James H. Anderson
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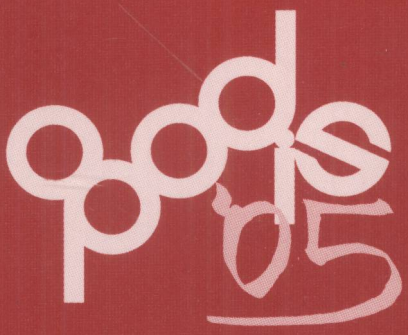
Principles of Distributed Systems

9th International Conference, OPODIS 2005
Pisa, Italy, December 2005
Revised Selected Papers



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Revised Selected Papers

Springer

Volume Editors

James H. Anderson
University of North Carolina at Chapel Hill
Department of Computer Science
Chapel Hill, USA
E-mail: anderson@cs.unc.edu

Giuseppe Prencipe
Università di Pisa
Dipartimento di Informatica
Largo Bruno Pontecorvo 3, 56100 Pisa, Italy
E-mail: prencipe@di.unipi.it

Roger Wattenhofer
ETH Zurich
Computer Engineering and Networks Laboratory
8092 Zurich, Switzerland
E-mail: wattenhofer@tik.ee.ethz.ch

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Preface

The 9th International Conference on Principles of Distributed Systems (OPODIS 2005) was held during December 12–14, 2005 in Pisa, Italy. It continued a tradition of successful conferences with friendly and pleasant atmospheres. Previous OPODIS conferences were held in Chantilly (1997), Amiens (1998), Hanoi (1999), Paris (2000), Mexico (2001), Reims (2002), La Martinique (2003), and Grenoble (2004).

The OPODIS conference constitutes an open forum for the exchange of state-of-the-art knowledge on distributed computing and systems among researchers from around the world. Following the tradition of the previous events, the 2005 program was composed of high-quality contributed papers by experts of international caliber in this scientific area. Papers were sought soliciting original research contributions to the theory, specifications, design and implementation of distributed systems, including:

- communication and synchronization protocols
- distributed algorithms, multiprocessor algorithms
- distributed collaborative environments
- embedded systems
- fault-tolerance, reliability, availability
- grid and cluster computing
- location- and context-aware systems
- mobile computing and networks
- peer-to-peer systems, overlay networks
- performance analysis of distributed algorithms and systems
- real-time systems
- security issues in distributed computing and systems
- sensor networks
- specification verification and testing of distributed systems

This year, a particular focus was placed on real-time systems and wireless networks.

In response to the call for papers for OPODIS 2005, 109 papers in the above areas were submitted from 30 countries from around the world. Each paper was reviewed by at least three reviewers, and judged according to scientific and presentation quality, originality and relevance to the conference topics. The Program Committee selected 30 papers for presentation at the conference. In addition to the submitted technical papers, the program included two exciting invited talks, by David Peleg (Weizmann Institute of Science, Israel), and by Giorgio Buttazzo (Scuola Superiore S. Anna of Pisa). We are grateful that these two distinguished experts accepted our invitation to share with us their views on various aspects of the field.

It is impossible to organize a successful program without the help of many individuals. We would like to express our appreciation to the authors of the submitted papers, the Program Committee members and the external referees. We would also like to thank the OPODIS Steering Committee members, in particular the chairman Philippas Tsigas, who supervised and supported the continuation of this event. We owe special thanks to the Organizing Committee chair, Giuseppe Prencipe (Università di Pisa, Italy), the publicity chair, Thomas Moscibroda (ETH Zurich, Switzerland), and Andreas Wetzel (ETH Zurich, Switzerland) for his assistance with the electronic submission and reviewing system.

December 2005 James H. Anderson and Roger Wattenhofer

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OPODIS 2005 was organized by the Dipartimento di Informatica, Università di Pisa, Italy.

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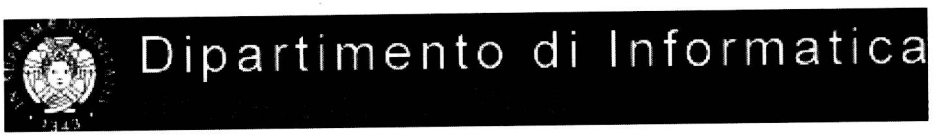

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Distributed Algorithms for Systems of Autonomous Mobile Robots

David Peleg*

Department of Computer Science, The Weizmann Institute of Science, Rehovot, Israel
david.peleg@weizmann.ac.il

Over the last five decades, mobile robots have been the focus of extensive research and development activities, with numerous applications for industrial tasks, military operations, search and rescue missions and space exploration, as well as some home applications.

Systems consisting of a group of autonomously operating mobile robots (sometimes referred to as *robot swarms*) have attracted considerable interest throughout the past twenty years, due to their potential for providing flexible, low-cost solutions in hazardous situations (e.g., military operations, toxic environments or fire fighting). The idea is to deal with such applications using swarms consisting of many small and simple robots, with very limited capabilities (e.g., low energy sources, limited communication means and weak processors). The use of tiny, functionally simple and cheap robots may make it acceptable to lose some of the robots, so long as the team manages to achieve its collective goals.

The main research efforts invested so far in mobile robots focused on the main engineering aspects of providing physical functionalities. Nevertheless, it seems clear that the design of very large robots swarms makes it essential to reconsider also control and coordination issues. For instance, managing the movements of a robot swarm involves new and interesting algorithmic problems due to the need to coordinate the movements of the individual robots and avoid collisions and over-crowding. Coordination tasks studied so far in the literature include gathering a robot swarm to a single point, pattern formation, flocking (or following a leader), partitioning, spreading and searching.

Most existing experimental settings of robot swarms involve small swarms (of, say, up to a dozen robots), which allow centralized control. However, future robot swarms, consisting of tens of thousands of robots, can no longer be controlled centrally in an efficient manner, and it seems that certain tasks may need to be managed by distributed protocols. Indeed, there have been a number of recent studies on distributed coordination and control protocols for robot swarms. From the point of view of the community of distributed algorithms and systems, this presents an interesting new distributed model that differs in a number of key aspects from the traditional models, and raises some intriguing research problems.

The talk will review this exciting research area, present some of the main problems and issues raised by it, and discuss directions for future study.

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J.H. Anderson, G. Prencipe, and R. Wattenhofer (Eds.): OPODIS 2005, LNCS 3974, p. 1, 2006.

Real-Time Issues in Mobile Wireless Networks

Giorgio Buttazzo

Scuola Superiore Sant'Anna, Pisa

The use of cooperating mobile robots is requested in an increasing number of application domains, including civil protection, surveillance, environmental monitoring, under-water exploration, and space missions. In most of these applications, the robot units are required to acquire sensory information, localize themselves in the environment, plan trajectories, avoid obstacles, and cooperate with the other robots to reach a common goal.

To achieve such objectives, the development of a team of cooperating robots poses several interesting problems from a research point of view, such as the real-time execution of acquisition and control processes, the efficient management of computational resources, the software control of energy consumption, the real-time communication protocols on wireless networks, and the development of distributed agreement algorithms for reaching a consensus in collective decisions. Moreover, small mobile robots are often controlled by micro-controllers having low computational power and limited resources, hence satisfying timing constraints requires the use of efficient operating systems and algorithms that can guarantee a predictable behavior both in normal and overload conditions.

This talk will present some of the most challenging problems to be solved in order to support the development of mobile wireless networks of cooperating robots.

J.H. Anderson, G. Prencipe, and R. Wattenhofer (Eds.): OPODIS 2005, LNCS 3974, p. 2, 2006.

A Lazy Concurrent List-Based Set Algorithm

Steve Heller[1], Maurice Herlihy[2], Victor Luchangco[1], Mark Moir[1], William N. Scherer III[3], and Nir Shavit[1]

[1] Sun Microsystems Laboratories
[2] Brown University
[3] University of Rochester

Abstract. List-based implementations of sets are a fundamental building block of many concurrent algorithms. A skiplist based on the lock-free list-based set algorithm of Michael will be included in the Java™ Concurrency Package of *JDK 1.6.0*. However, Michael's lock-free algorithm has several drawbacks, most notably that it requires all list traversal operations, including membership tests, to perform cleanup operations of logically removed nodes, and that it uses the equivalent of an atomically markable reference, a pointer that can be atomically "marked," which is expensive in some languages and unavailable in others.

We present a novel "lazy" list-based implementation of a concurrent set object. It is based on an optimistic locking scheme for inserts and removes, eliminating the need to use the equivalent of an atomically markable reference. It also has a novel wait-free membership test operation (as opposed to Michael's lock-free one) that does not need to perform cleanup operations and is more efficient than that of all previous algorithms.

Empirical testing shows that the new lazy-list algorithm consistently outperforms all known algorithms, including Michael's lock-free algorithm, throughout the concurrency range. At high load, with 90% membership tests, the lazy algorithm is more than twice as fast as Michael's. This is encouraging given that typical search structure usage patterns include around 90% membership tests. By replacing the lock-free membership test of Michael's algorithm with our new wait-free one, we achieve an algorithm that slightly outperforms our new lazy-list (though it may not be as efficient in other contexts as it uses Java's RTTI mechanism to create pointers that can be atomically marked).

1 Introduction

Lists are a fundamental building block for concurrent data structures, both in their own right, and as the basis for many types of search and dictionary data types [12]. We consider three kinds of list operations: inserting a list entry, removing a list entry, and testing whether an entry is in the list.

This paper introduces the *lazy list*, a simple new concurrent *list-based set* algorithm with a number of novel concurrency-related properties. To explain the novel aspects of lazy lists, we start with an overview of different ways to synchronize lists. *Coarse-grained* locking, which uses a single lock to protect the entire

J.H. Anderson, G. Prencipe, and R. Wattenhofer (Eds.): OPODIS 2005, LNCS 3974, pp. 3–16, 2006.