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The Mobile Agent Rendezvous Problem in the Ring

Evangelos Kranakis
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Synthesis Lectures on Distributed Computing Theory

Nancy Lynch, *Series Editor*

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The Mobile Agent Rendezvous Problem in the Ring Evangelos Kranakis,Danny Krizanc,Euripides Marcou,2022-05-31 Mobile agent computing is being used in fields as diverse as artificial intelligence computational economics and robotics Agents ability to adapt dynamically and execute asynchronously and autonomously brings potential advantages in terms of fault tolerance flexibility and simplicity This monograph focuses on studying mobile agents as modelled in distributed systems research and in particular within the framework of research performed in the distributed algorithms community It studies the fundamental question of how to achieve rendezvous the gathering of two or more agents at the same node of a network Like leader election such an operation is a useful subroutine in more general computations that may require the agents to synchronize share information divide up chores etc The work provides an introduction to the algorithmic issues raised by the rendezvous problem in the distributed computing setting For the most part our investigation concentrates on the simplest case of two agents attempting to rendezvous on a ring network Other situations including multiple agents faulty nodes and other topologies are also examined An extensive bibliography provides many pointers to related work not covered in the text The presentation has a distinctly algorithmic rigorous distributed computing flavor and most results should be easily accessible to advanced undergraduate and graduate students in computer science and mathematics departments Table of Contents Models for Mobile Agent Computing Deterministic Rendezvous in a Ring Multiple Agent Rendezvous in a Ring Randomized Rendezvous in a Ring Other Models Other Topologies LATIN 2004: Theoretical Informatics Martin Farach-Colton,2004-03-19 This volume contains the proceedings of the Latin American Theoretical Inf matics LATIN conference that was held in Buenos Aires Argentina April 5 8 2004 The LATIN series of symposia was launched in 1992 to foster interactions between the Latin American community and computer scientists around the world This was the sixth event in the series following S ao Paulo Brazil 1992 Valparaiso Chile 1995 Campinas Brazil 1998 Punta del Este Uruguay 2000 and Cancun Mexico 2002 The proceedings of these conferences were also published by Springer Verlag in the Lecture Notes in Computer Science series Volumes 583 911 1380 1776 and 2286 respectively Also as before we published a selection of the papers in a special issue of a prestigious journal We received 178 submissions Each paper was assigned to four program c mittee members and 59 papers were selected This was 80% more than the previous record for the number of submissions We feel lucky to have been able to build on the solid foundation provided by the increasingly successful previous LATINs And we are very grateful for the tireless work of Pablo Mart nez L opez the Local Arrangements Chair Finally we thank Springer Verlag for publishing these proceedings in its LNCS series *Structural Information and Communication Complexity* Ratislav Královic,Ondrej Sykora,2004-06-14 This book constitutes the refereed proceedings of the 11th International Colloquium on Structural Information and Communication Complexity SIROCCO 2004 held in Smolenice Castle Slowakia in June 2004 The 26 revised full papers presented were carefully reviewed and selected from 56 submissions Among the topics

addressed are WDM networks optical networks ad hoc networking computational graph theory graph algorithms radio networks routing shortest path problems searching labelling distributed algorithms communication networks approximation algorithms wireless networks scheduling NP completeness Byzantine environments Distributed Computing by Oblivious Mobile Robots Paola Flocchini,Giuseppe Prencipe,Nicola Santoro,2022-06-01 The study of what can be computed by a team of autonomous mobile robots originally started in robotics and AI has become increasingly popular in theoretical computer science especially in distributed computing where it is now an integral part of the investigations on computability by mobile entities The robots are identical computational entities located and able to move in a spatial universe they operate without explicit communication and are usually unable to remember the past they are extremely simple with limited resources and individually quite weak However collectively the robots are capable of performing complex tasks and form a system with desirable fault tolerant and self stabilizing properties The research has been concerned with the computational aspects of such systems In particular the focus has been on the minimal capabilities that the robots should have in order to solve a problem This book focuses on the recent algorithmic results in the field of distributed computing by oblivious mobile robots unable to remember the past After introducing the computational model with its nuances we focus on basic coordination problems pattern formation gathering scattering leader election as well as on dynamic tasks such as flocking For each of these problems we provide a snapshot of the state of the art reviewing the existing algorithmic results In doing so we outline solution techniques and we analyze the impact of the different assumptions on the robots computability power Table of Contents Introduction Computational Models Gathering and Convergence Pattern Formation Scatterings and Coverings Flocking Other Directions **Consistent Distributed Storage** Vincent Gramoli,Nicolas Nicolaou,Alexander A. Schwarzmann,2022-05-31 Providing a shared memory abstraction in distributed systems is a powerful tool that can simplify the design and implementation of software systems for networked platforms This enables the system designers to work with abstract readable and writable objects without the need to deal with the complexity and dynamism of the underlying platform The key property of shared memory implementations is the consistency guarantee that it provides under concurrent access to the shared objects The most intuitive memory consistency model is atomicity because of its equivalence with a memory system where accesses occur serially one at a time Emulations of shared atomic memory in distributed systems is an active area of research and development The problem proves to be challenging and especially so in distributed message passing settings with unreliable components as is often the case in networked systems We present several approaches to implementing shared memory services with the help of replication on top of message passing distributed platforms subject to a variety of perturbations in the computing medium **Network Topology and Fault-Tolerant Consensus** Dimitris Sakavalas,Lewis Tseng,2022-05-31 As the structure of contemporary communication networks grows more complex practical networked distributed systems become prone to component failures Fault tolerant consensus in message passing systems

allows participants in the system to agree on a common value despite the malfunction or misbehavior of some components It is a task of fundamental importance for distributed computing due to its numerous applications We summarize studies on the topological conditions that determine the feasibility of consensus mainly focusing on directed networks and the case of restricted topology knowledge at each participant Recently significant efforts have been devoted to fully characterize the underlying communication networks in which variations of fault tolerant consensus can be achieved Although the deduction of analogous topological conditions for undirected networks of known topology had shortly followed the introduction of the problem their extension to the directed network case has been proven a highly non trivial task Moreover global knowledge restrictions inherent in modern large scale networks require more elaborate arguments concerning the locality of distributed computations In this work we present the techniques and ideas used to resolve these issues Recent studies indicate a number of parameters that affect the topological conditions under which consensus can be achieved namely the fault model the degree of system synchrony synchronous vs asynchronous the type of agreement exact vs approximate the level of topology knowledge and the algorithm class used general vs iterative We outline the feasibility and impossibility results for various combinations of the above parameters extensively illustrating the relation between network topology and consensus

Impossibility Results for Distributed Computing Hagit Attiya,Faith Ellen,2022-06-01 To understand the power of distributed systems it is necessary to understand their inherent limitations what problems cannot be solved in particular systems or without sufficient resources such as time or space This book presents key techniques for proving such impossibility results and applies them to a variety of different problems in a variety of different system models Insights gained from these results are highlighted aspects of a problem that make it difficult are isolated features of an architecture that make it inadequate for solving certain problems efficiently are identified and different system models are compared

Introduction to Distributed Self-Stabilizing Algorithms Karine Altisen,Stéphane Devismes,Swan Dubois,Franck Petit,2022-05-31 This book aims at being a comprehensive and pedagogical introduction to the concept of self stabilization introduced by Edsger Wybe Dijkstra in 1973 Self stabilization characterizes the ability of a distributed algorithm to converge within finite time to a configuration from which its behavior is correct i e satisfies a given specification regardless the arbitrary initial configuration of the system This arbitrary initial configuration may be the result of the occurrence of a finite number of transient faults Hence self stabilization is actually considered as a versatile non masking fault tolerance approach since it recovers from the effect of any finite number of such faults in an unified manner Another major interest of such an automatic recovery method comes from the difficulty of resetting malfunctioning devices in a large scale and so geographically spread distributed system the Internet Pair to Pair networks and Delay Tolerant Networks are examples of such distributed systems Furthermore self stabilization is usually recognized as a lightweight property to achieve fault tolerance as compared to other classical fault tolerance approaches Indeed the overhead both in terms of time and space of

state of the art self stabilizing algorithms is commonly small This makes self stabilization very attractive for distributed systems equipped of processes with low computational and memory capabilities such as wireless sensor networks After more than 40 years of existence self stabilization is now sufficiently established as an important field of research in theoretical distributed computing to justify its teaching in advanced research oriented graduate courses This book is an initiation course which consists of the formal definition of self stabilization and its related concepts followed by a deep review and study of classical simple algorithms commonly used proof schemes and design patterns as well as premium results issued from the self stabilizing community As often happens in the self stabilizing area in this book we focus on the proof of correctness and the analytical complexity of the studied distributed self stabilizing algorithms Finally we underline that most of the algorithms studied in this book are actually dedicated to the high level atomic state model which is the most commonly used computational model in the self stabilizing area However in the last chapter we present general techniques to achieve self stabilization in the low level message passing model as well as example algorithms *Quorum Systems* Marko Vukolic,2022-06-01 A quorum system is a collection of subsets of nodes called quorums with the property that each pair of quorums have a non empty intersection Quorum systems are the key mathematical abstraction for ensuring consistency in fault tolerant and highly available distributed computing Critical for many applications since the early days of distributed computing quorum systems have evolved from simple majorities of a set of processes to complex hierarchical collections of sets tailored for general adversarial structures The initial non empty intersection property has been refined many times to account for e g stronger Byzantine adversarial model latency considerations or better availability This monograph is an overview of the evolution and refinement of quorum systems with emphasis on their role in two fundamental applications distributed read write storage and consensus Table of Contents Introduction Preliminaries Classical Quorum Systems Classical Quorum Based Emulations Byzantine Quorum Systems Latency efficient Quorum Systems Probabilistic Quorum Systems *Distributed Computing Pearls* Gadi Taubenfeld,2022-05-31 Computers and computer networks are one of the most incredible inventions of the 20th century having an ever expanding role in our daily lives by enabling complex human activities in areas such as entertainment education and commerce One of the most challenging problems in computer science for the 21st century is to improve the design of distributed systems where computing devices have to work together as a team to achieve common goals In this book I have tried to gently introduce the general reader to some of the most fundamental issues and classical results of computer science underlying the design of algorithms for distributed systems so that the reader can get a feel of the nature of this exciting and fascinating field called distributed computing The book will appeal to the educated layperson and requires no computer related background I strongly suspect that also most computer knowledgeable readers will be able to learn something new **Distributed Graph Coloring** Leonid Barenboim,Michael Elkin,2022-06-01 The focus of this monograph is on symmetry breaking problems in the message passing model of

distributed computing In this model a communication network is represented by a n vertex graph G V E whose vertices host autonomous processors The processors communicate over the edges of G in discrete rounds The goal is to devise algorithms that use as few rounds as possible A typical symmetry breaking problem is the problem of graph coloring Denote by the maximum degree of G While coloring G with 1 colors is trivial in the centralized setting the problem becomes much more challenging in the distributed one One can also compromise on the number of colors if this allows for more efficient algorithms Other typical symmetry breaking problems are the problems of computing a maximal independent set MIS and a maximal matching MM The study of these problems dates back to the very early days of distributed computing The founding fathers of distributed computing laid firm foundations for the area of distributed symmetry breaking already in the eighties In particular they showed that all these problems can be solved in randomized logarithmic time Also Linial showed that an O 2 coloring can be solved very efficiently deterministically However fundamental questions were left open for decades In particular it is not known if the MIS or the 1 coloring can be solved in deterministic polylogarithmic time Moreover until recently it was not known if in deterministic polylogarithmic time one can color a graph with significantly fewer than 2 colors Additionally it was open and still open to some extent if one can have sublogarithmic randomized algorithms for the symmetry breaking problems Recently significant progress was achieved in the study of these questions More efficient deterministic and randomized 1 coloring algorithms were achieved Deterministic 1 o 1 coloring algorithms with polylogarithmic running time were devised Improved and often sublogarithmic time randomized algorithms were devised Drastically improved lower bounds were given Wide families of graphs in which these problems are solvable much faster than on general graphs were identified The objective of our monograph is to cover most of these developments and as a result to provide a treatise on theoretical foundations of distributed symmetry breaking in the message passing model We hope that our monograph will stimulate further progress in this exciting area **Fault-tolerant Agreement in Synchronous Message-passing Systems** Michel Raynal,2022-06-01 Understanding distributed computing is not an easy task This is due to the many facets of uncertainty one has to cope with and master in order to produce correct distributed software A previous book Communication and Agreement Abstraction for Fault tolerant Asynchronous Distributed Systems published by Morgan Claypool 2010 was devoted to the problems created by crash failures in asynchronous message passing systems The present book focuses on the way to cope with the uncertainty created by process failures crash omission failures and Byzantine behavior in synchronous message passing systems i e systems whose progress is governed by the passage of time To that end the book considers fundamental problems that distributed synchronous processes have to solve These fundamental problems concern agreement among processes if processes are unable to agree in one way or another in presence of failures no non trivial problem can be solved They are consensus interactive consistency k set agreement and non blocking atomic commit Being able to solve these basic problems efficiently with provable guarantees allows applications

designers to give a precise meaning to the words cooperate and agree despite failures and write distributed synchronous programs with properties that can be stated and proved Hence the aim of the book is to present a comprehensive view of agreement problems algorithms that solve them and associated computability bounds in synchronous message passing distributed systems Table of Contents List of Figures Synchronous Model Failure Models and Agreement Problems Consensus and Interactive Consistency in the Crash Failure Model Expedite Decision in the Crash Failure Model Simultaneous Consensus Despite Crash Failures From Consensus to k Set Agreement Non Blocking Atomic Commit in Presence of Crash Failures k Set Agreement Despite Omission Failures Consensus Despite Byzantine Failures Byzantine Consensus in Enriched Models *New Models for Population Protocols* Othon Michail,Ioannis Chatzigiannakis,Paul G. Spirakis,2022-05-31 Wireless sensor networks are about to be part of everyday life Homes and workplaces capable of self controlling and adapting air conditioning for different temperature and humidity levels sleepless forests ready to detect and react in case of a fire vehicles able to avoid sudden obstacles or possibly able to self organize routes to avoid congestion and so on will probably be commonplace in the very near future Mobility plays a central role in such systems and so does passive mobility that is mobility of the network stemming from the environment itself The population protocol model was an intellectual invention aiming to describe such systems in a minimalistic and analysis friendly way Having as a starting point the inherent limitations but also the fundamental establishments of the population protocol model we try in this monograph to present some realistic and practical enhancements that give birth to some new and surprisingly powerful for these kind of systems computational models Table of Contents Population Protocols The Computational Power of Population Protocols Enhancing the model Mediated Population Protocols and Symmetry Passively Mobile Machines that Use Restricted Space Conclusions and Open Research Directions Acronyms Authors Biographies **The Theory of Timed I/O Automata, Second Edition** Dilsun Kaynar,Nancy Lynch,Roberto Segala,Frits Vaandrager,2022-06-01 This monograph presents the Timed Input Output Automaton TIOA modeling framework a basic mathematical framework to support description and analysis of timed computing systems Timed systems are systems in which desirable correctness or performance properties of the system depend on the timing of events not just on the order of their occurrence Timed systems are employed in a wide range of domains including communications embedded systems real time operating systems and automated control Many applications involving timed systems have strong safety reliability and predictability requirements which make it important to have methods for systematic design of systems and rigorous analysis of timing dependent behavior The TIOA framework also supports description and analysis of timed distributed algorithms distributed algorithms whose correctness and performance depend on the relative speeds of processors accuracy of local clocks or communication delay bounds Such algorithms arise for example in traditional and wireless communications networks of mobile devices and shared memory multiprocessors The need to prove rigorous theoretical results about timed distributed algorithms makes it important to have a suitable

mathematical foundation An important feature of the TIOA framework is its support for decomposing timed system descriptions In particular the framework includes a notion of external behavior for a timed I O automaton which captures its discrete interactions with its environment The framework also defines what it means for one TIOA to implement another based on an inclusion relationship between their external behavior sets and defines notions of simulations which provide sufficient conditions for demonstrating implementation relationships The framework includes a composition operation for TIOAs which respects external behavior and a notion of receptiveness which implies that a TIOA does not block the passage of time The TIOA framework also defines the notion of a property and what it means for a property to be a safety or a liveness property It includes results that capture common proof methods for showing that automata satisfy properties Table of Contents Introduction Mathematical Preliminaries Describing Timed System Behavior Timed Automata Operations on Timed Automata Properties for Timed Automata Timed I O Automata Operations on Timed I O Automata Conclusions and Future Work *Principles of Transactional Memory* Rachid Guerraoui,Michael Kapalka,2022-06-01 Transactional memory TM is an appealing paradigm for concurrent programming on shared memory architectures With a TM threads of an application communicate and synchronize their actions via in memory transactions Each transaction can perform any number of operations on shared data and then either commit or abort When the transaction commits the effects of all its operations become immediately visible to other transactions when it aborts however those effects are entirely discarded Transactions are atomic programmers get the illusion that every transaction executes all its operations instantaneously at some single and unique point in time Yet a TM runs transactions concurrently to leverage the parallelism offered by modern processors The aim of this book is to provide theoretical foundations for transactional memory This includes defining a model of a TM as well as answering precisely when a TM implementation is correct what kind of properties it can ensure what are the power and limitations of a TM and what inherent trade offs are involved in designing a TM algorithm While the focus of this book is on the fundamental principles its goal is to capture the common intuition behind the semantics of TMs and the properties of existing TM implementations Table of Contents Introduction Shared Memory Systems Transactional Memory A Primer TM Correctness Issues Implementing a TM Further Reading Opacity Proving Opacity An Example Opacity vs Atomicity Further Reading The Liveness of a TM Lock Based TMs Obstruction Free TMs General Liveness of TMs Further Reading Conclusions *Communication and Agreement Abstractions for Fault-Tolerant Asynchronous Distributed Systems* Michel Raynal,2022-06-01 Understanding distributed computing is not an easy task This is due to the many facets of uncertainty one has to cope with and master in order to produce correct distributed software Considering the uncertainty created by asynchrony and process crash failures in the context of message passing systems the book focuses on the main abstractions that one has to understand and master in order to be able to produce software with guaranteed properties These fundamental abstractions are communication abstractions that allow the processes to communicate consistently namely the

register abstraction and the reliable broadcast abstraction and the consensus agreement abstractions that allows them to cooperate despite failures As they give a precise meaning to the words communicate and agree despite asynchrony and failures these abstractions allow distributed programs to be designed with properties that can be stated and proved Impossibility results are associated with these abstractions Hence in order to circumvent these impossibilities the book relies on the failure detector approach and consequently that approach to fault tolerance is central to the book Table of Contents List of Figures The Atomic Register Abstraction Implementing an Atomic Register in a Crash Prone Asynchronous System The Uniform Reliable Broadcast Abstraction Uniform Reliable Broadcast Abstraction Despite Unreliable Channels The Consensus Abstraction Consensus Algorithms for Asynchronous Systems Enriched with Various Failure Detectors Constructing Failure Detectors **Decidability of Parameterized Verification** Roderick Bloem,Swen Jacobs,Ayrat Kalimov,Igor Konnov,2022-05-31 While the classic model checking problem is to decide whether a finite system satisfies a specification the goal of parameterized model checking is to decide given finite systems n parameterized by n N whether for all n N the system n satisfies a specification In this book we consider the important case of n being a concurrent system where the number of replicated processes depends on the parameter n but each process is independent of n Examples are cache coherence protocols networks of finite state agents and systems that solve mutual exclusion or scheduling problems Further examples are abstractions of systems where the processes of the original systems actually depend on the parameter The literature in this area has studied a wealth of computational models based on a variety of synchronization and communication primitives including token passing broadcast and guarded transitions Often different terminology is used in the literature and results are based on implicit assumptions In this book we introduce a computational model that unites the central synchronization and communication primitives of many models and unveils hidden assumptions from the literature We survey existing decidability and undecidability results and give a systematic view of the basic problems in this exciting research area SOFSEM 2008: Theory and Practice of Computer Science Viliam Geffert,2008-01-11 This volume contains the invited and the contributed papers selected for p th sentation at SOFSEM 2008 the 34 Conference on Current Trends in Theory and Practice of Computer Science which was held January 19 25 2008 in the Atrium Hotel Novy Smokovec High Tatras in Slovakia SOFSEM originally SOFtware SEMinar as an annual international c ference devoted to the theory and practice of computer science aims to foster cooperationamongprofessionalsfromacademiaandindustryworkinginallareas in this eld Developing over the years from a local event to a fully international and well established conference contemporary SOFSEM continues to maintain the best of its original Winter School aspects such as a high number of invited talks and in depth coverage of novel research results in selected areas within computer science SOFSEM 2008 was organized around the following tracks Foundations of Computer Science Chair Juhani Karhum aki Computing by Nature Chair Alberto Bertoni Networks Security and Cryptography Chair Bart Preneel Web Technologies Chair Pavol N avrat The SOFSEM 2008 Program

Committee consisted of 75 international perts representing active areas of the SOFSEM 2008 tracks with outstanding expertise and an eye for current developments evaluating the submissions with the help of 169 additional reviewers An integral part of SOFSEM 2008 was the traditional Student Research rum chaired by Ma ria Bielikov a organized with the aim of presenting student projectsinthetheoryandpracticeofcomputerscienceandtogivestudentsfe back on both originality of their scienti c results and on their work in progress *Mathematical Foundations of Computer Science 2005* Joanna Jedrzejowicz,Andrzej Szepietowski,2005-09-14 This volume contains the papers presented at the 30th Symposium on Mathematical Foundations of Computer Science MFCS 2005 held in Gdansk Poland from August 29th to September 2nd 2005 *Handbook of Parallel Computing* Sanguthevar Rajasekaran,John Reif,2007-12-20 The ability of parallel computing to process large data sets and handle time consuming operations has resulted in unprecedented advances in biological and scientific computing modeling and simulations Exploring these recent developments the Handbook of Parallel Computing Models Algorithms and Applications provides comprehensive coverage on a

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