THE PHOTOGRAMMETRIC RECORD

The Photogrammetric Record 32(158): 182–183 (June 2017)
DOI: 10.1111/phor.12187

BOOK REVIEW

PHOTOGRAMMETRIC COMPUTER VISION – STATISTICS, GEOMETRY, ORIENTATION AND RECONSTRUCTION. By Wolfgang Förstner and Bernhard P. Wrobel. *Springer International Publishing,* 2016. ISBN 978-3-319-11549-8. 816 pages with 59 colour figures. Price: £44·99 hardback; £35·99 eBook.

Textbooks are an essential component in the daily life of students, practitioners and researchers. In both photogrammetry and computer vision there are many very useful textbooks on these individual scientific fields. During the last few decades, however, we have observed a steady merging between photogrammetry and computer vision, reflected in the term *photogrammetric computer vision*.

Both authors, Wolfgang Förstner and Bernhard Wrobel, have been active architects in this merger. One is reminded of the paper "Computer vision and photogrammetry – mutual questions: geometry, statistics and cognition" by Förstner (2002). This paper is remarkable in the sense that the commonalities, but also the differences, between photogrammetry and computer vision were discussed in detail. Many items mentioned 15 years ago have found their way into the respective counter discipline today. This book on *Photogrammetric Computer Vision* can thus be seen as a logical continuation of the authors' academic work, dedicated to building bridges between photogrammetry and computer vision.

The book consists of three main parts: I – Statistics and Estimation; II – Geometry; and III – Orientation and Reconstruction. In total, 16 chapters plus an appendix are distributed over the three parts, covering 816 pages. Marginal notes help the reader to maintain an orientation within the book, but also leave space for their own notes. The structure allows readers to select single chapters for isolated study – the aim of the authors is to leave the constituent parts as stand-alone as possible. Depending on the prior knowledge and intention of the reader, section 1·3·2 provides hints on how to use the book, indicating which chapters might be of particular interest. This section even provides a graphical overview of the book's structure in order to enable a better orientation. Each of the three component parts is accompanied by an overall introduction; furthermore, each chapter closes with exercises which help the reader to assess whether the material has been understood. In addition, many algorithms are provided in pseudo-code.

Part I on "Statistics and Estimation" develops statistical knowledge and estimation methods up to a level needed to understand notions and methods used later in the book. Independent of that, this part is a very good recap of statistical basics. Estimation is addressed in Chapter 4 and provides the backbone for efficient and accurate handling of redundant observations in various problems. Besides linear and non-linear estimators based on the Gauss–Markov model, this chapter includes relevant topics such as outlier detection in the context of robust estimation.

Part II on "Geometry" guides the reader through all relevant aspects of geometry: homogeneous entity representation of points, lines and planes (Chapter 5); transformations (Chapter 6); geometric operations (Chapter 7); rotations (Chapter 8); oriented projective geometry (Chapter 9); and reasoning with uncertain geometric entities (Chapter 10). The authors consistently apply the calculus of algebraic projective geometry, a concept which might be new to some colleagues with a photogrammetric background. However, this representation has many advantages over computations using non-homogeneous coordinates. Besides other benefits, it offers the possibility of handling most geometric operations using matrix computations, and all relevant problems are bilinear in geometric entities, which makes statistical reasoning simpler. One strength of the book is the clear and consistent drawings. For instance, Euclidean and spherical normalisation of homogeneous coordinates are sketched early in Chapter 5. The same graphic is used again later on, so the reader is supported in understanding the concept of projective geometry, for example, when it comes to illustrating the intersection of entities. This part of the book provides an elaborate overview of all relevant items related to projective geometry. For researchers with a computer vision background the chapter on uncertainty propagation could be of particular interest as this topic might not be treated in "traditional" computer vision textbooks, while for photogrammetrists the comprehensive presentation of projective geometry and its relation to Euclidean space is certainly helpful.

The last part of the book deals with "Orientation and Reconstruction" and with more than 330 pages it is the largest of the three parts. Chapter 11 (overview) sets the scene: the authors embed the tasks treated in this final part into the overall problem of image analysis and scene interpretation. It is pointed out that problems related to computing the point and line structure of a scene, including camera calibration and orientation, represent core problems in image analysis. Following this motivation the subsequent chapters deal with geometry and orientation for single images (Chapter 12), image pairs (Chapter 13) and image triplets (Chapter 14). In Chapter 12, more than 30 pages are devoted to the description of the interior camera geometry of perspective and spherical camera models, including the mathematical modelling of lens errors. In this context, the definition of (partially) calibrated versus uncalibrated cameras, and the consequent provision of error estimation and propagation for all relevant parameters, makes this book stand out from others. In Chapter 14, the constraints induced by the trifocal tensor are described and its use for the reliable estimation of relative image orientation are emphasised. Chapter 15 focuses on bundle adjustment; not only are the theoretical aspects pointed out, but also more practically relevant problems such as how to handle large sparse matrices which typically occur in bundle blocks. Again, error estimation and propagation constitute a large part of this chapter, not to mention the elaborate treatment of self-calibration within a bundle adjustment. Chapter 16 is concerned with surface reconstruction. One needs to appreciate that this final chapter addresses the derivation of surfaces from existing 3D features (point clouds): in other words, feature matching using two or more images is assumed to be available already. In the end the surface reconstruction is formulated as an adjustment problem: how can one fit a parameterised surface to a given set of points, possibly also considering geometric constraints (for instance, break lines)?

All in all, this book forms a rich body of state-of-the-art knowledge in image geometry and related problems. However, due to the high level of mathematics required, graduate students may need to focus on selected topics. Ambitious MSc students and PhD researchers will, though, find it an invaluable resource. This book is the first of two volumes; the second one will appear at a future date and promises to tackle very relevant topics such as feature extraction and scene understanding. Both the photogrammetric and the computer vision communities should look forward to that book as much as this one.

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Reference

Förstner, W., 2002. Computer vision and photogrammetry – mutual questions: geometry, statistics and cognition. *Bildteknik/Image Science*, 151–164.