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Fabio Crosilla · Alberto Beinat ·
Andrea Fusiello · Eleonora Maset ·
Domenico Visintini

Advanced Procrustes Analysis Models in Photogrammetric Computer Vision

Springer

Fabio Crosilla
University of Udine
Udine, Italy

Alberto Beinat
University of Udine
Udine, Italy

Andrea Fusiello
University of Udine
Udine, Italy

Eleonora Maset
University of Udine
Udine, Italy

Domenico Visintini
University of Udine
Udine, Italy

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Preface

At the beginning of the 1980s, as Assistant Professor of Surveying at the Faculty of Engineering of University of Trieste, I was involved in some research problems relating to the optimal design of geodetic control networks. The optimization model that I introduced at that time foresaw the optimal rotation of the eigenvector matrix of a n-dimensional variance–covariance matrix of unknown 2D point coordinates of a control network in such a way to dispose the bidimensional point components of the original eigenvector matrix along directions as much as possible orthogonal to those of the forecast deformations. The identification of a computational tool, able to determine the optimal n-dimensional rotation matrix (with $n > 3$), was not easy. Fortunately, I was guided by University of Trieste statisticians to some books of multifactorial analysis where I could discover a chapter devoted to the so-called *Orthogonal Procrustes Analysis*, a set of algebraic least squares models used to directly perform transformations among corresponding matrix elements, that allowed me to easily solve my optimization problem.

At the end of the 1990s, on the occasion of the 60th birthday celebration of Prof. Erik Grafarend, I was asked to present at the two-day symposium "Quo vadis Geodesia?" a short introduction on Procrustes Analysis in geodetic sciences. This opportunity offered me the possibility to further deepen this topic and to glimpse the important properties of such algorithms for the direct solution of datum transformation problems in geodesy involving the determination of unknown rotations, translations, and isotropic scale factors. Subsequent studies allowed ing. Alberto Beinat and myself to apply some new isotropic Procrustes algorithms for the solution of the photogrammetric block adjustment by independent models, for the conformal updating of a cadastral map, and for the alignment of LiDAR point clouds. These last experiments took advantage also of the valuable contribution of Prof. Domenico Visintini. More recently, the development of innovative algorithms, that consider anisotropic Procrustes models, have permitted to Prof. Andrea Fusiello and myself to find an innovative solution to the image exterior orientation problem and to its extension to the photogrammetric bundle block adjustment. Finally, Dr. Eleonora Maset was capable to find the Procrustes solution of the exterior orientation problem starting from an *Errors-In-Variables* (EIV) model, i.e.,

for a model in which both sets of observations, image and external point coordinates, are characterized by error components.

Although the theme of Procrustes Analysis constitutes the argument of some volume chapters recently written on the topics of advanced algebraic computational problems in geodesy and geoinformatics (Awange and Grafarend 2005; Awange et al. 2010; Awange and Paláncz 2016), in the scientific literature it is not present, at the moment, a volume treating in a complete and thorough manner the analytical developments and the most significant applications of Procrustes Analysis in the field of photogrammetric computer vision and laser scanning.

The aim of this volume is therefore to collect under a unique roof the analytical models developed and experimented by the members of the research group *Geomatics and Computer Vision* of the Polytechnic Department of Engineering and Architecture of University of Udine in photogrammetric computer vision and laser scanning. The first part of the volume is devoted to the theory of Procrustes Analysis, with a detailed description of the different Procrustes models proposed and applied by the authors in the last decades. Before passing to the experimental part, some information about the basics of computer vision and some aspects of laser scanning technology and operational methodology are presented. This allows to introduce classical problems in photogrammetric computer vision and laser scanning that can be effectively solved by various Procrustes models, such as image exterior orientation, the photogrammetric bundle block and independent model adjustments and the LiDAR point cloud registration. Results obtained applying Procrustes Analysis in these fields are presented in the third part of this volume, showing also the robust version of some of the studied algorithms. The illustrated examples allow to highlight the potentiality of the proposed methods for the direct solution of nonlinear systems of equations, without any linearization of the equation systems, nor the knowledge of approximate values of the unknown parameters.

These days, characterized by a rapid growing of sensor system automation and miniaturization and by the availability of huge computational resources, we are witnessing a very fast methodological evolution of problem-solving tools in the field of photogrammetric computer vision and laser scanning. For this reason, the authors of this volume warmly wish the readers to enter into the fascinating field of Procrustes Analysis and to benefit of the many computational advantages offered by this technique.

Finally, as Head of the research group *Geomatics and Computer Vision* of the Polytechnic Department of Engineering and Architecture of University of Udine, I wish to express my gratitude to the group members for the effort put for the publication of the book. In particular, I need to thank Dr. Eleonora Maset, young Ph.D., for leading in a very effective way all the phases of the book assembly.

Udine, Italy Fabio Crosilla

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