CONTROL AND MANAGEMENT OF INTEGRATED INDUSTRIAL COMPLEXES

Edited by

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IFAC WORKSHOP ON CONTROL AND MANAGEMENT OF INTEGRATED INDUSTRIAL COMPLEXES

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PREFACE

This volume contains the proceedings of the International Federation of Automatic Control's workshop on the control and Management of integrated industrial complexes held in Toulouse, France over the period Sept. 6-8, 1977. This volume contains twenty three papers selected by the international program committee plus four invited survey papers. The aim of the workshop was to bring together experts from different disciplines in order to provide a synthesis of the diverse ways of looking at the problem of controlling industrial complexes.

In the light of the papers received, the scientific content of the workshop was divided into 6 sessions. The first of these dealt with the theory of organisations, the second with production planning and scheduling, the third with coordination theory, the fourth with decentralised stochastic control, the fifth with power system applications and the last one with other diverse applications. We have written a brief introduction to the papers in each session. However, four papers were not included in the preprints volume and these are added on to the end of the present volume. This means that where the reader see's for example an introduction to an article and then does not find the article immediately after the introductory section, he should look to the end of the volume for the article.

We beleive that this volume contains an up to date survey of the diverse ways of looking at integrated industrial complexes.

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(1) CNRS Centre National de la Recherche Scientifique
(2) IRIA Institut de Recherche en Informatique et Automatique
(3) DRME Direction de Recherche de Moyen et Essai
(4) DGRST Délégation Générale de Recherche Scientifique et Technique

CONTENTS

INTRODUCTION TO SECTION 1:
Theory of organisations

This section comprises one invited survey paper and 4 contributed papers The invited survey paper is by Professor A.P SAGE of the University of Virginia, USA and it is entitled"on the application of systems methodology to economic and organisational management of integrated industrial complexes"

In this paper the author points out that the combined use of interpretive structural modelling and decision analysis within an appropriate methodological framework offers much promise for the economic and organisational management of integrated industrial complexes. The author assesses the various techniques which could have a bearing on the problem . He starts by outlining hierarchical control and identification algorithms for large scale systems. He then assesses the role of structure in the behaviour of large scale system as well as the role of decision policy analysis. He examines in some detail the structure in multivariate group decision analysis. He then goes on to discuss the use of hierarchical system and game theoretic concepts in decision and policy analysis. He also outlines ways of evaluating the worth of direct and indirect costs and benefits of technological innovations in industrial complexes. Finally, he looks at the problem of implementation of decision analysis algorithms in decision making.

The first contributed paper is by A. NOMOTO of the Copal co. Ltd of Tokyo and it is entitled "Matrix management as metamorphosis in managerial m utations". In this paper the author describes matrix management as a useful structure for projects where personnel are drawn from diverse sections of the corporation. Various aspects of the problem are described.

The second contributed paper is by C.M SINGH and M.G SINGH of LAAS-CNRS, Toulouse and it is entitled "An exploratory analysis of organisational hierarchies from an Engineering point of view" . In this paper the authors attempt to bring to the attention of organisational theorists certain recent results in the theory of hierarchical optimisation and control which could lead to new insights into the understanding of organisational hierarchies. Both the traditional and modern approaches to hierarchies are treated.

In the traditional approach, it is usually assumed that the goals and aspirations of the members of the organisation are common whilst in the modern approach the goals may be contradictory. The authors argue that recent work on hierarchical control could provide a methodology for analysing quantitatively both the traditional and modern view points.

The third contributed paper is by P.K RAO of the administrative staff college of India and it is entitled "Hierarchical and decentralised planning and decision making a synthesis of analytic models". The aim of this paper is (i) to provide a brief survey of literature on analytic approaches to planning and decision making particularly in the context of development administration in large scale systems.

(ii) Synthesise the framework into a generalised multi-facet system configuration which enables consideration of various types of planning and decision making models as special cases.

The paper is divided into two parts. In the first part of the paper a survey is given of various types of planning and decision-making models, which could be classified as (i) monolithic where it is assumed that the solutions of a given class of parameters are known and by aggregation one can solve the complex problem with known structure and (ii) non-monolithic where the complex problem can be decomposed into a number of sub problems and coordinated to give an integrated solution to the problem. The inherent organisational structures are exposed in order to examine their operational feasibility. The role of information has been emphasised throughout the paper as the crucial element which affects the efficiencies of planning and decision-making both in hierarchical and decentralised types of systems.

After briefly surveying most of the literature on the subject, the second part of the paper deals with the process of synthesising various approaches into an integrated framework based on the following considerations

1) role of economic structure of organisation : market or non-market economic system or a mixed system
2) Structure of authority : hierarchical, non hierarchical or mixed structures
3) Stock and flow of information at each level of decision-making/planning
4) Motivational aspects : incentives and disincentives.
5) Formal decision models and associated algorithms.

In the process of evolving a unified model to cover all the above factors, it was found that in the generalised framework, by assigning special values or ranges of values to incentive and disincentive parameters one gets into the centrally controlled/hierarchical or decentralised type of decision-making. Also with appropriate adjustment of information flow and stock, a comparable efficiency in terms of optimising the stated objectives (subject to a system of constraints) can be attained . In special cases the efficiency can be nearly equal provided that the relative intensities of incentives and disincentives along with the role of information are property specified The model here emphasises the role of dynamic structure and incorporates the time dimension. After formulating the formal decision models a brief investigation into the algorithms useful for the purpose of solving the problem are also examined especially Mesarovics theory of hierarchical optimisation Bensoussan's iterative algorithms and improvements thereof.

Applications of the above framework to planning of water resources and large scale industrial complexes is outlined towards the end of this paper.

The final contributed paper is by J. KACPRZYK of the Polish Academy of Sciences and it is entitled "Fuzzy set theoretic approach to the optimization of social organisational structures"

In this paper, the problem of determining the optimal organizational structure of a given set of employees is considered. "optimality" implies the optimal structure, i.e the configuration of work places, and the optimal assignment of work places to employees. It is assumed that the following are known

- the characteristics of particular employees, i.e the values of parameters influencing their work results,
- the dependence of the work result on the above parameters,
- the dependence of the work result of the whole structure on the work results of particular employees.

The method is applicable mainly to nonproductive structures, e.g scientific, administrative, political in which it is evidently very difficult to determine and express quantitatively the above three elements. Moreover, the results of sociological, psychological etc. investigations, performed for such task, are usually in a verbal form and are unsuitable for transformation into a quantitative form.

The simplest and most adequate way of determining these three elements describing the structure is their verbal description. One can, therefore, apply the linguistic approach of Zadeh. Its basic feature is the use of : linguistic variables in place of numerical ones and fuzzy conditional statements for expressing simple relations between linguistic variables. Thus, if the parameters influencing the work result of an employee are assumed to be e.g the personal capabilities and the managerial capabilities of his direct superior, their values can be e.g high, medium, not low. The meaning of these terms is assumed to be a specified fuzzy set in an appropriate universe of discourse.
In turn, the dependence of the work result on those parameters is given verbally as well as by fuzzy conditional statements, e.g. if the capabilities of an employee are high and the managerial capabilities of his direct superior are medium or high, then his work result is good.
The meaning of such a statement is equated with a specified fuzzy relation.

The optimization process proceeds as follows. First of all, structures are generated. Then, for a given structure assignments of work places to employees are generated. For each combination structure - assignment. The work result of the whole set of employees is computed and compared with the best ones obtained so far. The comparison is performed by means of linguistic approximations, so that at the end the best structures and assignment are determined. The following possibilities of generating structures are given : the generation of all possible subsequent structures,

the random generation of structures,
the heuristic generation of structures and the optimization in a class of some predetermined structures. The ways of generating assignments are analogous. There is also the possibility of imposing constraints on structures and assignmentof work places considered.

Examples of the optimization of a structure of 20 employees with various descriptions of structures and various ways of generating structures and assignment are given

ON THE APPLICATION OF SYSTEMS METHODOLOGY TO ECONOMIC AND ORGANIZATIONAL MANAGEMENT OF INTEGRATED INDUSTRIAL COMPLEXES

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ABSTRACT

The combined use of interpretive structural modeling and decision analysis within an appropriate methodological framework offers much promise for the economic and organizational management of large integrated industrial complexes. A symbiotic blending of technical, administrative, political and societal concerns is necessary for the determination and incorporation of direct and indirect benefits and costs and nonquantifiable societal impacts into a hoped for standard normative procedure for assessing the worth of policies for technological innovations in industrial complexes. This paper surveys recent progress relative to these issues and discusses possible directions for future efforts directed at this needed synthesis.

1. INTRODUCTION

There have been many studies in recent times relative to control regulation and policy analysis of large scale systems. It is believed that a combination of structural considerations for large scale systems, policy and decision analysis considerations, together with hierarchical concepts for large dynamic systems can do much to enhance our ability to cope with the complexity inherent in large scale systems, including integrated industrial complexes. We will summarize efforts on these topics to date in the discussions to follow and indicate directions for present and future efforts. Our discussions will necessarily be brief. We will first describe our efforts and then relate these to many other studies in this important area.

2. HIERARCHICAL CONTROL AND IDENTIFICATION ALGORITHMS FOR LARGE SCALE SYSTEMS

The problem of linear system identification is concerned with finding a set of parameters for an assumed linear model structure by processing observations in some optimal manner. The solution to this problem becomes increasingly difficult as the size and complexity of the model increases and also as the constraints imposed upon the identification algorithms grow in severity. Approaches based on decomposition have recently been developed for solving large optimization problems. Two sequential algorithms, based on decomposition, for identification of states and parameters in large linear systems have been developed. Also error and sensitivity analysis algorithms for linear system identification using stochastic approximation as well as for linear system identification using stochastic approximation as well as for combined estimation and control algorithms utilizing possibly reduced order observers have been obtained.

Our approach involves decomposition of a large system model in a related objective function into a number of subsystems and related smaller objective functions. The resulting smaller estimation and control problems are then solved one at a time. The subsystems and smaller objective functions are coupled and the coupling variables impose constraints on the problems. We have utilized both standard hierarchical coordination procedures and decoupling of each infimal problem by orthogonal transformation of coupled variables into sets of orthogonal variables. The two identification algorithms for linear systems developed differ in the choice of model as well as in the choice of objective function and in the choice of decomposition method. In the first approach, an autoregressive model, a mean square error objective function, and a coordination based decomposition is used. The infimal problems resulting from the decomposition are resolved by the use of sequential stochastic approximation algorithms. If gain coefficients in the stochastic approximation algorithms are selected appropriately, the algorithm because identical to the Kalman minimum error variance filter. Development of this algorithm and its application to a problem associated with the design of an encoder for a digital speech transmission has been considered in reference (1).

The other algorithm utilizes a probablistic model, a joint entropy objective function, and an orthogonal transformation based decomposition. A joint entropy objective function is not dissimilar to that previously studied by several authors for resolution of problems in decision analysis. The entropy functional is applied to the problem of linear system identification by inverse filtering. A formulation leads to a sequential minimax entropy algorithm. The formulation appears to be such that it can readily be extended to nonlinear inverse filtering algorithms. Implementation of the minimax entropy algorithm leads to a lattice-type digital ladder filter structure. Although orthogonal transformations in the lattice-type digital structure are well known in the literature, their derivation and utilization for linear system identification by the use of the entropy measure appears to be new. Results of the research, including an example, are presented in (2).

Error and sensitivity analysis algorithms have been developed for the stochastic approximation algorithm for linear system identification. The usefulness of the algorithms as well as their development is discussed in reference (3) which determines performance limitations of a digital speech encoder based on our sequential stochastic approximation algorithms.

Optimum systems control algorithms for stochastic large scale systems are of interest for many applications to integrated industrial complexes. It would appear that large scale industrial and societal problems will be too fuzzy and too ill-defined for application of precise algorithms which result in optimum control determination. Nevertheless, such algorithms should certainly be applicable for large technical systems and for economic systems. We have surveyed existing methods and developed a new coordination method that appears potentially useful for large scale stochastic systems (4). Also, we have attempted to apply sensitivity algorithms for the development of suboptimal closed loop control in stochastic systems (5). Effort was initiated to develop sensitivity analysis algorithms for large scale combined estimation and control systems. Preliminary results of this effort including application of the algorithms to VTOL stochastic system design are reported in references (6) and (7). Further development and refinement of these approaches as well as the integration of them with emerging developments in decentralized control theory appears to represent a very interesting topic for future large scale system investigations.

These developments have been concerned with specific developments of system identification algorithms and related problems involving sensitivity and error analysis, and combined estimation and control. It is our belief that the heart of any systems engineering problem is the development of a precise understandable manageable tool to predict consequences of various alternatives. Otherwise, there is no device to indicate the extent to which objectives are achieved by the alternatives or costs associated with implementation of various alternatives.

Thus it would appear to be of great importance to consider problems of system identification, estimation, and control within the broad context of comprehensive planning and systems engineering methodology rather than just as separate isolated (and therefore theoretical) problems. It would appear that this can never be completely accomplished since everything in the universe is connected to a greater or lesser extent to everything else. Determination of boundaries (or what to leave out) may be approached from the viewpoint of the Hall activity matrix which appears one of the most definitive frameworks for systems engineering activities (8). This results in a hierarchical structure of objectives, activities, activities measures, objectives measures, needs, constraints, and alterables. It was conjectured that portrayal of these systems engineering program planning linkages could assist materially in determination of the structure of acceptable models for complex issues. Once the program planning linkages just delineated have been determined, we proceed to other steps in the systems engineering process. The seven steps of a systems activity (8), through which one must generally iterate several times, include:

Problem Definition
Value System Design
System Synthesis
Systems Analysis and Modeling
Optimization or Alternative Ranking
Decisionmaking
Planning for Action

In using an appropriate framework from systems engineering methodology to develop appropriate activities, we have a significantly greater opportunity to achieve satisfactory system design than by following a process which emphasizes one of the steps to the exclusion of others. Adequate attention is often not devoted to problem definition, value system design and system synthesis. It is these steps which result in the delineation of pertinent elements for construction of a system model, validation of the model, optimization, and decision making. Structural modeling concepts may be used to great advantage in determining appropriate models for large scale systems (9) which can be validated and optimized using the hierarchical concepts we have described in this section.

3. THE ROLE OF STRUCTURE IN THE BEHAVIOR OF LARGE SCALE SYSTEMS

We have been much concerned with investigation of the development and use of structure in systems engineering (9). Use of the word "structure" and the description, based on empirical knowledge, of phenomenological occurrences has traditionally been couched in ambitious terminology. Examples abound in the literature of "social structure," "personality structure," and "organizational structure." Engineering and the natural sciences have also been much concerned with structure and contributions which clarify structural knowledge in technology are quite numerous and quite sound. Unfortunately, correspondingly sound examples in the social sciences are, for the most part, lacking. The theory of directed graphs treats, in a systemic fashion, patterns of relationships among pairs of abstract elements. There have been numerous developments of graph theory in