

Preface

Vision or the ability to see is an important inborn capability of human, animals, and insects that enables them to interact with their environment. Recent advancement in computer technology led to the development of computer or machine-vision that tries to mimic vision in human and many living creatures such as insects. Attempts have been made to incorporate machine-vision in robots, unmanned aerial vehicles (UAVs), and machines with artificial intelligence. In this monograph, we consider “vision” in a more generalized sense. Here, the “eyes” that constitute a basic element of vision may correspond to sensors utilizing acoustic, electromagnetic, or other form of interaction with the environment or man-made machines. Hereafter, such “eyes” will be referred simply as “observers.” In most cases, only line-of-sight observations will be considered. Given an object under observation, what an observer sees in reference to the object can be characterized by the *visible set*. In machine-vision, emphasis is placed on the interpretation of the images captured by the observer. Here, we study the characterization and geometric properties of the visible set associated with an observer and the objects under observation. Emphasis is placed on determining the extent of visual coverage of the objects under observation. To differentiate the problems under consideration here from the so-called *vision-based problems* in machine-vision, we refer to them as *visibility-based problems*.

In physical situations, the observers may be stationary or mobile. The latter case leads to path planning problems involving the selection of observation paths. The path planning problems usually arise in mobile robots and vehicles for performing certain tasks without collision with obstacles. In sensor networks, one may use sensor-equipped mobile robots that move along appropriate paths for monitoring the environment efficiently. Thus, visibility and path planning are integrated into the problem formulations. When the observation is performed over a specified or the shortest possible time-interval, it may be necessary to consider the dynamics of the observer due to inertial and frictional effects in the optimal observation-path selection. This leads to visibility-based optimal observer motion planning problems.

This monograph deals with the formulation of various visibility-based path and motion planning problems motivated by applications in appropriate mathematical

framework. The solution of these problems calls for concepts and methods from many areas of applied mathematics such as computational geometry, set-covering, nonsmooth optimization, combinatorial optimization, and optimal control. Emphasis is placed on the formulation of new problems and methods of approach to these problems. Since geometry and visualization play important roles in the understanding of these problems, intuitive interpretations of the basic concepts are presented before detailed mathematical development. To fix ideas, a particular topic begins with simple cases illustrated by specific examples, and then progresses forward to more complex cases. No attempt is made to provide a survey of the enormous amount of related works pertaining to computational algorithms for computer vision, and nonvisibility-based mobile-robot path and motion planning. This monograph is directed primarily to students and researchers in engineering, computer science, and applied mathematics. An understanding of the mathematical development of the main results requires only basic knowledge of mathematical analysis, control, and optimization theories. Some exercises with various degrees of difficulty are provided at the end of the main chapters. The material presented here may serve as a portion of an introductory course or seminar on visibility-based optimal path and motion planning problems. Hopefully, this monograph is able to stimulate interest and further studies in this relatively new area.

I wish to dedicate this book to the memory of my parents who set me free at age 14 to choose my independent life's path in the United States; and to Dean Foster Strong of Caltech, whose exceptional assistance made my path through Caltech possible. Finally, I wish to acknowledge the support of the National Science Foundation and the Jet Propulsion Laboratory, Pasadena, California for the initial phase of this work.

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