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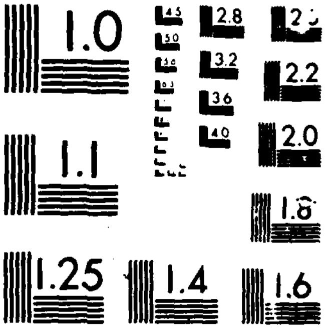
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STOCHASTIC MODELING AND SOLUTION TECHNIQUES
IN A TIME-VARYING ENVIRONMENT

Final Report

17 January 1983 through 30 September 1984

Office of Naval Research
Contract N00014-83-K-0217

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A. Computations Using the Randomization Technique

The randomization technique, which solves the Kolmogorov differential equations by viewing the continuous time Markov process as a uniformized embedded discrete parameter Markov chaian randomized by a Poisson process, was fully developed and published in Reference [2]. Applications of this technique to multi-echelon inventory systems are published in Reference [3]. Copies of the reprints for these references are attached to this report as an Appendix.

The numerical randomization technique was compared to a variety of simulation methods, including a brute force approach and others taking advantage to varying degrees of the uniformized embedded chain structure. This work is reported in Reference [4], which was presented at, and appears in the proceedings of, the Summer Systems Simulation Conference in Boston, July 23-25, 1984. A copy of this paper is also provided in the appendix.

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Work on handling large systems (over 100,000 states) by a truncated state-space approach has been completed and was presented at the joint national meeting of The Institute of Management Sciences and the Operations Research Society of America held in San Francisco on May 14-16, 1984. A journal article, Reference [1], will appear shortly. The technical paper version is included in the appendix. A system with over 100,000,000 states was solved by this approach.

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B. Optimization in a Time-varying Environment

Some initial progress has been made in studying optimization problems in a time-varying environment. Unlike the steady-state situations ~~was have~~ examined, the constraint functions are not monotone in all decision variables for all cases, which makes for less efficient use of implicit enumeration schemes. Nevertheless, implicit enumeration still appears to hold the most promise for our types of problems.

In many stochastic process modeling applications (e.g., to multi-echelon inventory systems), it is desirable to determine optimal values of the system decision variables (such as spares and repair capacities at the various system locations). Thus meaningful optimization problems, in terms of objective functions and constraints, must be formulated and solved. Both the formulation and the solution of such problems are more difficult in a transient environment.

We have started our work in this area by examining a single-echelon Markovian repairable item inventory system, known as the repairman problem, in which it is desired to keep M items operating. The system consists of M + y items in all, where y is the number of spares, and there are c repair channels available to repair failed items. The decision variables in such a systems are y and c, and we have identified such appropriate time-varying performance measures as (1) the expected number of operating items, and (2) the system availability, which is the probability that M items are operating. We have used the randomization technique to calculate the transient state probabilities, and thus the transient performance measures, and have experimentally verified that at each point in time the two performance measures above are monotonic nondecreasing functions of y and c.

Based on this observed monotonicity, the implicit enumeration algorithm of Sabbagh [5] has been used to determine the values of y and c that minimize a given cost function (of y and c only), subject to constraints stipulating that the availability at each time $t = kT/n$ $(k = 1,2,...,n)$ be not less than a value specified for that time (T is the length of the time horizon). Some modification of the basic implicit enumeration algorithm has been found to increase solution efficiency, and so we are now looking into other variations of the algorithm that will increase efficiency still further.

We are presently attempting to prove the observed monotonicity relations described above, by making use of results of Sonderman and Whitt [6] for the comparison of Markov chains.

In extending the approach described above to the optimization of a two-echelon Markovian repairable item inventory system, we conjectured and verified through randomization that monotonicity of the system availability with respect to the numbers of spares and repair channels does not necessarily hold for all points in time. We will thus seek an extension of the basic implicit enumeration approach that is applicable when full monontonicity of the problem functions does not hold.

In summary, we feel that a great deal of progress has been made to date. In addition to solving many aspects of these problems, our research has indicated what we believe to be very fruitful avenues of further work.

References

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[2] Gross, D. and D. R. Miller (1984). "The Randomization Technique as a Modeling Tool and Solution Procedure for Transient Markov Processes." Operations Research 32, 343-361.

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[5] Sabbagh, M. S. (1983). "A General Lexicographic Partial Enumeration Algorithm for the Solution of Integer Nonlinear Programming Problems." D.Sc. Dissertation, George Washington University.

[6] Sonderman, D. and W. Whitt (1976). "Comparing Continuous-time Markov Chains." School of Organization and Management, Yale University.

Appendix

Publications from the

Research Contract

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