Book Review: Wolfgang Förstner and Bernhard P. Wrobel, “Photogrammetric Computer Vision”

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Having been anticipated eagerly in the community for several years, this book finally appeared in the autumn of 2016. It is the most recent culmination point of the lifework of two distinguished German researchers, Wolfgang Förstner and Bernhard Wrobel, Professors emeriti at the University of Bonn and the Technical University of Darmstadt, respectively. Dedicated to the geometry of multiple view analysis, this book is unique in bringing together the geometrical concepts of photogrammetry and computer vision while at the same time giving a sound statistical treatment of the related topics. Its sheer volume of more than 800 pages indicates the enormous amount of knowledge accumulated by the authors: this book is weighty both physically and in terms of its content. It provides a modern and timely synopsis of geometrical problems in photogrammetry and computer vision.

The book starts with an introductory chapter making the reader familiar with different tasks in photogrammetry and computer vision, discussing the role of models in these fields and giving an overview about the structure of the book. In this context, the authors give something like a road map for reading the book, indicating clusters of chapters that can be read as self-contained texts on specific topics. They also suggest how to group various parts of the book for putting together the contents of basic and advanced courses of photogrammetry and computer vision. This information is very helpful for the readers, particularly for those who are also involved in teaching. The remaining 16 chapters are grouped into three parts. The first part consists of three chapters and introduces generic concepts of statistics and parameter estimation. The second part, consisting of six chapters, describes to the principles of projective geometry and its combination with statistics. The third part, also consisting of six chapters, is dedicated to image orientation and 3D surface reconstruction. An appendix dealing with basics and linear algebra completes the book.

Part I starts with an introduction to probability theory, discussing basic concepts of probability distributions and variance propagation (chapter 2). The following chapter presents the theory of hypothesis tests, while the last chapter of Part I is dedicated to parameter estimation. It presents all the estimation techniques relevant for photogrammetry and computer vision, but also methods for evaluating the quality of the results and for outlier detection. While providing the theoretical foundations of the statistical concepts required for understanding the remainder of the book, part I also provides a stand-alone tutorial text on adjustment theory and variance propagation. Despite being concise in the description of its topics, it gives a comprehensive overview about the theory of adjustment. It also provides the reader with many invaluable suggestions for the practical implementation of parameter estimation techniques by presenting the most important methods in the form of algorithms and by additionally giving hints for an efficient implementation, e.g. based on sparse matrices.

Part II starts with an introduction to the representation of 2D and 3D geometrical entities by homogeneous vectors or matrices (chapter 5). Chapter 6 describes transformations in projective geometry. It focusses on straight-line preserving transformations (collineations) and its specializations such as the similarity transformation and includes a discussion of invariants of such transformations. In addition, it also deals with transformations mapping points to hyperplanes (correlations). The following chapter (chapter 7) extensively discusses geometrical operations such as joins and intersections, all solved by matrix-vector products based on specific construction matrices, and methods for deriving distances and angles between geometrical entities. It also presents minimal solutions for determining transformations and conics. Due to their importance in modelling the imaging process and the movement of rigid objects, rotations are the topic of an entire chapter (chapter 8), explaining different representations and their mutual dependencies in detail. Chapter 9 introduces the concept of oriented projective geometry, for instance allowing decisions whether 3D points are in front of or behind the imaging plane. Chapters 5 to 9 constitute a stand-alone tutorial to the representation of geometric entities and (2D and 2D) transformations in projective geometry.

Chapter 10 brings together the concepts of projective geometry and uncertainty, leading to a modern framework for geometric reasoning and estimating geometric entities. It starts with a discussion of the representation of uncertainty for geometric entities. As the covariance matrices of homogeneous vectors may become singular, the authors introduce a minimal representation that leads to regular covariance matrices and also allows for dealing with points or lines at infinity in estimation procedures. This representation is based on the projection of homogeneous vectors to the tangent space on the unit sphere after spherical normalisation. Variance propagation, the next topic of this chapter, is relatively simple because most operations with homogeneous vectors take bilinear forms. Consequently, decisions about geometrical relations between entities such as points or lines based on statistical tests, requiring only one parameter (the significance level of the test). The remainder of the chapter is dedicated to overdetermined estimation problems, starting with closed form solutions for estimating lines, points, and planes as well as for estimating transformations. After that, iterative solutions for maximum likelihood estimation are described for some geometrical problems, most prominently the estimation of a homography from corresponding points. In this context, the authors take advantage of the minimal representations based on spherical normalization introduced earlier.

Part III starts with an overview on scene, camera and image models as well as an introduction to basic notions and tasks in orientation and 3D reconstruction (chapter 11). Chapter 12 is dedicated to the geometry of a single image and orientation tasks involving individual images. The description of the sensor models brings together the standard Euclidean and the projective representations of perspective cameras with and without distortion. In addition, it presents models for non-straight-line preserving mappings such as those required for working with Fisheye cameras. The discussion of orientation procedures is very comprehensive. It comprises both direct solutions requiring no approximate values and optimal solutions for the estimation of the unknown parameters, presenting different variants for estimating the projection matrix or the orientation parameters of the Euclidean representation. A discussion of 3D reconstruction techniques based on single images and additional scene knowledge concludes this chapter. Chapter 13 is dedicated to the geometry of the image pair. Again, it describes the geometrical concepts both in terms of Euclidean and projective geometry. After that, it focuses on estimation procedures based on homologous points, covering all the relevant cases and presenting algebraic solutions working without approximate values as well as iterative schemes for optimal parameter estimation. The 3D reconstruction of object points and the expected precision of the resultant points is presented next, followed by a brief discussion of absolute orientation. The chapter concludes with a comparison of different solutions for the orientation of the image pair. Chapter 14 discusses the geometry of the image triplet, introducing the concept of the trifocal tensor and giving direct solutions for estimating the parameters of that tensor as well as optimal solutions based on bundle adjustment. The general case of bundle block adjustment is the topic of chapter 15. In the context of block adjustment, the authors present methods for exploiting the sparsity of the resultant normal equation matrices, discuss the determination of the gauge of a block, and analyse the theoretical precision of the unknowns for specific block configurations. The solution for the general case of bundle adjustment is presented for both perspective and spherical cameras, along with considerations for quality control. Again, the authors put forward spherical normalisation as a way for dealing with points at infinity. An entire subchapter is dedicated to camera calibration, giving many practical hints for good image configurations, quality control and model selection. It is followed by a discussion of various aspects of obtaining approximate values by taking into consideration the results of the previous chapters. The discussion of bundle adjustment concludes with a discussion of view planning. The last chapter of the book is dedicated to surface reconstruction, focussing on techniques for estimating 2.5D elevation grids from reconstructed 3D points, covering different functional models and regularization techniques as well as outlier models and a discussion of the theoretical precision.

Part III discusses the topics that usually form the main content of books dedicated to photogrammetry. Readers with background knowledge in adjustment theory and projective geometry can use it as a stand-alone text giving a modern synopsis of the geometrical foundations of photogrammetry. The consistent treatment of the statistics of the described processes make this part unique. The only thing one could regret from a practical point of view for developers of photogrammetric systems is the absence of a discussion of line cameras and of the integration of direct sensor orientation.

Given the scope and the volume of the book, one could assume that it is difficult to navigate through it, but this is not the case: Firstly, there is a detailed index at the end of the book; secondly, the authors themselves give hints for navigating through it, identifying connections between clusters of chapters. Thirdly, the chapters are more or less self-contained, each starting with its own internal table of contents and an introductory section that sets the scene for readers who want to focus on the specific topic of a chapter to get started. At the end of each chapter, the book provides theoretical and practical exercises of different levels of complexity that support the understanding of its contents. On the homepage of the book, the authors provide supplementary material, including MATLAB code for solving some of these exercises.

This book is a great achievement. With few exceptions mentioned earlier, it gives a comprehensive overview of the geometrical concepts of photogrammetry and computer vision. Consequently, it will be invaluable as a book of reference for graduate students, researchers, software engineers and practitioners as well as for teachers involved in these subjects. The book may work a bit less well as the first point of contact with photogrammetry for undergraduate students. They might be overwhelmed by it because the contents of a beginners' course in photogrammetry are mixed with more advanced topics throughout the text. However, even at that level, it is relevant for deepening the students' knowledge, and it provides an excellent basis for advanced reading. For advanced readers, the clear structure by topic is certainly an advantage of the book.

Bibliographical details:

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