Combinatorial Engineering of Decomposable Systems

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VOLUME 2

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Combinatorial Engineering of Decomposable Systems

by

Mark Sh. Levin

Moscow, Russia

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This book is dedicated to the
Memory of My Parents:
Shmuil M. Levin, and
Revekka M. Levina (Bahnova).

Contents

Preface

In recent years, combinatorial building new complex systems has been an active area of research in design and planning. This situation depends on the fact that a lot of contemporary systems are very complicated and consist of various components which may be selected on the basis of catalogues. In the book, we describe this situation as combinatorial engineering of decomposable systems. We consider the following issues:

(a) a hierarchical combinatorial description of decomposable systems;

(b) functional operations of combinatorial engineering (e.g., analysis, design, comparison, transformation);

(c) basic combinatorial elements (e.g., chains, trees) and their proximity;

(d) approaches to structural modeling;

(e) compatibility of system components;

(f) basic problems of combinatorial synthesis (multicriteria selection, multiple-choice knapsack problem, morphological analysis, clique, morphological clique, etc.).

Mainly we examine the following: hierarchical system models, system components, design alternatives (DA's) for system components and their interconnections (Ins), estimates of DA's and Ins, and changes (transformation) in the systems.

Our material is based on the following fundamentals: (a) system analysis, systems engineering, and hierarchical approaches to the design and analysis of complex systems; (b) technology of decision making and artificial intelligence; and (c) combinatorial modeling and optimization.

The book presents the author's engineering/scientific experience and knowledge (e.g., engineering practice, management engineering, design of effective algorithms and solving schemes) in the analysis and design of complex multidisciplinary systems of various kinds (e.g., software, information support, or-

ganizations, planning, quality analysis, house-building, machine building, electronics, etc.).

Our investigation is based on

hierarchical morphological multicriteria design (HMMD)

that implements construction of a decomposable system (integrated system, composite software, plan, machine, etc.) from interconnected components. The research on HMMD consists of the following main parts:

(1) description of HMMD;

(2) support tools as follows: (a) basic problems, and models (design of hierarchical system models; multicriteria ranking of DA's, synthesis of composite DA's, etc.); (b) information aid; (c) proximity for complex objects; (d) organizational aid;

(3) application of HMMD to some combinatorial problems; and

(4) case studies.

Our text describes components of HMMD including interconnection among subsystems, multicriteria ranking, coordination of scales, composition problem, kinds of composite decisions, information support, procedures for analysis and refinement, comparison of system versions, and some organizational issues.

HMMD is related with various disciplines (e.g., decision making, cooperative work, combinatorial optimization, concurrent design, multi-agent systems, etc.).

Two main directions of our morphological approach can be pointed out:

1. Interactive Part. Interactive description, analysis, design, and transformation of decomposable systems. In this case, we intend the following:

1.1. Orientation to multidisciplinary studies, and education processes (graduate and post-graduate students, continuous education), including joint project execution.

1.2. A problem dimension is about 30...100 nodes, and 2...5 hierarchical levels of the system model.

1.3. Interactive user-oriented modes of solving processes.

1.4. Simple software with very limited required computer resources.

2. Computation Part. Solution of very large combinatorial problems on the basis of morphological macroheuristics. Note that these macroheuristics may be considered as a hierarchical modification of dynamic programming. This direction requires the use of powerful computer environments (including multi-processor systems). In the book, we only describe possible applications of some morphological heuristics for combinatorial optimization problems (e.g.,

traveling salesman problem, scheduling, multi-routing problem, and location problem). Evidently, this direction has to be continued on the basis of special computer experiments for very large problems including realistic ones. It is reasonable to compare the use of different approaches for the same problems, (e.g., traveling salesman problem, scheduling, and location):

(i) our morphological heuristics,
(ii) Branch-And-Bound Method, and
(iii) genetic and evolutionary methods, etc.
Thus this part is a research in progress.

The hopefulness of the author is based on the possible use of HMMD for student participation at the various stages of a multi-disciplinary project-oriented education. In this case, student teams can include students of different departments. The use of HMMD may improve the student skills in various significant domains:

(1) basic disciplines;
(2) communication skills;
(3) complex project execution and management; and
(4) system thinking.

Secondly, the monograph presents a set of essays on some significant topics as follows: (a) hierarchical design; (b) combinatorial models of synthesis; (c) comparison of structured systems; (d) transformation of system; etc. Also, the manuscript contains a battery of various applied examples (over 40) that may be useful for specialists of many domains. A special chapter of the book is oriented to educational issues.

Note that the book concurrently involves a bibliography of references central to hierarchical design problems, combinatorial synthesis, morphological approach, comparison of structural systems, system transformation, and some specific applications. For readers who are interested but unfamiliar with the references in these areas, the bibliography facilitates and encourages their researches.

In the main, our book addresses man-machine analysis and synthesis of complex systems on the basis of easy information processing by human. So our interactive viewpoint consists in the following:

Enabling to understand, to analyze, and to manage information by human at all stages of solving processes as follows:

(i) acquisition of initial information;
(ii) analysis/evaluation and management of intermediate information; and

(iii) analysis of resultant decisions.

For the above-mentioned goals we try to use the following:

1. Ordinal scales for initial, intermediate, and resultant information;

2. A limited volume of information (small dimension, number of presented elements as concepts, criteria, levels of scales, decisions, etc.); and

3. Easy presentation of information.

The next goal of the book consists of the following. In our opinion, needs of multi-disciplinary specialists are increasing. The book may be considered as a support material for preparation of the mutlidisciplinary specialists in the field of complex systems.

The additional goal centers the development of new software for HMMD. Three versions of the DSS COMBI for multicriteria ranking were developed in 1987, 1989, and 1991, accordingly ([294], [297], [317]). The authors of the system are Dr. M.Sh. Levin (general design, programming of prototype method, management, modeling, basic case studies) and A.A. Michailov (design, programming, modeling, some case studies). Note a morphological technique environment is realized in the DSS COMBI, including morphological graph-menu of solving process on the basis of the algorithms/procedures and data (estimates, preference relations). This system was presented at the Intl. Conf. on Subjective Probability, Utility and Decision Making (SPUDM) in Moscow (1989), at the Intl. Conf. on Multiple Criteria Decision Making in Fairfax (1990), and at the Intl. Conf. on Human-Computer Interaction EWHCI'93 in Moscow (1993), etc. The DSS COMBI was applied in education.

A hierarchical hypertext system for multicriteria analysis (methodology of multicriteria analysis; models; multicriteria descriptions of various objects; software packages; and well-known indices) was developed by M.Sh. Levin in 1988 [292]. The system is a simple attempt to hierarchical representation of information for complicated problem domains. The system was presented at the Intl. Conf. on Multi-objective Programming in Yalta (1988); at the SPUDM in Moscow (1989), at Intl. Conf. on HCI in Moscow (1993), etc.

The first software prototype of HMMD (interactive shell, base of case studies, heuristic algorithms for selection and composition, a helper) was developed within the scope of the project which was supported by Israeli Ministry of Trade and Industry (Jan.-Sept., 1992). The following team has executed the project: Dr. M.Sh. Levin (the author of project, general design, modeling, algorithms, management, case studies), Eng. B. Belayavsky (programming), and Eng. B. Sokolovsky (some case studies).

Our material is presented in an *engineering style* that includes a standard schematic description of realistic problems, formulations of corresponding mathematical models, solving schemes (algorithms, procedures), and numerical examples on the basis of standard tables, figures, and diagrams. Real-life applications are a result of or involve the implementation of materials presented in the book.

Thus each reader can understand basic problems, approaches to solve them, and approaches to build other close problems and solving schemes. Mathematical fundamentals may be found in referred literature.

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About the Author

Mark Sh. Levin is an Independent Researcher. He received M.S. degree in electronics from Moscow Technological University for Communication and Informatics (1970), M.S. degree in mathematics from Moscow State University(1975), and PhD degree (system analysis and combinatorial optimization) from Institute for System Analysis of Russian Academy of Sciences. He was with various Moscow R & D organizations as Engineer, Senior Engineer, and Head of Laboratory (1970-1983). After that he was Senior/Leading Scientist Researcher with Institute of Russian Committee of Standards, and with Institute for Computer-Aided Design of Russian Academy of Sciences, the Author of Project with Ofakim Center of Technology (Israel), a Visiting Researcher at The University of Aizu (Fukushima, Japan) and at School of Information Technology and Engineering of Ottawa University (Canada).

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