#### The Rice Parallel Processing Testbed †

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#### I. Introduction

One of the most important trends in high performance computing is the development and general availability of parallel processing systems. The designers and users of such systems have the difficult task of utilizing the available parallelism in both hardware and algorithms effectively to realize as much performance improvement as possible over sequential systems. This requires matching the structure of parallel programs with the structure of the concurrent system on which they are to execute. This in turn makes it necessary to develop performance evaluation techniques that are more sophisticated and cost-effective than those currently used. The Rice Parallel Processing Testbed (RPPT), the subject of this paper, is a major step in this direction.

Analysis of parallel systems is generally restricted to approximate models of the systems and their workloads that have been greatly simplified to make them tractable (for example, queueing models). Simulation can provide information about system performance at almost arbitrary levels of detail, but can be computationally expensive (as in the case of instruction level simulation), often forcing the simulator to use a less detailed but faster simulation model, with a concomitant loss of accuracy.

The RPPT is a simulation-based set of tools that permits the user to study the interaction of parallel programs and the parallel architectures that execute them. The simulation models for the architectures can be written at different levels of detail, permitting the user to trade off accuracy against computational efficiency. The architecture models are driven by the executions of real programs, rather than by statistical models of program resource demands. Data-dependent computation times, interprocess communications and synchronization delays, and other architecture-specific timing information are thus all accounted for with a high degree of accuracy. However, the simulations are less computationally demanding than an instruction-level simulation of the program's execution. The RPPT uses a technique called execution-driven simulation, in which the parallel program is executed directly on the simulation host machine. Timing information about the program's execution is generated dynamically with relatively low overhead.

By driving a simulation with the pseudo-concurrent execution of an actual parallel algorithm, an RPPT simulation uses a more accurate and realistic model of the workload of a parallel computing system than can be obtained with either statistical workload models or traces derived from the sequential execution of the algorithms. The efficiency of an RPPT simulation is improved further by only advancing simulation time when parallel processes interact. Therefore, execution-driven simulation offers a compromise between the high cost or low accuracy of techniques currently available for studying the interaction between hardware and software in parallel systems.

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Another important feature of the RPPT is its flexibility. Since the architecture models and the parallel programs are decoupled, an algorithm designer can test several different algorithms on a fixed architecture model. It is also possible to study the performance of a single algorithm on systems with fundamentally different basic architectures (e.g., a shared bus multiprocessor vs. a multiprocessor with a multistage interconnection network or a hypercube). This is especially important in the study of new concurrent architectures, particularly those intended for specific and/or dedicated applications.

The RPPT provides a computational tool for investigating concurrent algorithms and their interactions with parallel architectures. It can be used to investigate a number of issues concerning concurrent algorithm execution. These include:

- the effects of overhead due to inter-module communication in various parallel architectures;
- the performance degradation resulting from synchronization delays caused by concurrent processes that must communicate with one another;
- the overhead of process management, such as processcreation and activation or context switching;
- the impact of the constant multiplier found in the abstract expressions for the time complexities of concurrent algorithms and the influence of the architecture on this multiplier; and
- the effects of using different process granularities in concurrent algorithm implementations.

These issues are for the most part difficult or impossible toresolve using conventional performance evaluation tools.

The major significance of the approach is derived from its ability to provide accurate quantitative measures of performance that include the detrimental effects of communication overhead, synchronization delays, process management overhead, and process granularity. The RPPT provides the designer with an effective tool for comparing the performance of different organizations or the effects of small changes in a specific organization or algorithm. For dedicated systems, the actual application programs can be used, early in the design cycle, to generate performance estimates of a proposed organization.

The following section is a high-level overview of the RPPT and its components. This is followed by a discussion of execution-driven simulation and how the architecture model interacts with the parallel program. Section 4 deals with some of the more important aspects of the testbed implementation, and section 5 gives a brief example of the use of the RPPT. The last section describes the current status of the project.

#### 2. An Overview of the RPPT system

A user must provide three basic inputs to the RPPT: a concurrent program, a simulation model of the architecture, and a mapping of processes and data onto the model. The RPPT consists of six basic components that allow the user to specify

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chapters demonstrate low overhead practical solutions are attainable and not necessarily incompatible with performance considerations. The section on innovative compiler support in particular demonstrates how the benefits of application specificity may be obtained while reducing hardware cost and run time overhead **Proceedings of the 1988 ACM** SIGMETRICS Conference on Measurement and Modeling of Computer Systems, May 24-27, 1988, Santa Fe, New IBM Journal of Research and Development, 1991 The Cache Coherence Problem in Mexico, USA. 1988 Shared-Memory Multiprocessors Igor Tartalja, Veljko Milutinović, 1996-02-13 Almost all software solutions are developed through academic research and implemented only in prototype machines leaving the field of software techniques for maintaining the cache coherence widely open for future research and development This book is a collection of all the representative approaches to software coherence maintenance including a number of related efforts in the performance evaluation field The book presents a selection of 27 papers dealing with state of the art software solutions for cache coherence maintenance in shared memory multiprocessors It begins with a set of four introductory readings that provides a brief overview of the cache coherence problem and introduces software solutions to the problem The text defines and illustrates static and dynamic software schemes techniques for modeling performance evaluation mechanisms and performance evaluation studies The book is intended for the experienced reader in computer engineering but possibly a novice in the topic of cache coherence It also provides an in depth understanding of the problem as well as a comprehensive overview for multicomputer designers computer architects and compiler writers In addition it is a software coherence reference handbook for advanced undergraduate and typical graduate students in multiprocessing and multiprogramming Performance Engineering Reiner Dumke, Claus Rautenstrauch, Andreas Schmietendorf, Andre Scholz, 2003-06-29 areas Initially computer systems performance analyses were carried out primarily because of limited resources Due to ever increasing functional complexity of computational systems and user requirements performance engineering continues to play a major role in software development This book assesses the state of the art in performance engineering Besides revised chapters drawn from two workshops on performance engineering held in 2000 additional chapters were solicited in order to provide complete coverage of all relevant aspects The first part is devoted to the relation between software engineering and performance engineering the second part focuses on the use of models measures and tools finally case studies with regard to concrete technologies are presented Researchers professional software engineers and advanced students interested in performance analysis will find this book an indispensable source of information and reference Computer Sciences Technical Report, 2002 Proceedings of the 1988 ACM Sigmetrics Conference on Measurement and Modeling of Computer Systems, May 24-27, 1988, Santa Fe, New Mexico ACM Special Interest Group on Measurement, 1988

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