalevsky

Image Processing with Cellular Topology

 Springer

Vladimir Kovalevsky
Computer Science Department
University of Applied Sciences Berlin
Berlin, Germany

ISBN 978-981-16-5771-9 ISBN 978-981-16-5772-6 (eBook)
<https://doi.org/10.1007/978-981-16-5772-6>

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Singapore Pte Ltd. 2021

This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Abstract

The book explains why the definition of the boundary by means of the 4- and 8-neighborhood is wrong and suggests the use of the classical topological definition of the boundary while the digital image should be considered as an abstract cell complex. This approach has great significance in digital image processing. It allows a topological justification of many terms used in image processing. However, what is more important from the practical point of view is that we show how to work with cell complexes without the need of a large additional memory. We also suggest a graphical representation of boundaries in a cell complex. Three algorithms for tracing and encoding boundaries in binary, indexed, or color images are described. The code is free of loss of information so that the image can be exactly reconstructed from the code. The book also describes the theory of digital straight segments and an algorithm for dissolving a digital curve in digital straight segments. Another approach for dissolving digital curves into line segment is the polygonal approximation which is also presented in the book. The book considers different approaches to the detection of edges and suggests a new efficient method of edge detection usable for two- and three-dimensional images. Methods of efficiently encoding edges are suggested. Also, boundaries of subsets in a 3D space called surfaces are considered. Algorithms for efficiently encoding surfaces and for reconstructing 3D sets from the codes of all surfaces contained in this set are suggested. In the last chapter, the author suggests discussing the use of the classical definition of the derivative as the limit of the relation of the increment of the function divided by the increment of the argument while the latter tends to zero. This definition cannot be used for estimations of derivatives of non-analytical functions because it becomes wrong at small increments of the argument. Suggested is a useful method using an optimal value of the increment.

Contents

1	Introduction	1
	References	6
2	Boundary Presentation Using Abstract Cell Complexes	7
2.1	Abstract Cell Complexes	8
2.2	Coordinates of Cells	12
2.3	Boundaries in Cell Complexes	14
2.4	Graphical Presentation of Boundaries	15
	References	16
3	Boundary Tracing in Binary Images Using Cell Complexes	17
3.1	Algorithm “EncodeBin”	22
	Reference	27
4	Boundary Tracing and Encoding in Color Images	29
4.1	Rules of the Choice of the Direction of the Next Step	30
4.2	Encoding Boundaries with the CORB Algorithm	31
4.2.1	Properties of the Loops	37
4.2.2	The Sub-Algorithm “MakeTree”	38
4.2.3	The Sub-Algorithm “Restore”	42
4.2.4	Tracing Equations of Curves	45
4.3	Encoding Boundaries with the Algorithm “MakeLineList”	46
4.3.1	Restoration of Encoded Images	56
	References	59
5	Boundary Polygonization	61
5.1	Encoding Boundaries by Digital Straight Segments	61
5.1.1	Digital Straight Segments	63
5.1.2	Properties of Digital Straight Segments	64
5.1.3	Recognition of a DSS During the Tracing	72
5.1.4	Algorithms for Subdividing a Line into Digital Straight Segments	74

5.1.5	Inequalities for Cracks and Points of a DSS in Combinatorial Coordinates	81
5.2	Method of Additional Integer Parameters of DSS	83
5.2.1	Algorithm for Calculating the Additional Parameters	85
5.2.2	Algorithm for Encoding the Additional Parameters	87
5.2.3	Applications of DSS with Additional Parameters	88
5.3	Estimating the Length of Digital Curves	90
5.4	Polygonal Approximation	91
5.4.1	The Sector Method	91
5.4.2	Improvement of the Sector Method	93
5.4.3	Applications of Polygonal Approximation	99
5.4.4	Algorithm for Recognizing Circles in Distorted Images	102
5.4.5	Recognition of Ellipses in Distorted Images	106
5.4.6	Mathematical Foundation of Ellipse Recognition	106
5.4.7	Algorithm of Recognizing an Ellipse	108
	References	111
6	Edge Detection in 2D Images	113
6.1	Important Preprocessing	113
6.1.1	Sigma Filter: The Most Efficient One	116
6.1.2	Extreme Value Filter	121
6.2	The New Method of Edge Detection	125
6.3	Applications of Edge Detection	131
6.3.1	Image Compression by Means of Edge Detection	132
6.3.2	Recognition of Circular Objects	134
6.3.3	Recognition of Bicycles in Street Images	135
	References	137
7	Surface Traversing and Encoding in 3D Images	139
7.1	Algorithm “Spiral Tracing”	141
7.1.1	The Idea of the Spiral Tracing	141
7.1.2	The Reversible Tracing	145
7.1.3	Computer Experiments	148
7.1.4	Efficiency of Encoding	148
7.1.5	Examples of Codes	149
7.1.6	Conclusion	150
7.2	Algorithm CORB_3D for Traversing and Encoding Surfaces	150
7.2.1	Properties of the Bubbles	159
7.3	Theory of Digital Plane Patches	161
7.3.1	Properties of Digital Plane Patches	162
7.3.2	The Problem of the Segmentation of Surfaces into DPPs	166
7.3.3	The Partial Problem of the Recognition of a DPP	167
7.3.4	The Partial Problem of the “Choice”	169
	References	169

- 8 Edge Detection in 3D Images** 171
 - 8.1 Preprocessing of 3D Images 171
 - 8.1.1 Algorithm Sigma3D 172
 - 8.1.2 Algorithm Extrem3D 173
 - 8.2 Algorithm Edge3D 175
- 9 Discussion** 179
 - 9.1 Optimal Increment for Calculating Derivatives 179
 - 9.2 Conclusion 184
 - Reference 184