Reviews of Books and Papers in the Computer Field

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A. COMPUTER SYSTEM MODELS

R68-5 Models of Computational Systems—Cyclic to Acyclic Graph Transformations—David Martin and Gerald Estrin (*IEEE Trans. Electronic Computers*, vol. EC-16, pp. 70–79, February 1967).

Models of Computations and Systems—Evaluation of Vertex Probabilities in Graph Models of Computations—David Martin and Gerald Estrin (*J. ACM*, vol. 14, pp. 281–299, April 1967).

Experiments on Models of Computations and Systems—David Martin and Gerald Estrin (*IEEE Trans. Electronic Computers*, vol. EC-16, pp. 59–69, February 1967).

These three papers, based upon the first author's Ph.D. dissertation, are concerned with the problem of assignment and sequencing of computations on multiprocessor or parallel computer systems. Although individually the papers suffer from the usual abstracting difficulties, the results are significant and warrant serious study by readers interested in computer system modeling and analysis.

The "model" used is a transitive directed graph representing computations or programs (not systems). Vertices represent subcomputations and arcs represent data flow with associated control conditions; the vertices are weighted with estimates of execution times, and the arcs with branching probabilities or data transfer times. The directed arcs thus establish precedence conditions on the initiation of vertex activity. This graph model permits the introduction of mean path length or mean computation time which serves as a criterion for processor assignments and sequencing.

The first paper deals with the problem of removing cycles in a computational graph. Various types of cycles are examined and characterized by a *cycle factor*, N. In a deterministic case, N is the number of times a vertex within a cycle is executed, but in many cases of interest, N is a random variable. In the latter event, the authors use the mean value of N for the purposes of mean path length calculations. It is shown that this substitution results in a negatively biased approximation when the cyclic structure is embedded in a computational graph. The notion of an equivalent acyclic structure is then introduced; the equivalence is in the sense of temporally mean-value equivalent. That is, the equivalent acyclic structure has the same mean path length (execution time) as the original cyclic structure. The cyclic to acyclic transformation is a simple one: the mean execution time of each vertex within the cycle is multiplied by the cycle factor and the "feedback" arc is removed.

Unfortunately, the limitations of this equivalency relation is evident in two important later steps in the authors' procedure for evaluation of mean path lengths of computation graphs. First, the probability of reaching a vertex (the subject of the second paper) is not identical in the cyclic and acyclic equivalents because a vertex may be reached several different times in the cyclic case. Secondly, the embedding of cyclic and acyclic equivalents in a larger graph can lead to different mean path lengths because of the possibility of parallel arcs and the maximum operation involved in path length computations. Further, the nature of the approximation introduced by the acyclic equivalent depends upon the original graph in which the cyclic structure is embedded and the bias may be either positive or negative. Despite these limitations, the simple acyclic equivalency is used throughout the later development primarily for the sake of computational feasibility.

The second paper formulates procedures for the evaluation of the probability of reaching a vertex in a computation graph. These vertex probabilities are then used in the calculation of mean path lengths. (Actually, mean path length calculations are discussed in a later paper submitted to this TRANSACTIONS and available through the Computer Group Repository: Paper 67-61, *Computer Group News*, vol., p. 16, March 1967.) The various types of vertex input and output logic are discussed, and it is shown that pseudo-vertices may be used to reduce all vertices to simple logic: conjunctive (AND) or mutually EXCLUSIVE OR input logic, and mutual EXCLUSIVE OR (branching) or logical equivalence (AND) output logic. It is assumed that all branching conditions are independent and that the graph is properly connected with all vertex probabilities P_k satisfying $0<P_k\leq 1$. Vertex probability P_k is simply the probability of vertex w_k being connected to a subset of the set of origin or initial vertices.

A subgraph whose vertices have no EXCLUSIVE OR input or output logic (AND-type subgraph) is introduced as a representation of a computation of a computation graph. A partially ordered set of computations is represented by a collection of mutually exclusive AND-type subgraphs and may be viewed as an execution of a computation graph. The authors first propose a rather enumerative type of procedure for evaluating P_k which involves finding all AND-type subgraphs containing vertex w_k. This procedure is formulated in terms of a Boolean precedence matrix $[D]$, $n\times n$ where n is the number of vertices and $d_{ij}=1$ if vertex w_j is a predecessor of w_i. Note that $[D]$ is not a connection matrix since predecessors need not be immediate, and $d_{ij}=1$ also indicates w_i is a successor of w_j. By distinguishing between structural predecessors and logical predecessors and using the properties of $[D]$, the authors propose a second procedure which is not enumerative but iterative. This procedure involves the generation of precedence matrices which select predecessors satisfying both logical and structural conditions.

The remainder of this paper briefly explores the problem of dependent branching conditions and describes the a priori assignment and sequencing program of which the P_k computation is a subroutine. Rather large computation graphs derived from practical programs in X-ray crystallography and numerical weather prediction are also included as illustrations. This latter part of the paper somewhat overlaps the material in the third paper.

The contents of the third paper are primarily empirical results of the use of an a priori assignment and scheduling program on the above mentioned computation graphs, which are reproduced in this paper. Flow charts for the assignment and sequencing program are given in the second paper, not in this one. Starting with an initial assignment, the algorithm involves perturbations through movement of vertices or "clusters" of vertices based upon some type of urgency criterion. Interesting empirical results in graphical form are given for convergence properties of the assignment algorithm, effects of identical parallelism, cost of algorithm, and effects of size of cluster sets. Also, several studies of the sensitivity of the model to variations in branching probabilities, cycle factors, and unit operation times are described and associated data presented. Finally, a comparison of results with simulations using SIMSCRIPT, including execution times, is presented.

All in all, the results in these three papers contribute significantly to our knowledge of parallel processor modeling and system operation. A great deal more work is needed, particularly on features omitted from this model, such as storage allocation, characterization of memory organization, and dynamic assignments. Indeed, this reviewer believes that work of this type on computer system models is in its infancy. Much activity has recently been directed towards time-shared systems (see Scherr,[1] for example), but Karp and Miller[2] have also proposed a different computation graph model of parallel computations oriented to other fundamental problems.

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[1] A. L. Scherr, "An analysis of time-shared computer systems," Research Monograph 36, M.I.T. Press, Cambridge, Mass., 1967.
[2] R. M. Karp and R. E. Miller, "Properties of a model for parallel computations: Determinancy, termination, queuing," *SIAM J. Appl. Math.*, vol. 14, pp. 1390–1411, November 1966.

B. ANALOG AND HYBRID COMPUTATION

R68-6 Regression Analysis and Parameter Identification—A. I. Rubin, S. Driban, and W. W. Miessner (*Simulation*, vol. 9, no. 1, pp. 39–47, July 1967).

This paper was written in reaction to a body of literature on continuous parameter tracking that has by and large ignored the use of continuous regression techniques introduced by A. I. Rubin in an earlier paper.[1] The case for the use of continuous regression in the parameter tracking problem is presented in a concise and professional manner. A distinction is made between t, the "real world time" employed in the formulation of the model, and in the development of the regression performance measure, and τ, the "data processing time" employed in the steepest descent circuits that are performing the minimization of the performance measure with respect to the parameters. This distinction is an important contribution, both analytically and conceptually, to the parameter identification literature; the authors' belief that other workers in the field might profit from this distinction is well founded.

However, as might be expected, some critical comments are in order. The authors favorably compare the simplicity of their method to the output error method presented by Meissinger and Bekey.[2] This is not an entirely objective comparison inasmuch as the output error method is addressed to a more difficult version of the parameter identification problem. The performance measure of the output error method is of the form

$$\int_0^T (z - y)' A (z - y) dt$$

[1] A. I. Rubin, "Continuous regression techniques using analog computers," *IRE Trans. Electronic Computers*, vol. EC-11, pp. 691–699, October 1962.
[2] H. F. Meissinger and C. A. Bekey, "An analysis of continuous parameter identification methods," *Simulation*, vol. 6, pp. 94–102, February 1966.

where

- y is the vector of actual measured variables,
- z is the vector of the corresponding variables from the mathematical model, and
- A is a weighting matrix.

Note that this performance measure is not an explicit, known function of the unknown parameters in the model for determining z. Moreover there is no relationship between the number of components of y and the number of state variables in the model except the implicit requirement of model observability.

The performance measure employed by the authors is of the form

$$\int_0^T (\dot{y} - f(y, \alpha, t)'(\dot{y} - f(y, \alpha, t))dt$$

where

- $\dot{y} = f(y, \alpha, t)$ is the differential equation model,
- y is the measured state vector, and
- α is the vector of parameters.

Note that this performance measure is a known function of the parameters α which assumes complete knowledge of *all* the state variables in the system.

The authors indicate as a final note that there are techniques for estimating the unmeasured state variables in a system. Unfortunately they do not factor this observation back into their earlier discussions of method complexity and method performance.

In addition, the paper presents some three pages of analog computer block diagrams. In the opinion of this reviewer one or two paragraphs discussing the sequence of control operations employed in distinguishing between real time t and computer time τ would have been more helpful.

In summary, this paper presents and demonstrates the feasibility of a method for model determination of dynamic systems. Although some of the claims for generality and simplicity can be faulted, the method is obviously useful and this paper should be on the "must read list" of all concerned with the reduction of experimental data from dynamic systems.

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R68-7 Analog Simulation of Ferroresonant System Including Analysis of Hysteresis Loop—J. Santesmases *et al.* (*Proc. Internat'l Assoc. for Analog Computation*, vol. 9, pp. 76–80, April 1967).

The authors are to be congratulated on their perseverance in coming up with an analog circuit which permits simulation of some of the effects that are observed in a ferroresonant device.

From our standpoint the value of a technique is directly related to the ease and relative accuracy with which one can predetermine the effect of change in dimensional parameters such as size of airgap, or change in material properties such as hysterisis loss, upon the end performance of the device.

It is not clear to us at this point whether in fact the technique described would permit such practical results. Regretfully, we have not had the time to delve into the matter more deeply, and specifically into the physical significance of the constants used.

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