Preface

There are works which wait, and which one does not understand for a long time; the reason is that they bring answers to questions which have not yet been raised; for the question often arrives a terribly long time after the answer.

– Oscar Wilde

This edited volume is based on talks and discussions at the 11th Workshop on Theoretical Foundations of Computer Vision, entitled “Geometry, Morphology, and Computational Imaging,” which took place April 07–12, 2002, at Schloss Dagstuhl in Germany. The central subject of all contributions is the digital picture, representing real objects in a discrete or digitized form, which have to be printed, visualized, processed, analyzed, transformed, etc. The aspect of computational efficiency is always of great relevance due to the massive amount of data in a single digital picture. Therefore we have decided to focus the workshop and the ensuing volume on issues pertaining to the geometry and shape of objects in images, and efficient computational structures and algorithms for extracting and representing them. The contributions are of relevance for computer graphics, computer vision, image analysis, visualization, etc. — digital imaging, in short.

Researchers in digital geometry, mathematical morphology and computational geometry came together at this meeting, and the finally published papers were influenced not only by this meeting but also by a careful reviewing process. The editors decided to group all chapters into the following four parts.

Part I: Geometry: Models and Algorithms

The first part of this book is on geometric treatments of images. Kokichi Sugihara reconsiders in Chap. 1 the Minkowski algebra for figures and proposes a new formulation under the name of “hyperfigures” together with a physical interpretation. Peter Veehuert studies in Chap. 2 uncertain geometry in the plane where points are replaced by uncertainty regions, and proposes an algorithm for reestablishing global consistency of uncertain geometric relations in digital images.

In Chap. 3, Atsushi Imiya et al. define a medial axis of a random point set in low dimensions and develop an algorithm for extracting curve and surface skeletons. Mirela Tănase and Remco Veltkamp propose in Chap. 4 a novel type of decomposition for polygonal shapes based on the straight line skeleton.

Patrick Baker shows in Chap. 5 how lines rather than points can be used as the basic atoms of computer vision based on a prismatic line constraint based on reconstruction of local shape using line measurements and rotation only.

The last two chapters in Part I consider combinatorial aspects of digital halftoning. Tetsuo Asano et al. discuss several problems related to combinatorial and computational geometry and provide some algorithms. Kunihiko Sadakane
et al. propose an efficient evaluation of a halftoned image based on a discrepancy measure. They also propose algorithms to minimize the discrepancy measure.

**Part II: Property Measurements in the Grid and on Finite Samples**

The second part combines two papers on triangulated surfaces, two on length and surface area estimation (with special attention given to convergence rates), and two papers on approximating borders of sets of grid points in 2D or 3D space.

Lars Linsen and Hartmut Prautzsch consider in Chap. 8 local triangulations (fan clouds) as an efficient alternative to more costly triangular mesh generations for real-time rendering of complex three-dimensional scenes. Emanuele Danovaro et al. discuss in Chap. 9 discrete gradient fields defined on triangular meshes in 3D space, which leads to decompositions of scalar fields defined on simplicial complexes generalizing the watershed transform originally introduced for 2D morphological image segmentations.

Chapter 10 by David Coeurjolly et al. shows that global estimates of discrete normals support a method of multigrid-convergent surface area estimation for 3D objects given as subsets of the regular orthogonal grid (e.g., voxel data in 3D image analysis). Ryszard Kozera et al. assume discrete sampling of curves in Chap. 11, and study piecewise Lagrange interpolation with respect to the convergence rate of length estimators (and also of trajectories) in dependence of the distribution of samples on the given curve.

Akihiko Torii et al. discuss in Chap. 12 non-linear approximations of borders of connected sets of points in 2D or 3D regular orthogonal grids based on curvature analysis: the approximated shapes also allow a digitization at a higher resolution than that given in the original image data, and experiments illustrate such a resolution conversion. Isabelle Sivignon and David Coeurjolly approximate in Chap. 13 a connected set of points in the 3D regular orthogonal grid by a Euclidean polyhedron, following the optimality criterion of minimizing the number of vertices.

**Part III: Features, Shape and Morphology**

The third part of this book is devoted to the analysis of features and shapes in images. Such concerns can be categorized by a general name, morphology, which deals with various notions intermediate between the well-known worlds of topology and geometry, and in some sense it contains both.

A special branch of this field of research is the highly formalized theory of mathematical morphology, with its algebraic structure of operators based on orders and lattices, which is represented here by four papers. Chapter 14 by Christian Ronse deals with the so-called “flat operators” for grey-level images, and generalizes them to images where the numerically ordered grey-levels can be replaced by arbitrarily ordered elements, like colors, region labels, etc. In Chap. 15, Isabelle Bloch applies morphological operators to models in modal logic, and shows how new logical operations can be built in this way, with possible applications in spatial reasoning. Chapter 16 by Jos Roerdink proposes a model of multiresolution pyramids based on morphological operations, which
generalizes previous constructions. In Chap. 17, Ulrich Eckhardt studies the invariants of the median filter (which is in fact a “flat” morphological operator) by a combination of lattice-theoretical and topological methods; in this way he extends and corrects previous studies on this subject.

Mathematical morphology is not only a theory, it has many concrete applications. Akira Asano et al. devote Chap. 18 to the analysis of textures by the interaction of the image with a primitive shape taken at various sizes (the so-called “granulometry” or “morphological size distribution”); the shape is chosen by simulated annealing. Another approach to texture analysis is probabilistic, based on Gibbs random fields. Chapter 19 by Georgy Gimel’farb et al. belongs to this approach, it shows how to extract basic tiles forming texels (texture elements) from such a random field.

The topological structuration of features like edges is important both in image analysis and synthesis. In Chap. 20, Ullrich Köthe does this by introducing a combinatorial topological structure called the XPMap (extended planar map), which he applies to existing segmentation algorithms (edge detection, watershed, etc.).

Part IV: Computer Vision and Scene Analysis

The final part in this volume starts with two papers “at signal level,” discussing edge enhancement and Gaussian noise in an image. Corners in 2D images and line segments in 3D images are the subject of the next two chapters, followed by two contributions studying motion in a video sequence. The final chapter specifies a calibration method for panoramic cameras based on distributions of line segments in 3D space.

PeiFeng Zeng and Tomiro Hirata study in Chap. 21 the application of distance transforms for image enhancement: after calculating “transient areas” (which are defined by distances to edge segments), image values are adjusted for the purpose of contrast enhancement. Chapter 22 by Lyle Noakes and Ryszard Kozera discusses the impact of Gaussian image noise on shape recovery, assuming that a photometric stereo method is applied.

Hidekata Hontani and Kichiro Deguchi identify in Chap. 23 “dominant corners” in 2D polygonal contour figures, applying a scale-space method based on curvature flow. Chapter 24 by Yasushi Hirano et al. proposes two Voronoi-diagram-based features (degree of concentration, and the difference of density) allowing us to analyze spatial distributions of line segments in 3D space (e.g., occurring in the context of 3D medical imaging).

In Chap. 25, Daniel Keren et al. present a Bayes-based maximum-likelihood estimate for motion recovery between two successive frames of a video sequence, where special attention is paid to the recovery of the focus-of-expansion. The proposed global method leads to improved results, but incurs an increase in computational complexity. John Barron et al. consider a calculated optical flow field for successive frames, and apply in Chap. 26 a Kalman filter framework to depth recovery if camera translation can be assumed.

Chapter 27 is devoted to a recently developed architecture of panoramic cameras: a line-sensor rotates around an axis of revolution (radius $R$), with a
constant viewing angle $\omega$. It is shown that triples of line segments in a scene can be used for calibrating $R$ and $\omega$.

The editors thank all reviewers for their detailed responses and the authors for efficient collaboration in ensuring a high-quality publication. Beside the editors, the reviewers were:

Akira Asano         Ulrich Köthe
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Daniel Keren        Michael Werman
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December 2002       Tetsuo Asano, Reinhard Klette, Christian Ronse
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