Preface

The study of geometrical optics dates back to ancient Greek and Egyptian times. However, geometrical optics remains firmly rooted in the use of paraxial optics and skew-ray tracing equations. For many years, it has been known that the first- and second-order derivative matrices (i.e., Jacobian and Hessian matrices) of merit functions provide highly effective tools for the analysis and design of optical systems. However, computing these derivative matrices analytically is extremely challenging since ray-tracing equations are inherently recursive functions. To overcome this limitation, this book proposes a straightforward computational scheme for deriving the Jacobian and Hessian matrices of a ray and its optical path length using homogeneous coordinate notation.

The book represents both a modernization and an extension of my last book, *New Computation Methods for Geometrical Optics*, published in 2013 by Springer Singapore. Part I of the book reviews the basic principles and theories of skew-ray tracing, paraxial optics and primary aberrations. Much of the material is likely to be known to the readers. However, it serves as essential reading in laying down a solid foundation for the modeling work presented in Parts II and III of the book. Part II derives the Jacobian matrices of a ray and its optical path length. Although this issue is also addressed in other books and publications, the authors generally fail to consider all of the variables of a non-axially symmetrical system. The modeling work presented in Part II thus provides a more robust framework for the analysis and design of non-axially symmetrical systems such as prisms and head-up display. Importantly, Part II also presents a new method for determining the point spread function and modulation transfer function of an optical system such that the image quality can be evaluated accurately. Part III of the book proposes a computational scheme for deriving the Hessian matrices of a ray and its optical path length. The validity of the proposed method is demonstrated using various optical systems for illustration purposes. It is shown that the Hessian matrix approach overcomes the limitations of traditional finite difference methods and provides an effective means of determining an appropriate search direction when tuning the system variables in the system design process.

This book is intended to be used as a reference book for introductory graduate and senior undergraduate geometrical optics courses. With this in mind, the text contains numerous illustrative examples aimed at helping the reader understand the underlying theories and concepts of the related modeling work and proposed methods. It is noted that while aspherical lenses are common in the geometrical optics field nowadays, the book focuses deliberately on the simpler case of flat or spherical boundary surfaces in order to more clearly convey the main concepts and ideas. However, once students and self-taught practitioners have mastered the fundamentals described in this edition, they will find no problem in applying the related equations to the more complex case of aspherical lenses.

This book is dedicated to all the faculty and staff at the Department of Mechanical Engineering, National Cheng Kung University, Taiwan. Without their support and encouragement, this book would never have been possible. Special thanks are also extended to the Ministry of Science and Technology of Taiwan for the generous financial support provided every year to the author in developing the methodologies and underlying concepts presented in this book.

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