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Search and Classification Using Multiple Autonomous Vehicles

Decision-Making and Sensor Management

Springer

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This book is dedicated to my parents.

-Yue Wang

Preface

This book focuses on the real-time decision-making for large-scale domain search and object classification using Multiple Autonomous Vehicles (MAV). In recent years, MAV systems have attracted considerable attention and have been widely utilized. Of particular interest is their application to search and classification under limited sensory capabilities. Since search requires sensor mobility and classification requires a sensor to stay within the vicinity of an object, search and classification are two competing tasks. Therefore, there is a need to develop real-time sensor allocation decision-making strategies to guarantee task accomplishment. These decisions are especially crucial when the domain is much larger than the field-of-view of a sensor, or when the number of objects to be found and classified is much larger than that of available sensors.

In this book, the search problem is formulated as a coverage control problem, which aims at collecting enough data at every point within the domain to construct an awareness map. The object classification problem seeks to satisfactorily categorize the properties of each found object of interest. The decision-making strategies include both sensor allocation decisions and vehicle motion control. The awareness-, Bayesian-, and risk-based decision-making strategies are developed in sequence. The awareness-based approach is developed under a deterministic framework, while the latter two are developed under a probabilistic framework where uncertainty in sensor measurement is taken into account. The risk-based decision-making strategy also analyzes the effect of measurement cost. It is further extended to an integrated detection and estimation problem with applications in optimal sensor management. Simulation-based studies are performed to confirm the effectiveness of the proposed algorithms.

Chapter 1 provides an overview of the literature on MAV systems and their applications in domain search and object classification. The problem of decision-making and sensor management using MAVs is motivated to solve competing search and classification tasks under limited sensory resources. We provide a detailed study on coverage control in Chapter 2 under both deterministic and probabilistic frameworks. Corresponding to these coverage control formulations, we propose an awareness-based decision-making strategy in Chapter 3, a Bayesian-based decision-making

strategy in Chapter 4, and a risk-based decision-making strategy in Chapter 5. The awareness-based strategy is constructed based on the real-time information about the competing search and classification tasks. It models the level of awareness of an autonomous vehicle about the events occurring within the mission domain. The Bayesian-based strategy extends the deterministic work in Chapter 3 by including uncertainties in sensor perception. Bayes filter and probability theory is utilized in this framework. Build upon this, the risk-based strategy further considers the cost of taking more observations for better decision-making using Bayesian sequential detection method. Its application on the space situational awareness problem is investigated in detail. In Chapter 6, we integrate Bayesian sequential detection and Bayesian sequential estimation method for the sensor management in domain search and object classification. A summary of future research directions is presented in the concluding chapter.

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