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# Fault-tolerant Agreement in Synchronous Message-passing Systems

Michel Raynal

***SYNTHESIS LECTURES ON  
DISTRIBUTED COMPUTING THEORY***

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# Fault Tolerant Agreement In Synchronous Message Passing Systems Michel Raynal

**Paola Flocchini, Giuseppe  
Prencipe, Nicola Santoro**



## **Fault Tolerant Agreement In Synchronous Message Passing Systems Michel Raynal:**

**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.

*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 a 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

Fault-Tolerant Message-Passing Distributed Systems Michel Raynal, 2018-09-08 This book presents the most important fault tolerant distributed programming abstractions and their associated distributed algorithms in particular in terms of reliable communication and agreement which lie at the heart of nearly all distributed applications These programming abstractions distributed objects or services allow software designers and programmers to cope with asynchrony and the most important types of failures such as process crashes message losses and malicious behaviors of computing entities widely known under the term Byzantine fault tolerance The author introduces these notions in an incremental manner starting from a clear specification followed by algorithms which are first described intuitively and then proved correct The book also presents impossibility results in classic distributed computing models along with strategies mainly failure detectors and randomization that allow us to enrich these models In this sense the book constitutes an introduction to the science of distributed computing with applications in all domains of distributed systems such as cloud computing and blockchains Each chapter comes with exercises and bibliographic notes to help the reader approach understand and master the fascinating field of fault tolerant distributed computing

Decidability of Parameterized Verification Roderick Bloem, Swen Jacobs, Ayrat Khalimov, Igor Konnov, 2015-09-30 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  $n \in \mathbb{N}$  whether for all  $n \in \mathbb{N}$  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

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

**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      **Synthesis**

**Lectures on Distributed Computing Theory : Fault-tolerant Agreement in Synchronous Message-passing Systems**

M. Raynal,      **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      Distributed Graph Coloring Leonid Barenboim, Michael Elkin, 2013-07-01

The objective of our monograph is to cover the developments on the theoretical foundations of distributed symmetry breaking in the message passing model We hope that our monograph will stimulate further progress in this exciting area

**ICPP 2006** ,2006 Workshop on Web Services based Grid Applications WSGA Workshop on Parallel and Distributed Multimedia PDM the Workshop on Wireless and Sensor Networks WSN 3rd International Workshop on Embedded Computing EC 06 Workshop on Performance Evaluation of Networks for Parallel Cluster and Grid Computing Systems PEN PCGCS the 5th Workshop on Compile and Runtime Techniques for Parallel Computing CRTPC 8th Workshop on High Performance Scientific and Engineering Computing HPSEC 06      *Proceedings of the 33rd Annual ACM Symposium on Theory of Computing* ,2001      **Distributed Algorithms** Jean-Claude Bermond, Michel Raynal, 1989 This book includes the

papers presented at the Third International Workshop on Distributed Algorithms organized at La Colle sur Loup near Nice France September 26 28 1989 which followed the first two successful international workshops in Ottawa 1985 and

Amsterdam 1987 This workshop provided a forum for researchers and others interested in distributed algorithms on communication networks graphs and decentralized systems The aim was to present recent research results explore directions for future research and identify common fundamental techniques that serve as building blocks in many distributed algorithms Papers describe original results in all areas of distributed algorithms and their applications including distributed combinatorial algorithms distributed graph algorithms distributed algorithms for control and communication distributed database techniques distributed algorithms for decentralized systems fail safe and fault tolerant distributed algorithms distributed optimization algorithms routing algorithms design of network protocols algorithms for transaction management composition of distributed algorithms and analysis of distributed algorithms Publisher's website

**Network Topology and Fault-Tolerant Consensus** Dimitris Sakavalas, Lewis Tseng, 2019-05-13 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

**Who's who in France**, 2016

**A Message Passing System for a Fault Tolerant Parallel Processor** Russell Lawrence Heyda, 1987

**Efficient Verification of Fault-tolerant Message-passing Protocols** Péter Bokor, 2011

**Consistent Checkpointing in Message Passing Distributed Systems** Roberto Baldoni, Michel Raynal, Achour Mostefaoui, Jean-Michel Hélary, 1995

**Distributed Recovery Block Scheme-based Fault Tolerant Message Passing System** Wei Gu, 2000

**Fault-Tolerant Distributed Consensus in Synchronous Networks** Ashish Choudhury, Arpita Patra, 2025-03-24 Fault tolerant distributed consensus is a fundamental concept both in cryptography as well as distributed computing Ever since the inception of the problem by Lamport et al in 1982 the problem

has been widely studied both in cryptography as well as distributed computing community and several fundamental results have been obtained regarding the possibility feasibility and optimality of the consensus protocols in various network models and adversarial settings The problem has generated revived interest from several other communities over the last few years after the advent of Blockchain protocols Traditionally the consensus protocols are studied either in the synchronous or in the asynchronous communication setting and very often the protocols in the former category serve as the basis for the protocols in the latter category The focus of this book will be on the synchronous communication setting The book presents all the seminal possibility and feasibility results in this model ever since the inception of the consensus problem with formal security proofs Even though the synchronous corruption model may seem weaker than the more practical asynchronous communication model designing protocols in the synchronous model turns out to be non trivial and demands sophisticated and highly advanced techniques Moreover understanding protocols in the synchronous setting often constitutes the first stepping stone to understanding the more complex asynchronous consensus protocols The topic of synchronous consensus protocols in itself is a very vast and important topic to be covered in a single book



## Enjoying the Melody of Expression: An Mental Symphony within **Fault Tolerant Agreement In Synchronous Message Passing Systems Michel Raynal**

In some sort of used by monitors and the ceaseless chatter of instantaneous conversation, the melodic beauty and psychological symphony produced by the written term often fade into the background, eclipsed by the constant sound and disruptions that permeate our lives. However, situated within the pages of **Fault Tolerant Agreement In Synchronous Message Passing Systems Michel Raynal** an enchanting literary prize brimming with natural emotions, lies an immersive symphony waiting to be embraced. Crafted by a masterful musician of language, that charming masterpiece conducts visitors on an emotional trip, well unraveling the hidden melodies and profound affect resonating within each cautiously constructed phrase. Within the depths with this touching assessment, we shall examine the book is main harmonies, analyze their enthralling writing model, and surrender ourselves to the profound resonance that echoes in the depths of readers souls.

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web the working principle of the system is quite easy let understand it here in our system lm35 is the sensor that senses the  
temperature of its environment and based on it s value it generates an analog output voltage this analog voltage produced by  
the lm35 is then given as input to the bolt a0 pin

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web oct 27 2020 converting the lm35 output voltage into temperature to convert the output voltage of the sensor into the  
temperature in degree celsius you can use the following formula temperature c v out 10 with v out in millivolt mv so if the  
output of the sensor is 750 mv the temperature is 75 c

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web the lm35 is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature in c it can measure temperature more accurately than a using a thermistor the sensor circuitry is sealed and not subject to oxidation the lm35 generates a higher output voltage than thermocouples and

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web as the lm35 device draws only 60  $\mu$ a from the supply it has very low self heating of less than 0.1 c in still air the lm35 device is rated to operate over a 55 c to 150 c temperature range while the lm35c device is rated for a 40 c to 110 c range 10 with improved accuracy

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web lm35 s output is 10mv degree c which means for every degree rise in temperature the output of lm35 will rise by 10mv so if the output of lm35 is 220mv 0.22v the temperature will be 22 c so if room temperature is 32 c then the output of lm35 will be 320mv i.e 0.32v for detailed information check out basic s of lm35 temperature sensor

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web the lm35 is easy to use just connect the left pin to power 4v to 30v and the right pin to ground assuming the flat side of the sensor is facing you then the middle pin will have an analog voltage that is directly proportional linear to the temperature in c

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web characteristics of ic lm35 lm35 does not require external calibration with an accuracy of  $\frac{1}{4}$  c at room temperature or  $\frac{3}{4}$  c for the measurement range of 55 to 150 c it has a low output impedance linear output easy to operate and combined with the next circuit such as the control circuit lm35 can be operated with a single

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web it measures temperatures in any environment and all hvac applications using lm35 temperature to calculate the temperature the following steps will help you use an lm35 sensor to calculate the temperature start by building the circuit in the circuit ensure you connect gnd to the ground then power lm35 vcc with 5 operating voltage vs

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