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STATUS REPORT
on the Grant Project Entitled
"Performance and Evaluation of Real-Time Multicomputer Control Systems"

By

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1. INTRODUCTION

In this status report, we briefly outline the research accomplishments and activities during the period of September 1982 - August 1983.

The overall goal of this project is to develop a structured method for design and evaluation of real-time multicomputers/multiprocessors.

2. SUMMARY OF ACCOMPLISHMENTS

2.1. New Performance Measures

This work arose as a result of a realization that conventional performance measures are inappropriate and even misleading when used to characterize real-time systems such as aircraft. We have developed a set of performance measures for real-time control systems. These have been shown to be more appropriate than conventional measures. For details, see [1],[2],[8]. As a result of these new measures, the solution of several interesting problems such as the number-power tradeoff, the allocation of tasks to processors, and the optimal share-out of control information among distributed controllers has been facilitated.

2.2. Detailed Examples

To check the applicability of the performance measures to real-life systems, two typical examples are studied in detail; an idealized communications satellite [2] and an aircraft in the final stages of its landing [7],[9]. These examples have served to refine our performance measures and have lent them credibility.

2.3. Modeling of Error Detection Process

This is a *microscopic view* of real-time computers. In other words, error detection process is one of the fundamental issues that affect the overall performance of real-time computers. In this work, we have proposed a model to describe the entire error detection process. The detection mechanisms are divided into three classes which are signal level, function level detection mechanisms and diagnostic. For each class, we assign different performance measure and use these measures to evaluate detection capability of the whole system. When these detection mechanisms are neither perfect nor complete, the system will suffer from two undesirable results; one is the probability of putting out potentially erroneous results, the other is the additional recovery overhead. With the proposed model, we estimate these two effects and then discuss the design problem associated with the error detection process. Finally, the feasible space for detection mechanisms is outlined. For further details, see [3],[10].

2.4. Performance Evaluation of Rollback Recovery Methods

The principle of rollback recovery method is to save process states during the normal execution and to use the saved states for rescuing the failed process after an error is detected. To begin with, we consider the asynchronous recovery blocks and estimate the interval between two successive recovery lines which is the upper bound of rollback distance for this case. Then, two refinements of this asynchronous method: synchronized recovery blocks and pseudo recovery points, are discussed in regard to their overheads and performance. For details, see [4],[5].

2.5. Experiments on FTMP

Two experiments on FTMP were begun, and are expected to be completed by the end of this year. These are an investigation of paging in the FTMP, and error generation and detection. From the first experiment, a computation of the optimal page size will become possible. From the second, some experimental data for one of the error detection models described above will be obtained.

2.6. Optimal Size of an NMR Cluster

Due to the considerable overhead involved in voting and Byzantine general algorithms in an NMR cluster, increasing the size of the cluster to provide greater redundance is not always profitable. We have begun to develop an algorithm that will accept as inputs timing constraints and run-times of the individual computational jobs, the failure law of the processors, and the nature of the voting/Byzantine algorithm and produce as output, for a selected set of interconnection structures, the optimal number of processors in an NMR cluster. This work should be complete by the end of this year.

3. PARTICIPATING PERSONNEL

- Dr. Byung Kook Kim: visiting researcher in the area of real-time control

- Chandrasekar Mani Krishna: Ph.D. student

- Yann-Hang Lee: Ph. D. student

- Michael Woodbury: M. S. student

4. TRAVEL

- C. M. Krishna: attended the 20th Annual Allerton Conf. on Communications, Control, and Computing, University of Illinois, Urbana-Champaigne, IL., October 1982.

- K. G. Shin: visited NASA Langley Research Center for research review, January 1983.

- K. G. Shin: attended the IEEE Workshop for Reliable Computing Laboratories, NASA Langley Research Center, April 1983.

- K. G. Shin: attended the Performance'83, University of Maryland, College Park, MD., May 1983.

- K. G. Shin: attended the 13t Fault-Tolerant Computing Symposium, Milan, Italy, June 1983.

- C. M. Krishna and Y.-H. Lee: visited Airlab, NASA Langley Research Center, August 1983.

• K. G. Shin and Y.-H. Lee: attended the 1983 International Conference on Parallel Processing, Bellaire, MI, August 1983.

• K. G. Shin and C. M. Krishna: attended the 1983 SIGMETRICS Conference, Minneapolis, MN., August 1983.

5. TECHNICAL PAPERS AND REPORTS UNDER THE GRANT SUPPORT

The following technical papers/reports present in some detail the work accomplished thus far.

[1] C. M. Krishna and K. G. Shin, "Performance Measures for Fault-Tolerant Multiprocessor Controllers for Critical Processes," *Proc. of the 20th Annual Allerton Conf. on Communications, Control,* and Computing, University of Illinois, IL., October 1982.

[2] C. M. Krishna and K. G. Shin, "Performance Measures for Multiprocessor Controllers," **Performance'83**, A. K. Agrawala and S. K. Tripathi (eds.), North-Holland, pp. 229-250, 1983. and also published as *Computing Research Laboratory Report*, CRL-TR-1-82, University of Michigan, October 1982.

[3] K. G. Shin and Y. H. Lee, "Analysis of the Impact of Error Detection on Computer Performance," *Digest of FTCS-13*, and also published as *Computing Research Laboratory Report*, CRL-TR-2-82, University of Michigan, November 1982.

[4] Y. H. Lee and K. G. Shin, "Design and Evaluation of a Fault-Tolerant Multiprocessor Using Hardware Recovery Blocks," to appear in *IEEE Trans. on Computers*, and also published as *Computing Research Laboratory Report*, CRL-TR-6-82, University of Michigan, September 1982.

[5] K. G. Shin and Y. - H. Lee, "Analysis of Backward Error Recovery for Concurrent Processes with Recovery Blocks", *Proc. of the 1983 International Conf. on Parallel Processing*, Bellaire, MI, August 23-26, 1983. (Also this is being considered for *IEEE Trans. on Software Engineering*).

[6] C. M. Krishna and K. G. Shin, "Queueing Analysis of a Canonical Model of Real-Time Multiprocessors", *Proc. 1983 ACM SIGMETRICS Conf. on Measurement and Modelling of Computer Systems*, Minneapolis, MN, August 29-31, 1983.

[7] K. G. Shin, C. M. Krishna, and Y. - H. Lee, "The Application to the Aircraft Landing Problem of a Unified Method for Characterizing Real-Time Systems," To appear in *Proc. of Real-Time Systems Symposium*, Arlington, VA., December 6-8, 1983.

[8] K. G. Shin and C. M. Krishna, "New Performance Measures for Design and Evaluation of Real-Time Multiprocessors," submitted to *IEEE Trans. on Computers*.

[9] K. G. Shin, C. M. Krishna, and Y. - H. Lee, "A Unified Method for Evaluating Real-Time Computer Controllers: A Case Study," submitted to *IEEE Trans. on Computers.*

[10] K. G. Shin and Y. - H. Lee, "Error Detection Process: Model, Design, and Its Impact on Computer Performance," submitted to *IEEE Trans. on Computers.*

[11] C. M. Krishna, K. G. Shin, and Y. - H. Lee, "On Optimization Criteria for Checkpoint Placement", submitted to *Communications of ACM.*