Stochastic Dynamic Programming Based Approaches to Sensor Resource Management

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Abstract — *This paper describes a stochastic dynamic programming based approach to solve Sensor Resource Management (SRM) problems such as occur in tracking multiple targets with electronically scanned, multi-mode radar. Specifically, it formulates the SRM problem as a stochastic scheduling problem and develops approximate solutions based on the Gittins index rule. Novel results include a hybrid state stochastic model for the information dynamics of tracked targets, an exact index rule solution of the SRM problem for a simplified tracking model, and use of approximate dynamic programming to extend the index rule solution to more realistic models.*

Keywords: Sensor resource management, dynamic programming, Gittins index, multi-armed bandit.

1 Introduction

Modern sensor suites contain sensors that are agile, allowing fast redirection (e.g., electronic scanning) and fast switching between modes (e.g., radar modes such as SAR and MTI), giving a large number of control options. However, allocation of sensor resources is also subject to a variety of constraints: there may be many things to look at (complex environments with multiple targets), limited time to sense targets because of deadlines on the usefulness of information (urgent requests) or exposure to threat environments, sensors may have a limited field of view, and so on. Developing sensor control algorithms that satisfy such constraints and maximize the value of information obtained is the goal of Sensor Resource Management (SRM) research.

Stochastic dynamic programming [1] provides a principled, systematic approach to formulating and solving SRM problems [8]. However, its application requires paying the price of developing mathematical models for the problem formulation and then finding efficient algorithmic solutions. In this paper we describe new results in developing efficient solutions based on stochastic dynamic programming to solve SRM problems such as occur in tracking multiple targets with electronically scanned, multi-mode radar.

Specifically, we formulate the SRM problem as a stochastic scheduling (or multi-armed bandit) problem and develop approximate solutions based on the Gittins index rule [2]. Although there has been much research on index rules [7], [6], [3], [9], [5], there appear to be no applications to SRM except for the recent work by Krishnamurthy and Evans [4]. The reason for this is that the SRM problem, formulated as stochastic scheduling, doesn't usually satisfy the conditions necessary for the existence of an index rule solution. Thus, one is forced to develop approximations (e.g., the "restless bandit" work of [9], [5]). In this paper we show how to relax one of the "usual" conditions and to develop index rule–based SRM algorithms for kinematic tracking.

The new contributions of this paper include:

1. Stochastic scheduling formulation of SRM and a corresponding extension of the index rule solution to more general reward functions, more suitable for SRM problems.

2. Hybrid state stochastic model of information dynamics for tracking problems, which facilitates efficient solutions of stochastic dynamic programs and alleviates the "curse of dimensionality."

3. Exact index rule solution for a simple tracking model. This solution provides a basis for efficient approximations of more realistic tracking models.

4. Lookahead approximation of the stochastic dynamic program solution based on an index rule solution, applicable to more realistic tracking models.

Section 2 formulates the SRM problem as a stochastic scheduling problem and shows how to extend the index rule solution to more general types of reward functions. This section also discusses generalizations of the formulation to controlling sensors with variable dwell times and

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M.A. Dempster

Stochastic Scheduling And Dynamic Programming:

Stochastic Scheduling and Dynamic Programming Ger M. Koole,1995   *Stochastic Scheduling and Dynamic Programming* Gerhardus Martinus Koole,1992   Deterministic and Stochastic Scheduling M.A. Dempster,2012-12-06 This volume contains the proceedings of an Advanced Study and Re search Institute on Theoretical Approaches to Scheduling Problems The Institute was held in Durham England from July 6 to July 17 1981 It was attended by 91 participants from fifteen different countries The format of the Institute was somewhat unusual The first eight of the ten available days were devoted to an Advanced Study Insti tute with lectures on the state of the art with respect to deter ministic and stochastic scheduling models and on the interface between these two approaches The last two days were occupied by an Advanced Research Institute where recent results and promising directions for future research especially in the interface area were discussed Altogether 37 lectures were delivered by 24 lecturers They have all contributed to these proceedings the first part of which deals with the Advanced Study Institute and the second part of which covers the Advanced Research Institute Each part is preceded by an introduction written by the editors While confessing to a natural bias as organizers we believe that the Institute has been a rewarding and enjoyable event for everyone concerned We are very grateful to all those who have contributed to its realization   Stochastic Scheduling of Closed Queueing Network Production Systems Shirish Ekbote,1999   *Encyclopedia of Optimization* Christodoulos A. Floudas,Panos M. Pardalos,2008-09-04 The goal of the Encyclopedia of Optimization is to introduce the reader to a complete set of topics that show the spectrum of research the richness of ideas and the breadth of applications that has come from this field The second edition builds on the success of the former edition with more than 150 completely new entries designed to ensure that the reference addresses recent areas where optimization theories and techniques have advanced Particularly heavy attention resulted in health science and transportation with entries such as Algorithms for Genomics Optimization and Radiotherapy Treatment Design and Crew Scheduling   Multi-Agent Systems and Applications IV Michal Pechoucek,Paolo Petta,Laszlo Zsolt Varga,2005-09-06 The aim of the CEEMAS conference series is to provide a biennial forum for the presentation of multi agent research and development results With its p ticular geographicalorientation towards Central and Eastern Europe CEEMAS has become an internationally recognised event with participants from all over the world After the successful CEEMAS conferences in St Petersburg 1999 Cracow 2001 and Prague 2003 the 2005 CEEMAS conference takes place in Budapest The programme committee of the conference series consists of est lished researchers from the region and renowned international colleagues sh ing the prominent rank of CEEMAS among the leading events in multi agent systems In the very competitive eld of agent oriented conferences and workshops nowadays suchasAAMAS WI IAT EUMAS CIA MATES thespecialpro le of CEEMAS is that it is trying to bridge the gap between applied research achievements and theoretical research activities Our ambition is to provide a forum for presenting theoretical research with an evident application potential implemented application

prototypes and their properties as well as industrial case studies of successful but also unsuccessful agent technology deployments This is why the CEEMAS proceedings volume provides a collection of research and application papers The technical research paper section of the proceedings see pages 11 499 contains pure research papers as well as research results in application settings while the application papers section see pages 500 530 contains papers focused on application aspects The goal is to demonstrate the real life value and commercial reality of multi agent systems as well as to foster communication between academia and industry in this eld **Scheduling** Michael L. Pinedo,2016-02-10 This new edition provides an up to date coverage of important theoretical models in the scheduling literature as well as significant scheduling problems that occur in the real world It again includes supplementary material in the form of slide shows from industry and movies that show implementations of scheduling systems The main structure of the book as per previous edition consists of three parts The first part focuses on deterministic scheduling and the related combinatorial problems The second part covers probabilistic scheduling models in this part it is assumed that processing times and other problem data are random and not known in advance The third part deals with scheduling in practice it covers heuristics that are popular with practitioners and discusses system design and implementation issues All three parts of this new edition have been revamped and streamlined The references have been made completely up to date Theoreticians and practitioners alike will find this book of interest Graduate students in operations management operations research industrial engineering and computer science will find the book an accessible and invaluable resource Scheduling Theory Algorithms and Systems will serve as an essential reference for professionals working on scheduling problems in manufacturing services and other environments **Rollout Algorithms for Stochastic Scheduling Problems** Dimitri P. Bertsekas,David Alfred Castañon,Massachusetts Institute of Technology. Laboratory for Information and Decision Systems,1998 **Stochastic Scheduling of Parallel Queues with Set-up Costs** Izak Duenyas,1995 **Cloud Computing for Geospatial Big Data Analytics** Himansu Das,Rabindra K. Barik,Harishchandra Dubey,Diptendu Sinha Roy,2018-12-11 This book introduces the latest research findings in cloud edge fog and mist computing and their applications in various fields using geospatial data It solves a number of problems of cloud computing and big data such as scheduling security issues using different techniques which researchers from industry and academia have been attempting to solve in virtual environments Some of these problems are of an intractable nature and so efficient technologies like fog edge and mist computing play an important role in addressing these issues By exploring emerging advances in cloud computing and big data analytics and their engineering applications the book enables researchers to understand the mechanisms needed to implement cloud edge fog and mist computing in their own endeavours and motivates them to examine their own research findings and developments Control Techniques for Complex Networks Sean Meyn,2008 From foundations to state of the art the tools and philosophy you need to build network models **The Routledge Companion to Production and Operations Management** Martin K. Starr,Sushil K. Gupta,2017-03-27 This

remarkable volume highlights the importance of Production and Operations Management POM as a field of study and research contributing to substantial business and social growth The editors emphasize how POM works with a range of systems agriculture disaster management e commerce healthcare hospitality military systems not for profit retail sports sustainability telecommunications and transport and how it contributes to the growth of each Martin K Starr and Sushil K Gupta gather an international team of experts to provide researchers and students with a panoramic vision of the field Divided into eight parts the book presents the history of POM and establishes the foundation upon which POM has been built while also revisiting and revitalizing topics that have long been essential It examines the significance of processes and projects to the fundamental growth of the POM field Critical emerging themes and new research are examined with open minds and this is followed by opportunities to interface with other business functions Finally the next era is discussed in ways that combine practical skill with philosophy in its analysis of POM including traditional and nontraditional applications before concluding with the editors thoughts on the future of the discipline Students of POM will find this a comprehensive definitive resource on the state of the discipline and its future directions **Scheduling Policy Design Using Stochastic Dynamic Programming** Robert Glaubius,2009 Scheduling policies for open soft real time systems must be able to balance the competing concerns of meeting their objectives under exceptional conditions while achieving good performance in the average case Balancing these concerns requires modeling strategies that represent the range of possible task behaviors and solution techniques that are capable of effectively managing uncertainty in order to discover scheduling policies that are effective across the range of system modes We develop methods for solving a particular class of task scheduling problems in an open soft real time setting involving repeating non preemptable tasks that contend for a single shared resource We enforce timeliness by optimizing performance with respect to the proportional progress of tasks in the system We model this scheduling problem as an infinite state Markov decision process and provide guarantees regarding the existence of optimal solutions to this problem We derive several methods for approximating optimal scheduling policies and provide theoretical justification and empirical evidence that these solutions are good approximations to the optimal solution We consider cases in which task models are known and adapt reinforcement learning methods to learn task models when they are not available

Dynamic and Stochastic Multi-Project Planning Philipp Melchiors,2015 This book deals with dynamic and stochastic methods for multi project planning Based on the idea of using queueing networks for the analysis of dynamic stochastic multi project environments this book addresses two problems detailed scheduling of project activities and integrated order acceptance and capacity planning In an extensive simulation study the book thoroughly investigates existing scheduling policies To obtain optimal and near optimal scheduling policies new models and algorithms are proposed based on the theory of Markov decision processes and Approximate Dynamic programming Then the book presents a new model for the effective computation of optimal policies based on a Markov decision process Finally the book provides insights into the structure of

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