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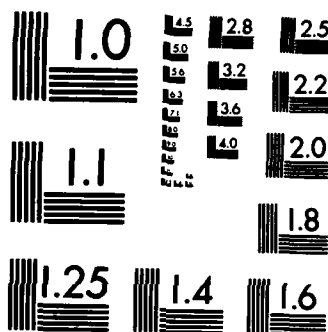   N00014-76-C-0578

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SIMULATION METHODOLOGY

by

Donald L. Iglehart

FINAL REPORT

December 1983

Prepared under Contract N00014-76-C-0578 (NR 042-343)

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DEPARTMENT OF OPERATIONS RESEARCH
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FINAL REPORT ON CONTRACT N00014-76-C-0578

This final report on contract N00014-76-C-0578 with Stanford
University, entitled **Simulation Methodology**, covers the period
January 1, 1976 to September 30, 1983. This contract partially
supported the research of the Principal Investigator and Project
Director, Dr. Donald L. Iglehart, as well as seven Ph.D. students
in the Department of Operations Research. The Ph.D. disserta-
tions of these students all appeared under this contract.

A.   Summary of Significant Accomplishments

This bibliography lists

During the period January 1, 1976 to September 30, 1983
thirty-one technical reports were issued. The principal topics
covered in this research were condition limit theorems for Markov
chains, variance reduction techniques for Markov chains, simula-
tion of response times in networks of queues, simulation of gen-
eralized semi-Markov processes and general state space Markov
chains, asymptotic theory for nonparameteric confidence inter-
vals, an autoregressive method for simulation output analysis,
simulation of non-Markovian systems, and simulation output analy-
sis for local area computer networks. Toward the end of this
period research began on the development of algorithms to opti-
mize systems parameters for simulation. An approach using
smoothing splines has been developed. This work was not complet-
ed and written up prior to the expiration of the contract. A
report on this work is still planned.

The work accomplished under this contract has significantly
enhanced the theoretical foundations for simulation output analy-
sis. Major improvements were made to the regenerative method for
generating confidence intervals for steady state system perfor-
mance characteristics. A new autoregressive method for handling
this problem was also developed. In addition, variance reduction
techniques designed to make our simulations more efficient were
established. Substantial progress was made in understanding how
to analyze output from non-Markovian systems. This area seems
particularly important for future developments. Our research
will continue in this direction.

B. <u>Technical Reports Issued on Contract N00014-76-C-0578</u>

	Author	Title	Report No.	Date of Report	
38.	Peichuen Kao	Conditioned Limit Theorems in Queueing Theory (<u>Journal of Applied Probability</u> <u>15</u> (1978), 280-291)	38	July	1976
39.	Richard Durrett	Conditioned Limit Theorems for Some Null Recurrent Markov Processes (<u>Annals of Probability</u> <u>6</u> (1978), 798-828)	39	August	1976
40.	Douglas P. Kennedy	On the Time to First Overflow in Dams with Inputs Forming a Markov Chain (<u>Journal of Applied Probability</u> <u>15</u> (1978), 171-178)	40	August	1976
41.	Philip Heidelberger	Variance Reduction Techniques for Simulating Markov Chains (published in <u>Proc. of 1977 Winter Simulation Conference</u>)	41	September	1977
42.	Philip Heidelberger	Variance Reduction Techniques for the Simulation of Markov Processes, I: Multiple Estimates (submitted for publication)	42	October	1977
43.	Donald L. Iglehart	Regenerative Simulation for Extreme Values	43	October	1977
44.	Philip Heidelberger	Variance Reduction Techniques for the Simulation of Markov Processes, II: Matrix Iterative Methods (submitted for publication)	44	January	1978
45.	Philip Heidelberger	Variance Reduction Techniques for the Simulation of Markov Processes, III: Increasing the Frequency of Regenerations (submitted for publication)	45	January	1978
46.	Donald L. Iglehart Peter A.W. Lewis	Regenerative Simulation with Internal Controls (<u>Journal of Association of Computing Machinery</u> <u>26</u> (1979), 271-282)	46	February	1978

	Author	Title	Report No.	Date of Report	
47.	Philip Heidelberger Donald L. Iglehart	Comparing Stochastic Systems Using Regenerative Simulation with Common Random Numbers (<u>Advances in Applied Probability</u> 11 (1979), 804-819)	47	May	1978
48.	Donald L. Iglehart Gerald S. Shedler	Regenerative Simulation of Response Times in Networks of Queues, II: Multiple Job Types (<u>Acta Informatica</u> 12 (1979), 159-175)	48	June	1978
49.	Donald L. Iglehart Gerald S. Shedler	Simulation Methods for Response Times in Networks of Queues (<u>Proceeding of 1979 Winter Simulation Conference</u>, I, 221-232)	49	August	1979
50.	Lawrence D. Fossett	Simulating Generalized Semi-Markov Processes (Ph.D. dissertation)	50	September	1979
51.	Donald L. Iglehart Gerald S. Shedler	Regenerative Simulation of Response Times in Networks of Queues: Statistical Efficiency (published in <u>Acta Informatica</u> 15 (1981), 347-363)	51	September	1979
52.	Donald L. Iglehart Gerald S. Shedler	Regenerative Simulation of Response Times in Networks of Queues (<u>Lecture Notes in Control and Information Sciences</u> series, Vol. 26, Springer-Verlag)	52	November	1979
53.	Peter W. Glynn	An Approach to Regenerative Simulation on a General State Space	53	July	1980
54.	Peter W. Glynn Donald L. Iglehart	Simulation Output Analysis for General State Space Markov Chains (published in <u>Applied Probability - ComputerScience: The Interface</u> I (1982), 71-88, Birkhäuser, Boston)	54	February	1981
55.	Peter W. Glynn	On the Markov Property of the $GI/G/\infty$ (published in <u>Advances in Applied Probability</u> 14 (1982), 191-194)	55	May	1981

	Author	Title	Report No.	Date of Report	
56.	Peter W. Glynn	On Variance Formulas for the Sample Mean in Finite State Markov Processes (to appear in _J. Stat. and Simulation_)	56	July	1981
57.	Donald L. Iglehart Gerald S. Shedler	Simulation for Passage Times in Closed, Multiclass Networks of Queues with General Service Times (submitted for publication)	57	July	1981
58.	Donald L. Iglehart Gerald S. Shedler	Statistical Efficiency of Regenerative Simulation Methods for Networks of Queues (_Advances in Applied Probability 15_ (1983), 183-197)	58	May	1982
59.	Peter W. Glynn	Coverage Error for Confidence Intervals Arising in Simulation Output Analysis (published in _Proc. of 1982 Winter Simulation Conference 12_ (1982), 369-375)	59	June	1982
60.	Peter W. Glynn	Some New Results in Regenerative Process Theory (Ph.D. dissertation)	60	July	1982
61.	Peter W. Glynn	Regenerative Aspects of the Steady/State Simulation Problem for Markov Chains (Ph.D. dissertation)	61	July	1982
62.	Peter W. Glynn	Regenerative Simulation of Harris Recurrent Markov Chains	62	July	1982
63.	Peter W. Glynn	Asymptotic Theory for Non-parametric Confidence Intervals (Ph.D. dissertation)	63	July	1982
64.	Donald L. Iglehart Mark L. Stone	Regenerative Simulation for Estimating Extreme Values (to appear in _Operations Research_, Dec. 1983)	64	July	1982
65.	Yung-Li Lily Jow	An Autoregressive Method for Simulation Output Analysis (Ph.D. dissertation)	65	December	1982

	Author	Title	Report No.	Date of Report	
66.	Donald L. Iglehart Gerald S. Shedler	Simulation of non-Markovian Systems, (IBM Journal of Research and Development, p. 477-479)	66	June	1983
67.	Donald L. Iglehart Gerald S. Shedler	Simulation Output Analysis for Local Area Computer Networks (Submitted to Acta Informatica.	67	September	1983
68.	Donald L. Iglehart Gerald S. Shedler	Simulation for Passage Times in Non-Markovian Networks of Queues (to appear in the Proceedings of the Stochastic Programming Conference, Lake Garda)	68	September	1983

C. ACKNOWLEDGEMENTS

D. L. Iglehart.

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December 28, 1983