MATHEMATICAL MODELING FOR STRUCTURAL ANALYSIS AND DESIGN

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Structural design can be defined as an iterative optimization process involving use of empirical information resulting from operational experience, while at the same time relying on predicted behavior derived from theories which attempt to replace experience. The objective of design is to provide adequate performance over the life of the system. In recent years there has been considerable research devoted to an examination of the abstract structure of the design process with the hope, if not yet the realization, of supplying a rational methodology for making design decisions, particularly where large and complex systems are concerned. One of the benefits that accrues from such activity is that of identifying and placing in perspective different categories of the design process, thereby indicating their inter-connection. As a result it is possible to pose sharper questions to be answered by specialists in various sub-system areas while maintaining at the same time an overall, integrated perspective and control of the design process, i.e., a "systems" viewpoint. This paper presents a brief review of some of the mathematical modeling and simulation techniques that appear to be useful in the structural design process, emphasizing the need for a carefully integrated approach to the treatment of sub-system problems.

The ingredients of design by mathematical simulation may be listed as follows:

1. Description of a tentative system configuration;
2. Specification of the operating conditions (input);
3. Choice of a parameterized structure for input-output relations;
4. Choice of state variables and development of an algorithm for predicting the evolution of the system;
5. Selection of a criterion function, in terms of state variables, by which performance can be judged;
6. Iterative modification of the system to search for optimum performance.

Taking these categories as a point of departure, an examination of some of the possibilities and problems attendant to development of a design methodology is made. Particular attention is given to the underlying inter-relationships between categories, use of concepts of control theory and the merging of "design art" with "design science" in the form of man-machine interactions. As an illustrative example, the problem of system identification in the context of material characterization, and its direct relation to numerical solution algorithms of field problems in mathematical physics is discussed. The direct implication of this interconnection is the imperative of viewing "materials characterization" and "structural analysis" as interdependent processes in system design. The concept of control, although familiar in the operation of systems, is perhaps less well understood as a useful concept in the design process. Of fundamental importance are ideas emerging from combinatorial mathematics and dynamic programming, leading to a methodology for selecting a policy for iterative modification of the design to seek optimum performance. Similarly, yet in a different context, the idea of feedback control is useful in studying problems of discretization or zoning in numerical analysis as well as zoning for system identification. These, as well as other aspects of the treatment of design via modeling and simulation are developed and illustrated in the paper.

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