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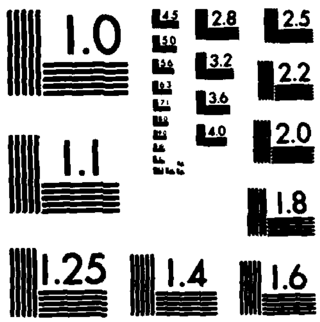

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PROBLEMS IN LARGE SCALE DYNAMIC SYSTEMS

Final Report

on

Research Contract N000-14-75-C-0738

February 1, 1982 - June 30, 1984

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The research study was focused on: (1) the tactical decision making by groups in a stationary environment and the determination of system equilibrium; (2) the development of a theory of dynamic decision making of groups in a manipulative environment; (3) development of decision systems for organizations; (4) generalized dynamic system descriptions, and (5) team cooperation in organizations. Each of these research activities are summarized below. Reports and papers resulting from the research activities are listed in the references.

1. Theory of Bargaining

Bargaining is a model for tactical decision making by a group in a stationary environment where each player observes the rules of the game. Thus, the outcome of a bargaining process is completely determined by (a) the rules of the game, (b) the individual preference, and (c) the information structure. In this research, we focused on the bargaining process which is formulated as an infinite game in extensive form.

In this game, bargainers make proposals and counterproposals alternately until an agreement is reached. A subgame-perfect, pure-strategy Nash equilibrium is then examined; its existence and uniqueness are proved using dynamic programming equations. Finally it is shown that the outcome realized by the unique subgame perfect, pure-strategy Nash equilibrium converges to the outcome predicted by one of the classical theories of bargaining, i.e., the Hicks-Zeuthen-Bishop theory, as the time between two consecutive bargaining sessions approaches zero. This result, stated in terms of a limiting theorem, thus uncovers a hidden but strong relation between the two completely different approaches to the bargaining problem.

To facilitate a rather complicated theoretical derivation of the above-mentioned main results, a new representation of games in extensive form is developed. This representation is introduced as a special case of general formulation of multiplayer dynamical systems. A few examples of bargaining problems are examined to illustrate the implications and the applications of the main results. Although the main results are obtained assuming a perfect information structure, preliminary discussions of a theory of bargaining with incomplete information are also included. Results are reported in [1,2].

2. Decision-Making Under Manipulative Environments

A new choice model was developed based on the exploration of the impact of instability or individual decision behavior. Instability is distinguished from uncertainty and defined as the inconstancy of the "rules of the game" under which decision making occurs. This necessitates an explicit consideration, absent in existing decision theory, of the set of rules constraining the activity of agents in a given situation.

Rational, self-interested individuals cannot be precluded from investing in attempts to change rules to their advantage. However, while rules can be violated by individuals, they can generally be changed only by group effort. Thus, unstable environments are characterized by the contention of groups over the rules that are to govern their relationship. This contrasts with standard bargaining theory where interaction occurs within given rules of the game. An unstable structure not only becomes a variable affecting the micro-behavior of individuals, its constitutent rules are themselves the outcome of the continuing conflict amongst groups. Therefore, to treat the rule-structure as a datum, as in standard decision theory, is a major assumption with serious implications.

Strategic interaction processes at the group level are analyzed by isolating and elaborating the key elements involved. These include the determinants of group strength, the types of strategic actions and mechanisms required for changing rules, and the determinants of the decision to challenge an existing rule-structure. These are synthesized into an integrated framework for the modeling of conflict situations. It is argued that such a multi-dimensional framework is needed to adequately explain the strategic behavior of individuals in unstable environments. Development of such an integrated model is given in the Ph.D. thesis by Anjum Mir [3]. Several papers are being prepared based on his thesis.

3. Decision Systems for Organizations

This research developed a framework on the design and assessment of decision systems for organizational decision making. A decision is an irrevocable allocation of resources, and any such action that affects the well-being of the members of the organization will be referred to as an organizational decision. Organizational decision making is then the process by which such decisions are made. In developing the foundation of decision systems for organizations, we have constructed three interacting views of the organizational decision making problem. These reflect the stages of the decision itself, the tasks that need to be performed in executing this process, and the roles that the members of the organization can play in arriving at the decision [4]. The integration of three interacting views led to the foundation of a new research and academic program within the Department of Engineering-Economic Systems. New research activities are now emerging from the results of such research within the Decision Systems Laboratory which was formed in 1983.

4. Generalized Dynamic Systems

This research focuses on system descriptions that go beyond the state space representation and are treated from the descriptor variable viewpoint. Such system descriptions arise naturally as a by-product of the modeling process. In such cases, one may result in rectangular descriptor systems (hereafter referred to as DS) as opposed tc square descriptor systems found in control theory framework.

Due to the fact that the descriptor variable approach is in its early stages of development, a great portion of this work is devoted to the development of the basic principles and computational techniques. As the first basic issue, conditions under which (DS) is solvable are examined. In particular, the notions of free-solvability and controlled-solvability together with necessary and sufficient conditions regarding solvability are presented. It is shown that the notion of controlled-solvability generalizes certain well-known subspace invariance concepts in system theory. As an example, the output nulling problem is discussed--yielding more general results than those presently available.

Two algorithms are developed for computing solutions to (DS). Both of the algorithms determine the solution(s) by computing a certain lower order system--termed a core system--from which other variables may be derived. One of the algorithms is employed to compute the maximal set of allowable initial conditions for the free system and the controlled system. The algorithm is also employed to derive a decomposition of the input vector into a set of control variables which may be freely selected and those which are chosen in a feedback manner.

As an application of the results, the rectangular descriptor system approach is applied to the observer design problem. The conceptual significance of the development is that it relates the well-established observer theory to the newly emerging descriptor variable approach. Morever, such a view allows further generalization. This is achieved by introducing the notion of a noncausal observer. It is shown that a noncausal observer may be employed to arrive at a closed-loop estimate of the state at some time point in the past--in a retrogressivse fashion. The closed-loop estimate is then 'swept forward' in an 'open-loop' manner to arrive at an asymptotically improving estimate of the current state. Such a result unifies a number of otherwise disparate techniques.

The research results are reported in the Ph.D. thesis by Hamid Razavi [5]. Several papers are prepared on this work.

5. Team Cooperation in Organization

In order to understand the dynamic behavior of team cooperation in an organization, a new methodology based on a simulated expert-environment (SEE) is developed. SEE is an interactive environment in which one can describe a problem both by analytical simulation models (e.g., difference equations, optimization and control models, etc.) and by encoding expert knowledge about the problems. Using such an environment, models are developed to simulate the dynamic behavior of team cooperation in situations where team members may have biased beliefs about their contribution to team performance, different risk profiles and many other behavioral assumptions which are difficult to analyze analytically. The research explored the different scenarios where efficient team performance can be achieved in spite of significant biases. Some of this research is reported in [6], main results will appear in a Ph.D. thesis by Pertti Lounamaa [7].

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[7] P. Lounamaa, Ph.D. thesis to be finished by March 1985 (Research has been completed.)

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