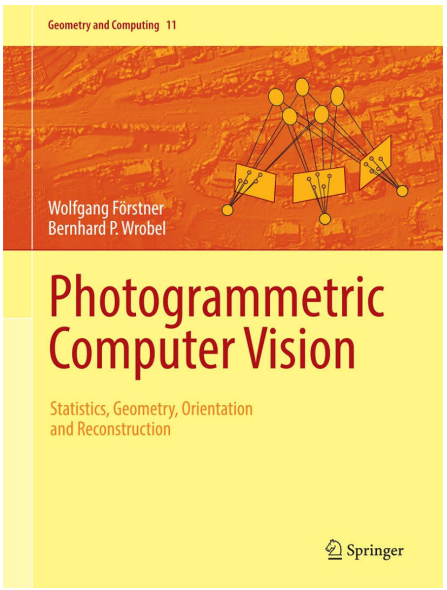

Photogrammetric Computer Vision: Statistics, Geometry, Orientation and Reconstruction

Wolfgang Förstner and Bernhard P. Wrobel.

Springer International Publishing, Switzerland, 2016. Hard cover ISBN 978-3-319-11549-8 $69.97 Amazon, e-book 978-3-319-11550-4, $55.99 Amazon. xvii and 816 pp, diagrams, images, tables, algorithms, index.

Reviewed by: Charles Toth, Research Professor, The Ohio State University, Columbus, Ohio and Stewart Walker, San Diego, California.

Photogrammetric Computer Vision represents a milestone publication in modern photogrammetry. Long years of intense labor by two legendary authors, eminent professors of geomatics from Bonn and Darmstadt, and a talented team of assistants, have produced a true *magnum opus,* a rare masterpiece, providing the most comprehensive description of the underlying theory at the intersection of photogrammetry and computer vision. The significance of the book is in a way mirrored by its huge weight and size (286 x 216 mm; 11.2 x 8.5 inches), with over 800 pages in small fonts.

The book opens with a short introduction, which immediately defines both photogrammetry and computer vision and thus explains their joint treatment in the book. While the authors are firm that they will not cover hardware, they say enough in a few pages to indicate the scope of photogrammetric applications and allow readers to link this book to more traditional texts. Importantly, the focus on probabilistic and statistical reasoning is succinctly justified. They include useful suggestions on how the book can be used for courses at different levels. These confirm that the contents far exceed anything that can be reasonably included in a single course.

Part I, "Statistics" and "Estimation" lays the critical ground work in three intense chapters. Chapter 2, "Probability Theory and Random Variables" is followed by the short Chapter 3 on "Testing". These set the tone for the book – an advanced level of discourse, reinforced by mathematical rigor and innumerable equations. The reader must therefore concentrate and expect slow progress, but will be amply repaid, especially by the key Chapter 4, "Estimation", well over a hundred pages covering models and estimation, i.e. it includes what most of us were brought up to call "least-squares adjustment". One of your reviewers experimented by revising the topic of variance components: the concise exposition on pages 91-93 is exemplary.

Part II, "Geometry", is a little longer and covers the elements that will be used in the photogrammetric processes themselves in Part III. As we were led to expect in Part I, the treatment is detailed and demanding. Chapters 5-10 cover "Homogenous Representations of Points, Lines and Planes", "Transformations", "Geometric Operations", "Rotations", "Oriented Projective Geometry" and "Reasoning with Uncertain Geometric Entities".

With 440 pages under our belts, we are ready for the entrée, Part III, "Orientation and Reconstruction". This brings the mathematical groundwork to bear on topics we all know: Chapter 11, "Overview", is a useful outline of the material to come in the next five chapters, "Geometry and Orientation of the Single Image", "Geometry and Orientation of the Image Pair", "Geometry and Orientation of the Image Triplet", "Bundle Adjustment" and "Surface Reconstruction". In Chapter 11, too, the authors present a taxonomy of cameras and explain their emphasis on "central" cameras, i.e. with a single viewpoint. Perhaps some readers will be disappointed that the "non-central" camera, i.e. no single viewpoint, enjoys less coverage, since it includes the pushbroom design used to acquire most satellite imagery; a special case. We are in familiar territory in Part III, the substance of photogrammetry, but the rigorous mathematical approach and the widespread use of techniques and nomenclature from computer vision provide a freshness. In Chapter 12, for example, well known concepts related to the single photo are presented and the collinearity equations are given in their standard form, but the reader is reminded that the image coordinates therein are inhomogenous, i.e. concepts from photogrammetry and computer vision

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are blended together in a seamless explanation. Never has a reader come to bundle adjustment so well prepared! Many of us have read papers in these areas to help our understanding, so this book can save much time and effort. The authors are very much leaders rather than followers, yet they masterfully weave hundreds of important sources into the narrative.

Textbooks often include appendices on topics such as matrix algebra. In this case there are 17 pages of "Basics and useful relations from linear algebra". This is no "dime tour" for the novice, as the appearance of "Laplacian development of a determinant" on the first page and the 177 equations indicate the advanced treatment provided. The 15 pages of references include almost 400 items, each with the page numbers on which it is cited. The book ends with a 16-page index, in three columns, in a 7-point font. Beyond that, there is a substantive, useful website, still under construction and containing slides, code, examples and other materials, at http://www.ipb.uni-bonn.de/book-pcv/. Indeed, the thinness of the errata at http://www.ipb.uni-bonn.de/book-pcv/pdfs/16-11-30-PCV-A-errata.pdf echoes your reviewers' pleasure in reporting that there are few typos or small mistakes; the care of the authors and their team of assistants has been complemented by that of the publisher. Thus, readers are given every resource possible to engage with the book's challenging content.

The coverage and depth of the material are clear from the above description, but the thoroughness and attention to detail deserve great emphasis. The authors do not shy from presenting difficult material, often with explanations from mathematics and statistics that may be inaccessible to some of the readership. We recommend that the use of the book be accompanied by other courses, for example engineering mathematics and probability and statistics. Similarly, readers will enjoy it more if they have first studied photogrammetry at a lower level and understand concepts such as cameras, stereoscopy, stereo models, triangulation, elevation extraction, orthorectification and the practical applications of these concepts. Fine textbooks such as *Elements of Photogrammetry* (Wolf), or *Introduction to Modern Photogrammetry* (Mikhail, Bethel, and McGlone) have their role here. The excellence of the material in this book is undergirded by careful cross-referencing and the occasional use of a didactic manner whereby important concepts, when they are first introduced, are written in italics in the outer margins. At the beginning of the book, there are five pages tabulating symbols and abbreviations. These authors do not cut corners! Equally importantly, there are exercises, including basics, computer exercises and proofs, at the end of each chapter for the reader to try and the website provides much-related material.

Most of us will be reluctant to leave *Observations and Least Squares*, the 1976 classic by Mikhail and Ackermann, behind. Many of us have become struggled to become comfortable with *Multiple View Geometry in Computer Vision* by Hartley and Zisserman. These invaluable references should certainly stay on the shelf, yet, armed with 2.8 kg (6.2 lb) of *Photogrammetric Computer Vision* and 2.9 (6.4) of the *Manual of Photogrammetry*, students have the firepower to address almost any photogrammetric challenge they meet. There is much in these pages to fascinate or test every photogrammetrist, from undergraduate to postdoc or seasoned professional. The book provides the most mathematical and statistical treatment of photogrammetry available. This is as it should be, because those who will move our science forward in the years to come must have training at the highest level. Moreover, the book will attract readers not only from the traditional, geomatics home of photogrammetry, but also from computer vision. The quality of research in the latter has richly enhanced the former over the past 30 years or so, as Professor Förstner himself has commented; thus a perspective that encourages the communities to cooperate through shared notation and nomenclature is a boon. We must repeat that this book is an advanced and demanding one, which raises the teaching of photogrammetry to a higher level; but those who use it as the basis for careful, conscientious study and master its content will be amply rewarded. It is astonishing that such a comprehensive, epochal resource should be so inexpensive – on 14 August 2017, the hardcover was available for $69.97 on Amazon Prime, i.e. with free shipping, and the e-book for $55.99. Whether this is a quirk or a sign of the times, enjoy the opportunity: purchase *Photogrammetric Computer Vision* immediately! On page 1, the authors give a hint that a second volume, on image processing, analysis and interpretation is in preparation – we can hardly wait.