

# FOUNDATIONS OF REAL-TIME COMPUTING Scheduling and Resource Management

edited by

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# Foundations Of Real Time Computing Scheduling And Resource Management

**Kim G. Larsen, Peter Niebert**



## **Foundations Of Real Time Computing Scheduling And Resource Management:**

*Foundations of Real-Time Computing: Scheduling and Resource Management* André M. van Tilborg, Gary M.

Koob, 2012-12-22 This volume contains a selection of papers that focus on the state of the art in real time scheduling and resource management Preliminary versions of these papers were presented at a workshop on the foundations of real time computing sponsored by the Office of Naval Research in October 1990 in Washington D C A companion volume by the title Foundations of Real Time Computing Formal Specifications and Methods complements this book by addressing many of the most advanced approaches currently being investigated in the arena of formal specification and verification of real time systems Together these two texts provide a comprehensive snapshot of current insights into the process of designing and building real time computing systems on a scientific basis Many of the papers in this book take care to define the notion of real time system precisely because it is often easy to misunderstand what is meant by that term Different communities of researchers variously use the term real time to refer to either very fast computing or immediate on line data acquisition or deadline driven computing This text is concerned with the very difficult problems of scheduling tasks and resource management in computer systems whose performance is inextricably fused with the achievement of deadlines Such systems have been enabled for a rapidly increasing set of diverse end uses by the unremitting advances in computing power per constant dollar cost and per constant unit volume of space End use applications of deadline driven real time computers span a spectrum that includes transportation systems robotics and manufacturing aerospace and defense industrial process control and telecommunications

**Foundations of Real-Time Computing: Scheduling and Resource Management**

André M. van Tilborg, Gary M. Koob, 2012-12-06 This volume contains a selection of papers that focus on the state of the art in real time scheduling and resource management Preliminary versions of these papers were presented at a workshop on the foundations of real time computing sponsored by the Office of Naval Research in October 1990 in Washington D C A companion volume by the title Foundations of Real Time Computing Formal Specifications and Methods complements this book by addressing many of the most advanced approaches currently being investigated in the arena of formal specification and verification of real time systems Together these two texts provide a comprehensive snapshot of current insights into the process of designing and building real time computing systems on a scientific basis Many of the papers in this book take care to define the notion of real time system precisely because it is often easy to misunderstand what is meant by that term Different communities of researchers variously use the term real time to refer to either very fast computing or immediate on line data acquisition or deadline driven computing This text is concerned with the very difficult problems of scheduling tasks and resource management in computer systems whose performance is inextricably fused with the achievement of deadlines Such systems have been enabled for a rapidly increasing set of diverse end uses by the unremitting advances in computing power per constant dollar cost and per constant unit volume of space End use applications of deadline driven real time

computers span a spectrum that includes transportation systems robotics and manufacturing aerospace and defense industrial process control and telecommunications

**Real Time Computing** Alexander D. Stoyenko, 2013-12-14 NATO s Division of Scientific and Environmental Affairs sponsored this Advanced Study Institute because it was felt to be timely to cover this important and challenging subject for the first time in the framework of NATO s ASI programme The significance of real time systems in everyone s life is rapidly growing The vast spectrum of these systems can be characterised by just a few examples of increasing complexity controllers in washing machines air traffic control systems control and safety systems of nuclear power plants and finally future military systems like the Strategic Defense Initiative SDI The importance of such systems for the well being of people requires considerable efforts in research and development of highly reliable real time systems Furthermore the competitiveness and prosperity of entire nations now depend on the early application and efficient utilisation of computer integrated manufacturing systems CIM of which real time systems are an essential and decisive part Owing to its key significance in computerised defence systems real time computing has also a special importance for the Alliance The early research and development activities in this field in the 1960s and 1970s aimed towards improving the then unsatisfactory software situation Thus the first high level real time languages were defined and developed RTL 2 Coral 66 Procol LTR and PEARL In close connection with these language developments and with the utilisation of special purpose process control peripherals the research on real time operating systems advanced considerably

Real-Time Database Systems Kam-Yiu Lam, Tei-Wei Kuo, 2006-04-18 In recent years tremendous research has been devoted to the design of database systems for real time applications called real time database systems RTDBS where transactions are associated with deadlines on their completion times and some of the data objects in the database are associated with temporal constraints on their validity Examples of important applications of RTDBS include stock trading systems navigation systems and computer integrated manufacturing Different transaction scheduling algorithms and concurrency control protocols have been proposed to satisfy transaction timing data temporal constraints Other design issues important to the performance of a RTDBS are buffer management index accesses and I/O scheduling Real Time Database Systems Architecture and Techniques summarizes important research results in this area and serves as an excellent reference for practitioners researchers and educators of real time systems and database systems

*Scheduling Computer and Manufacturing Processes* Jacek Blazewicz, Klaus H. Ecker, Erwin Pesch, Günter Schmidt, Jan Weglarz, 2013-06-29 Let us first describe the purpose of this book starting with the explanation of its title In general scheduling problems can be understood very broadly as the problems of allocating resources over time to perform a set of tasks being parts of some processes among which computational and manufacturing ones are most important Tasks individually compete for resources which can be of a very different nature e.g. manpower money processors machines energy tools The same is true for task characteristics e.g. ready times due dates relative urgency weights functions describing task processing in relation to allotted resources Moreover a structure of a set

of tasks reflecting precedence constraints among them can be defined in different ways. In addition, different criteria which measure the quality of the performance of a set of tasks can be taken into account. It is easy to imagine that scheduling problems understood so generally appear almost everywhere in real world situations. Of course there are many aspects concerning approaches for modeling and solving these problems which are of general methodological importance. On the other hand, however, some classes of scheduling problems have their own specificity which should be taken into account. Since it is rather impossible to treat all these classes with the same attention in a framework of one book, some constraints must be put on the subject area considered. In the case of this book, these constraints are as follows:

**Handbook of Real-Time and Embedded Systems** Insup Lee, Joseph Y-T. Leung, Sang H. Son, 2007-07-23 Real time and embedded systems are essential to our lives from controlling car engines and regulating traffic lights to monitoring plane takeoffs and landings to providing up to the minute stock quotes. Bringing together researchers from both academia and industry, the Handbook of Real Time and Embedded Systems provides comprehensive coverage.

*Foundations of Real-Time Computing: Formal Specifications and Methods* André M. van Tilborg, Gary M. Koob, 1991 This volume contains a selection of papers that focus on the state of the art in formal specification and verification of real time computing systems. Preliminary versions of these papers were presented at a workshop on the foundations of real time computing sponsored by the Office of Naval Research in October 1990 in Washington D C. A companion volume by the title Foundations of Real Time Computing Scheduling and Resource Management complements this book by addressing many of the recently devised techniques and approaches for scheduling tasks and managing resources in real time systems. Together, these two texts provide a comprehensive snapshot of current insights into the process of designing and building real time computing systems on a scientific basis. The notion of real time system has alternative interpretations, not all of which are intended usages in this collection of papers. Different communities of researchers variously use the term real time to refer to either very fast computing or immediate on line data acquisition or deadline driven computing. This text is concerned with the formal specification and verification of computer software and systems whose correct performance is dependent on carefully orchestrated interactions with time, e.g. meeting deadlines and synchronizing with clocks. Such systems have been enabled for a rapidly increasing set of diverse end uses by the unremitting advances in computing power per constant dollar cost and per constant unit volume of space. End use applications of real time computers span a spectrum that includes transportation systems, robotics and manufacturing, aerospace and defense, industrial process control and telecommunications.

Handbook on Scheduling Jacek Blazewicz, Klaus H. Ecker, Erwin Pesch, Günter Schmidt, Malgorzata Sterna, Jan Weglarz, 2019-04-25 This handbook provides a comprehensive introduction to the theory and applications of scheduling in advanced planning and computer systems. It addresses a broad audience including practitioners and researchers interested in scheduling as well as graduate and advanced undergraduate students in the fields of computer science and computer engineering operations.

research industrial and real time engineering management science business administration and information systems and applied mathematics The book begins by providing an introduction to and basic concepts from discrete mathematics Single and multiple processor systems are covered with a focus on multiprocessor tasks and hard real time systems Flow shop and open shop scheduling as well as scheduling in job shops are explained in detail Issues like limited processor availability time dependence resource constraints and imprecise computations are dealt with in dedicated chapters Special attention is given to online scheduling constraint programming and disjunctive scheduling The book also features applications and cases involving flexible manufacturing systems computer integrated production scheduling and logistics In particular it presents case studies on optimization procedures for the production of acrylic glass and of helicopter parts in a flexible manufacturing system an efficient decision support system for airport gate scheduling concrete delivery planning and berth and quay crane allocation at seaports

Handbook on Scheduling Jacek Błażewicz, Klaus H. Ecker, Erwin Pesch, Günter Schmidt, Jan Weglarz, 2007-06-12 This book provides a theoretical and application oriented analysis of deterministic scheduling problems in advanced planning and computer systems The text examines scheduling problems across a range of parameters job priority release times due dates processing times precedence constraints resource usage and more focusing on such topics as computer systems and supply chain management Discussion includes single and parallel processors flexible shops and manufacturing systems and resource constrained project scheduling Many applications from industry and service operations management and case studies are described The handbook will be useful to a broad audience from researchers to practitioners graduate and advanced undergraduate students

*Model Checking* Edmund M. Clarke, Orna Grumberg, Doron Peled, Doron A. Peled, 1999 This presentation of the theory and practice of model checking includes basic as well as state of the art techniques algorithms and tools and can be used as an introduction to the subject or a reference for researchers

**Synchronous Programming of Reactive Systems** Nicolas Halbwachs, 2013-06-29 This book will attempt to give a first synthesis of recent works concerning reactive system design The term reactive system has been introduced in order to avoid the ambiguities often associated with by the term real time system which although best known and more suggestive has been given so many different meanings that it is almost inevitably misunderstood Industrial process control systems transportation control and supervision systems signal processing systems are examples of the systems we have in mind Although these systems are more and more computerized it is surprising to notice that the problem of time in computer science has been studied only recently by pure computer scientists Until the early 1980s time problems were regarded as the concern of performance evaluation or of some unjustly scorned industrial computer engineering or at best of operating systems A second surprising fact in contrast is the growth of research concerning timed systems during the last decade The handling of time has suddenly become a fundamental goal for most models of concurrency In particular Robin Alilner's pioneering works about synchronous process algebras gave rise to a school of thought adopting the following abstract point

of view As soon as one admits that a system can instantaneously react to events i e

**Embedded System Design: Topics, Techniques and Trends** Achim Rettberg, Mauro Zanello, Rainer Dömer, Andreas Gerstlauer, Franz Rammig, 2010-05-09 Over recent years embedded systems have gained an enormous amount of processing power and functionality Many of the formerly external components can now be integrated into a single System on Chip This tendency has resulted in a dramatic reduction in the size and cost of embedded systems As a unique technology the design of embedded systems is an essential element of many innovations Embedded System Design Topics Techniques and Trends presents the technical program of the International Embedded Systems Symposium IESS 2007 held in Irvine California IESS is a unique forum to present novel ideas exchange timely research results and discuss the state of the art and future trends in the field of embedded systems Contributors and participants from both industry and academia take active part in this symposium The IESS conference is organized by the Computer Systems Technology committee TC10 of the International Federation for Information Processing IFIP Timely topics techniques and trends in embedded system design are covered by the chapters in this book including design methodology specification and modeling embedded software and hardware synthesis networks on chip distributed and networked systems and system verification and validation Particular emphasis is paid to automotive and medical applications A set of actual case studies and special aspects in embedded system design are included as well

**Formal Modeling and Analysis of Timed Systems** Kim G. Larsen, Peter Niebert, 2004-05-12 This book constitutes the thoroughly refereed post proceedings of the First International Workshop on Formal Modeling and Analysis of Timed Systems FORMATS 2003 held in Marseille France in September 2003 The 19 revised full papers presented together with an invited paper and the abstracts of two invited talks were carefully selected from 36 submissions during two rounds of reviewing and improvement All current aspects of formal method for modeling and analyzing timed systems are addressed among the timed systems dealt with are timed automata timed Petri nets max plus algebras real time systems discrete time systems timed languages and real time operating systems

**Hard Real-Time Computing Systems** Giorgio C Buttazzo, 2007-08-19 Real time computing plays a crucial role in our society since an increasing number of complex systems rely in part or completely on processor control Examples of applications that require real time computing include nuclear power plants railway switching systems automotive electronics air traffic control telecommunications robotics and military systems In spite of this large application domain most of the current real time systems are still designed and implemented using low level programming and empirical techniques without the support of a scientific methodology This approach results in a lack of reliability which in critical applications may cause serious environmental damage or even loss of life This book is a basic treatise on real time computing with particular emphasis on predictable scheduling algorithms The main objectives of the book are to introduce the basic concepts of real time computing illustrate the most significant results in the field and provide the basic methodologies for designing predictable computing systems useful in supporting critical control applications The book is written for instructional use and

is organized to enable readers without a strong knowledge of the subject matter to quickly grasp the material. Technical concepts are clearly defined at the beginning of each chapter and algorithm descriptions are reinforced through concrete examples, illustrations, and tables.

**Deadline Scheduling for Real-Time Systems** John A. Stankovic, Marco Spuri, Krithi Ramamritham, Giorgio C. Buttazzo, 2012-12-06. Many real time systems rely on static scheduling algorithms. This includes cyclic scheduling, rate monotonic scheduling, and fixed schedules created by off-line scheduling techniques such as dynamic programming, heuristic search, and simulated annealing. However, for many real time systems, static scheduling algorithms are quite restrictive and inflexible. For example, highly automated agile manufacturing, command control, and communications and distributed real time multimedia applications all operate over long lifetimes and in highly non-deterministic environments. Dynamic real time scheduling algorithms are more appropriate for these systems and are used in such systems. Many of these algorithms are based on earliest deadline first (EDF) policies. There exists a wealth of literature on EDF based scheduling with many extensions to deal with sophisticated issues such as precedence constraints, resource requirements, system overload, multi-processors, and distributed systems. *Deadline Scheduling for Real Time Systems: EDF and Related Algorithms* aims at collecting a significant body of knowledge on EDF scheduling for real time systems, but it does not try to be all-inclusive; the literature is too extensive. The book primarily presents the algorithms and associated analysis, but guidelines, rules, and implementation considerations are also discussed, especially for the more complicated situations where mathematical analysis is difficult. In general, it is very difficult to codify and taxonomize scheduling knowledge because there are many performance metrics, task characteristics, and system configurations. Also adding to the complexity is the fact that a variety of algorithms have been designed for different combinations of these considerations. In spite of the recent advances, there are still gaps in the solution space, and there is a need to integrate the available solutions. For example, a list of issues to consider includes preemptive versus non-preemptive tasks, uni-processors versus multi-processors, using EDF at dispatch time versus EDF based planning, precedence constraints among tasks, resource constraints, periodic versus aperiodic versus sporadic tasks, scheduling during overload, fault tolerance requirements, and providing guarantees and levels of guarantees meeting quality of service requirements. *Deadline Scheduling for Real Time Systems: EDF and Related Algorithms* should be of interest to researchers, real time system designers, instructors, and students either as a focussed course on deadline based scheduling for real time systems or more likely as part of a more general course on real time computing. The book serves as an invaluable reference in this fast-moving field.

*Model Checking, second edition* Edmund M. Clarke, Jr., Orna Grumberg, Daniel Kroening, Doron Peled, Helmut Veith, 2018-12-04. An expanded and updated edition of a comprehensive presentation of the theory and practice of model checking, a technology that automates the analysis of complex systems. Model checking is a verification technology that provides an algorithmic means of determining whether an abstract model representing, for example, a hardware or software design, satisfies a formal specification expressed as a temporal logic.

formula If the specification is not satisfied the method identifies a counterexample execution that shows the source of the problem Today many major hardware and software companies use model checking in practice for verification of VLSI circuits communication protocols software device drivers real time embedded systems and security algorithms This book offers a comprehensive presentation of the theory and practice of model checking covering the foundations of the key algorithms in depth The field of model checking has grown dramatically since the publication of the first edition in 1999 and this second edition reflects the advances in the field Reorganized expanded and updated the new edition retains the focus on the foundations of temporal logic model while offering new chapters that cover topics that did not exist in 1999 propositional satisfiability SAT based model checking counterexample guided abstraction refinement and software model checking The book serves as an introduction to the field suitable for classroom use and as an essential guide for researchers

**Foundations of Real-Time Computing: Formal Specifications and Methods** André M. van Tilborg, Gary M. Koob, 2012-10-12 This volume contains a selection of papers that focus on the state of the art in formal specification and verification of real time computing systems Preliminary versions of these papers were presented at a workshop on the foundations of real time computing sponsored by the Office of Naval Research in October 1990 in Washington D C A companion volume by the title Foundations of Real Time Computing Scheduling and Resource Management complements this book by addressing many of the recently devised techniques and approaches for scheduling tasks and managing resources in real time systems Together these two texts provide a comprehensive snapshot of current insights into the process of designing and building real time computing systems on a scientific basis The notion of real time system has alternative interpretations not all of which are intended usages in this collection of papers Different communities of researchers variously use the term real time to refer to either very fast computing or immediate on line data acquisition or deadline driven computing This text is concerned with the formal specification and verification of computer software and systems whose correct performance is dependent on carefully orchestrated interactions with time e g meeting deadlines and synchronizing with clocks Such systems have been enabled for a rapidly increasing set of diverse end uses by the unremitting advances in computing power per constant dollar cost and per constant unit volume of space End use applications of real time computers span a spectrum that includes transportation systems robotics and manufacturing aerospace and defense industrial process control and telecommunications

**Quality of Communication-Based Systems** Günter Hommel, 2012-12-06 Quality of Communication Based Systems presents the research results of students of the Graduiertenkolleg Communication Based Systems to an international community To stimulate the scientific discussion renowned experts have been invited to give their views on the research areas Formal specification and mathematical foundations of distributed systems using process algebra graph transformations process calculi and temporal logics Performance evaluation dependability modelling and analysis of real time systems with different kinds of timed Petri nets

Specification and analysis of communication protocols Reliability security and dependability in distributed systems Object orientation in distributed systems architecture Software development and concepts for distributed applications Computer network architecture and management Language concepts for distributed systems      **Parallel Algorithm Derivation and Program Transformation** Robert Paige, J.H. Reif, Ralph Wachter, 2007-08-28 This book contains selected papers from the ONR Workshop on Parallel Algorithm Design and Program Transformation that took place at New York University Courant Institute from Aug 30 to Sept 1 1991 The aim of the workshop was to bring together computer scientists in transformational programming and parallel algorithm design in order to encourage a sharing of ideas that might benefit both communities It was hoped that exposure to algorithm design methods developed within the algorithm community would stimulate progress in software development for parallel architectures within the transformational community It was also hoped that exposure to syntax directed methods and pragmatic programming concerns developed within the transformational community would encourage more realistic theoretical models of parallel architectures and more systematic and algebraic approaches to parallel algorithm design within the algorithm community The workshop Organizers were Robert Paige John Reif and Ralph Wachter The workshop was sponsored by the Office of Naval Research under grant number N00014 90 J 1421 There were 44 attendees 28 presentations and 5 system demonstrations All attendees were invited to submit a paper for publication in the book Each submitted paper was refereed by participants from the Workshop The final decision on publication was made by the editors There were several motivations for holding the workshop and for publishing papers contributed by its participants Transformational programming and parallel computation are two emerging fields that may ultimately depend on each other for success      Multimedia Systems Ralf Steinmetz, Klara Nahrstedt, 2013-03-09 Multimedia Systems discusses the basic characteristics of multimedia operating systems networking and communication and multimedia middleware systems The overall goal of the book is to provide a broad understanding of multimedia systems and applications in an integrated manner a multimedia application and its user interface must be developed in an integrated fashion with underlying multimedia middleware operating systems networks security and multimedia devices Fundamental characteristics of multimedia operating and distributed communication systems are presented especially scheduling algorithms and other OS supporting approaches for multimedia applications with soft real time deadlines multimedia file systems and servers with their decision algorithms for data placement scheduling and buffer management multimedia communication transport and streaming protocols services with their error control congestion control and other Quality of Service aware and adaptive algorithms synchronization services with their skew control methods and group communication with their group coordinating algorithms and other distributed services

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